APUS: AN INTRODUCTION TO NUTRITION



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APUS: An Introduction to Nutrition

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TABLE OF CONTENTS

APUS: An Introduction to Nutrition 1st Edition

- Licensing
- 1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet
  - 1.1: Chapter Introduction
  - 1.2: Defining Nutrition, Health, and Disease
  - 1.3: What Are Nutrients?
  - 1.4: Historical Perspectives on Food
  - 1.5: The Broad Role of Nutritional Science
  - 1.6: Health Factors and Their Impact
  - 1.7: Nutrition and the Media
  - 1.8: Assessing Personal Health
  - 1.9: Dietary Toolkit
  - 1.10: A Healthy Philosophy toward Food
  - 1.11: Understanding the Bigger Picture of Dietary Guidelines
  - 1.12: What Is Nutritional Balance and Moderation?
  - 1.13: National Goals for Nutrition and Health- Healthy People 2020
  - 1.14: Recommendations for Optimal Health
  - 1.15: Understanding Dietary Reference Intakes
  - 1.16: Discovering Nutrition Facts
  - 1.17: When Enough is Enough
  - 1.18: Foodborne Illness and Food Safety
  - 1.E: Nutrition and You (Exercises)
- 2: Gastrointestinal Tract
  - 2.1: Chapter Introduction
  - 2.2: The Basic Structural and Functional Unit of Life- The Cell
  - 2.3: Digestion and Absorption
  - 2.4: Nutrients Are Essential for Organ Function
  - 2.5: Energy and Calories
  - 2.6: Gastrointestinal Tract and Your Health
  - 2.E: Exercises
- 3: Carbohydrates
  - 3.1: Introduction to Carbohydrates
  - 3.2: A Closer Look at Carbohydrates
  - 3.3: Digestion and Absorption of Carbohydrates
  - 3.4: The Functions of Carbohydrates in the Body
  - 3.5: Looking Closely at Diabetes
  - 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
  - 3.7: Carbohydrates and Personal Diet Choices
  - 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
  - 3.E: Exercises
- 4: Lipids
  - 4.1: Chapter Introduction
  - 4.2: What Are Lipids?
  - 4.3: How Lipids Work
  - 4.4: Digestion and Absorption of Lipids
  - 4.5: Understanding Blood Cholesterol

- 4.6: Balancing Your Diet with Lipids
- 4.7: Lipids and the Food Industry
- 4.8: Lipids and Disease
- 4.9: A Personal Choice about Lipids
- 4.E: Exercises

- 5: Proteins
  - 5.1: Chapter Introduction
  - 5.2: Defining Protein
  - 5.3: The Role of Proteins in Foods- Cooking and Denaturation
  - 5.4: Protein Digestion, Absorption and Metabolism
  - 5.5: Protein's Functions in the Body
  - 5.6: Diseases Involving Proteins
  - 5.7: Proteins, Diet, and Personal Choices
  - 5.E: Proteins (Exercises)
- 6: Energy Metabolism
  - 6.1: Chapter Introduction
  - 6.2: Metabolism Overview
  - 6.3: Vitamins Important for Metabolism
  - 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
  - 6.5: Balancing Energy Input with Energy Output
  - 6.6: Too Little or Too Much Weight?
  - 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
  - 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
  - 6.E: Exercises
- 7: Nutrition and Cancer
  - 7.1: Chapter Introduction
  - 7.2: Carcinogenesis
  - 7.3: Diet and Cancer
- 8: Antioxidant Nutrients
  - 8.1: Chapter Introduction
  - 8.2: Generation of Free Radicals in the Body
  - 8.3: Antioxidant Micronutrients
  - 8.4: The Whole Nutrient Package versus Disease
  - 8.E: Exercises
- 9: Nutrients and Bone Metabolism
  - 9.1: Chapter Introduction
  - 9.2: Bone Structure and Function
  - 9.3: Bone Mineral Density is an Indicator of Bone Health
  - 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
  - 9.5: Other Essential Micronutrients for Bone Health
  - 9.6: Osteoporosis
  - 9.7: Risk Factors for Osteoporosis
  - 9.8: Osteoporosis Prevention and Treatment
  - 9.9: Deficiency, Supplementation, and Choices
  - 9.E: Nutrients Important for Bone Health (Exercises)
- 10: Water, Electrolytes, Acid-Base Balance
  - 10.1: Chapter Introduction
  - 10.2: Overview of Fluid and Electrolyte Balance
  - 10.3: Water's Importance to Vitality
  - 10.4: Regulation of Water Balance

- 10.5: Electrolytes Important for Fluid Balance
- 10.6: Consequences of Deficiency or Excess
- 10.7: Water Concerns
- 10.E: Water, Electrolytes, Acid-Base Balance (Exercises)

- 11: Nutrients Involved in Hematopoietic System
  - 11.1: Chapter Introduction
  - 11.2: Blood's Function in the Body and in Metabolism Support
  - 11.3: Vitamins Important for Metabolism and for Blood Function and Renewal
  - 11.4: Minerals Important for Blood Function and Renewal
  - 11.5: Iron-Deficiency Anemia
  - 11.E: Exercises
- 12: Maternal, Infant, Childhood, and Adolescent Nutrition
  - 12.1: Chapter Introduction
  - 12.2: The Human Life Cycle
  - 12.3: Pregnancy and Nutrition
  - 12.4: Infancy and Nutrition
  - 12.5: Nutrition in the Toddler Years
  - 12.6: Childhood and Nutrition
  - 12.7: Puberty and Nutrition
  - 12.8: Older Adolescence and Nutrition
  - 12.E: Exercises
- 13: Nutrition From Adulthood to the Elderly Years
  - 13.1: Chapter Introduction
  - 13.2: The Human Life Cycle Continues
  - 13.3: Young Adulthood and Nutrition
  - 13.4: Middle Age and Nutrition
  - 13.5: Old Age and Nutrition
  - 13.E: Exercises
- 14: Alcohol
  - 14.1: Introduction to Alcohol
  - 14.2: Alcohol Absorption and Metabolism
  - 14.3: Pros and Cons of Drinking Alcohol
  - 14.4: How Much to Drink?
- 15: Nutrition and Exercise
  - 15.1: Chapter Introduction
  - 15.2: Introduction to Nutrition and Physical Fitness
  - 15.3: Aerobic Exercise
  - 15.4: Anaerobic Exercise
  - 15.5: Nutrients that are critical to athletes
  - 15.6: Fitness Supplements and Steroids
  - 15.7: Fitness and Health
  - 15.8: Supplemental- Creating your own fitness plan
- 16: Additional Reading
  - 16.1: Food Politics and Perspectives
  - 16.2: The Politics of Food
  - 16.3: The Food Industry
  - 16.4: Food Cost and Inflation
  - 16.5: Sustainability
  - 16.6: A Fresh Perspective- Sustainable Food Systems
  - 16.7: Start Your Sustainable Future Today

- 16.8: The Issue of Food Security
- 16.9: Diets around the World
- 16.10: Why Make Dietary Changes?
- 16.11: Nutrition and Your Health
- 16.12: Diet Trends and Health
- 16.13: Threats to Health
- 16.14: Careers in Nutrition

- Index
- Index
- Glossary
- Detailed Licensing

APUS: An Introduction to Nutrition 2e (Byerley)

- Licensing
- 1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet
  - 1.1: Chapter Introduction
  - 1.2: Defining Nutrition, Health, and Disease
  - 1.3: What Are Nutrients?
  - 1.4: Historical Perspectives on Food
  - 1.5: The Broad Role of Nutritional Science
  - 1.6: Health Factors and Their Impact
  - 1.7: Nutrition and the Media
  - 1.8: Assessing Personal Health
  - 1.9: Dietary Toolkit
  - 1.10: A Healthy Philosophy Toward Food
  - 1.11: Understanding the Bigger Picture of Dietary Guidelines
  - 1.12: What Is Nutritional Balance and Moderation?
  - 1.13: National Goals for Nutrition and Health- Healthy People 2030
  - 1.14: Recommendations for Optimal Health
  - 1.15: Understanding Dietary Reference Intakes
  - 1.16: Discovering Nutrition Facts
  - 1.17: When Enough is Enough
  - 1.E: Nutrition and You (Exercises)
- 2: Gastrointestinal Tract
  - 2.1: Chapter Introduction
  - 2.2: The Basic Structural and Functional Unit of Life- The Cell
  - 2.3: Digestion and Absorption
  - 2.4: Nutrients Are Essential for Organ Function
  - 2.5: Energy and Calories
  - 2.6: Gastrointestinal Tract and Your Health
  - 2.E: Exercises
- 3: Carbohydrates
  - 3.1: Introduction to Carbohydrates
  - 3.2: A Closer Look at Carbohydrates
  - 3.3: Digestion and Absorption of Carbohydrates
  - 3.4: The Functions of Carbohydrates in the Body
  - 3.5: Looking Closely at Diabetes
  - 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
  - 3.7: Carbohydrates and Personal Diet Choices

- 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
- 3.E: Exercises

- 4: Lipids
  - 4.1: Chapter Introduction
  - 4.2: What Are Lipids?
  - 4.3: How Lipids Work
  - 4.4: Digestion and Absorption of Lipids
  - 4.5: Understanding Blood Cholesterol
  - 4.6: Balancing Your Diet with Lipids
  - 4.7: Lipids and the Food Industry
  - 4.8: Lipids and Disease
  - 4.9: A Personal Choice about Lipids
  - 4.E: Exercises
- 5: Proteins
  - 5.1: Chapter Introduction
  - 5.2: Defining Protein
  - 5.3: The Role of Proteins in Foods- Cooking and Denaturation
  - 5.4: Protein Digestion, Absorption and Metabolism
  - 5.5: Protein's Functions in the Body
  - 5.6: Diseases Involving Proteins
  - 5.7: Proteins, Diet, and Personal Choices
  - 5.E: Proteins (Exercises)
- 6: Energy Metabolism
  - 6.1: Chapter Introduction
  - 6.2: Metabolism Overview
  - 6.3: Vitamins Important for Metabolism
  - 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
  - 6.5: Balancing Energy Input with Energy Output
  - 6.6: Too Little or Too Much Weight?
  - 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
  - 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
  - 6.E: Exercises
- 7: Food Drivers That Impact Your Nutrition
  - 7.1: Foodborne Illness and Food Safety
  - 7.2: The Politics of Food
  - 7.3: The Food Industry
  - 7.4: Food Cost and Inflation
  - 7.5: Sustainability
  - 7.6: A Fresh Perspective- Sustainable Food Systems
  - 7.7: Start Your Sustainable Future Today
  - 7.8: The Issue of Food Security
  - 7.9: Diets around the World
  - 7.10: Why Make Dietary Changes?
  - 7.11: Nutrition and Your Health
  - 7.12: Diet Trends and Health
  - 7.13: Threats to Health
  - 7.14: Careers in Nutrition
- 8: Antioxidant Nutrients
  - 8.1: Chapter Introduction
  - 8.2: Generation of Free Radicals in the Body

- 8.3: Antioxidant Micronutrients
- 8.4: The Whole Nutrient Package versus Disease
- 8.E: Exercises

- 9: Nutrients and Bone Metabolism
  - 9.1: Chapter Introduction
  - 9.2: Bone Structure and Function
  - 9.3: Bone Mineral Density is an Indicator of Bone Health
  - 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
  - 9.5: Other Essential Micronutrients for Bone Health
  - 9.6: Osteoporosis
  - 9.7: Risk Factors for Osteoporosis
  - 9.8: Osteoporosis Prevention and Treatment
  - 9.9: Deficiency, Supplementation, and Choices
  - 9.E: Nutrients Important for Bone Health (Exercises)
- 10: Nutrients Involved in Hematopoietic System
  - 10.1: Chapter Introduction
  - 10.2: Blood's Function in the Body and in Metabolism Support
  - 10.3: Vitamins Important for Metabolism and for Blood Function and Renewal
  - 10.4: Minerals Important for Blood Function and Renewal
  - 10.5: Iron-Deficiency Anemia
  - 10.E: Exercises
- 11: Water, Electrolytes, Acid-Base Balance
  - 11.1: Chapter Introduction
  - 11.2: Overview of Fluid and Electrolyte Balance
  - 11.3: Water's Importance to Vitality
  - 11.4: Regulation of Water Balance
  - 11.5: Electrolytes Important for Fluid Balance
  - 11.6: Consequences of Deficiency or Excess
  - 11.7: Water Concerns
  - 11.E: Water, Electrolytes, Acid-Base Balance (Exercises)
- 12: Maternal, Infant, Childhood, and Adolescent Nutrition
  - 12.1: Chapter Introduction
  - 12.2: The Human Life Cycle
  - 12.3: Pregnancy and Nutrition
  - 12.4: Infancy and Nutrition
  - 12.5: Nutrition in the Toddler Years
  - 12.6: Childhood and Nutrition
  - 12.7: Puberty and Nutrition
  - 12.8: Older Adolescence and Nutrition
  - 12.E: Exercises
- 13: Nutrition From Adulthood to the Elderly Years
  - 13.1: Chapter Introduction
  - 13.2: The Human Life Cycle Continues
  - 13.3: Young Adulthood and Nutrition
  - 13.4: Middle Age and Nutrition
  - 13.5: Old Age and Nutrition
  - 13.E: Exercises
- 14: Alcohol
  - 14.1: Introduction to Alcohol
  - 14.2: Alcohol Absorption and Metabolism

- 14.3: Pros and Cons of Drinking Alcohol
- 14.4: How Much to Drink?

- 15: Nutrition and Exercise
  - 15.1: Chapter Introduction
  - 15.2: Introduction to Nutrition and Physical Fitness
  - 15.3: Aerobic Exercise
  - 15.4: Anaerobic Exercise
  - 15.5: Nutrients that are critical to athletes
  - 15.6: Fitness Supplements and Steroids
  - 15.7: Fitness and Health
  - 15.8: Supplemental- Creating your own fitness plan
- Index
- Index
- Glossary
- Detailed Licensing

00: Front Matter

- TitlePage
- InfoPage
- Table of Contents
- Licensing

Index

Glossary

Detailed Licensing

Licensing

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00: Front Matter

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TABLE OF CONTENTS

APUS: An Introduction to Nutrition 1st Edition

- Licensing
- 1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet
  - 1.1: Chapter Introduction
  - 1.2: Defining Nutrition, Health, and Disease
  - 1.3: What Are Nutrients?
  - 1.4: Historical Perspectives on Food
  - 1.5: The Broad Role of Nutritional Science
  - 1.6: Health Factors and Their Impact
  - 1.7: Nutrition and the Media
  - 1.8: Assessing Personal Health
  - 1.9: Dietary Toolkit
  - 1.10: A Healthy Philosophy toward Food
  - 1.11: Understanding the Bigger Picture of Dietary Guidelines
  - 1.12: What Is Nutritional Balance and Moderation?
  - 1.13: National Goals for Nutrition and Health- Healthy People 2020
  - 1.14: Recommendations for Optimal Health
  - 1.15: Understanding Dietary Reference Intakes
  - 1.16: Discovering Nutrition Facts
  - 1.17: When Enough is Enough
  - 1.18: Foodborne Illness and Food Safety
  - 1.E: Nutrition and You (Exercises)
- 2: Gastrointestinal Tract
  - 2.1: Chapter Introduction
  - 2.2: The Basic Structural and Functional Unit of Life- The Cell
  - 2.3: Digestion and Absorption
  - 2.4: Nutrients Are Essential for Organ Function
  - 2.5: Energy and Calories
  - 2.6: Gastrointestinal Tract and Your Health
  - 2.E: Exercises
- 3: Carbohydrates
  - 3.1: Introduction to Carbohydrates
  - 3.2: A Closer Look at Carbohydrates
  - 3.3: Digestion and Absorption of Carbohydrates
  - 3.4: The Functions of Carbohydrates in the Body
  - 3.5: Looking Closely at Diabetes
  - 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
  - 3.7: Carbohydrates and Personal Diet Choices
  - 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
  - 3.E: Exercises
- 4: Lipids
  - 4.1: Chapter Introduction
  - 4.2: What Are Lipids?
  - 4.3: How Lipids Work
  - 4.4: Digestion and Absorption of Lipids
  - 4.5: Understanding Blood Cholesterol

- 4.6: Balancing Your Diet with Lipids
- 4.7: Lipids and the Food Industry
- 4.8: Lipids and Disease
- 4.9: A Personal Choice about Lipids
- 4.E: Exercises

- 5: Proteins
  - 5.1: Chapter Introduction
  - 5.2: Defining Protein
  - 5.3: The Role of Proteins in Foods- Cooking and Denaturation
  - 5.4: Protein Digestion, Absorption and Metabolism
  - 5.5: Protein's Functions in the Body
  - 5.6: Diseases Involving Proteins
  - 5.7: Proteins, Diet, and Personal Choices
  - 5.E: Proteins (Exercises)
- 6: Energy Metabolism
  - 6.1: Chapter Introduction
  - 6.2: Metabolism Overview
  - 6.3: Vitamins Important for Metabolism
  - 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
  - 6.5: Balancing Energy Input with Energy Output
  - 6.6: Too Little or Too Much Weight?
  - 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
  - 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
  - 6.E: Exercises
- 7: Nutrition and Cancer
  - 7.1: Chapter Introduction
  - 7.2: Carcinogenesis
  - 7.3: Diet and Cancer
- 8: Antioxidant Nutrients
  - 8.1: Chapter Introduction
  - 8.2: Generation of Free Radicals in the Body
  - 8.3: Antioxidant Micronutrients
  - 8.4: The Whole Nutrient Package versus Disease
  - 8.E: Exercises
- 9: Nutrients and Bone Metabolism
  - 9.1: Chapter Introduction
  - 9.2: Bone Structure and Function
  - 9.3: Bone Mineral Density is an Indicator of Bone Health
  - 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
  - 9.5: Other Essential Micronutrients for Bone Health
  - 9.6: Osteoporosis
  - 9.7: Risk Factors for Osteoporosis
  - 9.8: Osteoporosis Prevention and Treatment
  - 9.9: Deficiency, Supplementation, and Choices
  - 9.E: Nutrients Important for Bone Health (Exercises)
- 10: Water, Electrolytes, Acid-Base Balance
  - 10.1: Chapter Introduction
  - 10.2: Overview of Fluid and Electrolyte Balance
  - 10.3: Water's Importance to Vitality
  - 10.4: Regulation of Water Balance

- 10.5: Electrolytes Important for Fluid Balance
- 10.6: Consequences of Deficiency or Excess
- 10.7: Water Concerns
- 10.E: Water, Electrolytes, Acid-Base Balance (Exercises)

- 11: Nutrients Involved in Hematopoietic System
  - 11.1: Chapter Introduction
  - 11.2: Blood's Function in the Body and in Metabolism Support
  - 11.3: Vitamins Important for Metabolism and for Blood Function and Renewal
  - 11.4: Minerals Important for Blood Function and Renewal
  - 11.5: Iron-Deficiency Anemia
  - 11.E: Exercises
- 12: Maternal, Infant, Childhood, and Adolescent Nutrition
  - 12.1: Chapter Introduction
  - 12.2: The Human Life Cycle
  - 12.3: Pregnancy and Nutrition
  - 12.4: Infancy and Nutrition
  - 12.5: Nutrition in the Toddler Years
  - 12.6: Childhood and Nutrition
  - 12.7: Puberty and Nutrition
  - 12.8: Older Adolescence and Nutrition
  - 12.E: Exercises
- 13: Nutrition From Adulthood to the Elderly Years
  - 13.1: Chapter Introduction
  - 13.2: The Human Life Cycle Continues
  - 13.3: Young Adulthood and Nutrition
  - 13.4: Middle Age and Nutrition
  - 13.5: Old Age and Nutrition
  - 13.E: Exercises
- 14: Alcohol
  - 14.1: Introduction to Alcohol
  - 14.2: Alcohol Absorption and Metabolism
  - 14.3: Pros and Cons of Drinking Alcohol
  - 14.4: How Much to Drink?
- 15: Nutrition and Exercise
  - 15.1: Chapter Introduction
  - 15.2: Introduction to Nutrition and Physical Fitness
  - 15.3: Aerobic Exercise
  - 15.4: Anaerobic Exercise
  - 15.5: Nutrients that are critical to athletes
  - 15.6: Fitness Supplements and Steroids
  - 15.7: Fitness and Health
  - 15.8: Supplemental- Creating your own fitness plan
- 16: Additional Reading
  - 16.1: Food Politics and Perspectives
  - 16.2: The Politics of Food
  - 16.3: The Food Industry
  - 16.4: Food Cost and Inflation
  - 16.5: Sustainability
  - 16.6: A Fresh Perspective- Sustainable Food Systems
  - 16.7: Start Your Sustainable Future Today

- 16.8: The Issue of Food Security
- 16.9: Diets around the World
- 16.10: Why Make Dietary Changes?
- 16.11: Nutrition and Your Health
- 16.12: Diet Trends and Health
- 16.13: Threats to Health
- 16.14: Careers in Nutrition

- Index
- Index
- Glossary
- Detailed Licensing

APUS: An Introduction to Nutrition 2e (Byerley)

- Licensing
- 1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet
  - 1.1: Chapter Introduction
  - 1.2: Defining Nutrition, Health, and Disease
  - 1.3: What Are Nutrients?
  - 1.4: Historical Perspectives on Food
  - 1.5: The Broad Role of Nutritional Science
  - 1.6: Health Factors and Their Impact
  - 1.7: Nutrition and the Media
  - 1.8: Assessing Personal Health
  - 1.9: Dietary Toolkit
  - 1.10: A Healthy Philosophy Toward Food
  - 1.11: Understanding the Bigger Picture of Dietary Guidelines
  - 1.12: What Is Nutritional Balance and Moderation?
  - 1.13: National Goals for Nutrition and Health- Healthy People 2030
  - 1.14: Recommendations for Optimal Health
  - 1.15: Understanding Dietary Reference Intakes
  - 1.16: Discovering Nutrition Facts
  - 1.17: When Enough is Enough
  - 1.E: Nutrition and You (Exercises)
- 2: Gastrointestinal Tract
  - 2.1: Chapter Introduction
  - 2.2: The Basic Structural and Functional Unit of Life- The Cell
  - 2.3: Digestion and Absorption
  - 2.4: Nutrients Are Essential for Organ Function
  - 2.5: Energy and Calories
  - 2.6: Gastrointestinal Tract and Your Health
  - 2.E: Exercises
- 3: Carbohydrates
  - 3.1: Introduction to Carbohydrates
  - 3.2: A Closer Look at Carbohydrates
  - 3.3: Digestion and Absorption of Carbohydrates
  - 3.4: The Functions of Carbohydrates in the Body
  - 3.5: Looking Closely at Diabetes
  - 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
  - 3.7: Carbohydrates and Personal Diet Choices

- 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
- 3.E: Exercises

- 4: Lipids
  - 4.1: Chapter Introduction
  - 4.2: What Are Lipids?
  - 4.3: How Lipids Work
  - 4.4: Digestion and Absorption of Lipids
  - 4.5: Understanding Blood Cholesterol
  - 4.6: Balancing Your Diet with Lipids
  - 4.7: Lipids and the Food Industry
  - 4.8: Lipids and Disease
  - 4.9: A Personal Choice about Lipids
  - 4.E: Exercises
- 5: Proteins
  - 5.1: Chapter Introduction
  - 5.2: Defining Protein
  - 5.3: The Role of Proteins in Foods- Cooking and Denaturation
  - 5.4: Protein Digestion, Absorption and Metabolism
  - 5.5: Protein's Functions in the Body
  - 5.6: Diseases Involving Proteins
  - 5.7: Proteins, Diet, and Personal Choices
  - 5.E: Proteins (Exercises)
- 6: Energy Metabolism
  - 6.1: Chapter Introduction
  - 6.2: Metabolism Overview
  - 6.3: Vitamins Important for Metabolism
  - 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
  - 6.5: Balancing Energy Input with Energy Output
  - 6.6: Too Little or Too Much Weight?
  - 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
  - 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
  - 6.E: Exercises
- 7: Food Drivers That Impact Your Nutrition
  - 7.1: Foodborne Illness and Food Safety
  - 7.2: The Politics of Food
  - 7.3: The Food Industry
  - 7.4: Food Cost and Inflation
  - 7.5: Sustainability
  - 7.6: A Fresh Perspective- Sustainable Food Systems
  - 7.7: Start Your Sustainable Future Today
  - 7.8: The Issue of Food Security
  - 7.9: Diets around the World
  - 7.10: Why Make Dietary Changes?
  - 7.11: Nutrition and Your Health
  - 7.12: Diet Trends and Health
  - 7.13: Threats to Health
  - 7.14: Careers in Nutrition
- 8: Antioxidant Nutrients
  - 8.1: Chapter Introduction
  - 8.2: Generation of Free Radicals in the Body

- 8.3: Antioxidant Micronutrients
- 8.4: The Whole Nutrient Package versus Disease
- 8.E: Exercises

- 9: Nutrients and Bone Metabolism
  - 9.1: Chapter Introduction
  - 9.2: Bone Structure and Function
  - 9.3: Bone Mineral Density is an Indicator of Bone Health
  - 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
  - 9.5: Other Essential Micronutrients for Bone Health
  - 9.6: Osteoporosis
  - 9.7: Risk Factors for Osteoporosis
  - 9.8: Osteoporosis Prevention and Treatment
  - 9.9: Deficiency, Supplementation, and Choices
  - 9.E: Nutrients Important for Bone Health (Exercises)
- 10: Nutrients Involved in Hematopoietic System
  - 10.1: Chapter Introduction
  - 10.2: Blood's Function in the Body and in Metabolism Support
  - 10.3: Vitamins Important for Metabolism and for Blood Function and Renewal
  - 10.4: Minerals Important for Blood Function and Renewal
  - 10.5: Iron-Deficiency Anemia
  - 10.E: Exercises
- 11: Water, Electrolytes, Acid-Base Balance
  - 11.1: Chapter Introduction
  - 11.2: Overview of Fluid and Electrolyte Balance
  - 11.3: Water's Importance to Vitality
  - 11.4: Regulation of Water Balance
  - 11.5: Electrolytes Important for Fluid Balance
  - 11.6: Consequences of Deficiency or Excess
  - 11.7: Water Concerns
  - 11.E: Water, Electrolytes, Acid-Base Balance (Exercises)
- 12: Maternal, Infant, Childhood, and Adolescent Nutrition
  - 12.1: Chapter Introduction
  - 12.2: The Human Life Cycle
  - 12.3: Pregnancy and Nutrition
  - 12.4: Infancy and Nutrition
  - 12.5: Nutrition in the Toddler Years
  - 12.6: Childhood and Nutrition
  - 12.7: Puberty and Nutrition
  - 12.8: Older Adolescence and Nutrition
  - 12.E: Exercises
- 13: Nutrition From Adulthood to the Elderly Years
  - 13.1: Chapter Introduction
  - 13.2: The Human Life Cycle Continues
  - 13.3: Young Adulthood and Nutrition
  - 13.4: Middle Age and Nutrition
  - 13.5: Old Age and Nutrition
  - 13.E: Exercises
- 14: Alcohol
  - 14.1: Introduction to Alcohol
  - 14.2: Alcohol Absorption and Metabolism

- 14.3: Pros and Cons of Drinking Alcohol
- 14.4: How Much to Drink?

- 15: Nutrition and Exercise
  - 15.1: Chapter Introduction
  - 15.2: Introduction to Nutrition and Physical Fitness
  - 15.3: Aerobic Exercise
  - 15.4: Anaerobic Exercise
  - 15.5: Nutrients that are critical to athletes
  - 15.6: Fitness Supplements and Steroids
  - 15.7: Fitness and Health
  - 15.8: Supplemental- Creating your own fitness plan
- Index
- Index
- Glossary
- Detailed Licensing

00: Front Matter

- TitlePage
- InfoPage
- Table of Contents
- Licensing

Index

Glossary

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

Front Matter

TitlePage
InfoPage
Table of Contents
Licensing

APUS: An Introduction to Nutrition

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TABLE OF CONTENTS

Licensing

1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet

- 1.1: Chapter Introduction
- 1.2: Defining Nutrition, Health, and Disease
- 1.3: What Are Nutrients?
- 1.4: Historical Perspectives on Food
- 1.5: The Broad Role of Nutritional Science
- 1.6: Health Factors and Their Impact
- 1.7: Nutrition and the Media
- 1.8: Assessing Personal Health
- 1.9: Dietary Toolkit
- 1.10: A Healthy Philosophy toward Food
- 1.11: Understanding the Bigger Picture of Dietary Guidelines
- 1.12: What Is Nutritional Balance and Moderation?
- 1.13: National Goals for Nutrition and Health- Healthy People 2020
- 1.14: Recommendations for Optimal Health
- 1.15: Understanding Dietary Reference Intakes
- 1.16: Discovering Nutrition Facts
- 1.17: When Enough is Enough
- 1.18: Foodborne Illness and Food Safety
- 1.E: Nutrition and You (Exercises)

2: Gastrointestinal Tract

- 2.1: Chapter Introduction
- 2.2: The Basic Structural and Functional Unit of Life- The Cell
- 2.3: Digestion and Absorption
- 2.4: Nutrients Are Essential for Organ Function
- 2.5: Energy and Calories
- 2.6: Gastrointestinal Tract and Your Health
- 2.E: Exercises

3: Carbohydrates

- 3.1: Introduction to Carbohydrates
- 3.2: A Closer Look at Carbohydrates
- 3.3: Digestion and Absorption of Carbohydrates
- 3.4: The Functions of Carbohydrates in the Body
- 3.5: Looking Closely at Diabetes
- 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
- 3.7: Carbohydrates and Personal Diet Choices
- 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
- 3.E: Exercises

4: Lipids

- 4.1: Chapter Introduction
- 4.2: What Are Lipids?

- 4.3: How Lipids Work
- 4.4: Digestion and Absorption of Lipids
- 4.5: Understanding Blood Cholesterol
- 4.6: Balancing Your Diet with Lipids
- 4.7: Lipids and the Food Industry
- 4.8: Lipids and Disease
- 4.9: A Personal Choice about Lipids
- 4.E: Exercises

5: Proteins

- 5.1: Chapter Introduction
- 5.2: Defining Protein
- 5.3: The Role of Proteins in Foods- Cooking and Denaturation
- 5.4: Protein Digestion, Absorption and Metabolism
- 5.5: Protein's Functions in the Body
- 5.6: Diseases Involving Proteins
- 5.7: Proteins, Diet, and Personal Choices
- 5.E: Proteins (Exercises)

6: Energy Metabolism

- 6.1: Chapter Introduction
- 6.2: Metabolism Overview
- 6.3: Vitamins Important for Metabolism
- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
- 6.5: Balancing Energy Input with Energy Output
- 6.6: Too Little or Too Much Weight?
- 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
- 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
- 6.E: Exercises

7: Nutrition and Cancer

- 7.1: Chapter Introduction
- 7.2: Carcinogenesis
- 7.3: Diet and Cancer

8: Antioxidant Nutrients

- 8.1: Chapter Introduction
- 8.2: Generation of Free Radicals in the Body
- 8.3: Antioxidant Micronutrients
- 8.4: The Whole Nutrient Package versus Disease
- 8.E: Exercises

9: Nutrients and Bone Metabolism

- 9.1: Chapter Introduction
- 9.2: Bone Structure and Function
- 9.3: Bone Mineral Density is an Indicator of Bone Health
- 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
- 9.5: Other Essential Micronutrients for Bone Health
- 9.6: Osteoporosis
- 9.7: Risk Factors for Osteoporosis

- 9.8: Osteoporosis Prevention and Treatment
- 9.9: Deficiency, Supplementation, and Choices
- 9.E: Nutrients Important for Bone Health (Exercises)

10: Water, Electrolytes, Acid-Base Balance

- 10.1: Chapter Introduction
- 10.2: Overview of Fluid and Electrolyte Balance
- 10.3: Water's Importance to Vitality
- 10.4: Regulation of Water Balance
- 10.5: Electrolytes Important for Fluid Balance
- 10.6: Consequences of Deficiency or Excess
- 10.7: Water Concerns
- 10.E: Water, Electrolytes, Acid-Base Balance (Exercises)

11: Nutrients Involved in Hematopoietic System

- 11.1: Chapter Introduction
- 11.2: Blood's Function in the Body and in Metabolism Support
- 11.3: Vitamins Important for Metabolism and for Blood Function and Renewal
- 11.4: Minerals Important for Blood Function and Renewal
- 11.5: Iron-Deficiency Anemia
- 11.E: Exercises

12: Maternal, Infant, Childhood, and Adolescent Nutrition

- 12.1: Chapter Introduction
- 12.2: The Human Life Cycle
- 12.3: Pregnancy and Nutrition
- 12.4: Infancy and Nutrition
- 12.5: Nutrition in the Toddler Years
- 12.6: Childhood and Nutrition
- 12.7: Puberty and Nutrition
- 12.8: Older Adolescence and Nutrition
- 12.E: Exercises

13: Nutrition From Adulthood to the Elderly Years

- 13.1: Chapter Introduction
- 13.2: The Human Life Cycle Continues
- 13.3: Young Adulthood and Nutrition
- 13.4: Middle Age and Nutrition
- 13.5: Old Age and Nutrition
- 13.E: Exercises

14: Alcohol

- 14.1: Introduction to Alcohol
- 14.2: Alcohol Absorption and Metabolism
- 14.3: Pros and Cons of Drinking Alcohol
- 14.4: How Much to Drink?

15: Nutrition and Exercise

- 15.1: Chapter Introduction
- 15.2: Introduction to Nutrition and Physical Fitness
- 15.3: Aerobic Exercise
- 15.4: Anaerobic Exercise
- 15.5: Nutrients that are critical to athletes
- 15.6: Fitness Supplements and Steroids
- 15.7: Fitness and Health
- 15.8: Supplemental- Creating your own fitness plan

16: Additional Reading

- 16.1: Food Politics and Perspectives
- 16.2: The Politics of Food
- 16.3: The Food Industry
- 16.4: Food Cost and Inflation
- 16.5: Sustainability
- 16.6: A Fresh Perspective- Sustainable Food Systems
- 16.7: Start Your Sustainable Future Today
- 16.8: The Issue of Food Security
- 16.9: Diets around the World
- 16.10: Why Make Dietary Changes?
- 16.11: Nutrition and Your Health
- 16.12: Diet Trends and Health
- 16.13: Threats to Health
- 16.14: Careers in Nutrition

Index

Index

Glossary

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet

In this Chapter, we provide an overview of nutrition as an evidence-based science and explore the concepts of health, wellness, and disease. We also provide an introduction to the different types of nutrients, health factors, personal health assessment, and the concept of sustainable food systems.

1.1: Chapter Introduction
1.2: Defining Nutrition, Health, and Disease
1.3: What Are Nutrients?
1.4: Historical Perspectives on Food
1.5: The Broad Role of Nutritional Science
1.6: Health Factors and Their Impact
1.7: Nutrition and the Media
1.8: Assessing Personal Health
1.9: Dietary Toolkit
1.10: A Healthy Philosophy toward Food
1.11: Understanding the Bigger Picture of Dietary Guidelines
1.12: What Is Nutritional Balance and Moderation?
1.13: National Goals for Nutrition and Health- Healthy People 2020
1.14: Recommendations for Optimal Health
1.15: Understanding Dietary Reference Intakes
1.16: Discovering Nutrition Facts
1.17: When Enough is Enough
1.18: Foodborne Illness and Food Safety
1.E: Nutrition and You (Exercises)

Template:HideTOC

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1.1: Chapter Introduction

Nutrition is an evidence-based science. Nutritional scientists continuously advance our knowledge of nutrition by building on prior research.

Video Link 1.1.1

Nutrition Quiz: Listen to what Americans think 100 Calories looks like.



As we get started on our journey into the world of health and nutrition, our first focus will be to demonstrate that nutritional science is an evolving field of study, continually being updated and supported by research, studies, and trials. Once we establish this, your confidence will be strengthened in nutritional science to help guide your eating habits. Let's begin with the story of hurry, curry, and worry: the story of *Helicobacter (H.) pylori*.

Peptic ulcers are painful sores in the gastrointestinal tract and can cause symptoms of abdominal pain, nausea, loss of appetite, and weight loss. The cure for this ailment took some time for scientists to figure out. If your grandfather complained to his doctor of symptoms of peptic ulcer, he was probably told to avoid spicy foods, alcohol, and coffee, and to manage his stress. In the early twentieth century, the medical community thought peptic ulcers were caused by what you ate and drank, and by stress. In 1915, Dr. Bertram W. Sippy devised the "Sippy diet" for treating peptic ulcers. Dr. Sippy advised patients to drink small amounts of cream and milk every hour in order to neutralize stomach acid. And then, increasingly, introduce soft bland foods with frequent meal times. For a while this diet sometimes worked, fooling both doctors and patients. However, the disappearance of peptic ulcer symptoms was likely the result of having a full stomach all the time, as the symptoms more often occur when the stomach is empty. Ultimately, the Sippy diet did not cure peptic ulcers and in the latter 1960s, scientists discovered the diet was associated with a significant increase in heart disease due to its high saturated fat content.

In the 1980s, Australian physicians Barry Marshall and Robin Warren Currey, R. "Ulcers—The Culprit Is *H. Pylori*!" National proposed a radical hypothesis—that the cause of ulcers was bacteria that could survive in the acidic environment of the stomach and small intestine. They met with significant opposition to their hypothesis but they persisted with their research. Their research led to an understanding that the spiral shape of the bacterium *H. pylori* allows it to penetrate the stomach's mucous lining, where it secretes an enzyme that generates substances to neutralize the stomach's acidity. This weakens the stomach's protective mucus, making the tissue more susceptible to the damaging effects of acid, leading to the development of sores and ulcers. *H. pylori* also prompt the stomach to produce even more acid, further damaging the stomach lining. Marshall actually drank a dish of *H. pylori* hoping to give himself an ulcer to prove his point. A few days later he was vomiting and had inflamed tissue in his stomach. The presence of H. pylori was confirmed. He then took an antibiotic and the symptoms of *H. pylori* infection dissipated. Experimental success? It still took years for the medical community to be entirely convinced of the link between peptic ulcers and *H. pylori*.

Video Link 1.1.2

YouTube Video about the discovery of H. *pylori*.



In 1994, the National Institutes of Health held a conference on the cause of peptic ulcers. There was scientific consensus that H. pylori cause most peptic ulcers and that patients should be treated with antibiotics. In 1996, the Food and Drug Administration (FDA) approved the first antibiotic that could be used to treat patients with peptic ulcers. Nevertheless, the link between H. pylori and peptic ulcers was not sufficiently communicated to health-care providers. In fact, 75 percent of patients with peptic ulcers in the late 1990s were still being prescribed antacid medications and advised to change their diet and reduce their stress. In 1997, the Centers for Disease Control and Prevention (CDC), alongside other public health organizations, began an intensive educational campaign to convince the public and health-care providers that peptic ulcers are a curable condition requiring treatment with antibiotics. Today, if you go to your primary physician you will be given the option of taking an antibiotic to eradicate *H. pylori* from your gut. Scientists have progressed even further and mapped the entire genome of H. pylori, which will hopefully aid in the discovery of even better drugs to treat peptic ulcers.

The *H. pylori* discovery was made recently, overturning a theory applied in our own time. The demystification of disease requires the continuous forward march of science, overturning old, traditional theories and discovering new, more effective ways to treat disease and promote health. In 2005, Marshall and Warren were awarded the prestigious Nobel Prize in medicine for their discovery that many stomach ulcers are caused by H. pylori—not by hurry, curry, and worry.

> *Make a commitment to empower yourself with scientific evidence as a strategy for achieving a healthier diet.*

A primary goal of this text is to provide you with information backed by nutritional science and with a variety of resources that use scientific evidence to optimize health and prevent disease. In this chapter, you will see that there are many conditions and deadly diseases that can be prevented by good nutrition. You will also discover the many other determinants of health and disease, how the powerful tool of scientific investigation is used to design dietary guidelines and recommendations that will promote health and prevent disease.

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1.2: Defining Nutrition, Health, and Disease

Learning Objective

- Explain the terms nutrition, health, health promotion, and disease prevention.

Your View of Food

Food is any nutritious substance that people or animals eat or drink, or that plants absorb, in order to maintain life and growth. Americans are bombarded with television programs that show where to find the best dinners, pizzas, and cakes, and the restaurants that serve the biggest and juiciest burgers. Other programs feature chefs battling to prepare meals, and the top places to burst your belly from consuming atomic chicken wings and deli sandwiches longer than a foot. There are also shows that feature bizarre foods from cultures around the world. How do you use the information from popular network food shows to build a nutritious meal? You don't—these shows are for entertainment. The construction of a nutritious meal requires learning about which foods are healthy and which foods are not, how foods and nutrients function in your body, and how to use scientific resources. This text is designed to provide you with the information necessary to make sound nutritional choices that will optimize health and help prevent disease.



Figure 1.2.1 The Nutrition Facts panel provides information to help you select foods so you can fill your plate wisely. © Shutterstock

How do you fill your plate?

The word nutrition first appeared in 1551 and comes from the Latin word *nutrire*, meaning "to nourish." Today, we define Nutritional science is the investigation of how an organism is nourished, and incorporates the study of how nourishment affects personal health, population health, and planetary health. Nutritional science covers a wide spectrum of disciplines. As a result, nutritional scientists can specialize in particular aspects of nutrition such as biology, physiology, immunology, biochemistry, education, psychology, sustainability, and sociology.

Without adequate nutrition the human body does not function optimally, and severe nutritional inadequacy can lead to disease and even death. The typical American diet is lacking in many ways, from not containing the proper amounts of essential nutrients, to being too speedily consumed, to being only meagerly satisfying. Dietitians are nutrition professionals who integrate their knowledge of nutritional science into helping people achieve a healthy diet and develop good dietary habits. The Academy of Nutrition and Dietetics (AND) is the largest organization of nutrition professionals worldwide and dietitians registered with the AND are committed to helping Americans eat well and live healthier lives. To learn more from the AND's nutritional advice, visit EatRight.Org

Your ability to wake up, to think clearly, to communicate, to hope, to dream, to go to school, to gain knowledge, to go to work, to earn a living, and to do all of the things that you like to do are dependent upon one factor—your health. Good health means you are able to function normally and work hard to achieve your goals in life. For the next few minutes, take some time to view snapshots of the insides of the refrigerators of American mechanics, doctors, school teachers, hunters, short-order cooks, college students, vegans, and more. Visit Mark Menjivar's portrait exhibition, "You Are What You Eat". Menjivar hopes these images will invoke new thoughts about, "How we care for our bodies. How we care for others. And how we care for the land." As you look at these

images think about your personal health, the health of your family and friends, and the health of this planet. These hopes encompass the inspirations for this book.

Interactive 1.2.1

Mark Menjivar has traveled around the United States taking photographs of the contents of refrigerators of numerous types of people. The portraits are available for viewing on his website under “You Are What You Eat.” Then click on "Refrigerators" on the left.

Nutrition and Health and Disease

In 1946, the World Health Organization (WHO) defined healthas “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.”World Health Organization. Preamble to the *Constitution of the World Health Organization* as adopted by the International Health Conference, New York, June 19–July 22, 1946. http://www.who.int/suggestions/faq/en/ This definition was adopted into the WHO constitution in 1948 and has not been ammended since. A triangle is often used to depict the equal influences of physical, mental, and social well-being on health (Figure 1.1). Disease is defined as any abnormal condition affecting the health of an organism, and is characterized by specific signs and symptoms. Signs refer to identifying characteristics of a disease such as swelling, weight loss, or fever. Symptoms are the features of a disease recognized by a patient and/or their doctor. Symptoms can include nausea, fatigue, irritability, and pain. Diseases are broadly categorized as resulting from pathogens (i.e., bacteria, viruses, fungi, and parasites), deficiencies, genetics, and physiological dysfunction. Diseases that primarily affect physical health are those that impair body structure (as is the case with osteoporosis), or functioning (as is the case with cardiovascular disease). Mental illnesses primarily affect mental and social well-being.

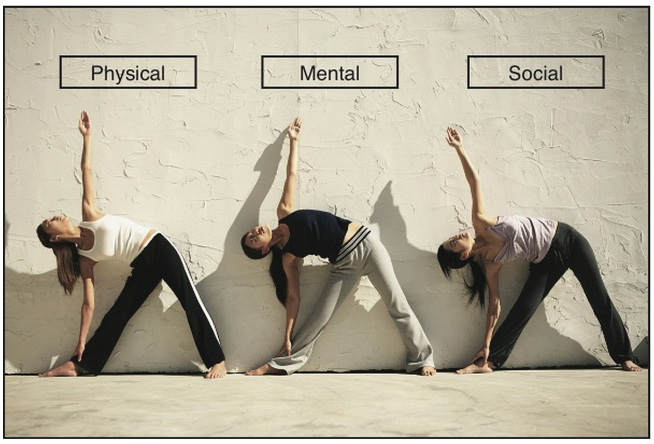


Figure 1.2.2: The Health Triangle. © Thinkstock

The foods we eat affect all three aspects of our health. For example, a teen with Type 2 diabetes (a disease brought on by poor diet) is first diagnosed by physical signs and symptoms such as increased urination, thirstiness, and unexplained weight loss. But research has also found that teens with Type 2 diabetes have impaired thinking and do not interact well with others in school, thereby affecting mental and social well-being. Type 2 diabetes is just one example of a physiological disease that affects all aspects of health—physical, mental, and social.

Public Health and Disease Prevention

In 1894, the first congressional funds were appropriated to the US Department of Agriculture (USDA) for the study of the relationship between nutrition and human health. Dr. Wilbur Olin Atwater was appointed as the Chief of Nutrition Investigations and is regarded as the “Father of Nutrition Science” in America. Under his guidance, the USDA released the first bulletin to the American public that contained information on the amounts of fat, carbohydrates, proteins, and food energy in various foods. Nutritional science advanced considerably in these early years, but it took until 1980 for the USDA and the US Department of Health and Human Services (HHS) to jointly release the first edition of *Nutrition and Your Health: Dietary Guidelines for Americans*.

Although the wide distribution of dietary guidelines did not come about until the 1980s, many historical events that demonstrated the importance of diet to health preceded their release. Assessments of the American diet in the 1930s led President Franklin D. Roosevelt to declare in his inaugural address on January 20, 1937, “I see one-third of our nation is ill-housed, ill-clad, and ill-nourished.” From the time of Atwater until the onset of the Great Depression, nutrition scientists had discovered many of the vitamins and minerals that are essential for the functioning of the human body. Their work and the acknowledgment by President FDR of the nutritional inadequacy of the American diet evoked a united response from scientists and government, leading to the enrichment of flour, the development of school lunch programs, and advancements of nutritional education in this country.

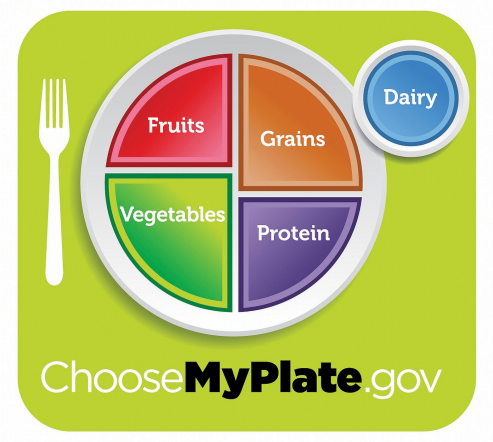


Figure 1.2.3: The Federal Government’s New and Improved Tool of Nutritional Communication

In the latter part of the twentieth-century nutrition scientists, public health organizations, and the American public increasingly recognized that eating too much of certain foods is linked to chronic diseases. We now know that diet-related conditions and diseases include: hypertension (high blood pressure), obesity, Type 2 diabetes, cardiovascular disease, some cancers, and osteoporosis. These diet-related conditions and diseases are some of the biggest killers of Americans with heart disease is the number one killer. The United States Department of Health and Human Services (HHS) reports that unhealthy diets and inactivity cause between 310,000 and 580,000 deaths every single year. According to the United States Department of Agriculture (USDA), eating healthier could save Americans over $70 billion per year and this does not include the cost of obesity, which is estimated to cost a further $117 billion per year. Unfortunately, despite the fact that the prevalence of these diseases can be decreased by healthier diets and increased physical activity, the Center for Disease Control (CDC) reports that the federal government spends one thousand times more to treat disease than to prevent it ($1,390 versus $1.21 per person each year). In 2015, the newest edition of the Dietary Guidelines for Americans identified obesity as the number one nutritional-related health problem in the United States and established strategies to combat its incidence and health consequences in the American population. A 2008 study in the journal *Obesity* reported that if current trends are not changed, 100 percent of Americans will be overweight or obese in 2048! Wang Y, et al. “Will All Americans Become Overweight or Obese? Estimating the Progression and Cost of the US Obesity Epidemic.” *Obesity* 10, no. 16 (October 2008): 2323–30. http://www.nature.com/oby/journal/v16/n10/full/oby2008351a.html In 2011, the US federal government released a new multimedia tool that aims to help Americans choose healthier foods from the five food groups (grains, vegetables, fruits, dairy, and proteins). The tool, called “Choose MyPlate,” is available at choosemyplate.gov.

Key Takeaways

- Health is defined as “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.” World Health Organization.
- Disease is defined as any abnormal condition that affects the health of an organism and is characterized by specific signs and symptoms.
- Nutrition is defined as the science of how we take in food and that food is utilized by our body.
- Disease affects all three aspects of the health triangle.
- Good nutrition provides a mechanism to promote health and prevent disease.
- Diet-related conditions and diseases include obesity, Type 2 diabetes, cardiovascular disease, some cancers, and osteoporosis.
- It took until the 1980s for the US federal government to develop a diet-related public policy designed to equip Americans with the tools to change to a healthier diet.

Discussion Starters

1. How might the way we nourish our bodies affect planetary health?
2. Debate your classmates: Should the federal government be concerned with what Americans eat?

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1.3: What Are Nutrients?

Learning Objective

- Define the word “nutrient” and identify the six classes of nutrients essential for health.
- List the three energy-yielding nutrients and their energy contribution.

What is in Food?

The foods we eat contain nutrients. Those nutrients that contain carbon are called organic while those that do not contain carbon are called inorganic. Nutrients are substances required by the body to perform its basic functions. Since the human body does not synthesize nutrients, they must be obtained from the diet, making them essential. Eating inadequate amounts can cause poor health.

Nutrients are used to produce energy, detect and respond to environmental surroundings, move, excrete wastes, respire (breathe), grow, and reproduce. There are six classes of nutrients required for the body to function and maintain overall health. These are carbohydrates, lipids, proteins, water, vitamins, and minerals. Foods also contain nonnutrients that may be harmful (such as cholesterol, dyes, and preservatives) or beneficial (such as phytochemicals like antioxidants and zoochemicals like omega-3 fatty acids).

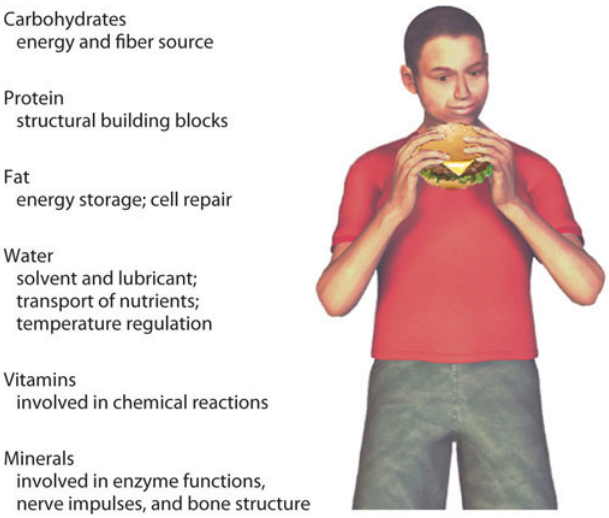


Figure 1.3.1: The Six Classes of Nutrients. Source: www.chemistry.wustl.edu/~edudev/LabTutorials/Vitamins/vitamins.html.

Macronutrients

Nutrients that are needed in large amounts (grams) are called macronutrients. There are three classes of macronutrients: carbohydrates, lipids, and proteins. These can be metabolically processed into cellular energy. The energy from macronutrients comes from their chemical bonds. This chemical energy is converted into cellular energy that is then utilized to perform work, allowing our bodies to conduct their basic functions. A unit of measurement of food energy is the calorie. On nutrition food labels the amount given for “calories” is actually equivalent to each calorie multiplied by one thousand. A kilocalorie (one thousand calories, denoted with a small “c”) is synonymous with the “Calorie” (with a capital “C”) on nutrition food labels. Water is also a macronutrient in the sense that you require a large amount of it, but unlike the other macronutrients it does not yield calories.

Carbohydrates

Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. The major food sources of carbohydrates are grains, milk, fruits, and vegetables, including starchy vegetables like potatoes. Nonstarchy vegetables also contain carbohydrates but in lesser quantities. Carbohydrates are broadly classified into two forms based on their chemical structure: fast-releasing carbohydrates often called simple sugars, and complex or slow-releasing carbohydrates also called polysacchrides.

Fast-releasing carbohydrates consist of one or two basic units. Examples of simple sugars include sucrose, the type of sugar you would have in a bowl on the breakfast table, and glucose, the type of sugar that circulates in your blood.

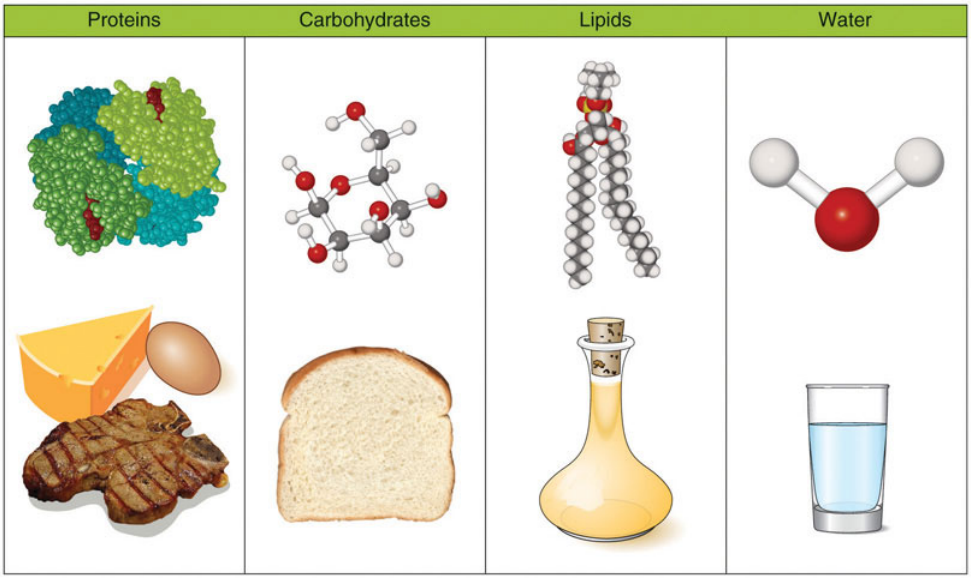


Figure 1.3.2: The Macronutrients: Carbohydrates, Lipids, Protein, and Water

Slow-releasing or complex carbohydrates are long chains of simple sugars that can be branched or unbranched. Starch is an example of a slow-releasing carbohydrate. During digestion, the small intestine breaks down all slow-releasing carbohydrates to simple sugars, mostly glucose. Glucose is then absorbed and transported to all our cells where it is stored in the form of glycogen, used to make energy, or used to build macromolecules. Fiber is also a slow-releasing carbohydrate, but it cannot be broken down in the human body and passes through the digestive tract undigested unless the bacteria that inhabit the gut break it down.

One gram of carbohydrates yields four kilocalories of energy for the cells in the body to perform work. In addition to providing energy and serving as building blocks for bigger macromolecules, carbohydrates are essential for proper functioning of the nervous system, heart, and kidneys. As mentioned, glucose can be stored in the body for future use. In humans, the storage molecule of carbohydrates is called glycogen and in plants, it is known as starches. Glycogen and starches are slow-releasing carbohydrates.

Lipids

Lipids are also a family of molecules composed of carbon, hydrogen, and oxygen, but unlike carbohydrates, they are insoluble in water. This class of molecules may be visible (for example vegetable oil) or invisible (for example, cream) in the food you eat. Lipids are found predominately in butter, oils, meats, dairy products, nuts, and seeds, and in many processed foods. The three main types of lipids are triglycerides (also called triacylglycerols), phospholipids, and sterols. The main job of lipids is to store energy. Lipids provide more energy per gram than carbohydrates (nine kilocalories per gram of lipids versus four kilocalories per gram of carbohydrates). In addition to energy storage, lipids serve as cell membranes, surround and protect organs, aid in temperature regulation, and regulate many other functions in the body. The main job of lipids is to store energy. Lipids provide more energy per gram than carbohydrates (nine kilocalories per gram of lipids versus four kilocalories per gram of carbohydrates). In addition to energy storage, lipids serve as cell membranes, surround and protect organs, aid in temperature regulation, and regulate many other functions in the body.

Proteins

Proteins are macromolecules composed of chains of subunits called amino acids which are the called the building blocks of protein. Amino acids are simple subunits composed of carbon, oxygen, hydrogen, and nitrogen. The food sources of protein come from animals such as meats, dairy products, seafood, and a variety of different plant-based foods, for example, soy, beans, and nuts. The word protein comes from a Greek word meaning “of primary importance,” which is an apt description of these macronutrients; they are also known colloquially as the “workhorses” of life. Proteins provide four kilocalories of energy per gram; however providing energy is not protein’s most important function. Proteins provide structure to bones, muscles, and skin, and play a role in conducting most of the chemical reactions that take place in the body. Scientists estimate that greater than one-hundred thousand different proteins exist within the human body.

Water

There is one other nutrient that we must have in large quantities: water. Water does not contain carbon, but is composed of two hydrogens and one oxygen per molecule of water. More than 60 percent of your total body weight is water. Without it, nothing could be transported in or out of the body, chemical reactions would not occur (acts as a solvent), organs would not be cushioned, joints would not be lubricated, and body temperature would fluctuate widely. On average, an adult consumes just over two liters of water per day from food and drink. According to the "rule of threes," a generalization supported by survival experts, a person can survive three minutes without oxygen, three days without water, and three weeks without food. Since water is so critical for life's basic processes, the amount of water input and output is supremely important, a topic we will explore in detail in Chapter 7.

Micronutrients

Micronutrients are nutrients required by the body in lesser amounts but are still essential for carrying out bodily functions. Micronutrients include all the essential minerals and vitamins. There are thirteen vitamins and sixteen essential minerals (See Table 1.3.1 and Table 1.3.2 for a complete list and their major functions). In contrast to carbohydrates, lipids, and proteins, micronutrients are not directly used for making energy, but they assist in the process as being part of enzymes (i.e., coenzymes). Enzymes are proteins that catalyze chemical reactions in the body and are involved in all aspects of body functions from producing energy to digesting nutrients to building macromolecules. Micronutrients play many roles in the body.

Vitamins

The thirteen vitamins are organic compounds (carbon-based) categorized as either water-soluble or fat-soluble. The water-soluble vitamins are vitamin C and all the B vitamins, which include thiamine, riboflavin, niacin, pantothenic acid, pyroxidine, biotin, folate, and cobalamin. The fat-soluble vitamins are A, D, E, and K. Vitamins are required to perform many functions in the body (regulatory and metabolic capacity) such as making red blood cells, synthesizing bone tissue, and playing a role in normal vision, nervous system function, and immune system function. Some function in chemical reactions involved in the release of energy from carbohydrates, fat, protein, and alcohol. Vitamins do not supply energy directly and are not structural; they enable chemical reactions to occur.

Table 1.03.1: Vitamins and Their Major Functions

Vitamins	Major Functions
Water-soluble	
B_1 (thiamine)	Coenzyme, energy metabolism assistance
B_2 (riboflavin)	Coenzyme, energy metabolism assistance
B_3 (niacin)	Coenzyme, energy metabolism assistance
B_5 (pantothenic acid)	Coenzyme, energy metabolism assistance
B_6 (pyroxidine)	Coenzyme, amino acid synthesis assistance
Biotin	Coenzyme
Folate	Coenzyme, essential for growth
B_{12} (cobalamin)	Coenzyme, red blood cell synthesis
C	Collagen synthesis, antioxidant
Fat-soluble	
A	Vision, reproduction, immune system function
D	Bone and teeth health maintenance, immune system function
E	Antioxidant, cell membrane protection
K	Bone and teeth health maintenance, blood clotting

Vitamin deficiencies can cause severe health problems. For example, a deficiency in niacin causes a disease called pellagra, which was common in the early twentieth century in some parts of America. The common signs and symptoms of pellagra are known as the “4D’s—diarrhea, dermatitis, dementia, and death.” Until scientists found out that better diets relieved the signs and symptoms of pellagra, many people with the disease ended up in insane asylums awaiting death (Video 1.3.1). Other vitamins were also found to prevent certain disorders and diseases such as scurvy (vitamin C), night blindness (vitamin A), and rickets (vitamin D).

Minerals

Minerals are solid inorganic substances that form crystals and are classified depending on how much of them we need. Trace minerals, such as molybdenum, selenium, zinc, iron, and iodine, are only required in a few milligrams or less and macrominerals, such as calcium, magnesium, potassium, sodium, and phosphorus, are required in hundreds of milligrams. Minerals function in structural, regulatory, and metabolic capacities. Building bone and teeth are an example of a structural function; while maintaining fluid balance, building bone tissue, synthesizing hormones, transmitting nerve impulses, contracting and relaxing muscles, and protecting against harmful free radicals are examples of regulatory and metabolic processes. Minerals do not supply energy directly.

Table 1.3.2: Minerals and Their Major Functions

Minerals	Major Functions
Macro or Major Minerals (>100 mg/day)	
Sodium	Fluid balance, nerve transmission, muscle contraction
Chloride	Fluid balance, stomach acid production
Potassium	Fluid balance, nerve transmission, muscle contraction
Calcium	Bone and teeth health maintenance, nerve transmission, muscle contraction, blood clotting
Phosphorus	Bone and teeth health maintenance, acid-base balance
Magnesium	Protein production, nerve transmission, muscle contraction
Sulfur	Protein production
Microminerals or Trace (<100 mg/day)	
Iron	Carries oxygen, assists in energy production
Zinc	Protein and DNA production, wound healing, growth, immune system function
Iodine	Thyroid hormone production, growth, metabolism
Selenium	Antioxidant
Copper	Coenzyme, iron metabolism
Manganese	Coenzyme
Fluoride	Bone and teeth health maintenance, tooth decay prevention
Chromium	Assists insulin in glucose metabolism
Molybdenum	Coenzyme
	Ultra Trace Minerals
Nickel	Coenzyme
Aluminum	Exact biological function unknown
Silicon	promotes bone and connective tissue health; exact biological function unknown

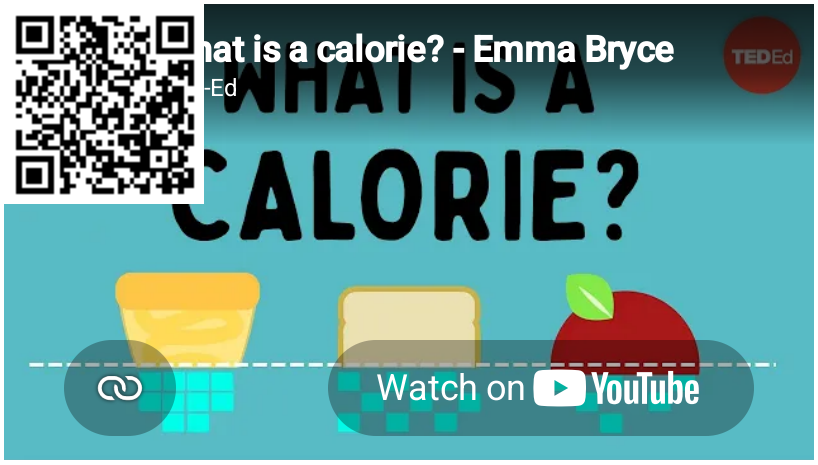
Minerals	Major Functions
Vanadium	similar to phosphate; exact biological function unknown
Arsenic	Exact biological function unknown; may play a role in converting methionine to its active metabolites
Boron	Exact biological function unknown; may play a role in cell membrane characteristics and transmembrane signaling



***Video 1.3.1**: This video provides a brief history of Dr. Joseph Goldberger's discovery that pellagra was a diet-related disease.*

Food Energy and Food Quality

Though this is only Chapter 1, you have already seen the words "Calories" and "Energy" used several times. In everyday life, you have probably heard people talk about how many Calories they burned on the treadmill or how many Calories are listed on a bag of chips. Calories are a measure of energy. It takes quite a lot of Calories (energy) to keep us alive. Even if a person is in a coma, they still burn approximately 1000 Calories of energy in order for their heart to beat, their blood to circulate, their lungs to breathe, etc... We burn even more calories when we exercise. The carbohydrates, fats, and proteins we eat and drink provide calories for us (and alcohol as well if we choose to consume it). Sometimes people refer to these nutrients as "energy yielding". As you read above, carbohydrates provide 4 Calories for every gram we consume; proteins provide 4 Calories for every gram we consume; fats provide 9 Calories for every gram we consume and alcohol provides 7 Calories of energy for every gram we consume. Vitamins, minerals, and water do not provide any calories, even though they are still essential nutrients. Please watch the following Ted Ed video called "What is a Calorie" which will describe in more detail what a Calorie is and why you may want to know how many Calories you are consuming compared to how many you are burning each day.



***Video 1.03.2**: This video describes a calorie. We hear about calories all the time: How many calories are in this cookie? How many are burned by doing 100 jumping jacks, or long-distance running, or fidgeting? But what is a calorie, really? And how many of*

them do we actually need? Emma Bryce explains how a few different factors should go into determining the recommended amount for each person.

One measurement of food quality is the amount of nutrients it contains relative to the amount of energy (Calories) it provides. High-quality foods are nutrient dense, meaning they contain lots of the nutrients relative to the amount of Calories they provide. Nutrient-dense foods are the opposite of "empty-calorie" foods such as carbonated sugary soft drinks, which provide many calories and very little, if any, other nutrients. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it. The quantity of nutrients present in foods can be influenced by farming conditions, ripeness of plants when harvested, cooking processes, and length of time it is stored.

Food: A Better Source of Nutrients

It is better to get all your micronutrients from the foods you eat as opposed to from supplements. Supplements contain only what is listed on the label, but foods contain many more macronutrients, micronutrients, and other chemicals, like antioxidants that benefit health. While vitamins, multivitamins, and supplements are a $20 billion industry in this country and more than 50 percent of Americans purchase and use them daily, there is no consistent evidence that they are better than food in promoting health and preventing disease. Dr. Marian Neuhouser, associate of the Fred Hutchinson Cancer Research Center in Seattle, says that "… scientific data are lacking on the long-term health benefits of supplements. To our surprise, we found that multivitamins did not lower the risk of the most common cancers and also had no impact on heart disease."Woodward, K. "Multivitamins Each Day Will Not Keep Common Cancers Away; Largest Study of Its Kind Provides Definitive Evidence that Multivitamins Will Not Reduce Risk of Cancer or Heart Disease in Postmenopausal Women." Fred Hutchinson Cancer Research Center. *Center News* 16 (February 2009). http://www.fhcrc.org/about/pubs/center_news/online/2009/02/multivitamin_study.html

Key Takeaways

- Foods contain nutrients that are essential for our bodies to function.
- Four of the nutrient classes required for bodily function are needed in large amounts. They are carbohydrates, lipids, proteins, and water, and are referred to as macronutrients.
- Two of the classes of nutrients are needed in lesser amounts but are still essential for bodily function. They are vitamins and minerals.
- One measurement of food quality is the amount of essential nutrients a food contains relative to the amount of energy it has (nutrient density).

Discussion Starters

1. Make a list of some of your favorite foods and visit the "What's In the Foods You Eat?" search tool provided by the USDA. What are some of the nutrients found in your favorite foods?

   http://www.ars.usda.gov/Services/docs.htm?docid=17032

2. Have a discussion in class on the "progression of science" and its significance to human health as depicted in the video on pellagra (Video 1.3.1).

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1.4: Historical Perspectives on Food

Learning Objectives

- Contrast ancient perspectives on food and nutrition with more modern explanatory systems

Throughout history, our relationship with food has been influenced by changing practices and perspectives. From the invention of agriculture to the birth of refrigeration, technological advances have also affected what we eat and how we feel about our food. Therefore, it can be helpful to examine theories and customs related to diet and nutrition across different civilizations and time periods.

Civilizations and Time Periods

Diet and cuisine have undergone enormous changes from ancient times to today. The basic diet of the ancient era consisted of cereals, legumes, oil, and wine. These staples were supplemented by vegetables and meat or fish, along with other items, such as honey and salt. During the Middle Ages, poor people consumed meager diets that consisted of small game supplemented with either barley, oat, or rye, while the wealthy had regular access to meat and fish, along with wheat.Our Food Recipes. “European Medieval Food.” © 2011–2012. www.our-food-recipes.com/medieval-food.html. During the Industrial Revolution, diets became more varied, partly because of the development of refrigeration and other forms of food preservation. In the contemporary era, many people have access to a wide variety of food that is grown locally or shipped from far-off places.



Picture 1.4.1 Flatbread made from barley or wheat was a staple in the traditional diet during the ancient era. (CC -BY-SA 3.0; Jonathunder).

Hunters and Gatherers

Human beings lived as hunters and gatherers until the invention of agriculture. Following a nomadic lifestyle, early people hunted, fished, and gathered fruit and wild berries, depending on their location and the availability of wild plants and wild game. To aid their constant quest for food, humans developed weapons and tools, including spears, nets, traps, fishing tackle, and the bow and arrow.Our Food Recipes. “Pre Historic Food.” © 2011–2012. www.our-food-recipes.com/pre-historic-food.html.

The Beginning of Agriculture

About ten thousand years ago, people began to cultivate crops and domesticate livestock in Mesopotamia, an area of the world that is known today as the Middle East. Agriculture flourished in this region due to the fertile floodplain between the Euphrates and Tigris Rivers, and early crops included wheat, barley, and dates. The development of agriculture not only enriched the diet of these early people, it also led to the birth of civilization as farmers began to settle into sizable, stable communities.Bioworld. “History of Agriculture.” Accessed October 10, 2011. www.bioworldusa.com/agriculture/history-agriculture.

One of the most fertile regions of the ancient world was located along the Nile River Valley in ancient Egypt. The rich soil yielded several harvests per year. Common crops were barley, wheat, lentils, peas, and cabbage, along with grapes, which were used to make wine. Even poor Egyptians ate a reasonably healthy diet that included fish, vegetables, and fruit. However, meat was primarily a privilege of the rich. Popular seasonings of this era included salt, pepper, cumin, coriander, sesame, fennel, and

dill.Experience Ancient Egypt. “Ancient Egyptian Food: The Pharaonic Diet.” © 2009–2011. http://www.experience-ancient-egypt.com/ancient-egyptian-food.html.

The “Three Sisters”

Thousands of years ago, across an area that encompasses Mexico and Central America today,Foundation for the Advancement of Mesoamerican Studies. “Mesoamerica.” Accessed October 10, 2011. http://www.famsi.org/. Mesoamerican farmers cultivated three major plants—squash, beans, and maize (also known as corn). Known as the “three sisters,” these crops proved to be both complementary and sustainable. Corn provides a pole for bean vines to climb. The roots of bean vines provide nitrogen that helps corn grow. These vines also stabilize corn stalks by making them less vulnerable to the wind. Shallow-rooted squash vines prevent the evaporation of soil moisture, while their spiny plants discourage predators. Both of these attributes aid the cultivation of all three crops.Renee’s Garden. “Celebrate the Three Sisters,” During the post-Columbian era, Native American groups adopted the practice of interplanting squash, beans, and maize, and now thousands of years later, many small farmers continue to cultivate the “three sisters.”

Meals Determined Social Status

In ancient Rome, differences in social standing affected the diet. For people of all socioeconomic classes, breakfast and lunch were typically light meals that were often consumed in taverns and cafes. However, dinners were eaten at home and were taken much more seriously. Wealthy senators and landowners ate meals with multiple courses, including appetizers, entrees, and desserts. Rich Romans also held extravagant dinner parties, where guests dined on exotic foods, such as roasted ostrich or pheasant. In contrast, people of the lower classes ate mostly bread and cereals.PBS. “Home Life.” *The Roman Empire in the First Century*. © 2006 Devillier Donegan Enterprises. http://www.pbs.org/empires/romans/empire/home.html. The average person ate out of clay dishes, while wealthy people used bronze, gold, or silver.

Social status determined the kinds of food that people consumed in many other parts of the world as well. In ancient China, emperors used their wealth and power to hire the best chefs and acquire delicacies, such as honey, to sweeten food. Dishes of the ancient era included steamed Mandarin fish, rice and wheat noodles, and fried prawns. Imperial cuisine also included improved versions of dishes that were consumed by the common people, such as soups and cereals.China.org. “The History of Chinese Imperial Cuisines.” © China Information Center. Accessed December 5, 2011. http://www.china.org.cn/english/imperial/25995.htm.

The Medieval Era

The eating habits of most people during the Medieval Era depended mainly on location and financial status. In the feudal system of Europe, the majority of the population could not afford to flavor their food with extravagant spices or sugar. In addition, transporting food was either outrageously expensive or out of the question due to the inability to preserve food for a long period of time. As a result, the common diet consisted of either wheat, meat, or fish, depending on location. The typical diet of the lower classes was based on cereals and grains, porridge, and gruel. These staples were supplemented with seasonal fruits, vegetables, and herbs. Wine, beer, and cider were also common, and were often safer to drink than the unsanitized, untreated water.

The Crusades

During the Medieval Era, soldiers from Europe waged war over religion in the Middle East in military campaigns that came to be known as the Crusades. Upon their return, the crusaders brought back new foods and spices, exposing Europeans of the Middle Ages to unusual flavors. Cooking with exotic spices, such as black pepper, saffron, and ginger, became associated with wealth because they were expensive and had to be imported.

Food Preservation in the Past

During the Medieval and Renaissance eras, most meals consisted of locally grown crops because it was extremely difficult to transport food over long distances. This was mostly due to an inability to preserve food for long periods. At that time, food preservation consisted mostly of drying, salting, and smoking. Pickling, which is also known as brining or corning, was another common practice and involved the use of fermentation to preserve food.

The Modern Era

The modern era began in North America and Europe with the dawn of the Industrial Age. Before that period, people predominantly lived in agrarian communities. Farming played an important role in the development of the United States and Canada. Almost all areas of the country had agrarian economies dictated by the harvesting seasons.

People noticed that certain foods were needed for health. For example, British sailors in the 1700's observed that limes could prevent scurvy. In the late 1700 and into the 1900s, physicians and scientists began to look at the relationship between food deficiencies and the development of disease more closely by looking at physical signs during the absence of specific foods.

In the 1800s, society began to change as new machines made it easier to cultivate crops and to package, ship, and store food. The invention of the seed drill, the steel plow, and the reaper helped to speed up planting and harvesting. Also, food could be transported more economically as a result of developments in rail and refrigeration. These and other changes ushered in the modern era and affected the production and consumption of food.

Food Preservation in Modern Times

Technological innovations during the 1800s and 1900s also changed the way we cultivate, prepare, and think about food. The invention and refinement of the refrigerator and freezer made it possible for people to store food for much longer periods. This, in turn, allowed for the transportation of food over greater distances. For example, oranges grown in Florida would still be fresh when they arrived in Seattle.

Prior to refrigeration, people relied on a number of different methods to store and preserve food, such as pickling. Other preservation techniques included using sugar or honey, canning, and preparing a confit, which is one of the oldest ways to preserve food and involves salting meat and cooking it in its own fat. To store foods for long periods, people used iceboxes or kept vegetables, such as potatoes, onions, and winter squash, in cellars during the winter months.

During the early 1900s, scientists began to identify nutrients. In 1922, McCollum showed vitamin D deficiency caused rickets in children.

The Great Depression

During the Great Depression of the 1930s, the United States faced incredible food shortages and many people went hungry. This was partly because extreme droughts turned parts of the Midwest into a Dust Bowl, where farmers struggled to raise crops. Millions of Americans were unemployed or underemployed and were forced to wait in long bread lines for free food. This was also a period of incredible reforms, as the government worked to provide for and protect the people. Some important changes included subsidies and support for suffering farmers.

World War II

Food shortages also occurred during World War II in the 1940s. At that time, people voluntarily made due with less to ensure that soldiers training and fighting overseas had the supplies they needed. To focus on saving at home, government programs included rationing food (particularly meat, butter, and sugar), while the media encouraged families to plant their own fruits and vegetables in “victory” (backyard) gardens.

In the 1950s, several vitamins and essential minerals were discovered and research focused on nutrient deficiencies.

Contemporary Life

Today, agriculture remains a large part of the economy in many developing nations. In fact, nearly 50 percent of the world’s labor is employed in agriculture.Bioworld. “History of Agriculture.” Accessed October 10, 2011. www.bioworldusa.com/agriculture/history-agriculture. In the United States however, less than 2 percent of Americans produce food for the rest of the population.Gold, M.V. “Sustainable Agriculture: Definitions and Terms.” US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1. Also, most farms are no longer small-scale or family-owned. Large-scale agribusiness is typical for both crop cultivation and livestock rearing, including concentrated animal feeding operations. Conventional farming practices can include abuses to animals and the land. Therefore, more and more consumers have begun to seek out organic and locally grown foods from smaller-scale farms that are less harmful to the environment.

Other changes also affect food production and consumption in the modern era. The invention of the microwave in the 1950s spurred the growth of frozen foods and TV dinners. Appliances such as blenders and food processors, toasters, coffee and espresso machines, deep fryers, and indoor grills have all contributed to the convenience of food preparation and the kinds of meals that people enjoy cooking and eating.

Nutrition scientists expanded their research to include optimal nutrition, nutritional pharmacology, nutrient excesses, disease patterns, and food security.

Diet Trends Over Time

Today, consumers can choose from a huge variety of dietary choices that were not available in the past. For example, strawberries can be purchased in New York City in wintertime, because they are quickly and easily transported from places where the crop is in season, such as California, Mexico, or South America. In the western world, especially in North America, food products are also relatively cheap. As a result, there is much less disparity between the diets of the lower and upper classes than in the past. It would not be unusual to find the same kind of meat or poultry served for dinner in a wealthy neighborhood as in a poorer community.

Key Takeaways

Perspectives and practices related to food and nutrition have greatly changed from the ancient era to today. In the ancient world, location and economic status had a profound effect on what people ate. Also, societies often were based on crop cultivation and livestock rearing, which influenced how people ate, worked, and lived. During the Medieval Era, people became more exposed to food from other parts of the world because of the growing ability to ship goods and because of the Crusades, among other factors. Technological advances, such as refrigeration and the microwave, have had huge effects on the way food is produced and consumed.

Discussion Starter

1. Compare and contrast the diet of a civilization from the ancient world or the Medieval Era to the food choices of today. In what ways has our diet changed? In what ways has it remained the same?

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1.5: The Broad Role of Nutritional Science

Learning Objective

- Provide an example of how the scientific method works to promote health and prevent disease.

How to Determine the Health Effects of Food and Nutrients

Similar to the method by which a police detective finally charges a criminal with a crime, nutritional scientists discover the health effects of food and its nutrients by following a process known as scientific method. The scientific method involves five steps: 1) ask a question or make an observation; 2) investigate the current and past literature to determine what is known about that observation or question; 3) construct a hypothesis; 4) test that hypothesis using experimental procedure; and 5) analyze the results and draw conclusions.

Below is an illustration of the scientific method at work—in this case to prove that iodine is a nutrient. Zimmerman, M.B. "Research on Iodine Deficiency and Goiter in the 19th and Early 20th Centuries." *J Nutr* 138, no. 11 (November 2008): 2060–63. Carpenter, K.J. "David Marine and the Problem of Goiter." *J Nutr* 135, no.4 (April 2005): 675–80. In 1811, French chemist Bernard Courtois was isolating saltpeter for producing gunpowder to be used by Napoleon's army. To carry out this isolation he burned some seaweed and in the process observed an intense violet vapor that crystallized when he exposed it to a cold surface. He sent the violet crystals to an expert on gases, Joseph Gay-Lussac, who identified the crystal as a new element. It was named iodine, the Greek word for violet. The following scientific record is some of what took place in order to conclude that iodine is a nutrient.

Observation. Eating seaweed is a cure for goiter, a gross enlargement of the thyroid gland in the neck.

- **Hypothesis.** In 1813, Swiss physician Jean-Francois Coindet hypothesized that the seaweed contained iodine and he could use just iodine instead of seaweed to treat his patients.
- **Experimental test.** Coindet administered iodine tincture orally to his patients with goiter.
- **Interpret results.** Coindet's iodine treatment was successful.
- **Gathering more evidence.** Many other physicians contributed to the research on iodine deficiency and goiter.

Hypothesis. French chemist Chatin proposed that the low iodine content in food and water of certain areas far away from the ocean were the primary cause of goiter and renounced the theory that goiter was the result of poor hygiene.

- **Experimental test.** In the late 1860s the program, "The stamping-out of goiter," started with people in several villages in France being given iodine tablets.
- **Results.** The program was effective and 80 percent of goitrous children were cured.

Hypothesis. In 1918, Swiss doctor Bayard proposed iodizing salt as a good way to treat areas endemic with goiter.

- **Experimental test.** Iodized salt was transported by mules to a small village at the base of the Matterhorn where more than 75 percent of school children were goitrous. It was given to families to use for six months.
- **Results.** The iodized salt was beneficial in treating goiter in this remote population.
- **Experimental test.** Physician David Marine conducted the first experiment of treating goiter with iodized salt in America in Akron, Ohio.
- **Results.** This study conducted on over four-thousand school children found that iodized salt prevented goiter.

Conclusions. Seven other studies similar to Marine's were conducted in Italy and Switzerland that also demonstrated the effectiveness of iodized salt in treating goiter. In 1924, US public health officials initiated the program of iodizing salt and started eliminating the scourge of goiterism. Today more than 70 percent of American households use iodized salt and many other countries have followed the same public health strategy to reduce the health consequences of iodine deficiency.

Evidence-Based Approach to Nutrition

It took more than one hundred years from iodine's discovery as an effective treatment for goiter until public health programs recognized it as such. Although a lengthy process, the scientific method is a productive way to define essential nutrients and determine their ability to promote health and prevent disease. The scientific method is part of the overall evidence-based approach to designing nutritional guidelines. An evidence-based approach to nutrition includes:Briss, P.A., et al. "Developing an Evidence-Based Guide to Community Preventive Services—Methods." *Am J Prev Med* 18, no. 1S (2000): 35–43.' Myers, E. "Systems for Evaluating Nutrition Research for Nutrition Care Guidelines: Do They Apply to Population Dietary Guidelines?" *J Am Diet Assoc* 103, no. 12, supplement 2 (December 2003): 34–41.

- Defining the problem or uncertainty (e.g., the rate of colon cancer is higher in people who eat red meat)
- Formulating it as a question (e.g., Does eating red meat contribute to colon cancer?)
- Setting criteria for quality evidence
- Evaluating the body of evidence
- Summarizing the body of evidence and making decisions
- Specifying the strength of the supporting evidence required to make decisions
- Disseminating the findings

The Food and Nutrition Board of the Institute of Medicine, a nonprofit, nongovernmental organization, constructs its nutrient recommendations (i.e., Dietary Reference Intakes, or DRI) using an evidence-based approach to nutrition. The entire procedure for setting the DRI is documented and made available to the public. The same approach is used by the USDA and HHS, which are departments of the US federal government. The USDA and HHS websites are great tools for discovering ways to optimize health; however, it is important to gather nutrition information from multiple resources as there are often differences in opinion among various scientists and public health organizations. While the new *Dietary Guidelines*, published in 2015, have been well-received by some, there are nongovernmental public health organizations that are convinced that some pieces of the guidelines may be influenced by lobbying groups and/or the food industry. For example, the Harvard School of Public Health (HSPH) feels the government falls short by being "too lax on refined grains."The Harvard School of Public Health. "New US Dietary Guidelines: Progress, Not Perfection." © 2012 The President and Fellows of Harvard College. The guidelines recommend getting at least *half* of grains from whole grains—according to the HSPH this still leaves too much consumption of refined grains.

For a list of reliable sources that advocate good nutrition to promote health and prevent disease using evidence-based science see Table 1.05.1. In this Chapter, we will further discuss distinguishing criteria that will enable you to wade through misleading nutrition information and instead gather your information from reputable, credible websites and organizations.

Table 1.5.1: Web Resources for Nutrition and Health

Organization	Website
Governmental	
US Department of Agriculture	http://www.usda.gov/wps/portal/usda/usdahome
USDA Center for Nutrition Policy and Promotion	www.cnpp.usda.gov/
US Department of Health and Human Services	http://www.hhs.gov/
Centers for Disease Control and Prevention	http://www.cdc.gov/
Food and Drug Administration	http://www.fda.gov/
Healthy People	http://www.healthypeople.gov/2020/default.aspx
Office of Disease Prevention and Health Promotion	odphp.osophs.dhhs.gov/
Health Canada	http://www.hc-sc.gc.ca/
International	
World Health Organization	http://www.who.int/en/
Food and Agricultural Organization of the United Nations	http://www.fao.org/
Nongovernmental	
Harvard School of Public Health	www.hsph.harvard.edu/nutritionsource/index.html
Mayo Clinic	http://www.mayoclinic.com/
Linus Pauling Institute	http://lpi.oregonstate.edu/
American Society for Nutrition	http://www.nutrition.org/
American Medical Association	http://www.ama-assn.org/
American Diabetes Association	http://www.diabetes.org/
The Academy of Nutrition and Dietetics	http://www.eatright.org/
Institute of Medicine: Food and Nutrition	www.iom.edu/Global/Topics/Food-Nutrition.aspx
Dietitians of Canada	http://www.dietitians.ca/

Types of Scientific Studies

There are many types of scientific studies that can be used to provide supporting evidence for a particular hypothesis. The various types of studies include epidemiological studies, interventional clinical trials, and randomized clinical interventional trials.

Epidemiological studies are observational studies that look for health patterns and are often the front-line studies for public health. The CDC defines epidemiological studies as scientific investigations that define frequency, distribution, and patterns of health events in a population. Thus, these studies describe the occurrence and patterns of health events over time. The goal of an epidemiological study is to find factors associated with an increased risk for a health event, though these sometimes remain elusive. An example of an epidemiological study is the Framingham Heart Study, a project of the National Heart, Lung and Blood Institute and Boston University that has been ongoing since 1948. This study first examined the physical health and lifestyles of 5,209 men and women from the city of Framingham, Massachusetts and has now incorporated data from the

children and grandchildren of the original participants. One of the seminal findings of this ambitious study was that higher cholesterol levels in the blood are a risk factor for heart disease. The Framingham Heart Study, a project of the National Heart, Lung, and Blood Institute and Boston University. “History of the Framingham Heart Study.” Epidemiological studies are a cornerstone for examining and evaluating public health and some of their advantages are that they can lead to the discovery of disease patterns and risk factors for diseases, and they can be used to predict future healthcare needs and provide information for the design of disease prevention strategies for entire populations. Some shortcomings of epidemiological studies are that investigators cannot control environments and lifestyles, a specific group of people studied may not be an accurate depiction of an entire population, and these types of scientific studies cannot directly determine if one variable causes another. Scientists regard epidemiological studies as a starting place for ideas about what types of lifestyle choice MAY contribute to a disease. They can show a correlation between two things happening but not whether one factor CAUSED the other. My favorite example of this is a thought experiment where a make-believe scientist observes (through epidemiological studies) that gray hair often goes along with Alzheimer's Disease. Wouldn't it be silly for that scientist to predict that gray hair CAUSES Alzheimer's Disease? Could that scientist easily test that silly prediction? Suppose that scientist dyed a group of people's hair gray to see if the color gray truly increased their risk of Alzheimer's Disease. The whole thing is silly but I think you get the point. Epidemiological studies may give us ideas but those ideas need clinical trials to figure out what the patterns mean.

There are many different types of study designs including randomized controlled trials, cohort study (prospective observational study), case-control study, cross-sectional study, and case reports. Each has its strengths and weaknesses and the selection of the study type depends on the hypothesis being tested and the resources available.

A cohort study (prospective observational study) is a clinical study in which a group of people with a particular condition or treatment, for example, lung cancer or patients taking an antihypertensive, is followed over time. In addition, a second cohort of people that do not have that condition or treatment is followed and compared to the first group with the condition. Here is an example of a cohort study: Zacche MM, Giarenis I, Thiagamoorthy G, Robinson D, Cardozo L. Is there an association between aspects of the metabolic syndrome and overactive bladder? A prospective cohort study in women with lower urinary tract symptoms. Eur J Obstet Gynecol Reprod Biol. 2017 Aug 2;217:1-5. https://www.ncbi.nlm.nih.gov/pubmed/28826038

A case-control study does not follow people over time and pre-selects individuals with a particular result (the cases), for example, people with osteoporosis (outcome), and then interviews that group or checks their records to determine what specific experience they had. From this information, an odds ratio is calculated to determine the odds of having an experience with the outcome of having the experience without the outcome. Here is an example of a cohort study: Alvarado-Esquivel C, Maldonado-Soto E, Sanchez-Anguiano LF, Hernandez-Tinoco J, Ramos-Nevarez A, Cerrillo-Soto SM, Sandoval-Carrilo AA, Salas-Pacheco JM, Antuna-Salcido EI, Estrada-Martinez S, Guido-Arreola CA. Lack of Serological and Molecular Association between Toxoplasma Gondii Exposure and Obesity: A Case-Control Study. Int J Biomed Sci. 2017 Jun;13(2):74-78.

Cross-sectional studies look at a single point in time or time interval in a particular population. Exposure and outcome are determined simultaneously. Here is an example of a cohort study: Nygaard L, Skallerup A, Olesen SS, Køhler M, Vinter-Jensen L, Kruse C, Vestergaard P, Rasmussen HH. Osteoporosis in patients with intestinal insufficiency and intestinal failure: Prevalence and clinical risk factors. Clin Nutr. 2017 Aug 5. pii: S0261-5614(17)30259-5. doi:10.1016/j.clnu.2017.07.018. [Epub ahead of print]

Case reports involve cases with a particular outcome. No control group is involved. The report may include one subject or several subjects. Here is an example of a cohort study: Meade RD, D'Souza AW, Krishen L, Kenny GP. The physiological strain incurred during electrical utilities work over consecutive work shifts in hot environments: A case report. J Occup Environ Hyg. 2017 Aug 21:0. doi: 10.1080/15459624.2017.1365151. [Epub ahead of print]

Some studies may involve the use of a placebo which is a harmless medicine, procedure or task that has no therapeutic effect. Instead, it may have a powerful psychological benefit.

Interventional clinical trial studies are scientific investigations in which a variable is changed between groups of people. When well done, this type of study allows one to determine causal relationships. An example of an interventional clinical trial study is the Dietary Approaches to Stop Hypertension (DASH) trial published in the April 1997 issue of *The New England Journal of Medicine*.Appel, L. J., et al. “A Clinical Trial of the Effects of Dietary Patterns on Blood Pressure.,” *N Engl J Med* 336 (April 1997): 1117–24. In this study, 459 people were randomly assigned to three different groups; one was put on an average American control diet, a second was put on a diet rich in fruits and vegetables, and the third was put on a combination diet rich in fruits, vegetables, and low-fat dairy products with reduced saturated and total fat intake. The groups remained on the diets for eight weeks. Blood pressures were measured before starting the diets and after eight weeks. Results of the study showed that the group on the combination diet had significantly lower blood pressure at the end of eight weeks than those who consumed the control diet. The authors concluded that the combination diet is an effective nutritional approach to treat high blood pressure. The attributes of high-quality clinical interventional trial studies are:

- those that include a control group, which does not receive the intervention, to which you can compare the people who receive the intervention being tested;
- those in which the subjects are randomized into the group or intervention group, meaning a given subject has an equal chance of ending up in either the control group or the intervention group. This is done to ensure that any possible confounding variables are likely to be evenly distributed between the control and the intervention groups;
- those studies that include a sufficient number of participants.

What are confounding variables? These are factors other than the one being tested that could influence the results of the study. For instance, in the study, we just considered, if one group of adults did less physical activity than the other, then it could be the amount of physical activity rather than the diet being tested that caused the differences in blood pressures among the groups.

The limitations of these types of scientific studies are that they are difficult to carry on for long periods of time, are costly, and require that participants remain compliant with the intervention. Furthermore, it is unethical to study certain interventions. (An example of an unethical intervention would be to advise one group of pregnant mothers to drink alcohol to determine the effects of alcohol intake on pregnancy outcome because we know that alcohol consumption during pregnancy damages the developing fetus.)

Randomized clinical interventional trial studies are powerful tools to provide supporting evidence for a particular relationship and are considered the "gold standard" of scientific studies. A randomized clinical interventional trial is a study in which participants are assigned by chance to separate groups that compare different treatments. Neither the researchers nor the participants can choose which group a participant is assigned. However, from their limitations, it is clear that epidemiological studies complement interventional clinical trial studies and both are necessary to construct strong foundations of scientific evidence for health promotion and disease prevention.

Other scientific studies used to provide supporting evidence for a hypothesis include laboratory studies conducted on animals or cells. An advantage of this type of study is that they typically do not cost as much as human studies and they require less time to conduct. Other advantages are that researchers have more control over the environment and a number of confounding variables can be significantly reduced. Moreover, animal and cell studies provide a way to study relationships at the molecular level and are also helpful in determining the exact mechanism by which a specific nutrient causes a change in health. An animal model can closely mimic the exact disease in humans. The disadvantage of these types of studies is that researchers are not working with whole humans and thus the results may not be relevant. Nevertheless, well-conducted animal and cell studies that can be repeated by multiple researchers and obtain the same conclusion are definitely helpful in building the evidence to support a scientific hypothesis.

Evolving Science

Science is always moving forward, albeit sometimes slowly. One study is not enough to make a guideline or a recommendation or cure a disease. Science is a stepwise process that builds on past evidence and finally culminates into a well-accepted conclusion. Unfortunately, not all scientific conclusions are developed in the interest of human health and it is important to know where a scientific study was conducted and who provided the money. Indeed, just as an air quality study paid for by a tobacco company diminishes its value in the minds of readers, so does one on red meat performed at a laboratory funded by a national beef association.

Science can also be contentious even amongst experts that don't have any conflicting financial interests. To see scientists debating over the nutritional guidelines, watch Video 1.5.1. Contentious science is actually a good thing as it forces researchers to be of high integrity, well-educated, well-trained, and dedicated. It also instigates public health policy makers to seek out multiple sources of evidence in order to support a new policy. An agreement involving many experts across multiple scientific disciplines is necessary for recommending dietary changes to improve health and prevent disease. Although a somewhat slow process, it is better for our health to allow the evidence to accumulate before incorporating some change in our diet.

http://www.youtube.com/embed/KBryEJXSaLk

Video 1.5.1: *Debate" This we 29, 2011, demonstrates how science is always evolving and how debate among nutrition science experts influences policy deci rd School of Public Health, in collaboration with Reuters.*

Nutritional Science Evc

One of the newest areas in th al science is the scientific discipline of nutritional genetics, also called nutrigenomics. Genes are part of DNA and contain the genetic information that makes up all our traits. Genes are codes for proteins and when they are turned "on" or "off," they change how the body works. While we know that health is defined as more than just the absence of disease, there are currently very few accurate genetic markers of good health. Rather, there are many more genetic markers for disease. However, science is evolving and nutritional genetics aims to identify what nutrients to eat to "turn on" healthy genes and "turn off" genes that cause disease. Eventually, this field will progress so that a person's diet can be tailored to their genetics. Thus, your DNA will determine your optimal diet.

www.youtube.com/v/-K7w59tHFMI

Video 1.5.2: *Nutrigenomics: A the new scientific discipline of nutrigenomics and its potential impact on diet and health.*

Using Science and Tec nge the Future

As science evolves, so does t n be used to create a healthy diet, optimize health, and prevent disease. Picture yourself not too far into the future: you are wear y watch" that painlessly samples your blood, and downloads the information to your cell phone, which has an app that evaluates the nutrient profile of your blood and then recommends a snack or dinner menu to assure you maintain adequate nutrient levels. What else is not far off? How about another app that provides a shopping list that adheres to all dietary guidelines and is emailed to the central server at your local grocer who then delivers the food to your home? The food is then stored in your smart fridge which documents your daily diet at home and delivers your weekly dietary assessment to your home computer. At your computer, you can compare your diet with other

diets aimed at weight loss, optimal strength training, reduction in risk for specific diseases or any other health goals you may have. You may also delve into the field of nutritional genetics and download your gene expression profiles to a database that analyzes yours against millions of others.



Figure 1.5.1: *The "Smart Fridge". Source: http://www.yankodesign.com/2010/05/28/smart-fridge-is-your-new-recipe-card/.*

Key Takeaways

- The scientific method is an organized process of inquiry used in nutritional science to determine if the food suspect fits the claim.
- The scientific method is part of the overall evidence-based approach to designing nutritional guidelines that are based on facts.
- There are different types of scientific studies—epidemiological studies, randomized clinical interventional trial studies, and laboratory animal and cell studies—which all provide different, complementary lines of evidence.
- It takes time to build scientific evidence that culminates as a commonly accepted conclusion.
- Agreement of experts across multiple scientific disciplines is a necessity for recommending dietary changes to improve health and help to prevent disease.
- Science is always evolving as more and more information is collected.

Discussion Starters

1. What are some of the ways in which you think like a scientist and use the scientific method in your everyday life? Any decision-making process uses at least pieces of the scientific method. Think about some of the major decisions you have made in your life and the research you conducted that supported your decision. For example, what computer brand do you own? Where is your money invested? What college do you attend?
2. Do you use technology, appliances, and/or apps that help you to optimize your health?

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1.6: Health Factors and Their Impact

Learning Objective

- Explain the role that genetics, environment, life cycle, and lifestyle play in health status.
- Describe economic, social, cultural, and emotional determinants that affect personal choices of foods.

In addition to nutrition, health is affected by genetics, the environment, life cycle, and lifestyle. These factors are referred to as "determinants" of health and they all interact with each other. For example, family income influences the food choices available and the quantity and quality of food that can be purchased, which of course affects nutrition. Except for nutrition and lifestyle, these factors can be difficult or impossible to change.

Genetics

Everyone starts out in life with the genes handed down to them from the families of their mother and father. Genes are responsible for your many traits as an individual and are defined as the sequences of DNA that code for all the proteins in your body. The expression of different genes can determine the color of your hair, skin, and eyes, and even if you are more likely to be fat or thin and if you have an increased risk for a certain disease. The sequence of DNA that makes up your genes determines your genetic makeup, also called your genome, which is inherited from your mother and father. In 2003, the Human Genome Project was completed and now the entire sequence of DNA in humans is known. It consists of about three billion individual units and contains between twenty-five and thirty thousand genes. The human genome that was sequenced was taken from a small population of donors and is used as a reference DNA sequence for the entire population. Each of us has a similar but unique DNA sequence. Only identical twins and cloned animals have the exact same DNA sequence.



Figure 1.6.1: Identical twins are the only individuals in the world that have identical DNA, sharing the same genotype. However, their phenotype is different, meaning that their identical DNA is expressed differently. Marian and Vivian Brown, identical twins, photographed by Christopher Michel.

Now that we understand the map of the human genome, let's enter the fields of nutrigenomics and epigenetics. Recall that nutrigenomics is an emerging scientific discipline aimed at defining healthy genes and not-so-healthy genes and how nutrients affect them. Currently, scientists cannot change a person's DNA sequence. But they have discovered that chemical reactions in the body can turn genes "on" and "off," causing changes in the amounts and types of proteins expressed. Epigenetics is another rapidly advancing scientific field in which researchers study how chemical reactions turn genes "on" and "off" and the factors that influence the chemical reactions. Some of these factors are now known to be nutrients. Researchers at the Genetic Science Learning Center at the University of Utah conducted an experiment in which some pregnant mice were fed a diet containing folate, choline, vitamin B_{12}, and betaine, and other pregnant mice were fed a diet that did not contain these nutrients and chemicals. Both groups of pregnant mice were also fed bisphenol A, a chemical in plastic, which alters DNA by inhibiting a specific chemical reaction. The mice born from the mother fed the supplemented diet were brown, thin, and healthy. The mice born from the mother fed the unsupplemented diet were yellow, fat, and unhealthy. This is a dramatic example of how nutrients change not the sequence of DNA, but which genes are expressed. These two mice look different but have identical DNA sequences. Thus, not only do the things you eat determine your health but so do the things your mother ate during pregnancy. Moreover, other studies have

demonstrated what your dad ate—and what your grandmother ate while she was pregnant with your mother!—also can affect your gene expression and, consequently, your health. Does this make it OK for you to blame your mother and father for all of your shortcomings? No. Genetics are important in determining your health, but they are certainly not the only determinant.

? Interactive 1.6.1

This is a good animation of the central foundation of modern biology. Turn "on" a gene, make messenger RNA, and make protein. Spin the dial all the way to the left to turn off the expression, and then slowly move it to the right.

http://learn.genetics.utah.edu/content/epigenetics/control/

Source: Genetic Science Learning Center at the University of Utah.



***Video 1.6.1**: Diet during Pregnancy. Watch as Jen discovers how what you eat during pregnancy affects the health of your baby.*

The Life Cycle

The life cycle of human beings originates from a fertilized egg, which develops into a fetus that is eventually born as a baby. A baby develops into a child, transitions through the wonderful phase of adolescent to an adult, and then into old age and eventually death (Figure 1.6.1). The current average life expectancy in America is approaching eighty. To see how this compares with other countries, see Interactive 1.06.2.

? Interactive 1.6.2: The World Bank

Visit this public database from the World Bank to learn how the life expectancy in America differs from those in other countries.

http://www.google.com/publicdata?ds=wb-wdi&met_y=sp_dyn_le00_in&idim=country:USA&dl=en&hl=en&q=america+average+life+expectancy

A person's stage of life influences their health and nutritional requirements. For example, when you are an adolescent, your bones grow quickly. More calcium, a bone-building nutrient, is required in the diet during this life stage than at other ages. As you get older, the aging process affects how your body functions. One effect of aging, apparently earlier in women than in men, is the deterioration of bone tissue. As a result, women over age fifty-one need more calcium in their diet than younger adult women. Another life-cycle stage, pregnancy, requires several adjustments to nutrition compared to nonpregnant women. It is recommended that a pregnant woman consumes more protein than a nonpregnant woman to support growth and development, and to consume more of some vitamins, such as folate, to prevent certain birth defects. The USDA provides information on healthy diets for many different stages of the life cycle on their website. Healthy aging requires eating a diet that matches one's life stages to support the body's specific physiological requirements. What else is known to help a person age slowly and gracefully? Diets high in vegetables and fruits are associated with increased longevity and a decreased risk of many diseases.



***Figure 1.6.2**: The Life Cycle: The Forward March to Old Age and Ultimately Death. © Shutterstock*

Environment

Your environment has a large influence on your health, genetics, life cycle, and lifestyle. Scientists say that the majority of your expressed traits are a product of your genes and environment, of which nutrition is a component. An example of this interaction can be observed in people who have the rare genetic disorder, phenylketonuria (PKU). The clinical signs of PKU are mental retardation, brain damage, and seizures and are caused by the build-up of the amino acid phenylalanine and its metabolites (breakdown products produced during metabolism) in the body. The high level of phenylalanine in a person who has PKU is the result of a change in the gene that encodes for an enzyme that converts phenylalanine into the amino acid tyrosine. This genetic change, called a mutation, causes the enzyme to not function properly.

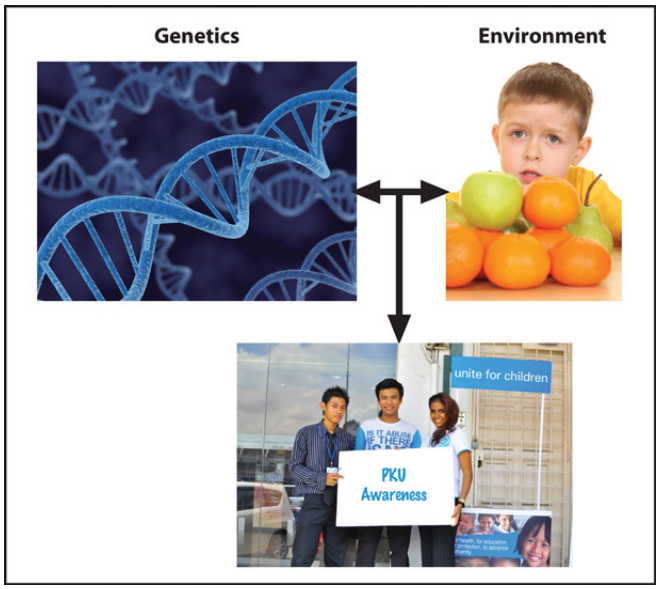


Figure 1.6.3: The interplay of genetics and environment can determine the consequences of disease. Sources: http://topnews.co.uk/214471-rare-disorder-known-phenylketonuria and www.georgiapku.org/AboutUs.html. © Shutterstock

In this country and many others, all newborn babies are screened for PKU in order to diagnose and treat the disease before the development of mental retardation and brain damage. Once diagnosed, PKU is treated by strict adherence to a diet low in phenylalanine, consisting mostly of fruits, vegetables, and grains. Adhering to this diet for life allows an individual with PKU to lead a normal life without suffering the consequences of brain damage, mental retardation, or seizures. In the example of PKU, the consequences of a genetic mutation are modified by diet. Thus, a person's genes can make them more susceptible to a particular disease, or cause a disease, and their environment can decrease or increase the progression and severity of the condition.

Socioeconomic Status

Multiple aspects of a person's environment can affect nutrition, which in turn affects health. One of the best environmental predictors of a population's health is socioeconomic status. Socioeconomic status is a measurement made up of three variables: income, occupation, and education. Socioeconomic status affects nutrition by influencing what foods you can afford and

consequently, food choice and food quality. Nutrition and health are generally better in populations that have higher incomes, better jobs, and more education. On the other hand, the burden of disease is highest in the most disadvantaged populations. A commentary in the *Journal of the American Medical Association* reports that the lower life expectancy of populations of lower socioeconomic status is largely attributable to increased death from heart disease.Fiscella, K. and D. Tancredi. "Socioeconomic Status and Coronary Heart Disease Risk Prediction." *JAMA* 300, no. 22 (2008): 2666–68. The American Heart Association states that having a healthy diet is one of the best weapons to fight heart disease and it is therefore essential that all socioeconomic status groups have access to high-quality, nutrient-dense foods. The disparities in nutrition and health in America are directly related to the disparity in socioeconomic status. Other dimensions that affect health disparity are race, ethnic group, sex, sexual identity, age, disability, and geographic location. The issue of inequitable health among Americans is recognized by the federal government and one of the overarching goals of Healthy People 2020, a large program managed by the HHS, is to "Achieve health equity, eliminate disparities, and improve the health of all groups." To work toward this monumental goal, the HHS is actively tracking disease patterns, chronic conditions, and death rates among the many different types of people that live in the United States. This will be further discussed in Chapter 2.

? Interactive 1.06.3

To see the differences in causes of death for different sexes, races, and age groups, visit the website of Healthy People and compare the top ten causes of death for different populations.

http://www.healthypeople.gov/2020/default.aspx

Lifestyle

One facet of lifestyle is your dietary habits. Recall that we discussed briefly how nutrition affects health. A greater discussion of this will follow in subsequent chapters in this book as there is an enormous amount of information regarding this aspect of lifestyle. Dietary habits include what a person eats, how much a person eats during a meal, how frequently meals are consumed, and how often a person eats out at restaurants. Other aspects of lifestyle include physical activity level, recreational drug use, and sleeping patterns, all of which play a role in health and impact nutrition. Following a healthy lifestyle improves your overall health.

In 2008, the HHS released the *Physical Activity Guidelines for Americans*. The HHS states that "Being physically active is one of the most important steps that Americans of all ages can take to improve their health. The *2008 Physical Activity Guidelines for Americans* provides science-based guidance to help Americans aged six and older improve their health through appropriate physical activity." The guidelines recommend exercise programs for people in many different stages of their lifecycle and for pregnant women and adults and children who have disabilities. The HHS reports that there is strong evidence that increased physical activity decreases the risk of early death, heart disease, stroke, Type 2 diabetes, high blood pressure, and certain cancers; prevents weight gain and falls; and improves cognitive function in the elderly. Also unveiled recently are the *Canadian Physical Activity Guidelines*, which are available at the website of The Canadian Society for Exercise Physiology.

? .

http://www.health.gov/PAGuidelines/default.aspx

Recreational Drug Use

Recreational drug use, which includes tobacco-smoking and alcohol consumption along with narcotic and other illegal drug use, has a large impact on health. Smoking cigarettes causes lung cancer, eleven other types of cancer, heart disease, and several other disorders or diseases that markedly decrease quality of life and increase mortality. In the United States, smoking causes more than four hundred thousand deaths every single year, which is far more than deaths associated with any other lifestyle component. Centers for Disease Control and Prevention. "Smoking and Tobacco Use." Last updated March 21, 2011. Also, according to the CDC, excessive alcohol intake causes an estimated seventy-five thousand deaths per year. Centers for Disease Control and Prevention. "Alcohol and Drug Use." Last updated June 7, 2012. http://www.cdc.gov/healthyyouth/alcoholdrug/ Staying away from excessive alcohol intake lowers blood pressure, the risk from injury, heart disease, stroke, liver problems, and some types of cancer. Abstaining from alcohol also aids in weight loss and increases the money in your wallet. While heavy drinking of alcoholic beverages is associated with several bad health effects, consuming alcohol in moderation has been found to promote health such as reducing the risk for heart disease and Type 2 diabetes in some people. The HHS defines drinking in moderation as no more than one drink a day for women and two drinks a day for men.

Illicit and prescription drug abuse are associated with decreased health and is a prominent problem in the United States. The health effects of drug abuse can be far-reaching including increased risk for stroke, heart disease, cancer, lung disease, and liver disease.

Sleeping Patterns

Inadequate amounts of sleep, or not sleeping well, can also have remarkable effects on a person's health. In fact, sleeping can affect your health just as much as diet or exercise. At least 10 percent of Americans have chronic insomnia.National Sleep Foundation. "Can't Sleep? What to Know about Insomnia." Accessed February 12, 2012. Scientific studies have shown that insufficient sleep increases the risk for heart disease, Type 2 diabetes, obesity, and depression. Abnormal breathing during sleep, a condition called sleep apnea, is also linked to an increased risk for chronic disease.

? Exercise 1.6.5

Go to the HHS website and discover the many tools at your fingertips to live a healthier lifestyle.

www.healthfinder.gov/prevention/

Nutrition, Genetics, Environment, and Lifestyle Interact to Affect Health

The Pima Indians who inhabit parts of southern Arizona and the Pima Indians that live across the border in Mexico are genetically and culturally similar, but there are vast differences in the health of these two populations. In America, the Pima Indians have the highest rate of obesity and Type 2 diabetes compared to any other ethnic group. However, the Pima Indians who live in Mexico do not share these same health problems because of a complex interplay between nutrition, genetics, environment, and lifestyle. Over one hundred years ago, the Pima Indians were farmers, hunters, and gatherers and their diets consisted of about 70 percent carbohydrate, 15 percent protein, and 10 to 15 percent fat. Typical of the lives of farmers, hunters, and gatherers a century ago, they lived through times of feast and times of famine. The geneticist James Neel proposed in 1962 that the Pima Indians carried a "thrifty gene" that makes them very efficient at storing fat during times of plenty so they do not starve when food is scarce.

After World War II, the Pima Indians in America either went back to reservations in southern Arizona or moved to the cities for work. They rapidly adopted the American diet and lifestyle and consumed high-fat, processed foods and refined grains and were more sedentary than their counterparts in Mexico, who retained their more traditional diet and lifestyle. Today, the typical American Pima Indian diet obtains more than 40 percent of calories from fat. The "thrifty gene" in the American Pima Indian population increased their susceptibility to the consequences of the high-fat American diet and sedentary lifestyle because they were genetically better at storing fat than others. The story of the Pima Indians and the difference between the health of their populations in America and Mexico demonstrates the interactions between nutrition, genetics, environment, and lifestyle. Indeed, preliminary studies suggest that when American Pima Indians switch back to the diets of their ancestors and consume beans, corn, grains, and greens and other low-fat, high-fiber plant foods, the benefits are weight loss and reduced risk of chronic disease. The health status of American Pima Indians is considered "a canary in the coal mine, " meaning they provide a warning to the American people.

Although the health consequences of the American diet and lifestyle in Pima Indians appeared rapidly in their population, all Americans that partake in the current trends of American diet and lifestyle are at risk. On the lighter side (literally!), the new studies that show changing back to more traditional diets markedly improved the health of the American Pima Indians suggest that all Americans can reduce their risk for diet-related diseases even when their genetic susceptibility for these diseases is high.

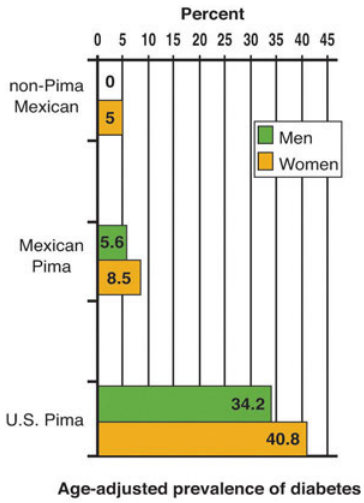


Figure 1.6.4: The Interplay of nutrition, genetics, environment, and lifestyle affects health. Pima Indians living in America are genetically similar to those who live in Mexico, but differences in their nutrition, environment, and lifestyle changes their health. Source: paleobioticslab.com/general-interest-articles/so-go-the-pimas-so-go-the-rest-of-us/.

Tools for Change

Heed the warning of the Pima Indians and seek out ways to establish a more traditional dietary pattern. The American diet in the nineteenth century consisted of less meat, less processed food, and more home-grown fruits, vegetables, and whole grains. Think of ways to include these types of foods in your diet or partake in some of the traditional foods of a particular ethnic group in your community. Visit the following websites to find out the unique foods of some traditional diets.

- Traditional Mediterranean diet: www.oldwayspt.org/mediterraneandiet
- Native Tech: http://www.nativetech.org/recipes/index.php
- Traditional foods, with recipes, by country: http://www.foodbycountry.com/index.html

Personal Choice: The Challenge of Choosing Foods

From visiting websites about traditional foods of different cultures and ethnic groups, you may have noticed that a few more things besides environment and lifestyle that influence the foods you choose to eat. Different foods affect energy level, mood, how much is eaten, how long before you eat again, and if cravings are satisfied. We have talked about some of the physical effects of food on your body, but there are other effects too. Food regulates your appetite and how you feel. Multiple studies have demonstrated that some high-fiber foods and high-protein foods decrease appetite by slowing the digestive process and prolonging the feeling of being full. The effects of individual foods and nutrients on mood are not backed by consistent scientific evidence, but in general most studies support that healthier diets are associated with a decrease in depression and improved well-being. To date, science has not been able to track the exact path in the brain that occurs in response to eating a particular food, but it is quite clear that foods, in general, stimulate emotional responses in people.

Food also has psychological, cultural, and religious significance, so your personal choices of food affect your body, mind, and soul. The social implications of food have a great deal to do with what people eat, as well as how and when. Special events in individual lives—from birthdays to funerals—are commemorated with equally special foods. Being aware of these forces can help people make healthier food choices—and still honor the traditions and ties they hold dear. Typically, eating kosher food means a person is Jewish; eating fish on Fridays during Lent means a person is Catholic; fasting during the ninth month of the Islamic calendar means a person is Muslim. On New Year's Day, people from New England like to combine pork and sauerkraut as a way to eat their way to luck. Several hundred miles away in the southern United States, people eat Hoppin' John, a favorite local dish made with black-eyed peas and pork, while fish is the "lucky" food of choice for Japanese Americans. National food traditions are carried to other countries when people immigrate. American cuisine would not be what it is today without the contributions of Italian, Chinese, Mexican, and other immigrants.

Factors that Drive Food Choices

Along with these influences, a number of other factors affect the dietary choices individuals make, including:

- **Taste, texture, and appearance.** Individuals have a wide range of tastes which influence their food choices, leading some to dislike milk and others to hate raw vegetables. Some foods that are very healthy, such as tofu, may be unappealing at first to many people. However, creative cooks can adapt healthy foods to meet most peoples' taste.
- **Economics.** Access to fresh fruits and vegetables may be scant, particularly for those who live in economically disadvantaged or remote areas, where cheaper food options are limited to convenience stores and fast food.
- **Early food experiences.** People who were not exposed to different foods as children, or who were forced to swallow every last bite of overcooked vegetables, may make limited food choices as adults.
- **Habits.** It's common to establish eating routines, which can work both for and against optimal health. Habitually grabbing a fast food sandwich for breakfast can seem convenient, but might not offer substantial nutrition. Yet getting in the habit of drinking an ample amount of water each day can yield multiple benefits.
- **Culture.** The culture in which one grows up affects how one sees food in daily life and on special occasions.
- **Geography.** Where a person lives influences food choices. For instance, people who live in Midwestern US states have less access to seafood than those living along the coasts.
- **Advertising.** The media greatly influences food choice by persuading consumers to eat certain foods.
- **Social factors.** Any school lunchroom observer can testify to the impact of peer pressure on eating habits, and this influence lasts through adulthood. People make food choices based on how they see others and want others to see them. For example, individuals can purchase cheap and fast pizzas or opt for high-end versions at fancy restaurants.
- **Health concerns.** Some people have significant food allergies, to lactose or peanuts for example, and need to avoid those foods. Others may have developed health issues, which require them to follow a low-salt diet. In addition, people who have never worried about their weight have a very different approach to eating than those who have long struggled with excess pounds.
- **Emotions.** There is a wide range in how emotional issues affect eating habits. When faced with a great deal of stress, some people tend to overeat, while others find it hard to eat at all.
- **Green food/Sustainability choices.** Based on a growing understanding of diet as a public and personal issue, more and more people are starting to make food choices based on their environmental impact. Realizing that their food choices help shape the world, many individuals are opting for a vegetarian diet, or, if they do eat animal products, striving to find the most "cruelty-free" options possible. Purchasing local and organic food products and items grown through sustainable products also helps shrink the size of one's dietary footprint.

Key Takeaways

In this section, you discovered that there are many determinants that affect your health status. You can change some of them and others you cannot. All the determinants of health interact together in influencing your health.

- The expression of genes determines all of your traits including your risk for certain diseases. Nutrients can change the way genes are turned "on" and "off," consequently affecting health.
- Certain stages of life require changes in nutrition to maintain bodily functions, such as growing.
- The traits that a person has are largely a product of their genes and environment. One aspect of a person's environment is socioeconomic status, which is dependent on income, occupation, and education. Socioeconomic status is one of the best environmental predictors of a population's health.
- Besides dietary habits, other components of lifestyle which affect health are physical activity level, recreational drug use, and sleeping patterns.
- Nutrition, genetics, environment, and lifestyle interplay on health.
- Cultural and religious tradition, along with social values can affect food choices. The foods you choose to eat affect your appetite and feelings. Numerous factors other than nutrition drive food choices.

Discussion Starters

1. What types of diseases and/or conditions are present in your family?
2. Discuss the different cultures and religions that are represented by the people in your classroom and learn the different foods that they choose to eat.

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1.7: Nutrition and the Media

Learning Objectives

- List at least four sources of reliable and accurate nutrition information.

A motivational speaker once said, “A smart person believes half of what they read. An *intelligent* person knows which half to believe.” In this age of information where instant Internet access is just a click away, it is easy to be misled if you do not know where to go for reliable nutrition information. There are a few websites that can be consistently relied upon for accurate material that is updated regularly.



Figure 1.7.1: Right information or wrong information? How can you know? © Shutterstock

Using Eyes of Discernment

“New study shows that margarine contributes to arterial plaque.” “Asian study reveals that two cups of coffee per day can have detrimental effects on the nervous system.” How do you react when you read news of this nature? Do you boycott margarine and coffee? When reading nutrition-related claims, articles, websites, or advertisements always remember that one study does not substantiate a fact. One study neither proves nor disproves anything. Readers who may be looking for complex answers to nutritional dilemmas can quickly misconstrue such statements and be led down a path of misinformation. Listed below are ways that you can develop discerning eyes when reading nutritional news.

1. The scientific study under discussion should be published in a peer-reviewed journal, such as the *Journal of the International Society of Sports Nutrition*. Question studies that come from less trustworthy sources (such as non peer-reviewed journals or websites) or that are not published.
2. The report should disclose the methods used by the researcher(s). Did the study last for three or thirty weeks? Were there ten or one hundred participants? What did the participants actually do? Did the researcher(s) observe the results themselves or did they rely on self reports from program participants?
3. Who were the subjects of this study? Humans or animals? If human, are any traits/characteristics noted? You may realize you have more in common with certain program participants and can use that as a basis to gauge if the study applies to you.
4. Credible reports often disseminate new findings in the context of previous research. A single study on its own gives you very limited information, but if a body of literature supports a finding, it gives you more confidence in it.
5. Peer-reviewed articles deliver a broad perspective and are inclusive of findings of many studies on the exact same subject.
6. When reading such news, ask yourself, “Is this making sense?” Even if coffee does adversely affect the nervous system, do you drink enough of it to see any negative effects? Remember, if a headline professes a new remedy for a nutrition-related topic, it may well be a research-supported piece of news, but more often than not it is a sensational story designed to catch the attention of an unsuspecting consumer. Track down the original journal article to see if it really supports the conclusions being drawn in the news report.

When reading information on websites, remember the following criteria for discerning if the site is valid:

1. Who sponsors the website?
2. Are names and credentials disclosed?

3. Is an editorial board identified?
4. Does the site contain links to other credible informational websites? Even better, does it reference peer-reviewed journal articles? If so, do those journal articles actually back up the claims being made on the website?
5. How often is the website updated?
6. Are you being sold something at this website?
7. Does the website charge a fee?

Trustworthy Sources

Now let's consider some reputable organizations and websites from which you can obtain valid nutrition information.

1. **Centers for Disease Control and Prevention (CDC):** The Centers for Disease Control and Prevention (http://www.cdc.gov) distributes an online newsletter called *CDC Vital Signs*. This newsletter is a valid and credible source for up-to-date public health information and data regarding food, nutrition, cholesterol, high blood pressure, obesity, teenage drinking, and tobacco usage.
2. **The Academy of Nutrition and Dietetics (AND):** The AND promotes scientific evidenced-based, research-supported food and nutrition related information on its website, http://www.eatright.org. It is focused on informing the public about recent scientific discoveries and studies, weight-loss concerns, food safety topics, nutrition issues, and disease prevention.
3. **US Department of Agriculture (USDA):** The USDA site fnic.nal.usda.gov has more than twenty-five hundred links to dietary, nutrition, diet and disease, weight and obesity, food-safety and food-labeling, packaging, dietary supplement and consumer questions sites. Using this interactive site, you can find tips and resources on how to eat a healthy diet, my Foodapedia, and a food planner, among other sections.
4. **US Department of Health and Human Services (HHS):** The HHS website, HealthFinder.gov, provides credible information about healthful lifestyles and the latest in health news. A variety of online tools are available to assist with food-planning, weight maintenance, physical activity, and dietary goals. You can also find healthful tips for all age groups, tips for preventing disease, and on daily health issues in general.
5. **Dietitians of Canada:** Dietitians of Canada, http://www.dietitians.ca/, is the national professional association for dietitians. It provides trusted nutrition information to Canadians and health professionals.
6. **Health Canada:** Health Canada, http://www.hc-sc.gc.ca/index-eng.php, is the Federal department that helps Canadians improve their health. Its website also provides information about health-related legislation.

Key Takeaways

- Reliable nutritional news will be based upon solid scientific evidence, supported by multiple studies, and published in peer-reviewed journals. Be sure the website you use for information comes from a credible and trustworthy source, such as the USDA Food and Nutrition Center, the HHS, and the CDC.

Discussion Starter

1. Discuss why it is important to get information from proper and credible sources and not to rely upon single study findings.

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1.8: Assessing Personal Health

Learning Objectives

- Discuss ways of assessing your personal health status and your diet.
- Set a goal to adopt, maintain, or improve a nutrition-related practice.
- Formulate an effective, long-term, personal health and nutrition plan.

You may remember that when you were younger your mother or grandmother made you swallow that teaspoonful of cod liver oil because she said it was good for you. You don't have to have a PhD to know some of the basic ways you can adapt your life to be healthier. However, the mainstream media inundates the American population with health cures and tips, making it confusing to develop the best plan for your health. This section will equip you with tools to assess and improve your health. To find some other reliable sources on health see video below.

? Exercise 1.8.1: Quackwatch!

With all of the false Nutrition information out there, we need to be able to figure out which websites are reliable and which ones are simply quackery (false nutrition information)! Here is a website which will help you figure out who is trying their best to give you good information on nutrition and health and who is lying!

https://quackwatch.org/04ConsumerEdu...nonrecorg.html

Nutritional Status

The food you eat every day influences your health. For your body to function optimally, you need to eat the appropriate amount of nutrients daily to supports routine chemical processes. If you deviate from the "optimal" amount and consume too much or too little of a nutrient, you could become under- or over-nourished. This imbalance is called malnutrition and is your nutritional status.



Video 1.8.1 *What is malnutrition? Both over and under nutrition.*

Undernutrition occurs when someone does not eat enough calories, water, or other essential nutrients to meet their needs for cellular activities. You can be deficient in one nutrient or several nutrients simultaneously. Signs of undernutrition don't show immediately but is usually a slow process. Many different factors can play a role in its development including but not limited to decreased dietary intake, excessive losses, or increased requirements. These result in a depletion of tissue stores that lead to biochemical changes resulting in clinical signs or symptoms.

Overnutrition occurs when an excess consumption of calories, water, and/ or a nutrient(s) occur. For example, today, many people are overweight or obese because they consume too many calories. This state can be accompanied by an unobservable deficiency in other nutrients or undernutrition in other nutrients. It is possible to experience both over and undernutrition at the same time. Americans are at a greater risk of developing overnutrition.

You can also have an imbalance in nutrients, for example, zinc and copper that will cause a poor nutritional status.

Next, we will discuss ways you can assess your personal health to check your nutritional status.

Personal Health Assessment

One of the easiest places to begin a personal health assessment is by examining the results from your last physical. Often a person will leave the doctor's office without these results. Remember that the results belong to you and having this information on hand provides you with much of what you need to keep track of your health. Many of the results in that assessment are related to nutritional status.

During a physical, the nurse will obtain anthropometric values such as weight, height, length (babies), circumference (waist for adults and head for babies) skinfold thickness, etc. Then the nurse typically examines blood pressure. Blood pressure is a measurement of the forces in the arteries that occur during each heart beat. It is a principle vital sign and an indicator of cardiovascular health. A desirable blood pressure is 120 over 80 mmHg. After the nurse, generally, the doctor will also conduct a clinical examination which includes a medical history and physical exam.

In most circumstances, a physical includes biochemical indices such as blood, urine, feces, sweat and hair tests. These tests measure many health indicators, and you have to request the results. Once you have the results in hand, it is good practice to file them in a binder so you can compare them from year to year. This way you can track your blood-cholesterol levels and other blood lipid levels and blood glucose levels. These are some of the more general measurements taken, but in many instances, blood tests also examine liver and kidney function, vitamin and mineral levels, hormone levels, and disease markers. Your doctor uses all of these numbers to assess your health and you can use them to play a more active role in keeping track of your health.



Figure 1.8.1: Don't forget to get the results of your physical the next time you visit your doctor. They will help you keep track of your health. (National Cancer Institute, an agency part of the National Institutes of Health; Linda Bartlett (Photographer)).

Hearing and vision are additionally part of a general health assessment. If you wear glasses, contacts, or a hearing aid you already are aware of how important it is to know the results of these exams. If you have not experienced vision or hearing problems yet your likelihood of experiencing them markedly increases over the age of forty. Another component of overall health is oral health. The health of your teeth, gums, and everything else in your mouth are an integral component of your overall health. This becomes apparent when a person experiences a tooth infection, which if left untreated significantly impairs physical, mental, and social well-being.

Other indicators of health that you can measure yourself are body mass index (BMI) and fitness. BMI is simply a ratio of an individual's weight and height. More specifically BMI is calculated using an individual's body weight (in kilograms, or kg) divided by the square of their height (in meters) and the unit of measurement is kg/m^2. You can calculate this yourself or use one of the many BMI calculators on the web (see Interactive). BMI is a standardized measurement that indicates if a person is underweight, of normal weight, overweight, or obese and is based on data from the average population. It has some limitations. One limitation is that it does not take into account how much of your weight is made up of muscle mass, which weighs more than fat tissue. BMI and other measurements of body composition and fitness are more fully discussed elsewhere.

? Interactive 1.8.1

One of the better websites for assessing your health is available at the Institute for Good Medicine from the Pennsylvania Medical Society. Note: to convert your weight in pounds into kilograms simply divide by divide your weight in pounds by 2.2. For example: 160 pounds divided by 2.2 = 72.7 kilograms.

www.myfamilywellness.org/MainMenuCategories/YouYourPhysician/YourHealthToolkit

This personal health assessment has focused primarily on physical health, but remember that mental and social well-being also affect health. During a physical, a doctor will ask how you are feeling, if you are depressed, and if you are experiencing behavioral problems. Be prepared to answer these questions truthfully, so that your doctor can develop a proper treatment plan to manage these aspects of health. Interactive 1.8 provides some tools to assess your mental and social well-being.

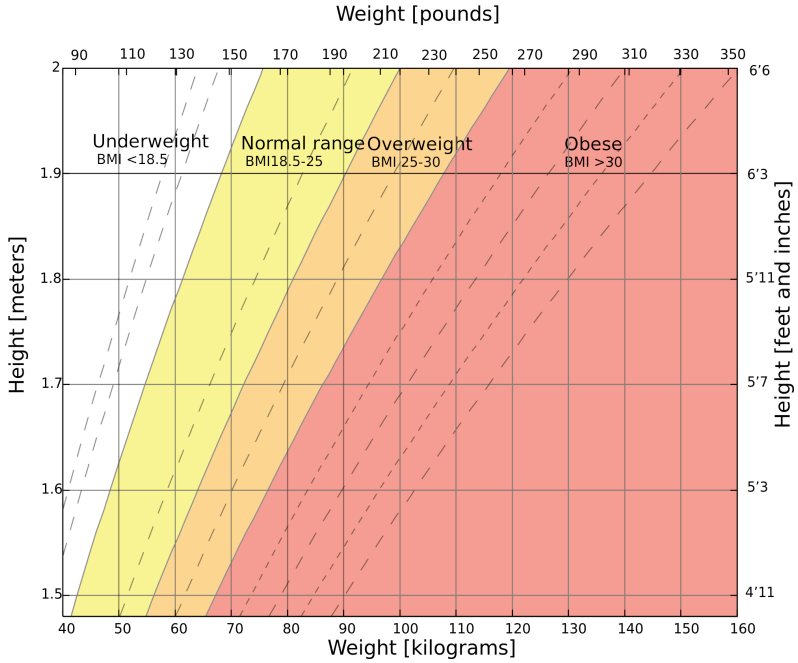


Figure 1.8.2: A graph of body mass index is shown above. By lining up weight and height you can find out in which range an adult person falls. Left of normal range means too thin, to the right of normal means too fat. Dashed lines give a rough idea of how much too thin or how much too fat a person is. (Public Domain).

Taking charge of your health will pay off and equip you with the knowledge to better take advantage of your doctor's advice during your next physical. Health calculators, such as those that calculate BMI, ideal weight, target heart rate among many others, and personal health assessments will help you to take charge of your health, but they should not take the place of visiting your doctor.

Dietary Assessment

The first step in assessing your diet is to find out if the foods you eat are good for your health and provide you with all the nutrients you need. Begin by recording in a journal what you eat every day, including snacks and beverages. Then visit the USDA website, www.choosemyplate.gov/myplate/index.aspx, which has various tools to help you assess your diet. You can track calories over time, diet quality, and find many other tools to evaluate your daily food consumption. The questions these tools can help answer include: How much food do you have to eat to match your level of activity? How many calories should you eat? What are the best types of food to get the most nutrients? What nutrients are contained in different foods? How do you plan a menu that contains all the nutrients you need? Make the first step and assess your diet. This book will provide you with interactive resources, videos, and audio files to empower you to create a diet that improves your health.

Nutrition scientists use a variety of different dietary assessment tools to determine the nutrients intake of individuals or groups. Dietitians may use these same tools with their clients. The 24-hour recall, as the name implies, asks the person to remember what they ate the last 24 hours. Dietary records cover a longer period; usually, 3 - 7 days and the person writes down what they ate at the time it is eaten. A trained person then checks the record for accuracy. The diet history method asks an individual what they usually eat. The information is collected in a historical perspective. Finally, the food frequency questionnaire asks the respondent to recall how often and how much they eat a particular food. Each of these methods has pros and cons and which one is used depends on the strength and weakness of that tool to quantitate what a person is or has eaten.

Family Medical History

Because genetics play a large role in defining your health it is a good idea to take the time to learn some of the diseases and conditions that may affect you. To do this, you need to record your family's medical history. Start by simply drawing a chart that details your immediate family and relatives. Many families have this and you may have a good start already. The next time you attend a family event start filling in the blanks. What did people die from? What country did Grandpa come from? While this may be a more interesting project historically, it can also provide you with a practical tool to determine what diseases you might be more susceptible to. This will allow you to make better dietary and lifestyle changes early on to help prevent a disease from being handed down from your family to you. It is good to compile your information from multiple relatives.

Lifestyle Assessment

A lifestyle assessment includes evaluating your personal habits, level of fitness, emotional health, sleep patterns, and work-life balance. Many diseases are preventable by simply staying away from certain lifestyles. Don't smoke, don't drink excessively, and don't do recreational drugs. Instead, make sure you exercise. Find out how much to exercise by reading the *2008 Physical Activity Guidelines for Americans*. There is a wealth of scientific evidence that increased physical activity promotes health, prevents disease, and is a mood enhancer. Emotional health is often hard to talk about; however a person's quality of life is highly affected by emotional stability. Harvard's Women's Health Watch notes six reasons to get enough sleep: Sleep promotes healthy brain function, while lack of sleep can cause weight gain and increase appetite, decrease safety (falling asleep while driving), make a person moody and irritable, decrease health of the cardiovascular system and prevent the immune system from functioning well.Harvard Health Publications. "Importance of Sleep: Six Reasons Not to Scrimp on Sleep." *Harvard's Women's Health Watch* (January 2006). © 2000–2012 Harvard University. http://www.health.harvard.edu/press_releases/importance_of_sleep_and _health Finding balance between work and life is a difficult and continuous process involving keeping track of your time, taking advantage of job flexibility options, saying no, and finding support when you need it. Work-life balance can influence what you eat too.

Key Takeaways

This section equips you with some tools to assess your lifestyle and make changes towards a healthier one.

- **Step 1.** Take charge of tracking your personal health.
- **Step 2.** Assess your diet and identify where it can be changed to promote health and prevent disease.
- **Step 3.** Start finding out the medical history of your family and identify the diseases you may be more susceptible to getting.
- **Step 4.** Assess your lifestyle by evaluating your personal habits, emotional health, sleep patterns, and work-life balance.
- **Step 5.** Start living a healthier life.

Discussion Starters

1. What websites in Interactive 1.8 did you find to be the most helpful in the assessment of your health?
2. Share your comments on these tools with your classmates and get their opinions, too.

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1.9: Dietary Toolkit

The dietary toolkit contains numerous ideas to help you achieve a healthy diet.

Let's talk about a toolkit for a healthy diet. The first thing in it would be the Recommended Daily Allowances (RDAs). Then we could add the Dietary Reference Intakes (DRIs), the Estimated Average Requirements (EARs), and the Tolerable Upper Limits (ULs). All of these tools are values for important nutrients, calculated to meet the health needs of different age groups. But long before the dietary toolkit full of acronyms such as DRI, RDA, EAR, and UL, daily standards were created with the single goal of keeping workers alive and toiling in the factories and workhouses of the early Industrial Revolution. In the late nineteenth-century powerhouse tycoons operated without fear of legal consequences and paid their workers as little as possible in order to maximize their own profits. Workers could barely afford housing, and depended on what their bosses fed them at the workhouses to fend off starvation.



Figure 1.9.1: Without programs like food stamps, workers and military personnel often had to accept whatever meager rations were given to them by their employers. People eating at a soup kitchen. Montreal, Canada. Public domain image.

Living conditions in those days show that the term "starvation wages" was not just a figure of speech. Here's a typical day's menu:

- **Breakfast.** 1-pint porridge, one 6-ounce piece of bread.
- **Lunch.** Beef broth one day, boiled pork and potatoes the next.
- **Dinner.** 1-pint porridge, one 6-ounce piece of bread.

As public awareness about these working conditions grew, so did public indignation. Experts were eventually called in to create the first dietary guidelines, which were designed only to provide a typical individual with what they needed to survive each day and no more. It wasn't until World War I that the British Royal Society first made recommendations about the nutrients people needed to be healthy, as opposed to merely surviving. They included ideas we now take for granted, such as making fruits and vegetables part of the diet and giving milk to children. Since then, most governments have established their own dietary standards. Food is a precious commodity, like energy, and controlling the way it is distributed confers power. Sometimes this power is used to influence other countries, as when the United States withholds food aid from countries with regimes of which it disapproves. Governments can also use their power over food to support their most fragile citizens with food relief programs, such as the Supplemental Nutrition Assistance Program (SNAP) and the Women, Infants, and Children Supplemental Food Program (WIC).

The US government has also established dietary standards to help citizens follow a healthy diet. The first of these were the Recommended Daily Allowances (RDAs), published in 1943 because of the widespread food shortages caused by World War II. During the war, the government rationed sugar, butter, milk, cheese, eggs, coffee, and canned goods. Limited transportation made it hard to distribute fruits and vegetables. To solve this problem, the government encouraged citizens to plant "victory gardens" to produce their own fruits and vegetables. More than twenty million people began planting gardens in backyards, empty lots, and on rooftops. Neighbors pooled their resources and formed cooperatives, planting in the name of patriotism.

Today in the United States, there are various measures used to maintain access to nutritious, safe, and sufficient food to the citizenry. Many of these dietary guidelines are provided by the government, and are found at the Food and Drug Administration's (FDA) new website, ChooseMyPlate.gov. We call this collection of guidelines the "dietary toolkit."

Note

How will you use the dietary toolkit?

The government works to provide citizens with information, guidance, and access to healthy foods. How will you decide which information to follow? What are the elements of a healthy diet, and how do you figure out ways to incorporate them into your personal diet plan? The dietary toolkit can be likened to a mechanics toolkit, with every tool designed for a specific task(s). Likewise, there are many tools in the dietary toolkit that can help you build, fix, or maintain your diet for good health. In this chapter you will learn about many of the tools available to you.

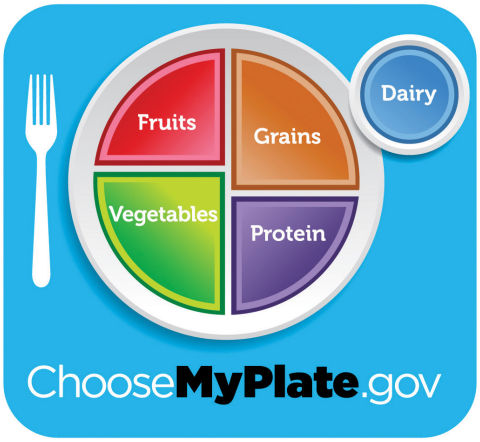


Figure 1.9.2: Today, the US government sets dietary guidelines that provide evidence-based nutrition information designed to improve the health of the population. Source: US Department of Agriculture.

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1.10: A Healthy Philosophy toward Food

Learning Objectives

- Explain why nutrition is important to health.

"Tell me what you eat, and I will tell you what you are" wrote the French lawyer and politician, Antheime Brillat-Savarin in his book, *Physiologie du Gout, ou Meditations de Gastronomie Transcendante*, in 1826. Almost one hundred years later, nutritionist Victor Lindlahr wrote in an ad in 1923, "Ninety percent of the diseases known to man are caused by cheap foodstuffs. You are what you eat." Today, we know this phrase simply as, "You are what you eat."

Good nutrition equates to receiving enough (but not too much) of the macronutrients (proteins, carbohydrates, fats, and water) and micronutrients (vitamins and minerals) so that the body can stay healthy, grow properly, and work effectively. The phrase "you are what you eat" refers to the fact that your body will respond to the food it receives, either good or bad. Processed, sugary, high-fat, and excessively salted foods leave the body tired and unable to perform effectively. By contrast, eating fresh, natural whole foods fuels the body by providing what it needs to produce energy, promote metabolic activity, prevent micronutrient deficiencies, ward off chronic disease, and to promote a sense of overall health and well-being.

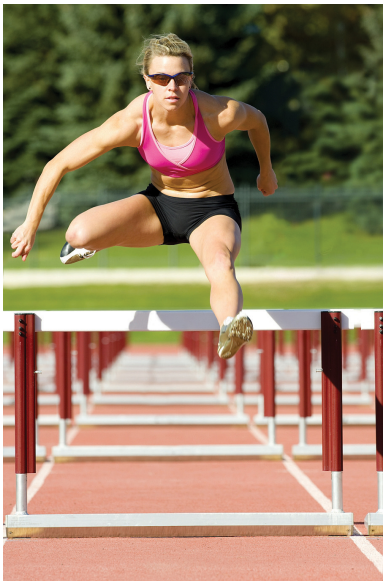


Figure 1.10.1: Nutrition provides the body with the nutrients it needs to perform all activities, from taking a breath to strenuous athletic activity. © Dreamstime

Table 1.10.1: Why Nutrition Is Important to Health

Protein	Necessary for tissue formation, cell reparation, and hormone and enzyme production. It is essential for building strong muscles and a healthy immune system.
Carbohydrates	Provide a ready source of energy for the body and provide structural constituents for the formation of cells.
Fat	Provides stored energy for the body, functions as structural components of cells and also as signaling molecules for proper cellular communication. It provides insulation to vital organs and works to maintain body temperature.
Vitamins	Regulate body processes and promote normal body-system functions.
Minerals	Regulate body processes, are necessary for proper cellular function, and comprise body tissue.

Water	Transports essential nutrients to all body parts, transports waste products for disposal, and aids with body temperature maintenance.

Undernutrition, Overnutrition, and Malnutrition

For many, the word “malnutrition” produces an image of a child in a third-world country with a bloated belly, and skinny arms and legs. However, this image alone is not an accurate representation of the state of malnutrition. For example, someone who is 150 pounds overweight can also be malnourished. Malnutrition refers to one not receiving proper nutrition and does not distinguish between the consequences of too many nutrients or the lack of nutrients, both of which impair overall health. Undernutrition is characterized by a lack of nutrients and insufficient energy supply, whereas overnutrition is characterized by excessive nutrient and energy intake. Overnutrition can result in obesity, a growing global health threat. Obesity is defined as a metabolic disorder that leads to an over accumulation of fat tissue. A person can be over nourished in one nutrient and undernourished in other nutrients.

Although not as prevalent in America as it is in developing countries, undernutrition is not uncommon and affects many subpopulations, including the elderly, those with certain diseases, and those in poverty. Many people who live with diseases either have no appetite or may not be able to digest food properly. Some medical causes of malnutrition include cancer, inflammatory bowel syndrome, AIDS, Alzheimer’s disease, illnesses or conditions that cause chronic pain, psychiatric illnesses, such as anorexia nervosa, or as a result of side effects from medications. Overnutrition is an epidemic in the United States and is known to be a risk factor for many diseases, including Type 2 diabetes, cardiovascular disease, inflammatory disorders (such as rheumatoid arthritis), and cancer.

Growth and Development

From birth to adulthood, nutrients fuel proper growth and function of all body cells, tissue, and systems. Without proper amounts of nutrients, growth and development are stunted. Some nutrient deficiencies manifest right away, but sometimes the effects of undernutrition aren’t seen until later in life. For example, if children do not consume proper amounts of calcium and vitamin D, peak bone mass will be reduced compared to what it would be had adequate amounts of these nutrients been consumed. When adults enter old age without adequate bone mass, they are more susceptible to osteoporosis, putting them at risk for bone fractures. Therefore, it is vital to build bone strength through proper nutrition during youth because it cannot be done in later life.MedicineNet.com. “Nutrients for the Growing Years.” Last reviewed August 13, 2003. http://www.medicinenet.com/script/main/art.asp?articlekey=10054.

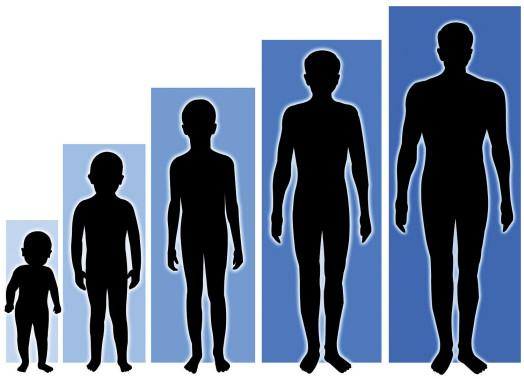


Figure 1.10.2: Proper growth throughout the life stages depends upon proper nutrition. © Dreamstime

The Healing Process

With all wounds, from a paper cut to major surgery, the body must heal itself. Healing is facilitated through proper nutrition,MacKay, D., ND, and A. L. Miller, ND. “Nutritional Support for Wound Healing.” *Alternative Medicine Review* 8, no. 4 (2003): 359–77. while malnutrition inhibits and complicates this vital process. The following nutrients are important for proper healing:



Figure 1.10.3: Healing, a critical function of a healthy body, is facilitated by adequate nutrition.

- **Vitamin A.** Helps to enable the epithelial tissue (the thin outer layer of the body and the lining that protects your organs) and bone cells form.
- **Vitamin C.** Helps form collagen, an important protein in many body tissues.
- **Protein.** Facilitates tissue formation.
- **Fats.** Play a key role in the formation and function of cell membranes.
- **Carbohydrates.** Fuel cellular activity, supplying needed energy to support the inflammatory response that promotes healing.

Now that we have discussed the importance of proper nutrition for your body to perform normal tissue growth, repair, and maintenance, we will discuss ways of achieving a healthy diet.

Key Takeaways

- Nutrition promotes vitality and an overall sense of health and well-being by providing the body with energy and nutrients that fuel growth, healing, and all body systems and functions. Good nutrition will also help to ward off the development of chronic disease.
- A person is malnourished by being either undernourished or overnourished. Malnutrition results when the body does not receive the required amounts of calories, fats, proteins, carbohydrates, vitamins, and minerals necessary to keep the body and its systems in good functioning order.

Discussion Starter

1. Describe what the phrase, “You are what you eat” means. Do you notice how you feel after eating certain types of foods? How might this relate to your overall health?

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1.11: Understanding the Bigger Picture of Dietary Guidelines

Learning Objectives

- Describe the major themes of the *2015 Dietary Guidelines for Americans*.

The first US dietary recommendations were set by the National Academy of Sciences in 1941. The recommended dietary allowances (RDA) were first established out of concern that America's overseas World War II troops were not consuming enough daily nutrients to maintain good health. The first Food and Nutrition Board was created in 1941, and in the same year set recommendations for the adequate intakes of caloric energy and eight essential nutrients. These were disseminated to officials responsible for food relief for armed forces and civilians supporting the war effort. Since 1980, the dietary guidelines have been reevaluated and updated every five years by the advisory committees of the US Department of Agriculture (USDA) and the US Department of Health and Human Services (USDHHS). The guidelines are continually revised to keep up with new scientific evidence-based conclusions on the importance of nutritional adequacy and physical activity to overall health. While dietary recommendations set prior to 1980 focused only on preventing nutrient inadequacy, the current dietary guidelines have the additional goals of promoting health, reducing chronic disease, and decreasing the prevalence of overweight and obesity. The guidelines are also used to provide a scientific basis for the USDA school food lunch program and the Food Stamp program.

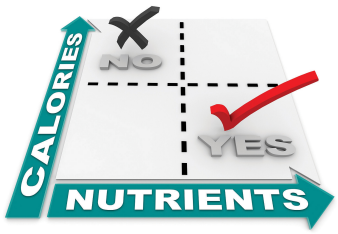


Figure 1.11.1: Dietary guidelines help people to stay on a healthful track by drawing attention to the overall scope of their diet and lifestyle. © Dreamstime

Why Are Guidelines Needed?

Instituting nation-wide standard policies provides consistency across organizations and allows health-care workers, nutrition educators, school boards, and elder-care facilities to improve nutrition and subsequently the health of their respective populations. At the same time, the goal of the *2015 Dietary Guidelines* is to provide packaged informative guidelines that will help any interested person in obtaining optimal nutritional balance and health. The eighth edition of the *Dietary Guidelines* was released in 2015 and focuses improving overall eating patterns. Former USDA Secretary Tom Vilsack says, "The bottom line is that most Americans need to trim their waistlines to reduce the risk of developing diet-related chronic disease. Improving our eating habits is not only good for every individual and family, but also for our country." The *Dietary Guidelines* are formulated by the Food and Nutrition Board of the Institute of Medicine (IOM) from the review of thousands of scientific journal articles by a consensus panel consisting of more than two thousand nutrition experts with the overall mission of improving the health of the nation.



Figure 1.11.2: The major theme of the *2015 Dietary Guidelines for Americans* is a healthy eating pattern combined with regular physical activity.

Major Themes of the *2015 Dietary Guidelines*

The *2015 Dietary Guidelines* consists of five major action steps for the American public to improve their eating habits. It also includes several key recommendations. These five steps are as follows:

- Follow a healthy eating pattern across the lifespan.
- Focus on variety, nutrient density, and amount.
- Limit calories from added sugars and saturated fats and reduce sodium intake.
- Shift to healthier food and beverage choices.
- Support healthy eating patterns for all.

We will discuss the highlights of each chapter of the *2015 Dietary Guidelines*; however, if you are interested in reading more, visit the USDA website, https://health.gov/dietaryguidelines/2015/guidelines/.

How should you develop a healthy eating plan to best achieve your goals of losing weight, gaining weight, or maintaining weight? We will start with some basics and move on to healthy eating patterns.

To provide further guidance, several key recommendations are provided. These should be applied in their entirety because of their interconnectedness.

Consume a healthy eating pattern that accounts for all foods and beverages within an appropriate calorie level.

A health heating pattern includes:

- A variety of vegetables from all of the subgroups - dark green, red and orange, legumes (beans and peas), starchy, and other
- Fruits, especially whole fruits
- Grains, at least half of which are whole grains
- Fat-free or low-fat dairy, including milk, yogurt, cheese, and/or fortified soy beverages
- A variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds, and soy products
- Oils

The following components of the diet should be limited in order to achieve a healthy eating pattern:

- Consume less than 10 percent of calories per day from added sugars
- Consume less than 10 percent of calories per day from saturated fats
- Consume less than 2,300 milligrams (mg) per day of sodium
- If alcohol is consumed, it should be consumed in moderation - up to one drink per day for women and up to two drinks per day for men - and only by adults of legal drinking age.

Finally, all Americans regardless of age should meet the *Physical Activity Guidelines for Americans*.

Foods and Food Components to Reduce

High consumptions of certain foods, such as those high in saturated and trans fat, sodium, and added sugars may contribute to the increased incidence of chronic disease. Additionally, excessive consumption of these foods replaces the intake of more nutrient-dense foods.

Table 1.11.1: A Little Less of These, Please

Dietary Constituent	Health Implications	Recommendations
Excess sodium	High blood pressure	Limit intake to 2,300 mg daily
SoFAS (solid fats and added sugars)	Obesity, Type 2 diabetes, CVD, cancer	Avoid if possible
Too much alcohol	Impaired liver function, impaired motor function	No more than one drink per day for women; No more than two drinks per day for men
Too much saturated fat	Cardiovascular disease	Limit intake to < 10 percent of total calories
Trans fats	Cardiovascular disease	Minimal, if any consumption

Dietary Constituent	Health Implications	Recommendations
Cholesterol	Cardiovascular disease	Minimal, if any consumption
Alcohol		Drink in moderation if you have to drink
Caffeine		Drink in moderation (no more than three to five 8 oz cups/day)

The average person consumes 3,400 milligrams of sodium per day, mostly in the form of table salt. The *2015 Dietary Guidelines* recommend that Americans reduce their daily sodium intake to less than 2,300 milligrams. If you are over the age of fifty-one, are African American, or have cardiovascular risk factors, such as high blood pressure or diabetes, sodium intake should be reduced even further to 1,500 milligrams. The *Dietary Guidelines* also recommend that less than 10 percent of calories come from saturated fat, and those fat calories should be obtained by eating foods high in unsaturated fatty acids. Cholesterol intake should be decreased to below 300 milligrams per day and trans fatty acid consumption kept to a bare minimum. The *Dietary Guidelines* stresses the importance of limiting the consumption of foods with refined grains and added sugars, and introduce the new term, SoFAS, which is an acronym for *solid fats and added sugars*, both of which are to be avoided in a healthy diet plan. Nelson, J. and K. Zeratsky. "Dietary Guidelines Connect SoFAS and Weight Gain." Mayo Clinic, *Nutrition-Wise* (blog). August 25, 2010. www.mayoclinic.com/health/dietary-guidelines/MY01417. Moreover, if alcohol is consumed, it should be consumed only in moderation, which for women it is not more than one drink per day and for men is not more than two drinks per day. The macronutrients protein, carbohydrates, and fats contribute considerably to total caloric intake. The IOM has made recommendations for different age groups on the percentage of total calories that should be obtained from each macronutrient class (Table 2.5).

Table 1.11.2: Recommendations for Macronutrient Intake As Percentage of Total Calories

Age Group	Protein (%)	Carbohydrates (%)	Fat (%)
Children (1–3)	5–20	45–65	30–40
Children and Adolescents (4–18)	10–30	45–65	25–35
Adults (>19)	10–35	45–65	20–35

Source: *2010 Dietary Guidelines*.

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1.12: What Is Nutritional Balance and Moderation?

Learning Objectives

- Define the components of a healthful diet.

Achieving a Healthy Diet

Achieving a healthy diet is a matter of balancing the quality and quantity of food that is eaten. There are five key factors that make up a healthful diet:

- A diet must be adequate, by providing sufficient amounts of each essential nutrient, as well as fiber and calories.
- A balanced diet results when you do not consume one nutrient at the expense of another, but rather get appropriate amounts of all nutrients.
- Calorie control is necessary so that the amount of energy you get from the nutrients you consume equals the amount of energy you expend during your day's activities.
- Moderation means not eating to the extremes, neither too much nor too little.
- Variety refers to consuming different foods from within each of the food groups on a regular basis.

A healthy diet is one that favors whole foods. As an alternative to modern processed foods, a healthy diet focuses on "real" fresh whole foods that have been sustaining people throughout the millenniums. Whole foods supply the needed vitamins, minerals, protein, carbohydrates, fats, and fiber that are essential to good health. Commercially prepared and fast foods are often lacking nutrients and often contain inordinate amounts of sugar, salt, saturated and trans fats, all of which are associated with the development of diseases such as atherosclerosis, heart disease, stroke, cancer, obesity, high cholesterol, diabetes, and other illnesses. A balanced diet is a mix of food from the different food groups (vegetables, legumes, fruits, grains, protein foods, and dairy).

Adequacy

An adequate diet is one that favors nutrient-dense foods. Nutrient-dense foods are defined as foods that contain many essential nutrients per calorie. Nutrient-dense foods are the opposite of "empty-calorie" foods, such as sugary carbonated beverages, which are also called "nutrient-poor." Nutrient-dense foods include fruits and vegetables, lean meats, poultry, fish, low-fat dairy products, and whole grains. Choosing more nutrient-dense foods will facilitate weight loss, while simultaneously providing all necessary nutrients.

Tools for Change

Does your diet contain nutrient-dense foods? Record your eating habits for one week. Note the sugary, fatty, and calorie-heavy foods you most often consume. Look at Table 2.2 to decide what you can substitute those foods with.

Table 1.12.1: The Smart Choice: Nutrient-Dense Food Alternatives

Instead of…	Replace with…
Sweetened fruit yogurt	Plain fat-free yogurt with fresh fruit
Whole milk	Low-fat or fat-free milk
Cheese	Low-fat or reduced-fat cheese
Bacon or sausage	Canadian bacon or lean ham
Sweetened cereals	Minimally sweetened cereals with fresh fruit
Apple or berry pie	Fresh apple or berries
Deep-fried French fries	Oven-baked French fries or sweet potato baked fries
Fried vegetables	Steamed or roasted vegetables
Sugary sweetened soft drinks	Seltzer mixed with 100 percent fruit juice

Instead of…	Replace with…
Recipes that call for sugar	Experiment with reducing amount of sugar and adding spices (cinnamon, nutmeg, etc…)
Source: US Department of Agriculture. “Food Groups.” www.choosemyplate.gov/food-groups/.	

Balance

Balance the foods in your diet. Achieving balance in your diet entails not consuming one nutrient at the expense of another. For example, calcium is essential for healthy teeth and bones, but too much calcium will interfere with iron absorption. Most foods that are good sources of iron are poor sources of calcium, so in order to get the necessary amounts of calcium and iron from your diet, a proper balance between food choices is critical. Another example is that while sodium is a vital nutrient, an overabundance of it can contribute to congestive heart failure and chronic kidney disease. Remember, everything must be consumed in the proper amounts.



Figure 1.12.1: With careful planning, a balanced diet providing optimal nutrition can be achieved and maintained. © Shutterstock

Moderation

Eat in moderation. Moderation is crucial for optimal health and survival. Burgers, French fries, cake, and ice cream each night for dinner will lead to health complications. But as part of an otherwise healthful diet and consumed only on a weekly basis, this should not have too much of an impact on overall health. If this is done once per month, it will have even less of an impact upon overall health. It’s important to remember that eating is, in part, about enjoyment and indulging with a spirit of moderation. This fits within a healthy diet.

Calorie Control

Monitor food portions. For optimum weight maintenance, it is important to ensure that energy consumed from foods meets the energy expenditures required for body functions and activity. If not, the excess energy contributes to gradual, steady weight gain. In order to lose weight, you need to ensure that more calories are burned than consumed. Likewise, in order to gain weight, calories must be eaten in excess of what is expended daily.

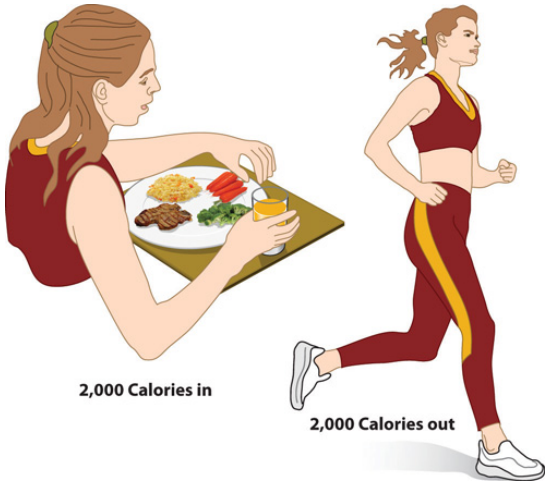


Figure 1.12.2: The number of calories consumed should always match the number of calories being expended by the body to maintain a healthy weight.© Networkgraphics

Variety

Variety involves eating different foods from all the food groups. Eating a varied diet helps to ensure that you receive all the nutrients necessary for a healthy diet. One of the major drawbacks of a monotonous diet is the risk of consuming too much of some nutrients and not enough of others. Trying new foods can also be a source of pleasure—you never know what foods you might like until you try them.

Table 1.12.2: Food Choices for a Healthful Diet

Grain	Vegetable	Fruit	Dairy	Protein
Whole-grain products, brown rice, quinoa, barley, buckwheat, millet, wild rice, oats, rye berries, sorghum, bulgur, kasha, farrow, wheat berries, corn, amaranth, spelt, Teff	**Dark green:** broccoli, collards, kale, romaine lettuce, spinach, turnip greens, watercress	apples, apricots, bananas	all fluid milk (fat free, low-fat, reduced-fat, whole milk, lactose-free), fortified soy milk, yogurt	**Meats:** beef, ham, lamb, pork, veal
	Red and orange: Acorn squash, butternut squash, carrots, pumpkin, red peppers, sweet potatoes	**Berries:** strawberries, blueberries, raspberries, cherries, grapefruit, kiwi fruit, lemons, limes, mangoes	**Hard natural cheeses:** cheddar, mozzarella, Swiss, parmesan	**Poultry:** chicken, goose, turkey, duck
	Beans and peas: Black beans, black-eyed peas, chickpeas, kidney beans, lentils, navy beans, pinto beans, soybeans, split peas, white beans	**Melons:** cantaloupe, honey dew, watermelon	**Soft cheeses:** ricotta, cottage	**Eggs**
	Starchy: Cassava, green bananas, green peas, green lima beans, plantains, potatoes, taro, water chestnuts	**Other fruits:** nectarines, oranges, peaches, pears, papaya, pineapple, plums, prunes		**Beans and peas:** (see vegetable column)

Grain	Vegetable	Fruit	Dairy	Protein
	Other vegetables: Asparagus, avocado, bean sprouts, beets, Brussels sprouts, cabbage, cauliflower, celery, eggplant, green beans, green peppers, mushrooms, okra, onions, parsnips			**Nuts and seeds:** almonds, cashews, hazelnuts, peanuts, pecans, pistachios, pumpkin seeds, sesame seeds, sunflower seeds, walnuts
				Seafood: catfish, cod, flounder, haddock, halibut, herring, mackerel, pollock, porgy, salmon, sea bass, snapper, swordfish, trout, tuna
				Shellfish: scallops, muscles, crab, lobster

Source: Adapted from www.choosemyplate.gov/food-groups/protein-foods.html.

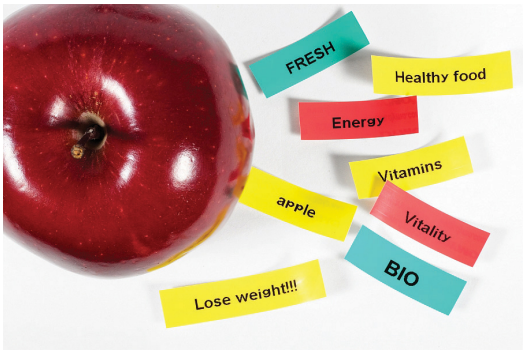


Figure 1.12.3: Scientific evidence confirms that a diet full of fresh whole foods reduces the risks for developing chronic disease and helps maintain a healthy weight. © Dreamstime

Video Link 1.12.1:

Different Types of Grains: In this video, a registered dietitian discusses the benefits of eating whole grains. http://www.ehow.com/video_4983984_different-types-grains.html

Developing a healthful diet can be rewarding, but be mindful that all of the principles presented must be followed to derive maximal health benefits. For instance, introducing variety in your diet can still result in the consumption of too many high-calorie, nutrient-poor foods and inadequate nutrient intake if you do not also employ moderation and calorie control. Using all of these principles together will afford you lasting health benefits.



Figure 1.12.4: Widening your food palate will increase your intake of vital nutrients. © Dreamstime

Key Takeaways

- A healthful diet is adequate in providing proper amounts of nutrient-dense foods, is balanced in relation to food types so that one nutrient is not consumed at the expense of another, practices calorie control by supplying food energy to match energy output, is moderate in unwanted constituents, and draws from a variety of nutritious foods.
- Nutrient-dense foods contribute to daily nutritional requirements while limiting caloric intake, thus allowing people to either lose weight safely or to maintain a healthy weight.

Discussion Starters

1. Discuss the principles of a healthy diet. How can you employ these principles in your diet, if you are not already?
2. Review the list of grains in Table 1.12.23. Pick one that you have not tried before. Make a dish using this grain. Discuss with your classmates your experience eating this new food.

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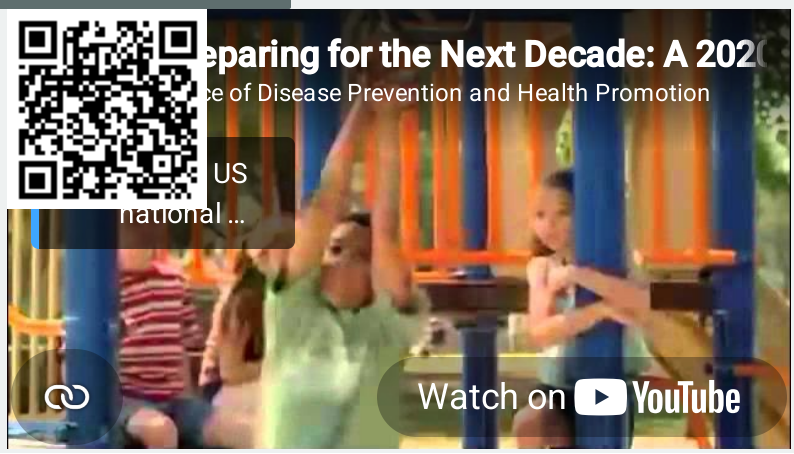
1.13: National Goals for Nutrition and Health- Healthy People 2020

Learning Objectives

- State the Healthy People 2020 nutrition- and weight-status goals.
- List three related objectives for the Healthy People 2020 program.

The Healthy People 2020 program, launched in 2010, is a ten-year national program instituted by the US government with objectives aimed at improving the health of all Americans. Similar to the *2010 Dietary Guidelines*, it has been established to promote longer lives free of preventable disease, disability, injury, and premature death. With a revived intent on identifying, measuring, tracking, and reducing health disparities through a "determinants of health approach," Healthy People 2020 will strive to create the social and physical environments that promote good health for all and to promote quality of life, healthy development, and healthy behaviors across all life stages. This means that the understanding of what makes and keeps people healthy is consistently refined. The determinants of health approach reflects the evidence from outside factors that greatly affect the health of individuals.US Department of Health and Human Services. "About Healthy People." Last updated August 22, 2017. http://www.healthypeople.gov/2020/about/default.aspx It takes into consideration the circumstances in which people are born, live, work, and age. It also reflects the conditions that shape their circumstances such as money, power, and resources at the local, national, and global levels. Social determinants of health are primarily accountable for the lack of fair health opportunities and the unjust differences in health status that exist within and between countries.World Health Organization. "Social Determinants of Health." © 2017. http://www.who.int/social_determinants/en/.

Video 1.13.1: Preparing for the Next Decade



Video 1.13.1: *Preparing for the Next Decade: A 2020 Vision for Healthy People (click to see video)*

Helping People Make Healthy Choices

It is not just ourselves, the food industry, and the federal government that shapes our choices of food and physical activity, but also our sex, genetics, disabilities, income, religion, culture, education, lifestyle, age, and environment. All of these factors must be addressed by organizations and individuals that seek to make changes in dietary habits. The socioeconomic model incorporates all of these factors and is used by health-promoting organizations, such as the United States Department of Agriculture (USDA) and Health and Human Services (HHS) to determine multiple avenues through which to promote healthy eating patterns, to increase levels of physical activity, and to reduce the risk of chronic disease for all Americans.



Figure 1.13.1: The socioeconomic model helps organizations and the government to plan and promote effective healthy-eating programs tailored to specific populations. © Networkgraphics

Lower economic prosperity influences diet specifically by lowering food quality, decreasing food choices, and decreasing access to enough food. Food insecurity is the inability to meet one's food needs all the time. We think of this in developing countries, but it also occurs in the United States and other developing countries. For children, food insecurity is associated with impaired physical and mental health. As a result of the recent financial crisis in America in 2008, the number of people who struggle to have enough to eat is rising and approaching fifty million (15% of the population). In response to these recent numbers, USDA Secretary Tom Vilsack said, “These numbers are a wake-up call…for us to get very serious about food security and hunger, about nutrition and food safety in this country.”Amy Goldstein, “Hunger a Growing Problem in America, USDA Reports,” *Washington Post*, 17 November 2009. www.washingtonpost.com/wp-dyn/content/article/2009/11/16/AR2009111601598.html. The Federal government has several programs to help. These include Food Stamps, WIC (Woman, Infant, and Children) program, school food lunch program, and SNAP (Supplemental Nutrition Assistance Program). Most programs are administered by the USDA>

Video 1.13.2: Determinants of Health

Video 1.13.2: *Determinants of Health Approach in Healthy People 2020 (click to see video)*

Goals for Nutrition and Weight Status

While Healthy People 2020 has many goals and objectives, we are going to focus on the two goals for nutrition and weight status. They are to promote health and reduce the risk of developing chronic diseases by encouraging Americans to consume healthful diets and to achieve and maintain healthy body weights. Nutrition criteria are reflective of a solid scientific foundation for health and weight management. Emphasis is on modifying individual behavior patterns and habits, and having policies and environments that will support these behaviors in various settings, such as schools and local community-based organizations.



Figure 1.13.2: One of the ways that Healthy People 2020 strives to promote good health and nutrition is by bringing together multiple agencies and groups dedicated to achieving the Healthy People 2020 nationwide objectives. © Shutterstock

Healthy People 2020 has defined their mission as:

- Identify nationwide health improvement priorities
- Increase public awareness and understanding of the determinants of health, disease, and disability, and the opportunities for progress
- Provide measurable objectives and goals that are applicable at the national, state, and local levels
- Engage multiple sectors to take actions to strengthen policies and improve practices that are driven by the best knowledge
- Identify critical research, evaluation, and data-collection needs

Healthy People 2020 has set key recommendations as follows:

- Consume a variety of nutrient-dense foods within and across the food groups, especially whole grains, fruits, vegetables, low-fat or fat-free milk or milk products, and lean meats and other protein sources
- Limit the intake of saturated fat and trans fats, cholesterol, added sugars, sodium (salt), and alcohol
- Limit caloric intake to meet caloric needs Department of Health and Human Services. “Nutrition and Weight Status.” HealthyPeople.gov. Last updated May 1, 2012. http://healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=29



Figure 1.13.3: Consuming nutrient-dense foods and limiting portion sizes of food will contribute to weight management. Avoiding excessive amounts of anything allows room for many food types in the diet. © Dreamstime

Tools for Change

If you wait many hours between meals, there is a good chance you will overeat. To refrain from overeating try consuming small meals at frequent intervals throughout the day as opposed to two or three large meals. Eat until you are satisfied, not until you feel “stuffed.” Eating slowly and savoring your food allows you to both enjoy what you eat and have time to realize that you are full before you get overfull. Your stomach is about the size of your fist but it expands if you eat excessive amounts of food at one sitting. Eating smaller meals will diminish the size of your appetite over time so you will feel satisfied with smaller amounts of food.

Benefits of Following the Healthy People 2020 Goals

Nutrition and weight status are important to children’s growth and development. In addition, healthy eating habits will decrease risks for developing chronic health conditions such as obesity, malnutrition, anemia, cardiovascular disease, high blood pressure,

dyslipidemia (poor lipid profiles), Type 2 diabetes, osteoporosis, dental disease, constipation, diverticular disease, and certain types of cancer.National Digestive Disease Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. “Am I at Risk for Type 2 Diabetes?” *NIH Publication No. 09-4805* (November 2008). Last updated December 6, 2011. diabetes.niddk.nih.gov/dm/pubs/riskfortype2/.

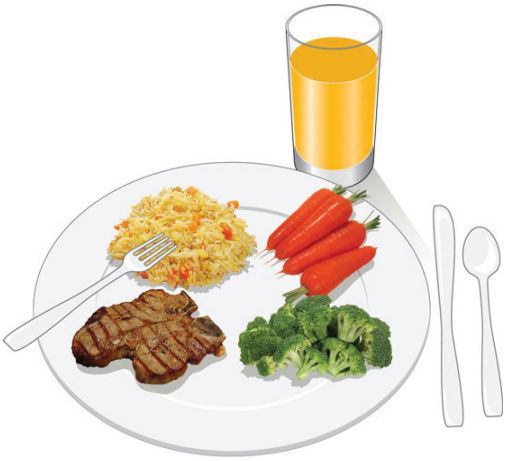


Figure 1.13.4: Following the *2010 Dietary Guidelines* will promote nutrition, weight loss, and weight maintenance as well as the reduction of chronic disease. © Networkgraphics

Meeting the recommended intake for energy needs by adopting a balanced eating regimen as promoted by the USDA’s My Food Plate tool will assist people in losing and maintaining weight and in improving overall health.

Objectives Related to the Healthy People 2020 Goals

Seven out of every ten deaths in the United States are caused by chronic diseases, such as heart disease, cancer, and diabetes, and three-quarters of the country’s health spending goes toward the cost of treating these diseases. Helping people lose weight, maintain a healthy weight, and prevent chronic disease by improving dietary habits requires providing education about food and nutrition, assuring access to healthier food options, and promoting the desire and ability to become physically active. Some of the Healthy People 2020 program’s related objectives are discussed below.

1. **Improve health, fitness, and quality of life through daily physical activity.** The Healthy People 2020 objectives for physical activity are based on the *2008 Physical Activity Guidelines for Americans* and reflect the strong scientific evidence supporting the benefits of physical activity. More than 80 percent of the current US population, from youth to adults, is not meeting these guidelines. Healthy People 2020 highlights the way that one’s level of physical activity is affected by environmental factors such as the availability of safe sidewalks, bike lanes, trails, and parks. It also highlights the legislative policies that improve access to facilities that promote physical activity. Understanding that personal, social, economic, and environmental barriers to physical activity all have a part in determining a population’s physical activity level, is an important part of being able to provide interventions that foster physical activity. Consistent physical activity is necessary for preventing chronic disease, improving bone health, decreasing body fat, and preventing an early death.

Video 1.13.3: Active versus Sedentary Lifestyles



Video 1.13.3: *This video provides a short overview of leading an active life versus a sedentary life.*

2. **Increase the quality, availability, and effectiveness of educational and community-based programs designed to prevent disease and injury, improve health, and enhance the quality of life.** Healthy eating is a learned behavior. By increasing the number of community-based programs (schools, workplace, health-care facilities, local community groups) that offer guidance for healthy eating and lifestyle choices, people of all ages will learn good eating habits and will gain access to good food choices to help improve their diet and overall health.
3. **Improve the development, health, safety, and well-being of adolescents and young adults.** Adolescents (ten to nineteen years of age) and young adults (twenty to twenty-four years of age) constitute 21 percent of the population of the United States. The financial burdens of preventable health problems and associated long-term costs of chronic diseases in this demographic group have the potential to be vast and will be the result of attitudes and behaviors initiated during adolescence. For example, the annual adult health-related financial burden of cigarette smoking, which usually starts by age eighteen, is $193 billion.Adhikari, B. et al. “Smoking-Attributable Mortality, Years of Potential Life Lost, and Productivity Losses—United States, 2000–2004.” *MMWR CDC Surveill Summ* 57, no. 45 (November 14, 2008): 1226–8. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5745a3.htm.



Figure 1.13.5: Healthy children will lead to a healthy adult population with less disease, lower healthcare costs, and increased longevity. © Shutterstock

4. **Reduce the consumption of calories from solid fats and added sugar (SoFAS) in the population aged two years and older.** A diet high in SoFAS contributes to excessive weight gain and poor health. Added sugars provide no nutritional value to foods. Excessive fat and sugar intake promote tooth decay, obesity, Type 2 diabetes, unhealthy cholesterol levels, and heart disease. Being overweight increases susceptibility to develop high blood pressure, diabetes, cardiovascular diseases, and certain types of cancer. The evidence is clear that many chronic diseases are linked to unhealthy dietary patterns. Excessive consumption of SoFAS, in combination with the lack of plant-based foods, may contribute to higher rates of developing chronic diseases.

For more information on Healthy People 2020 and its related objectives for nutrition and weight status, please visit the website http://www.healthypeople.gov/2020.

Key Takeaways

- Healthy People 2020 is a health initiative with a ten-year objective of helping Americans improve health and well-being, and to live long, healthy lives. Among its many objectives are to promote health and reduce the risk of developing chronic diseases by encouraging Americans to consume healthful diets and to achieve and maintain healthy body weights.
- The goals of Healthy People 2020 are founded upon a determinants of health approach, which means they are reflective of the circumstances in which people are born, live, and work, as well as the conditions that shape their circumstances such as money, power, and resources at the local, national, and global levels. Diet patterns are influenced by genetics, environment, and cultural values. All of these things must be considered to provide the optimal approach to improving the health of the American population.
- Decreasing caloric intake and increasing physical activity are important strategies in achieving the goals of the Healthy People 2020 program.

Discussion Starters

1. Think of fun ways to increase physical activity in your life. Watch the video below for ideas.

   How to Avoid a Sedentary Lifestyle (click to see video)

2. Review some of the Healthy People 2020 nutrition and physical activity program objectives. What objectives would you like to see enacted in your community? Why is this important to you? http://www.healthypeople.gov/2020

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1.14: Recommendations for Optimal Health

Learning Objectives

- Design a quality diet plan using MyPlate Daily Food Plan.
- State recommendation(s) for fruit and vegetable consumption and list the potential benefits of this eating program.

For many years, the US government has been encouraging Americans to develop healthful dietary habits. In 1992 the food pyramid was introduced, and in 2005 it was updated. This was the symbol of healthy eating patterns for all Americans. However, some felt it was difficult to understand, so in 2011, the pyramid was replaced with Choose MyPlate.

The Choose MyPlate program uses a tailored approach to give people the needed information to help design a healthy diet. The plate is divided according to the amount of food and nutrients you should consume for each meal. Each food group is identified with a different color, showing the food variety that all plates must have. Aside from educating people about the type of food that is best to support optimal health, the new food plan offers the advice that it is okay to enjoy food, just eat less of it.US Department of Agriculture. Accessed August 22, 2017. http://www.choosemyplate.gov/.

Video 1.14.1: Introducing the New Food Icon: MyPlate



Video 1.14.1: *This video provides an introduction to the new MyPlate food guide.*

Building a Healthy Plate: Choose Nutrient-Rich Foods

Planning a healthy diet using the MyPlate approach is not difficult. According to the icon, half of your plate should have fruits and vegetables, one-quarter should have whole grains, and one-quarter should have protein. Dairy products should be low-fat or non-fat. The ideal diet gives you the most nutrients within the fewest calories. This means choosing nutrient-rich foods.

Fill half of your plate with red, orange, and dark green vegetables and fruits, such as kale, collard greens, tomatoes, sweet potatoes, broccoli, apples, oranges, grapes, bananas, blueberries, and strawberries in main and side dishes. Vary your choices to get the benefit of as many different vegetables and fruits as you can. You may choose to drink fruit juice as a replacement for eating fruit. (As long as the juice is 100 percent fruit juice and only half your fruit intake is replaced with juice, this is an acceptable exchange.) For snacks, eat fruits, vegetables, or unsalted nuts.

Fill a quarter of your plate with whole grains such as 100 percent whole-grain cereals, breads, crackers, rice, and pasta. Half of your daily grain intake should be whole grains. Read the ingredients list on food labels carefully to determine if a food is comprised of whole grains.

Video 1.14.2: Tools for Change

Consider the information in this video:



Video 1.14.2: *Buying Local: The Importance of Locally Produced and Organically Grown Foods to Local Economy. (click to see video)*

Identify which vegetables and fruits are in season and local to your area. By consuming in-season, local foods you cut down on transportation costs (emission and financial) and you are likely to get fresher produce. You also support your local farms by purchasing their produce.



Figure 1.14.1: Make sure at least half of your daily grain intake comes from whole-grain foods. © Shutterstock

Select a variety of protein foods to improve nutrient intake and promote health benefits. Each week, be sure to include a nice array of protein sources in your diet, such as nuts, seeds, beans, legumes, poultry, soy, and seafood. The recommended consumption amount for seafood for adults is two 4-ounce servings per week. When choosing meat, select lean cuts. Be conscious to prepare meats using little or no added saturated fat, such as butter.



Figure 1.14.2: Remember to vary your selections of protein. Lentils contain good amounts of protein and make great meals. Try using lentils or beans as a meat substitute each week. © Thinkstock

If you enjoy drinking milk or eating milk products, such as cheese and yogurt, choose low-fat or nonfat products. Low-fat and nonfat products contain the same amount of calcium and other essential nutrients as whole-milk products, but with much less fat and calories. Calcium, an important mineral for your body, is also available in lactose-free and fortified soy beverage and rice beverage products. You can also get calcium in vegetables and other fortified foods and beverages.

Oils are essential for your diet as they contain valuable essential fatty acids, but the type you choose and the amount you consume is important. Be sure the oil is plant-based rather than based on animal fat. You can also get oils from many types of fish, as well as avocados, and unsalted nuts and seeds. Although oils are essential for health they do contain about 120 calories per tablespoon. It is vital to balance oil consumption with total caloric intake. The Nutrition Facts label provides the information to help you make healthful decisions.

In short, substituting vegetables and fruit in place of unhealthy foods is a good way to make a nutrient-poor diet healthy again. Vegetables are full of nutrients and antioxidants that help promote good health and reduce the risk for developing chronic diseases such as stroke, heart disease, high blood pressure, Type 2 diabetes, and certain types of cancer. Regularly eating fresh fruits and vegetables will boost your overall health profile.

Discretionary Calories

When following a balanced, healthful diet with many nutrient-dense foods, you may consume enough of your daily nutrients before you reach your daily calorie limit. The remaining calories are discretionary (to be used according to your best judgment). To find out your discretionary calorie allowance, add up all the calories you consumed to achieve the recommended nutrient intakes and then subtract this number from your recommended daily caloric allowance. For example, someone who has a recommended 2,000-calorie per day diet may eat enough nutrient-dense foods to meet requirements after consuming only 1,814 calories. The remaining 186 calories are discretionary. These calories may be obtained from eating an additional piece of fruit, adding another teaspoon of olive oil on a salad or butter on a piece of bread, adding sugar or honey to cereal, or consuming an alcoholic beverage.US Department of Agriculture. “MyPyramid Education Framework.” Accessed July 22, 2012. http://www.choosemyplate.gov

The amount of discretionary calories increases with physical activity level and decreases with age. For most physically active adults, the discretionary calorie allowance is, at most, 15 percent of the recommended caloric intake. By consuming nutrient-dense foods, you afford yourself a discretionary calorie allowance.

Table 1.14.1: Sample Menu Plan Containing 2,000 Calories

Meal	Calories	Total Meal/Snack Calories
Breakfast		
1 scrambled egg	92	
with sliced mushrooms and spinach	7	
½ whole-wheat muffin	67	
1 tsp. margarine-like spread	15	
1 orange	65	
8 oz. low-sodium tomato juice	53	299
Snack		
6 oz. fat-free flavored yogurt	100	
with ½ c. raspberries	32	132
Lunch		
1 sandwich on pumpernickel bread	160	
with smoked turkey deli meat,	30	
4 slices tomato	14	
2 lettuce leaves	3	

Meal	Calories	Total Meal/Snack Calories
1 tsp. mustard	3	
1 oz. baked potato chips	110	
½ c. blueberries, with 1 tsp. sugar	57	
8 oz. fat-free milk	90	467
Snack		
1 banana	105	
7 reduced-fat high-fiber crackers	120	225
Dinner		
1 c. Greek salad (tomatoes, cucumbers, feta)	150	
with 5 Greek olives,	45	
with 1.5 tsp. olive oil	60	
3 oz. grilled chicken breast	150	
½ c. steamed asparagus	20	
with 1 tsp. olive oil,	40	
with 1 tsp. sesame seeds	18	
½ c. cooked wild rice	83	
with ½ c. chopped kale	18	
1 whole-wheat dinner roll	4	
with 1 tsp. almond butter	33	691
(Total calories from all meals and snacks = 1,814)		
Discretionary calorie allowance: 186		

Healthy Eating Index

To assess whether the American diet is conforming to the *2010 Dietary Guidelines*, the Center for Nutrition Policy and Promotion (CNPP), a division of the USDA, uses a standardized tool called the Healthy Eating Index (HEI). US Department of Agriculture. "Healthy Eating Index." Last modified March 14, 2012. www.cnpp.usda.gov/healthyeatingindex.htm. The first HEI was developed in 1995 and revised in 2006. This tool is a simple scoring system of dietary components. The data for scoring diets is taken from national surveys of particular population subgroups, such as children from low-income families or Americans over the age of sixty-five. Diets are broken down into several food categories including milk, whole fruits, dark green and orange vegetables, whole grains, and saturated fat, and then a score is given based on the amount consumed. For example, a score of ten is given if a 2,000-kilocalorie diet includes greater than 2.6 cups of milk per day. If less than 10 percent of total calories in a diet are from saturated fat, a score of eight is given. All of the scores are added up for the different food categories and the diets are given an HEI score. Using this standardized diet-assessment tool at different times, every ten years, for instance, the CNPP can determine if the eating habits of certain groups of the American population are getting better or worse. The HEI tool provides the federal government with information to make policy changes to better the diets of American people. For more information on the HEI, visit this website: www.cnpp.usda.gov/healthyeatingindex.htm.

Key Takeaways

- The Food Pyramid has been replaced by MyPlate, a system that was designed to be easier to implement. The new MyPlate encourages all plates to be filled with fruits and vegetables (50 percent), protein (25 percent), and grains (25 percent). Half of

daily grain intake should be from whole-grain sources. Dairy choices should be switched to low-fat or non-fat sources.

- A diet rich in fresh fruits and vegetables will help you lose and/or maintain weight, will lower your risk for stroke, heart disease, high blood pressure, Type 2 diabetes, and certain types of cancer, and will boost your overall health profile.
- By choosing nutrient-dense foods, you may have discretionary calories to “spend” at the end of the day.

Discussion Starter

1. As you analyze the new MyPlate, how do your regular dietary habits compare to this new format? What changes, if any, will you have to make to your breakfast? Lunch? Dinner?

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1.15: Understanding Dietary Reference Intakes

Learning Objectives

- Use the Dietary Reference Intakes to determine daily nutrient recommendations.

Dietary Reference Intakes (DRI) are the recommended levels for specific nutrients and consist of a number of different types of recommendations. This DRI system is used in both the United States and Canada.

Dietary Reference Intakes: A Brief Overview

The most recent recommendations from the Food and Nutrition Board are the "Dietary Reference Intakes" (DRI). The DRI include 4 sets of standards:

- Recommended Dietary Allowances (RDA): average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%-98%), healthy people.
- Adequate Intakes (AI): established when evidence is insufficient to develop an RDA and is set at a level assumed to ensure nutritional adequacy.
- Tolerable Upper Intake Levels (UL): maximum daily intake unlikely to cause adverse health effects.
- Estimated Average Requirements (EARs): expected to satisfy the needs of 50% of the people in that age group based on a review of the scientific literature.

The DRIs are not minimum or maximum nutritional requirements and are not intended to fit everybody. They are to be used as guides only for the majority of the healthy population. https://ods.od.nih.gov/Health_Information/Dietary_Reference_Intakes.aspx

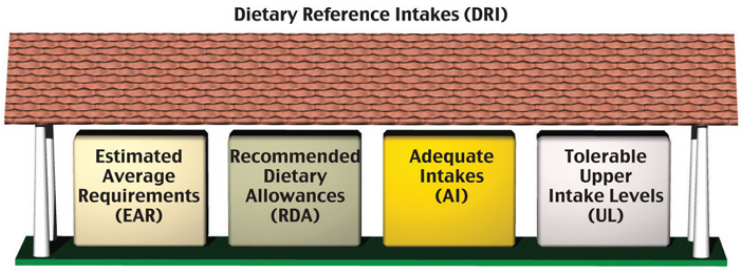


Figure 1.15.1: The DRIs are inclusive of all four reference values. © Networkgraphics

DRIs are important not only to help the average person determine whether their intake of a particular nutrient is adequate, they are also used by health-care professionals and policy makers to determine nutritional recommendations for special groups of people who may need help reaching nutritional goals. This includes people who are participating in programs such as the Special Supplemental Food Program for Women, Infants, and Children. The DRI is not appropriate for people who are ill or malnourished, even if they were healthy previously.

Determining Dietary Reference Intakes

Each DRI value is derived in a different way. See below for an explanation of how each is determined:

1. **Estimated Average Requirements (EAR).** The EAR for a nutrient is determined by a committee of nutrition experts who review the scientific literature to determine a value that meets the requirements of 50 percent of people in their target group within a given life stage and for a particular sex. The requirements of half of the group will fall below the EAR and the other half will be above it. It is important to note that, for each nutrient, a specific bodily function is chosen as the criterion on which to base the EAR. For example, the EAR for calcium is set using a criterion of maximizing bone health. Thus, the EAR for calcium is set at a point that will meet the needs, with respect to bone health, of half of the population. EAR values become the scientific foundation upon which RDA values are set.
2. **Recommended Daily Allowances (RDA).** Once the EAR of a nutrient has been established, the RDA can be mathematically determined. While the EAR is set at a point that meets the needs of half the population, RDA values are set to meet the needs of the vast majority (97 to 98 percent) of the target healthy population. It is important to note that RDAs are not the same thing as individual nutritional requirements. The actual nutrient needs of a given individual will be different than the RDA. However, since we know that 97 to 98 percent of the population's needs are met by the RDA, we can assume that if a person is consuming

the RDA of a given nutrient, they are most likely meeting their nutritional need for that nutrient. The important thing to remember is that the RDA is meant as a *recommendation* and meeting the RDA means it is very likely that you are meeting your actual *requirement* for that nutrient.

The RDA was established by the Food and Nutrition Board of the National Academy of Sciences. It was first published in 1941 in the "interest of national defense." During World War II, many potential soldiers did not qualify for military duty because they were malnourished. Also, in many places during the war and after the war, food had to be rationed. It was important that everyone received the nutrients they needed. Now, the criteria for establishing the RDA is based on the EAR for healthy individuals. That requirement is increased by 30-50% to cover the need of most people (all but 3% of the population).

The "R" in RDA does not mean required but is for recommended. The RDA is designed to satisfy the nutrient requirement for most healthy individuals and thus, exceeds the nutrient need for most people. The "D" does not mean daily, but dietary. A person does not need to meet the RDA every day but is the average intake needed every 3-7 days.

The RDA is categorized by age, sex, lactation, and pregnancy. Only nineteen nutrients of the approximately 45 essential nutrients have an RDA. We need to eat a variety of foods to get all our nutrients and the RDA is built on that assumption.

For what do we use the RDA? It is best used for populations or large groups of people, for example, school lunch programs. It is not useful for individuals although it is often used to assess an individual's diet.

Understanding the Difference

There is a distinct difference between a requirement and a recommendation. For instance, the DRI for vitamin D is a *recommended* 600 international units each day. However, in order to find out your true personal *requirements* for vitamin D, a blood test is necessary. The blood test will provide an accurate reading from which a medical professional can gauge your required daily vitamin D amounts. This may be considerably more or less than the DRI, depending on what your level actually is.

1. **Adequate Intake (AI).** AIs are created for nutrients when there is insufficient consistent scientific evidence to set an EAR for the entire population. As with RDAs, AIs can be used as nutrient intake goals for a given nutrient. For example, there has not been sufficient scientific research into the particular nutritional requirements of infants. Consequently, all of the DRI values for infants are AIs derived from nutrient values in human breast milk. For older babies and children, AI values are derived from human milk coupled with data on adults. The AI is meant for a healthy target group and is not meant to be sufficient for certain at-risk groups, such as premature infants.
2. **Tolerable Upper Intake Levels (UL).** The UL was established to help distinguish healthful and harmful nutrient intakes. Developed in part as a response to the growing usage of dietary supplements, ULs indicate the highest level of continuous intake of a particular nutrient that may be taken without causing health problems. When a nutrient does not have any known issue if taken in excessive doses, it is not assigned a UL. However, even when a nutrient does not have a UL it is not necessarily safe to consume in large amounts.

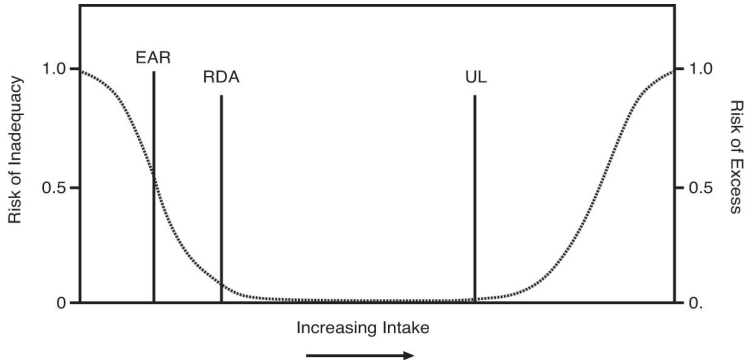


Figure 1.15.2: DRI Graph. This graph illustrates the risks of nutrient inadequacy and nutrient excess as we move from a low intake of a nutrient to a high intake. Starting on the left side of the graph, you can see that when you have a very low intake of a nutrient, your risk of nutrient deficiency is high. As your nutrient intake increases, the chances that you will be deficient in that nutrient decrease. The point at which 50 percent of the population meets their nutrient need is the EAR, and the point at which 97 to 98 percent of the population meets their needs is the RDA. The UL is the highest level at which you can consume a nutrient without it being too much—as nutrient intake increases beyond the UL, the risk of health problems resulting from that nutrient increases. Source: Institute of Medicine. © 2012 National Academy of Sciences. All Rights Reserved. www.iom.edu.

3. **Acceptable Macronutrient Distribution Ranges (AMDR).** The Acceptable Macronutrient Distribution Range (AMDR) is the calculated range of how much energy from carbohydrates, fats, and protein is recommended for a healthy diet. People who do not reach the AMDRs for their target group increase their risk of developing health complications.

Table 1.15.1: AMDR Values for Adults

Nutrient	Value (percentage of Calories)
Fat	20.0–35.0
Carbohydrate	45.0–65.0
Protein	10.0–35.0
Polyunsaturated fatty acids	5.0–10.0
alpha - Linolenic acid	0.6–1.2

Source: Food and Nutrition Board of the Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. (Washington, DC: National Academies Press, 2002).

Tips for Using the Dietary Reference Intakes to Plan Your Diet

You can use the DRIs to help assess and plan your diet. Keep in mind when evaluating your nutritional intake that the values established have been devised with an ample safety margin and should be used as guidance for optimal intakes. Also, the values are meant to assess and plan average intake over time; that is, you don't need to meet these recommendations every single day—meeting them on average over several days is sufficient.

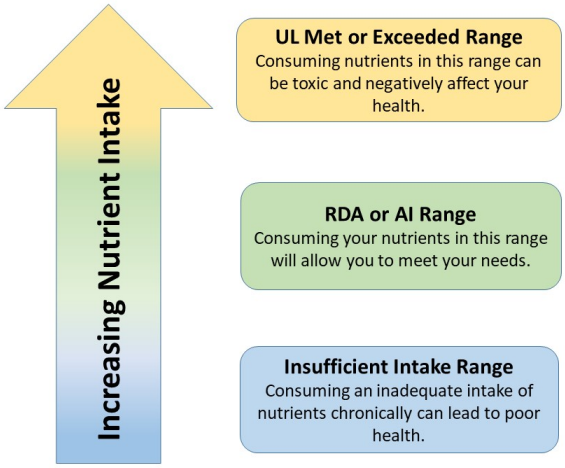


Figure 1.15.2: Relationship among insufficient intake, RDA, and UL.

Estimated Energy Requirements (EER)

Energy is not a nutrient but is required in the body for metabolic processes, physiological functions, muscular activity, heat production, growth and synthesis of new tissues. It is released from food components by oxidation. The main sources of energy are carbohydrates, proteins, fats and, to a lesser degree, alcohol. Energy requirements vary with age, gender, body size and activity, recommendations are needed for each age and gender group.

Two separate terms can, therefore, be used to express and determine Estimated Energy Requirements (EER). The Estimated Energy Requirement for Maintenance (EERM or actual energy requirement) is the dietary energy intake that is predicted to maintain energy balance (plus extra needs for pregnancy, lactation, and growth) in healthy individuals or groups of individuals at current levels of body size and level of physical activity. The Desirable Estimated Energy Requirement (DEER, or energy reference value) is the dietary energy intake that is predicted to maintain energy balance (plus extra needs for pregnancy, lactation and growth) in healthy individuals or groups of individuals of a defined gender, age, weight, height and level of physical activity consistent with good health and/or development.

Key Takeaways

- Nutrient-intake recommendations set for healthy people living in the United States and Canada are known as Dietary Reference Intakes.

- The DRIs includes the AI, EAR, RDA, and UL for micronutrients and the AMDR ranges for energy-yielding macronutrients. The DRI provides a set of standards for researchers and government policy-makers and specifies nutrient consumption guidelines for individuals.

Discussion Starter

1. Why do you think it is important for the government to set the DRI standards? How will you use this information for your personal dietary choices?

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1.16: Discovering Nutrition Facts

Learning Objectives

- Use the Nutrition Facts panel to discover the nutritional information of food.

The Labels on Your Food

Understanding the significance of dietary guidelines and how to use DRIs in planning your nutrient intakes can make you better equipped to select the right foods the next time you go to the supermarket.

In the United States, the Nutrition Labeling and Education Act passed in 1990 and came into effect in 1994. In Canada, mandatory labeling came into effect in 2005. As a result, all packaged foods sold in the United States and Canada must have nutrition labels that accurately reflect the contents of the food products. There are several mandated nutrients and some optional ones that manufacturers or packagers include. The FDA oversees mandatory labeling of foods. Table 1.16.1 lists the mandatory and optional inclusions. These are regulated but the FDA.

Table 1.16.1: Mandatory and Optional Inclusions on Nutrition Labels

Mandatory Inclusion	Optional Inclusion
Total Calories	Calories from saturated fats
Calories from fat	Polyunsaturated fat
Total fat	Monounsaturated fat
Saturated fat	Potassium
Cholesterol	Soluble fiber
Total carbohydrates	Sugar alcohol
Dietary fiber	Other carbohydrates
Sugars	Percent of vitamin A present as beta-carotene
Vitamins A and C	Other essential vitamins and minerals
Calcium	
Iron	

Source: US Food and Drug Administration. “Food Labeling Guide.” Last updated August 3, 2016. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm

There are other types of information that are required by law to appear somewhere on the consumer packaging. They include:

- Name and address of the manufacturer, packager, or distributor
- Statement of identity, what the product actually is
- Net contents of the package: weight, volume, measure, or numerical count
- Ingredients, listed in descending order by weight
- Nutrient information of serving size and daily values

The Nutrition Facts panel provides a wealth of information about the nutritional content of the product. The information also allows shoppers to compare products. Because the serving sizes are included on the label, you can see how much of each nutrient is in each serving to make the comparisons. Knowing how to read the label is important because of the way some foods are presented. For example, a bag of peanuts at the grocery store may seem like a healthy snack to eat on the way to class. But have a look at that label. Does it contain one serving or multiple servings? Unless you are buying the individual serving packages, chances are the bag you picked up is at least eight servings, if not more.

According to the 2010 health and diet survey released by the FDA, 54 percent of first-time buyers of a product will check the food label and will use this information to evaluate fat, calorie, vitamin, and sodium content.US Food and Drug Administration. “Survey Shows Gain in Food-Label Use, Health/Diet Awareness.” March 2, 2010. www.fda.gov/ForConsumers/ConsumerUpdates/ucm202611.htm#FoodLabelHighlights. The survey also notes that more Americans are using food labels and are showing an increased awareness of the connection between diet and health. Having reliable food labels is a top priority of the FDA, which has a new initiative to prepare guidelines for the food industry to construct “front of package” labeling that will make it even easier for Americans to choose healthy foods. Stay tuned for the newest on food labeling by visiting the FDA website: www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm.

Interactive Link 1.16.1: The Food Label and You.

The FDA has prepared a new video about nutrition labeling that is packed with helpful information. You can watch the full-length video or individual segments. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm275409.htm#fullvideo

Reading the Label

On May 20, 2016, the FDA announced the new Nutrition Facts Panel. In the figure below, the original label and the new format label are shown. We will compare and contrast both labels because we are a transition phase between the original label and the new format label. You may have seen a few packages with the new label, while most continue to carry the original label.

Both Nutrition Facts panels give you information on the serving size and how many servings are in the container. The new format has expanded the size of this area. For example, a label on a box of crackers might tell you that twenty crackers equal one serving and that the whole box contains 10 servings. All other values listed thereafter, from the calories to the dietary fiber, are based on this one serving. On the panel, the serving size is followed by the number of calories and then a list of selected nutrients.

You will also see “Percent Daily Value” on the far right-hand side. With the new label, the Daily Value (DV) has been updated so the values on the original label do not match the new label even though the calories, serving size and servings per package are the same. The % DV helps you determine if the food is or is not a good source of a particular nutrient. The DV represents the recommended amount of a given nutrient based on the Reference Daily Intake (RDI) and DRI of that nutrient in a 2,000-kilocalorie diet. Daily reference values (DRV) is set for all nutrients. The percentage of DV represents the proportion of the total daily recommended amount that you will get from one serving of the food. The DV is not age specific or gender specific. For example, on the food label in Figure 1.16.1, the percent DV of calcium for one serving is 20 percent, which means that one serving provides 20 percent of the daily recommended calcium intake.

Several nutrients have been dropped from the label - vitamin A and C because these are no longer low in the American diet. Added to the new label is "added sugar." This number reflects the amount of sugar or sugar-like substances the manufacturer added to the package.

Here is a website with more explanation: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm



Figure 1.16.1: Determining Your Nutrient Allowances per Day. Pictured here is a sample label. Source: FDA. "Changes to the Nutrition Facts Label." Last updated June 19, 2017. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm#images

Generally, a percent DV of 5 is considered low and a percent DV of 20 is considered high. This means, as a general rule, for fat, saturated fat, trans fat, cholesterol, or sodium, look for foods with a low percent DV. Alternatively, when concentrating on essential mineral or vitamin intake, look for a high percent DV. To figure out your fat allowance remaining for the day after consuming one serving, look at the percent DV for fat, which is 18 percent, and subtract it from 100 percent. To know this amount in grams of fat, read the footnote of the food label to find that the recommended maximum amount of fat grams to consume per day for a 2,000 kilocalories per day diet is 65 grams. Eighteen percent of sixty-five equals about 12 grams. This means that 53 grams of fat are remaining in your fat allowance. Remember, to have a healthy diet the recommendation is to eat less than this amount of fat grams per day, especially if you want to lose weight.

Table 1.16.2: DVs Based on a Caloric Intake of 2,000 Calories (For Adults and Children Four or More Years of Age)

Food Component	DV
Total fat	78 g
Saturated fat	20 g
Cholesterol	300 mg
Sodium	2,300 mg
Potassium	4,700 mg
Total carbohydrate	275 g
Dietary fiber	28 g
Protein	50 g
Added Sugar	50 g
Calcium	1,300 mg
Iron	18 mg
Vitamin D	20 mcg

Source: FDA, https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm

Of course, this is a lot of information to put on a label and some products are too small to accommodate it all. In the case of small packages, such as small containers of yogurt, candy, or fruit bars, permission has been granted to use an abbreviated version of the Nutrition Facts panel. To learn additional details about all of the information contained within the Nutrition Facts panel, see the following website: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm

Video Link 1.16.2: How to Read Food Labels.

Pay attention to the fine print when grocery shopping. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm275409.htm#fullvideo

Claims on Labels

In addition to mandating nutrients and ingredients that must appear on food labels, any nutrient-content claims must meet certain requirements. For example, a manufacturer cannot claim that a food is fat-free or low-fat if it is not, in reality, fat-free or low-fat. Low-fat indicates that the product has three or fewer grams of fat; low salt indicates there are fewer than 140 milligrams of sodium, and low-cholesterol indicates there are fewer than 20 milligrams of cholesterol and two grams of saturated fat. See Table 1.16.3 for some examples.US Food and Drug Administration. "Additional Requirements for Nutrient Content Claims." Appendix B in *Food Labeling Guide* (August 2016). https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm

Table 1.16.3: Common Label Terms Defined

Nutrient Content Claim	What the Claim Means Per Serving
High (rich in, excellent source)	20% or more of the Daily Value
Good	10% to 19% of the Daily Value
More	Contains at least 10% more of the Daily Value for vitamins, minerals, protein, dietary fiber, or potassium.*
Light	Has at least ⅓ fewer calories or 50% less fat.* If more than half the calories are from fat, fat content must be reduced by 50
Less or fewer	Has 25% less of a nutrient or of calories
Calorie Claims	

Nutrient Content Claim	What the Claim Means Per Serving
Calorie free	Less than 5 calories
Low calorie	40 calories or less
Reduced calories	At least 25% fewer calories*
Sugar Claims	
Sugar-free	Less than 0.5 gram sugars
Reduced sugar	At least 25% less sugar*
Fiber Claims (If food is not low in total fat, the label must state total fat in conjunction with the fiber claims.)	
High fiber	5 grams or more
Good source of fiber	2.5 grams to 4.9 grams
More or added fiber	At least 2.5 grams more*
Sodium Claims	
Sodium free or salt-free	Less than 5 milligrams sodium
Very low sodium	35 milligrams of sodium or less
Low sodium	140 milligrams of sodium or less
Reduced sodium	At least 25% less sodium*
Light in sodium	At least 50% less sodium
Salt-free	Less than 5 milligrams sodium
Fat Claims	
Fat-free	Less than 0.5 gram fat
Low fat	3 grams or less total fat
Reduced fat	At least 25% less fat than the regular version
Saturated Fat Claims	
Saturated fat-free	Less than 0.5 gram saturated fat and less than 0.5 gram trans fatty acids
Low in saturated fat	1 gram or less saturated fat & no more than 15% calories from saturated fat
Reduced saturated fat	At least 25% less saturated fat* and reduced by more than 1 gram fat
Note: Trans-fat has no FDA-defined nutrient content claims.	
Cholesterol Claims	
Cholesterol free	Less than 2 milligrams cholesterol and 2 grams or less saturated fat
Low cholesterol	20 milligrams or less cholesterol and 2 grams or less saturated fat
Reduced cholesterol	At least 25% less cholesterol and 2 grams or less saturated fat*
Lean Claims	
Lean	Contains less than 10 grams total fat, 4.5 grams or less saturated fat, and less than 95 milligrams cholesterol
Extra lean	Contains less than 5 grams total fat, less than 2 grams saturated fat, and less than 95 milligrams cholesterol
*compared to the reference, or regular, food this would replace	

Source: US Food and Drug Administration. "Food Labeling Guide." Last updated August 2016. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm and http://www.clemson.edu/extension/hgic/food/nutrition/nutrition/dietary_guide/hgic4061.html

Health Claims

Often we hear news of a particular nutrient or food product that contributes to our health or may prevent disease. A health claim is a statement that links a particular food with a reduced risk of developing a disease. As such, health claims such as "reduces heart disease," must be evaluated by the FDA before it may appear on packaging. Prior to the passage of the NLEA products that made such claims were categorized as drugs and not food. All health claims must be substantiated by scientific evidence in order for it to be approved and put on a food label. To avoid having companies making false claims, laws also regulate how health claims are presented on food packaging. In addition to the claim being backed up by scientific evidence, it may never claim to cure or treat the disease. For a detailed list of approved health claims, visit: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/default.htm

Qualified Health Claims

While health claims must be backed up by *hard* scientific evidence, qualified health claims have *supportive* evidence, which is not as definitive as with health claims. The evidence may suggest that the food or nutrient is beneficial. Wording for this type of claim may look like this: "Supportive but not conclusive research shows that consumption of EPA and DHA omega-3 fatty acids may reduce the risk of coronary artery disease. One serving of [name of food] provides [X] grams of EPA and DHA omega-3 fatty acids. [See nutrition information for total fat, saturated fat, and cholesterol content.]US Food and Drug Administration. "FDA Announces Qualified Health Claims for Omega-3 Fatty Acids." December 14, 2014. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm073992.htm

Structure/Function Claims

Some companies claim that certain foods and nutrients have benefits for health even though no scientific evidence exists. In these cases, food labels are permitted to claim that you may benefit from the food because it may boost your immune system, for example. There may not be claims of diagnosis, cures, treatment, or disease prevention, and there must be a disclaimer that the FDA has not evaluated the claim.US Food and Drug Administration. "Claims That Can Be Made for Conventional Foods and Dietary Supplements." April 2016. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm111447.htm.

Allergy Warnings

Food manufacturers are required by the FDA to list on their packages if the product contains any of the eight most common ingredients that cause food allergies. These eight common allergens are as follows: milk, eggs, peanuts, tree nuts, fish, shellfish, soy, and wheat. (More information on these allergens will be discussed elsewhere). The FDA does not require warnings that cross contamination may occur during packaging, however, most manufacturers include this advisory as a courtesy. For instance, you may notice a label that states, “This product is manufactured in a factory that also processes peanuts.” If you have food allergies, it is best to avoid products that may have been contaminated with the allergen.

Key Takeaways

- The Nutrition Labeling and Education Act made it a law that foods sold in the United States have a food label that provides the accurate contents of nutrients within them. Canada has a similar law.
- A Nutrition Facts panel gives information on a number of servings per container, the amount of calories per serving, and the amounts of certain nutrients.
- The percent DV is the percentage of the amount of the nutrient in the food in relationship to its recommended intake. It is a guide to help you determine if a food is a good or poor source of nutrients.
- To keep companies from making false claims, the FDA provides regulation for food manufacturers in putting labels on packages that promote health. Allergens must also be listed on food labels. Sometimes cross contamination does occur during packaging. Most food manufacturers voluntarily list this information. If you have a food allergy, it is best to avoid any product that has even had the possibility of coming in contact with a known allergen.

Discussion Starter

1. Recall the food you buy from the supermarket on a regular basis. How many of the food products you purchase regularly are nutrient-dense? How many are nutrient-poor? What foods can you substitute in place of the nutrient-poor food choices?

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1.17: When Enough is Enough

Learning Objectives

- Judge food portion sizes for adequacy.

Estimating Portion Size

Have you ever heard the expression, “Your eyes were bigger than your stomach?” This means that you thought you wanted a lot more food than you could actually eat. Amounts of food can be deceiving to the eye, especially if you have nothing to compare them to. It is very easy to heap a pile of mashed potatoes on your plate, particularly if it is a big plate, and not realize that you have just helped yourself to three portions instead of one.

The food industry makes following the *2015 Dietary Guidelines* a challenge. In many restaurants and eating establishments, portion sizes have increased, use of solid fats and added sugar (SoFAS) has increased, and consequently, the typical meal contains more calories than it used to. In addition, our sedentary lives make it difficult to expend enough calories during normal daily activities. In fact, more than one-third of adults are not physically active at all.

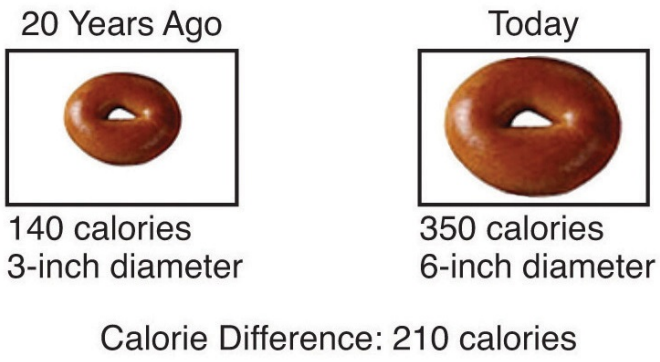


Figure 1.17.1: As food sizes and servings increase it is important to limit the portions of food consumed on a regular basis.

Dietitians have come up with some good hints to help people tell how large a portion of food they really have. Some suggest using common items such as a deck of cards while others advocate using your hand as a measuring rule. See Table 1.17.1 for some examples.American Cancer Society. “Controlling Portion Sizes.” Last revised June 30, 2014. http://www.cancer.org/Healthy/EatHealthyGetActive/TakeControlofYourWeight/controlling-portion-sizes.

Table 1.17.1: Determining Food Portions

Food Product	Amount	Object Comparison	Hand Comparison
Pasta, rice	½ c.	Tennis ball	Cupped hand
Fresh vegetables	1 c.	Baseball	
Cooked vegetables	½ c.	Cupped hand	
Meat, poultry, fish	3 oz.	Deck of cards	Palm of your hand
Milk or other beverages	1 c.	Fist	
Salad dressing	1 Tbsp.	Thumb	
Oil	1 tsp.	Thumb tip	

Video 1.17.1: Managing a Healthy Diet: Judging Healthy Portion Sizes



Video 1.17.1: *A dietitian shows how to compare food sizes with hands and other objects.(click to see video)*

MyPlate Planner

Estimating portions can be done using the MyPlate Planner. Recall that the MyPlate symbol is divided according to how much of each food group should be included with each meal. Note the MyPlate Planner Methods of Use:

- Fill half of your plate with vegetables such as carrots, broccoli, salad, and fruit.
- Fill one-quarter of your plate with lean meat, chicken, or fish (about 3 ounces)
- Fill one-quarter of your plate with a whole grain such as ⅓ cup rice
- Choose one serving of dairy
- Add margarine or oil for preparation or addition at the table

Table 1.17.2: Meal Planning Guidelines

Carbohydrates	Meats/Proteins	Fats	Free Foods
Choose three servings with each meal.	Choose one to three servings with each meal.	Choose one to two servings with each meal.	Use as desired.
Examples of *one* serving:	Examples of *one* serving:	Examples of *one* serving:	Examples
Breads and Starches • 1 slice bread or small roll • ⅓ c. rice or pasta • ½ c. of cooked cereal or potatoes • ¾ c. dry cereal • ½ c. corn	• 1 oz. lean meat, poultry, or fish • 1 egg • 1 oz. cheese • ¾ c. low-fat cottage cheese	• 1 tsp. margarine, oil, or mayonnaise • 1 Tbsp. salad dressing or cream cheese	**Foods with less than 20 calories per serving.*** • Most vegetables • Sugar-free soda • Black coffee or plain tea
Fruits • 1 piece, such as a small pear • 1 c. fresh fruit • ½ c. canned fruit • ½ c. fruit juice			
Milk • 1 c. skim or low fat • 1 c. unsweetened low-fat yogurt			

Key Takeaways

- Judging portion sizes can be done using your hand or household objects in comparison. It can also be done using the MyPlate guide to determine how much food is a portion for that meal.

Discussion Starter

1. Why is it important to judge portion sizes properly? Explain why it can be tricky to read food labels and figure out the caloric content for one serving.

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1.18: Foodborne Illness and Food Safety

Learning Objectives

- Describe the ideal environment for microorganisms to reproduce.
- Give examples of bacteria, viruses, parasites, and molds that have the potential to cause foodborne illness.
- Discuss government efforts to protect the health of the population, and precautions consumers can take to protect themselves.

Foodborne illness is another serious threat to health. Sometimes called "food poisoning," foodborne illness is a common public health problem that can result from exposure to a pathogen or a toxin via food or beverages. Raw foods, such as seafood, produce, and meats, can all be contaminated during harvest (or slaughter for meats), processing, packaging, or during distribution, though meat and poultry are the most common source of foodborne illness. For all kinds of food, contamination also can occur during preparation and cooking in a home kitchen or in a restaurant. In many developing nations, contaminated water is also a major source of foodborne illness.

Many people are affected by foodborne illness each year, making food safety a very important issue. Annually, one out of six Americans becomes sick after consuming contaminated foods or beverages.Centers for Disease Control and Prevention. "Food Safety at CDC." Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html. Foodborne illness can range from mild stomach upset to severe symptoms, or even fatalities. The problem of food contamination can not only be dangerous to your health, it can also be harmful to your wallet. Medical costs and lost wages due to salmonellosis, just one foodborne disease, are estimated at over $1 billion per year.

At-Risk Groups

No one is immune from consuming contaminated food. But, whether you become seriously ill depends on the microorganism, the amount you have consumed, and your overall health. In addition, some groups have a higher risk than others for developing severe complications to foodborne disease. Who is most at risk? Young children, elderly people, and pregnant women all have a higher chance of becoming very sick after consuming contaminated food. Other high-risk groups include people with compromised immune systems due to HIV/AIDS, immunosuppressive medications (such as after an organ transplant), and long-term steroid use for asthma or arthritis. Exposure to contaminated food could also pose problems for diabetics, cancer patients, people who have liver disease, and people who have stomach problems as a result of low stomach acid or previous stomach surgery. People in all of these groups should handle food carefully, make sure that what they eat has been cooked thoroughly, and avoid taking any chances that could lead to exposure.

The Major Types of Foodborne Illness

Foodborne illnesses are either infectious or toxic in nature. The difference depends on the agent that causes the condition. Microbes, such as bacteria, cause food infections, while toxins, such as the kind produced by molds, cause intoxication. Different diseases manifest in different ways, so signs and symptoms can vary with the source of contamination. However the illness occurs, the microbe or toxin enters the body through the gastrointestinal tract, and as a result, common symptoms include diarrhea, nausea, and abdominal pain. Additional symptoms may include vomiting, dehydration, lightheadedness, and rapid heartbeat. More severe complications can include a high fever, diarrhea that lasts more than three days, prolonged vomiting, bloody stools, and signs of shock.

One of the biggest misconceptions about foodborne illness is that it is always triggered by the last meal that a person ate. However, it may take several days or more before the onset of symptoms. If you develop a foodborne illness, you should rest and drink plenty of fluids. Avoid antidiarrheal medications, because they could slow the elimination of the contaminant.

Food Infection

According to the CDC, more than 250 different foodborne diseases have been identified.Centers for Disease Control and Prevention. "Food Safety at CDC." Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html. Most are food infections, which means they are caused by food contaminated by microorganisms, such as bacteria, by microscopic animals called parasites, or by viruses. The infection then grows inside the body and becomes the source of symptoms. Food infections can be sporadic and often are not reported to physicians. However, occasional outbreaks occur that put communities, states, and provinces, or even entire nations at risk. For example, in 1994, an outbreak of the infection salmonellosis occurred in the United States due to contaminated ice cream. An estimated 224,000 people became ill. In 1988, contaminated clams resulted in an outbreak of hepatitis A in China, which affected about 300,000 people.World Health Organization. "Food Safety and Foodborne Illness." *Fact Sheet*, no. 237. Last reviewed December 2015. http://www.who.int/mediacentre/factsheets/fs399/en/.

The Reproduction of Microorganisms

Bacteria, one of the most common agents of food infection, are single-celled microorganisms that are too small to be seen with the human eye. Microbes live, die, and reproduce, and like all living creatures, they depend on certain conditions to survive and thrive. In order to reproduce within a food, microorganisms require the following:

- **Temperature.** Between 40°F and 140°F, which is called the danger zone, bacteria grow rapidly.
- **Time.** More than two hours in the danger zone.
- **Water.** High moisture content is helpful. Fresh fruits and vegetables have the highest moisture content.
- **Oxygen.** Most microorganisms need oxygen to grow and multiply, but a few are anaerobic and do not.

- **Acidity and pH Level.** Foods that have a low level of acidity (or a high pH level) provide an ideal environment since most microorganisms grow best around 7.0 pH and not many will grow below 4.0 pH. Examples of higher pH foods include meat, seafood, milk, and corn. Examples of low pH foods include citrus fruits, sauerkraut, tomatoes, and pineapples.
- **Nutrient Content.** Microorganisms need protein, starch, sugars, fats, and other compounds to grow. Typically high-protein foods are better for bacterial growth.

Food Intoxication

Other kinds of foodborne illness are food intoxications, which are caused by natural toxins or harmful chemicals. These and other unspecified agents are major contributors to episodes of acute gastroenteritis and other kinds of foodborne illness.Scallan, E. et al. “Foodborne Illness Acquired in the United States—Unspecified Agents.” *Emerg Infect Diseases* 17, no. 1. Like pathogens, toxins and chemicals can be introduced to food during cultivation, harvesting, processing, or distribution. Some toxins can lead to symptoms that are also common to food infection, such as abdominal cramping, while others can cause different kinds of symptoms and complications, some very severe. For example, mercury, which is sometimes found in fish, can cause neurological damage in infants and children. Exposure to cadmium can cause kidney damage, typically in elderly people.

The Causes of Food Contamination

Both food infections and food intoxications can create a burden on health systems when patients require treatment and support, and on food systems, when companies must recall contaminated food or address public concerns. It all begins with the agent that causes the contamination. When a person ingests a food contaminant, it travels to the stomach and intestines. There, it can interfere with the body’s functions and make you sick. In the next part, we will focus on different types of food contaminants and examine common microbes, toxins, chemicals, and other substances that can cause food infections and intoxications. Let’s begin with pathogens, which include bacteria and viruses. About one hundred years ago, typhoid fever, tuberculosis, and cholera were common diseases caused by food and water contaminated by pathogens. Over time, improvements in food processing and water treatment eliminated most of those problems in North America. Today, other bacteria and viruses have become common causes of food infection.

Bacteria

All foods naturally contain small amounts of bacteria. However, poor handling and preparation of food, along with improper cooking or storage can multiply bacteria and cause illness. In addition, bacteria can multiply quickly when cooked food is left out at room temperature for more than a few hours. Most bacteria grow undetected because they do not change the color or texture of food or produce a bad odor. Freezing and refrigeration slow or stop the growth of bacteria, but does not destroy the bacteria completely. The microbes can reactivate when the food is taken out and thawed.



Figure 1.18.1: Salmonella was first identified in 1885 and many types of this kind of bacteria exist. The incidence of Salmonella infections has risen dramatically in the past few decades. Color-enhanced scanning electron micrograph showing Salmonella Typhimurium (red) invading cultured human cells (Credit: Rocky Mountain Laboratories, NIAID, NIH). Image is public domain.

Many different kinds of bacteria can lead to food infections. One of the most common is *Salmonella*, which is found in the intestines of birds, reptiles, and mammals. *Salmonella* can spread to humans via a variety of different animal-origin foods, including meats, poultry, eggs, dairy products, and seafood. The disease it causes, salmonellosis, typically brings about fever, diarrhea, and abdominal cramps within twelve to seventy-two hours after eating. Usually, the illness lasts four to seven days, and most people recover without treatment. However, in individuals with weakened immune systems, *Salmonella* can invade the bloodstream and lead to life-threatening complications, such as a high fever and severe diarrhea. Centers for Disease Control and Prevention. “Salmonella.” Last updated December 19, 2011. http://www.cdc.gov/salmonella/.

The bacterium *Listeria monocytogenes* is found in soft cheeses, unpasteurized milk, deli meats, and seafood. It causes a disease called listeriosis that can bring about fever, headache, nausea, and vomiting. *Listeria monocytogenes* mostly affects pregnant women, newborns, older adults, and people with cancer and compromised immune systems. This bacteria can grow at refrigerator temperatures.

The food infection *E. coli* is caused by *Escherichia coli*. Sources include raw or undercooked meat, raw vegetables, unpasteurized milk, minimally processed ciders and juices, and contaminated drinking water. Symptoms can occur a few days after eating and include watery and bloody diarrhea, severe stomach cramps, and dehydration. More severe complications may include colitis, neurological symptoms, stroke, and hemolytic uremic syndrome. In young children, an *E. coli* infection can cause kidney failure and death.

The bacterium *Clostridium botulinum* causes botulism. Sources include improperly canned foods, lunch meats, and garlic. An infected person may experience symptoms within four to thirty-six hours after eating. Symptoms could include nerve dysfunction, such as double vision, inability to swallow, speech difficulty, and progressive paralysis of the respiratory system. Botulism can also be fatal.

Campylobacter jejuni causes the disease campylobacteriosis. It is the most commonly identified bacterial cause of diarrhea worldwide. Consuming undercooked chicken, or food contaminated with the juices of raw chicken, is the most frequent source of this infection. Other sources include raw meat and unpasteurized milk. Within two to five days after consumption, symptoms can begin and include diarrhea, stomach cramps, fever, and bloody stools. The duration of this disease is about seven to ten days.

The food infection shigellosis is caused by *Shigella*, of which there are several types. Sources include undercooked liquid or moist food that has been handled by an infected person. The onset of symptoms occurs one to seven days after eating and can include stomach cramps, diarrhea, fever, and vomiting. Another common symptom is blood, pus, or mucus in stool. Once a person has had shigellosis, the individual is not likely to get infected with that specific type again for at least several years. However, they can still become infected with other types of *Shigella*.

Staphylococcus aureus causes staphylococcal food poisoning. Food workers who carry this kind of bacteria and handle food without washing their hands can cause contamination. Other sources include meat and poultry, egg products, cream-filled pastries, tuna, potato and macaroni salad, and foods left unrefrigerated for long periods of time. Symptoms can begin thirty minutes to eight hours after eating and include diarrhea, vomiting, nausea, stomach pain, and cramps. This food infection usually lasts one to two days.

Found in raw oysters and other kinds of seafood, *Vibrio vulnificus* belongs to the same family as the bacteria which cause cholera. This food contaminant can result in the *Vibrio* infection. Symptoms can begin anywhere from six hours to a few days after consumption and include chills, fever, nausea, and vomiting. This disease is very dangerous and can result in fatalities, especially in people with underlying health problems.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated September 1, 2016. www.cdc.gov/foodsafety/foodborne-germs.html.

Viruses

Viruses are another type of pathogen that can lead to food infections, however they are less predominant than bacteria. **Hepatitis A** is one of the more well-known food-contaminating viruses. Sources include raw shellfish from polluted water, and food handled by an infected person. This virus can go undetected for weeks and, on average, symptoms do not appear until about one month after exposure. At first, symptoms include malaise, loss of appetite, nausea, vomiting, and fever. Three to ten days later, additional symptoms can manifest, including jaundice and darkened urine. Severe cases of a hepatitis A can result in liver damage and death.

The most common form of contamination from handled foods is the **norovirus**, which is also known as the Norwalk-like virus, or the calicivirus. Sources include raw shellfish from polluted water, salads, sandwiches, and other ready-to-eat foods handled by an infected person. The norovirus causes gastroenteritis and within one to three days it leads to symptoms, such as nausea, vomiting, diarrhea, stomach pain, headache, and a low-grade fever.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html.

Parasitic Protozoa

Food-contaminating parasitic protozoa are microscopic organisms that may be spread in food and water. Several of these creatures pose major problems to food production worldwide. They include *Anisakis*, microscopic worms that invade the stomach or the intestines. Sources of this parasite include raw fish. This parasite can result in the Anisakis infection, with symptoms that begin within a day or less and include abdominal pain, which can be severe.

Cryptosporidium lives in the intestines of infected animals. Another common source is drinking water when heavy rains wash animal wastes into reservoirs. One major problem with this pathogen is that it is extremely resistant to disinfection with chlorine. *Cryptosporidium* causes the disease cryptosporidiosis, with symptoms that begin one to twelve days after exposure and include watery stools, loss of appetite, vomiting, a low-grade fever, abdominal cramps, and diarrhea. For HIV/AIDS patients and others with weakened immune systems, the disease can be severe and sometimes can lead to death.

Giardia lamblia is another parasite that is found in contaminated drinking water. In addition, it lives in the intestinal tracts of animals and can wash into surface water and reservoirs, similar to *Cryptosporidium*. *Giardia* causes giardiasis, with symptoms that include abdominal cramping and diarrhea within one to three days. Although most people recover within one to two weeks, the disease can lead to a chronic condition, especially in people with compromised immune systems.

The parasite *Toxoplasma gondii* causes the infection toxoplasmosis, which is a leading cause of death attributed to foodborne illness in the United States. More than sixty million Americans carry *Toxoplasma gondii*, but very few have symptoms. Typically, the body’s immune system keeps the parasite from causing disease. Sources include raw or undercooked meat and unwashed fruits and vegetables. Handling the feces of a cat with an acute infection can also lead to the disease.Centers for Disease Control and Prevention. “Parasites.” Last updated October 6, 2015. https://www.cdc.gov/parasites/food.html.

Mold Toxins

Warm, humid, or damp conditions encourage mold to grow on food. **Molds** are microscopic fungi that live on animals and plants. No one knows how many species of fungi exist, but estimates range from ten- to three-hundred thousand. Unlike single-celled bacteria, molds are multicellular, and under a microscope look like slender mushrooms. They have stalks with spores that form at the ends. The spores give molds their color and can be

transported by air, water, or insects. Spores also enable mold to reproduce. Additionally, molds have root-like threads that may grow deep into food and be difficult to see. The threads are very deep when a food shows heavy mold growth. Foods that contain mold may also have bacteria growing alongside it.



Figure 1.18.2: Mold can grow on fruits, vegetables, grains, meats, poultry, and dairy products, and typically appears as gray or green “fur.” Moldy nectarines that were in a refrigerator. The nectarine with black mold is also affecting the nectarine underneath. from Roger McLassus 1951.

Some molds, like the kind found in blue cheese, are desirable in foods, while other molds can be dangerous. The spores of some molds can cause allergic reactions and respiratory problems. In the right conditions, a few molds produce mycotoxins, which are natural, poisonous substances that can make you sick if they are consumed. Mycotoxins are contained in and around mold threads, and in some cases, may have spread throughout the food. The Food and Agriculture Organization of the United Nations estimates that mycotoxins affect 25 percent of the world’s food crops. They are found primarily in grains and nuts, but other sources include apples, celery, and other produce.

The most dangerous mycotoxins are **aflatoxins**, which are produced by strains of fungi called *Aspergillus* under certain temperature and humidity conditions. Contamination has occurred in peanuts, tree nuts, and corn. Aflatoxins can cause aflatoxicosis in humans, livestock, and domestic animals. Symptoms include vomiting and abdominal pain. Possible complications include liver failure, liver cancer, and even death. Many countries try to limit exposure to aflatoxins by monitoring their presence on food and feed products.US Department of Agriculture, Food Safety and Inspection Service. “Molds on Food: Are They Dangerous?” Last modified August 22, 2013. https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/molds-on-food-are-they-dangerous_/ct_index .

Poisonous Mushrooms

Like molds, mushrooms are fungi and the poisonous kind produces mycotoxins that can cause food intoxication. Toxic mushrooms, also known as toadstools, can cause severe vomiting and other symptoms. However, only a few varieties are fatal. Toxic mushrooms cannot be made safe by cooking, freezing, canning, or processing. The only way to avoid food intoxication is to refrain from eating them. Mushroom guides can help wild gatherers distinguish between the edible and toxic kinds.US Department of Agriculture, Food Safety and Inspection Service. “Molds on Food: Are They Dangerous?” Last modified August 22, 2013. https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/molds-on-food-are-they-dangerous_/ct_index.

Pesticides

Pesticides are important in food production to control diseases, weeds, insects, and other pests. They protect crops and ensure a large yield. However, synthetic pesticides can leave behind residues, particularly on produce, that can be harmful to human health. Foods that contain the highest levels of pesticide residue include conventionally-grown peaches, apples, bell peppers, celery, nectarines, strawberries, cherries, pears, spinach, lettuce, and potatoes. Foods that contain the lowest levels of pesticide residue include avocados, pineapples, bananas, mangoes, asparagus, cabbage, and broccoli.Hoffman, M. MD. “Safer Foods for a Healthier You.” Web MD. © 2009 WebMD, LLC. http://www.webmd.com/health-ehome-9/pesticides-hormones-in-food. In many cases, the amount of pesticide exposure is too small to pose a risk. However, harmful exposures can lead to certain health problems and complications, including cancer. Also, infants and young children are more susceptible to the hazards of pesticides than adults. In addition, using synthetic pesticides, herbicides, and fertilizers contributes to soil and water pollution and can be hazardous to farm workers.

To protect the public and their workers, many farmers now rely on alternatives to synthetic pesticide use, including crop rotation, natural pesticides, and planting nonfood crops nearby to lure pests away. Some consumers choose to reduce their exposure to pesticides by purchasing organic produce. Organic foods are grown or produced without synthetic pesticides or fertilizer, and all growers and processors must be certified by the US Department of Agriculture (USDA). Although pesticides cannot be applied to organic foods, pesticide residues may still occasionally be found on foods. However, conventionally-grown produce should be fine for fruits and vegetables that appear on the low-residue list.

Pollutants

Pollutants are another kind of chemical contaminant that can make food harmful. Chemical runoff from factories can pollute food products and drinking water. For example, **dioxins** are chemical compounds created in industrial processes, such as manufacturing and bleaching pulp and paper. Fish that swim in dioxin-polluted waters can contain significant amounts of this pollutant, which causes cancer. When metals contaminate food, it

can result in serious and even life-threatening health problems. A common metal contaminant is lead, which can be present in drinking water, soil, and air. Lead exposure most often affects children, who can suffer from physical and mental developmental delays as a result.

Methyl mercury occurs naturally in the environment and is also produced by human activities. Fish can absorb it, and the predatory fish that consume smaller, contaminated fish can have very high levels. This highly toxic chemical can cause mercury poisoning, which leads to developmental problems in children, as well as autoimmune effects. A condition called Minamata disease was identified in 1956 in Japan. It was named for the town of Minamata, which was the site of an environmental disaster when methyl mercury was released into the surface water near a factory. Many residents experienced neurological issues, including numbness in hands and feet, muscle weakness, a narrowing of the field of vision, damage to hearing and speech, and ataxia, which is a lack of muscle coordination.Ministry of the Environment, Government of Japan. “Minamata Disease: The History and Measures.” © 2002. Accessed December 21, 2011. http://www.env.go.jp/en/chemi/hs/minamata2002/.

PCBs, or polychlorinated biphenyls, are man-made organic compounds that are used commercially. Like methyl mercury, higher concentrations of this contaminant are found in predatory fish. Health effects include physical and neurological development in children, and this compound is potentially a carcinogen. PCB contamination also can affect the immune, reproductive, nervous, and endocrine systems.US Environmental Protection Agency. “Health Effects of PCBs.” Last updated August 08, 2008. http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/effects.htm.

Protecting the Public Health

Most foodborne infections go unreported and undiagnosed. However, the CDC estimates that about seventy-six million people in the United States become ill from foodborne pathogens or other agents every year. In North America, a number of government agencies work to educate the public about food infections and intoxications, prevent the spread of disease, and quell any major problems or outbreaks. They include the CDC, the FDA, the USDA, and Health Canada, among other organizations.

Efforts on the Governmental Level

A number of government agencies work to ensure food safety and to protect the public from foodborne illness. The USDA and the FDA enforce laws regarding the safety of domestic and imported food. In addition, the Federal Food, Drug, and Cosmetic Act of 1938 gives the FDA authority over food ingredients. The CDC tracks outbreaks, identifies the causes of food infection and intoxication, and recommends ways to prevent foodborne illness. Other government agencies that play a role in protecting the public include the Food Safety and Inspection Service, a division of the USDA, which enforces laws regulating meat and poultry safety. The Agricultural Research Service, which is the research arm of the USDA, investigates a number of agricultural practices, including those related to animal and crop safety. The National Institute of Food and Agriculture conducts research and education programs on food safety for farmers and consumers. Also, the Environmental Protection Agency (EPA) regulates public drinking water.

Government agencies also monitor the use of pesticides. The EPA approves pesticides and other chemicals used in agriculture and sets limits on how much residue can remain on food. The FDA analyzes food for surface residue and waxes. Processing methods can either reduce or concentrate pesticide residue in foods. Therefore, the Food Quality Protection Act, which was passed in 1996, requires manufacturers to show that pesticide levels are safe for children.

In Canada, Health Canada works with local governments, industries, and consumers to establish food safety throughout the nation. The agency’s scientists assess health risks from foodborne contaminants, conduct research, and evaluate data to better understand the effects of pathogens, chemicals, and other foodborne agents on the body. Health Canada also monitors the levels of contaminants in foods and estimates the exposure of consumers. Another organization, the Canadian Food Inspection Agency, enforces the safety policies and standards set by Health Canada. They safeguard livestock, along with crops and other plants, to protect the public.

Efforts within the Food Industry

The Hazard Analysis Critical Control Points (HACCP) is a system within the food industry designed to promote food safety and prevent contamination by identifying all areas in food production and retail where contamination could occur. Companies and retailers determine the points during processing, packaging, shipping, or shelving where hazards could occur. Those companies or retailers must then take measures to prevent, control, or eliminate the potential for food contamination. The USDA requires the food industry to follow HACCP for meat and poultry, while the FDA requires it for seafood, low-acid canned-food, and juice. HACCP is voluntary for all other food products.

Efforts on the Consumer Level: What You Can Do

Consumers can also take steps to prevent foodborne illness and protect their health. Although you can often detect when mold is present, you can’t see, smell, or taste bacteria or other agents of foodborne disease. Therefore, it is crucial to take measures to protect yourself from disease. The four most important steps for handling, preparing, and serving food are:

1. **Clean.** Scrub hands at least 20 seconds in warm soapy water before handling food. Clean surfaces often and wash utensils after each use. Scrub fruits and vegetables (even if you plan to peel them) under running water.
2. **Separate.** Don’t cross-contaminate food during preparation and storage. Use separate cutting boards for produce and for meat, poultry, seafood, and eggs. Store food products separately in the refrigerator.
3. **Cook.** Heat food to proper temperatures. Use a food thermometer to check the temperature of food while it is cooking. Keep food hot after it has been cooked.
4. **Chill.** Refrigerate any leftovers within two hours. Never thaw or marinate food on the counter. Know when to keep food and when to throw it out. It can be helpful to check the website http://www.stilltasty.com, which explains how long refrigerated food remains fresh.US Department of

Health and Human Services. “Keep Food Safe.” Food Safety.gov. Accessed August 23, 2017. http://www.foodsafety.gov/keep/index.html.

Buying Food

It is best to buy your food from reputable grocers with clean, sanitary facilities, that keep products at appropriate temperatures. Consumers should examine food carefully before they purchase it. It is important to look at food in glass jars, check the stems on fresh produce, and avoid bruised fruit. Do not buy canned goods with dents or bulges, which are at risk of contamination with *Clostridium botulinum*. Fresh meat and poultry are usually free from mold but cured and cooked meats should be examined carefully. Also, avoid torn, crushed, or open food packages, and do not buy food with frost or ice crystals, which indicates that the product has been stored for a long time, or thawed and refrozen. It is also a good idea to keep meat, poultry, seafood, and eggs separate from other items in your shopping cart as you move through the grocery store.



Video 1.18.1: *Start at the Store: Prevent Foodborne Illness. This video provides tips to follow when selecting and purchasing food at the supermarket to help to prevent foodborne illness and protect your health (click to see video).*

Storing Food

Refrigerate perishable foods quickly; they should not be left out for more than two hours. The refrigerator should be kept at 40°F (or 4°C) or colder, and checked periodically with a thermometer. Store eggs in a carton on a shelf in the refrigerator, and not on the refrigerator door where the temperature is warmest. Wrap meat packages tightly and store them at the bottom of the refrigerator, so juices won’t leak out onto other foods. Raw meat, poultry, and seafood should be kept in a refrigerator for only two days. Otherwise, they should be stored in the freezer, which should be kept at 0°F (or −18°C). Store potatoes and onions in a cool, dark place, but not under a sink because leakage from pipes could contaminate them. Empty cans of perishable foods or beverages that have been opened into containers, and promptly place them in a refrigerator. Also, be sure to consume leftovers within three to five days, so mold does not have a chance to grow.

Preparing Food

Wash hands thoroughly with warm, soapy water for at least twenty seconds before preparing food and every time after handling raw foods. Washing hands is important for many reasons. One is to prevent cross-contamination between foods. Also, some pathogens can be passed from person to person, so hand washing can help to prevent this. Fresh fruits and vegetables should also be rinsed thoroughly under running water to clean off pesticide residue.California Department of Pesticide Regulation. “Pesticides and Food: How We Test for Safety.” *Pesticide Info: What You Should Know about Pesticides*, no. #E09/REV. Accessed December 21, 2011. www.cdpr.ca.gov/docs/dept/factshts/residu2. This is particularly important for produce that contains a high level of residue, such as apples, pears, spinach, and potatoes. Washing also removes most dirt and bacteria from the surface of produce.

Other tips to keep foods safe during preparation include defrosting meat, poultry, and seafood in the refrigerator, microwave, or in a water-tight plastic bag submerged in cold water. Never defrost at room temperature because that is an ideal temperature for bacteria to grow. Also, marinate foods in the refrigerator and discard leftover marinade after use because it contains raw juices. Always use clean cutting boards, which should be washed with soap and warm water by hand or in a dishwasher after each use. Another way to sanitize cutting boards is to rinse them with a solution of 5 milliliters (1 teaspoon) chlorine bleach to about 1 liter (1 quart) of water. If possible, use separate cutting boards for fresh produce and for raw meat. Also, wash the top before opening canned foods to prevent dirt from coming into contact with food.

Cooking Food

Cooked food is safe to eat only after it has been heated to a temperature that is high enough to kill bacteria. You cannot judge the state of “cooked” by color and texture alone. Instead, use a food thermometer to be sure. The appropriate minimum cooking temperature varies depending on the type of food. Seafood should be cooked to an internal temperature of 145°F, beef, lamb, and pork to 160°F, ground chicken and turkey to 165°F, poultry breasts to 170°F, and whole poultry and thighs to 180°F. When microwaving, rotate the dish and stir contents several times to ensure even cooking.

Serving Food

After food has been cooked, the possibility of bacterial growth increases as the temperature drops. So, food should be kept above the safe temperature of 140°F, using a heat source such as a chafing dish, warming tray, or slow cooker. Cold foods should be kept at 40°F or lower. When serving food, keep it covered to block exposure to any mold spores hanging in the air. Use plastic wrap to cover foods that you want to remain moist, such as fresh fruits, vegetables, and salads. After a meal, do not keep leftovers at room temperature for more than two hours. They should be refrigerated as promptly as possible. It is also helpful to date leftovers, so they can be used within a safe time, which is generally three to five days when stored in a refrigerator.

Key Takeaways

Foodborne illness is caused by pathogens, such as bacteria and viruses, toxins, such as those produced by molds and poisonous mushrooms, and chemical contaminants, such as pesticide residues and pollutants. A number of government agencies work to regulate food, manage outbreaks, and inform the public about foodborne illness and food safety. Consumers also should take measures to protect their health, including following the rules for four key steps: clean, separate, cook, and chill.

Discussion Starter

1. Discuss tactics that government agencies or consumer groups could take to educate the public about food safety. What key points do you think consumers need to know about foodborne illness and food safety? How do you think government organizations or other groups can best get that information out to the public?

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1.E: Nutrition and You (Exercises)

It's Your Turn

1. You are writing a short article for the *Daily News*. Explain how health means much more than a mere absence of disease.
2. Create a table that summarizes the six classes of nutrients and their major functions.
3. List five ideas on how to change the nutrition of Americans to protect their health and the health of the planet.
4. Draw a diagram that shows the role that nutrition plays in human health.
5. Write three ways in which cultural, religious, and social values affect dietary eating patterns.
6. Compare and contrast the Nutrition Facts label on two of your favorite foods. Make a smart choice for eating the most nutrient-dense food option. Which food did you select and why?

Apply It

1. Explore the nutritional and health information provided by the USDA, the HSS, and the IOM. Make a pros and cons list on how helpful the information from each of these sources was to you.
2. Revisit the photographs of the inner contents of refrigerators by Mark Menjivar. Describe how factors associated with a person's environment, lifestyle, and culture may affect the personal food choices in at least six different refrigerators.
3. Write a paragraph on your opinion of the role of the federal government in promoting health and preventing disease in Americans.
4. You have been hired to write a two-page article for a weekly magazine about why nutrition is important to health. Using simple terms and a good supply of photographs, create your article. Be prepared to share your project with the class.
5. Record a food diary this week. At the end of the week, circle the foods that contain SoFAS. Next, to each food, write a substitute food to replace it. Record a food diary next week. Be sure to eat the substitute foods you have selected to replace the foods that contained the SoFAS.
6. Search the Internet for sites that claim to give you nutritional advice. Check to see who sponsors the sites and if the site is trying to sell you a product or service. Compare the information found on the sites to those recommended in this text. What similarities do you notice? What differences do you notice?

Expand Your Knowledge

1. Conduct an assessment of your diet. Begin by recording what you eat every day, including snacks and beverages, in a journal. Then visit the website, www.choosemyplate.gov/myplate/index.aspx, which has tools to help you assess your diet. Calculate your average daily calorie consumption.
2. Conduct an informal survey of five of your friends and family members. Create a questionnaire with ten to fifteen questions pertaining to their perception of food, their favorite food shows, what restaurants they frequent, what they purchase from the grocery store each week, etc. Ask questions about their general eating habits and record the answers. Next, get a camera and take pictures of the insides of their refrigerators. What have you learned about their eating habits? What advice would you give them? Review all the material and put it together in a report. Be prepared to share your findings.
3. Define eight steps your community can take to build a more sustainable food system. Visit the websites of Toronto's and California's plans to help provide you with some good ideas to accomplish the challenge.
    - Toronto's plan for a sustainable food system: wx.toronto.ca/inter/health/food.nsf/Resources/340ACEEDBF1B2D6085257738000B22F2/$file/Cultivating%20Food%20Connections%20report.pdf
    - California's plan for a sustainable food system: http://www.vividpicture.net/

1. You have just been hired at the local Boys and Girls club in an inner city neighborhood that happens to have a large high school drop-out rate. You have been put in charge of creating physical and nutritional opportunities for the community. Your goal for the first quarter is to enroll one hundred students in an exercise/nutrition program. You must develop two programs.
    - Define each program and state its objectives
    - Describe the ways in which the program will benefit participants
    - List ways in which you will encourage enrollment
    - Create a marketing flyer for each program

2. You are planning a big meal for a surprise graduation party for your friend. You expect fifty guests to attend. Using the information you have learned regarding healthy eating and food portions, plan a healthful meal. Determine how much protein, vegetables, fruits, and starch you will need to purchase to feed everyone comfortably. Write down a detailed list so that you can shop and prepare your budget accordingly. Share your results with the class.
3. You are a Registered Dietitian who has been asked to help a vegan patient adjust their eating habits to get more nutrients from their diet and halt unwanted weight loss. Develop a week's worth of meals to help this person have balance in their diet.

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CHAPTER OVERVIEW

2: Gastrointestinal Tract

Because we know that you may not have a background in biology, we start with a tour through the human body, from the single cell to the full organism, we set up for a discussion about the processes of digestion and absorption, followed by explorations of the other organ systems. After that, we discuss the concept of energy and calories. We also discuss some disorders and diseases related to nutritional health.

2.1: Chapter Introduction
2.2: The Basic Structural and Functional Unit of Life- The Cell
2.3: Digestion and Absorption
2.4: Nutrients Are Essential for Organ Function
2.5: Energy and Calories
2.6: Gastrointestinal Tract and Your Health
2.E: Exercises

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2.1: Chapter Introduction

Big take away

- Eat your way to health.

"Let food be thy medicine and medicine be thy food." These words, espoused by the Greek physician Hippocrates over two thousand years ago, bear much relevance on our food choices and their connection to our health. Today, the scientific community echoes Hippocrates' statement as it recognizes some foods as *functional foods*. The Academy of Nutrition and Dietetics defines functional foods as "whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels."



Figure 2.1.1: Do you understand the relationship between food and health? © Thinkstock

In the latter nineteenth century, a Russian doctor of immunology, Elie Metchnikoff, was intrigued by the healthy life spans of people who lived in the tribes of the northern Caucasus Mountains. What contributed to their long life span and their resistance to life-threatening diseases? A possible factor lay wrapped up in a leather satchel used to hold fermented milk. One legend recounts that Mohammed, the great prophet of Islam, revealed this recipe to members of the Orthodox faith on the condition that they would not tell anyone outside of the faith how to create such a good-feeling beverage. The tribes, under Mohammed's direction, combined a tiny amount of small grains that resembled white broccoli with milk in a leather satchel. This bag was hung from a doorway in a house, so that all who passed would hit the bag, mixing up the contents. The result was a refreshing, slightly carbonated, creamy beverage with tangy overtones.

Observing the connection between the beverage and longevity, Dr. Elie Metchnikoff began his research on beneficial bacteria and the longevity of life that led to his book, *The Prolongation of Life*. He studied the biological effects and chemical properties of the kefir elixir whose name came from the Turkish word "kef" or "pleasure." Intrigued, the Russian Society of Physicians went on a quest to locate the recipe in order to prescribe this drink to their patients. However, just as instructed, no one would share the recipe. As a result, the mission of obtaining this highly guarded recipe was placed on the Blandov brothers, who owned the Moscow Dairy and some holdings in the Caucasus Mountains.

The Blandov brothers had a beautiful employee, Irina Sakharova, whom they sent to the courts of the Caucasus tribe of Prince Bek-Mirza Barchorov in order to charm the recipe out of him. The prince immediately fell in love with Irina. As time went on, Irina asked the prince for some kefir grains. He refused, explaining that he was forbidden from sharing this secret and feared the consequences of violating religious law. Irina returned home when she realized that she would never pry the recipe from the prince. However, on orders from the heartbroken prince, Irina was kidnapped and brought back to marry him. She was taken aback and

refused this proposal. Her refusal was rejected and the marriage was arranged. The Blandov brothers courageously stole into the tribe the night before the marriage and managed to free Irina. Insulted and still seeing a way to retrieve the kefir grains, Irina brought her case before the Russian Czar, charging the prince with kidnapping. Upon review of the evidence, it was ruled in her favor and Irina won her case. As part of her grievance repayment, Irina requested some kefir grains. Bound by law, the prince had to comply. Irina gave the grains to the Blandov brothers who mass-produced kefir from these kernels. To this day, kefir is one of the most widely enjoyed beverages in Russia.

Kefir has since found its way into America, where it is marketed in several flavors and can be found at your local grocery store. It is one product of the billion-dollar functional food industry marketed with all sorts of health claims from improving digestion to preventing cancer. What is the scientific evidence that kefir is a functional food? Expert nutritionists agree that probiotics, such as kefir, reduce the symptoms of lactose intolerance and can ward off virally caused diarrhea. While some health claims remain unsubstantiated, scientific studies are ongoing to determine the validity of other health benefits of probiotics.

You Decide

Will you eat your way to health with probiotic foods?

Knowing how to maintain the balance of friendly bacteria in your intestines through proper diet can promote overall health. Recent scientific studies have shown that probiotic supplements positively affect intestinal microbial flora, which in turn positively affect immune system function. As good nutrition is known to influence immunity, there is great interest in using probiotic foods and other immune-system-friendly foods as a way to prevent illness. In this chapter, we will explore not only immune system function but also all other organ systems in the human body. We will learn the process of nutrient digestion and absorption, which further reiterates the importance of developing a healthy diet to maintain a healthier you. The evidence abounds that food can indeed be “thy medicine.”

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2.2: The Basic Structural and Functional Unit of Life- The Cell

Learning Objectives

- Diagram the components of a cell.
- Describe the organization of the human body.

What distinguishes a living organism from an inanimate object? A living organism conducts self-sustaining biological processes. A cell is the smallest and most basic form of life. Robert Hooke, one of the first scientists to use a light microscope, discovered the cell in 1665. In all life forms, including bacteria, plants, animals, and humans, the cell was defined as the most basic structural and functional unit. Based on scientific observations over the next 150 years, scientists formulated the cell theory, which is used for all living organisms no matter how simple or complex. The cell theory incorporates three principles:

- Cells are the most basic building units of life.
- All living things are composed of cells.
- New cells are made from preexisting cells, which divide into two.

Who you are has been determined because of two cells that came together inside your mother's womb. The two cells containing all of your genetic information (DNA) united to begin making new life. Cells divided and differentiated into other cells with specific roles that led to the formation of the body's numerous body organs, systems, blood, blood vessels, bone, tissue, and skin. As an adult, you are comprised of trillions of cells. Each of your individual cells is a compact and efficient form of life—self-sufficient, yet interdependent upon the other cells within your body to supply its needs.

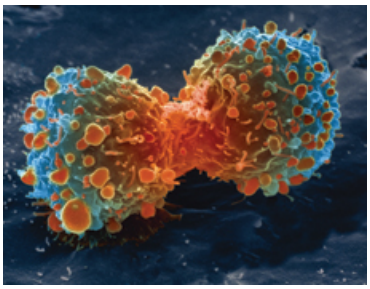


Figure 2.2.1: One cell divides into two, which begins the creation of millions of more cells that ultimately become you. (Public Domain; National Institutes of Health).

Independent single-celled organisms must conduct all the basic processes of life: it must take in nutrients (energy capture), excrete wastes, detect and respond to its environment, move, breathe, grow, and reproduce. Even a one-celled organism must be organized to perform these essential processes. All cells are organized from the atomic level to all its larger forms. Oxygen and hydrogen atoms combine to make the molecule water (H_2O). Molecules bond together to make bigger macromolecules. The carbon atom is often referred to as the backbone of life because it can readily bond with four other elements to form long chains and more complex macromolecules. Four macromolecules—carbohydrates, lipids, proteins, and nucleic acids—make up all of the structural and functional units of cells.

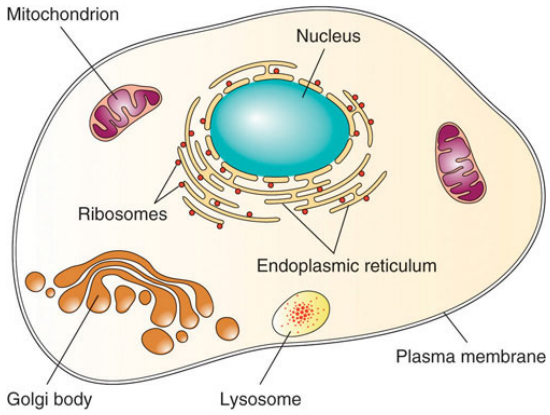


Figure 2.2.2: The cell is structurally and functionally complex.

Although we defined the cell as the “most basic” unit of life, it is structurally and functionally complex (Figure 2.2.1). A cell can be thought of as a mini-organism consisting of tiny organs called organelles. The organelles are structural and functional units constructed from several macromolecules bonded together. A typical animal cell contains the following organelles: the nucleus (which houses the genetic material DNA), mitochondria (which generate energy), ribosomes (which produce protein), the endoplasmic reticulum (which is a packaging and transport facility), and the Golgi apparatus (which distributes macromolecules). In addition, animal cells contain little digestive pouches, called lysosomes and peroxisomes, which break down macromolecules and destroy foreign invaders. All of the organelles are anchored in the cell’s cytoplasm via a cytoskeleton. The cell’s organelles are isolated from the surrounding environment by a plasma membrane.

Video 2.2.1: Discovery Video: Cells

This video describes the importance of cells in the human body.



Tissues, Organs, Organ Systems, and Organisms

Unicellular (single-celled) organisms can function independently, but the cells of multicellular organisms are dependent upon each other and are organized into five different levels in order to coordinate their specific functions and carry out all of life’s biological processes.

- **Cells.** Cells are the basic structural and functional unit of all life. Examples include red blood cells and nerve cells.
- **Tissues.** Tissues are groups of cells that share a common structure and function and work together. There are four types of human tissues: connective, which connects tissues; epithelial, which lines and protects organs; muscle, which contracts for movement and support; and nerve, which responds and reacts to signals in the environment.
- **Organs.** Organs are a group of tissues arranged in a specific manner to support a common physiological function. Examples include the brain, liver, and heart.
- **Organ systems.** Organ systems are two or more organs that support a specific physiological function. Examples include the digestive system and central nervous system. There are eleven organ systems in the human body (Table 3.2.1).
- **Organism.** An organism is the complete living system capable of conducting all of life’s biological processes.

Table 2.2.1: The Eleven Organ Systems in the Human Body and Their Major Functions

Organ System	Organ Components	Major Function
Circulatory	heart, blood/lymph vessels, blood, lymph	Transport nutrients and waste products
Digestive	mouth, esophagus, stomach, intestines	Digestion and absorption
Endocrine	all glands (thyroid, ovaries, pancreas)	Produce and release hormones
Immune	white blood cells, lymphatic tissue, marrow	Defend against foreign invaders
Integumentary	skin, nails, hair, sweat glands	Protective, body temperature regulation
Muscular	skeletal, smooth, and cardiac muscle	Body movement

Organ System	Organ Components	Major Function
Nervous	brain, spinal cord, nerves	Interprets and responds to stimuli
Reproductive	gonads, genitals	Reproduction and sexual characteristics
Respiratory	lungs, nose, mouth, throat, trachea	Gas exchange
Skeletal	bones, tendons, ligaments, joints	Structure and support
Urinary	kidneys, bladder, ureters	Waste excretion, water balance

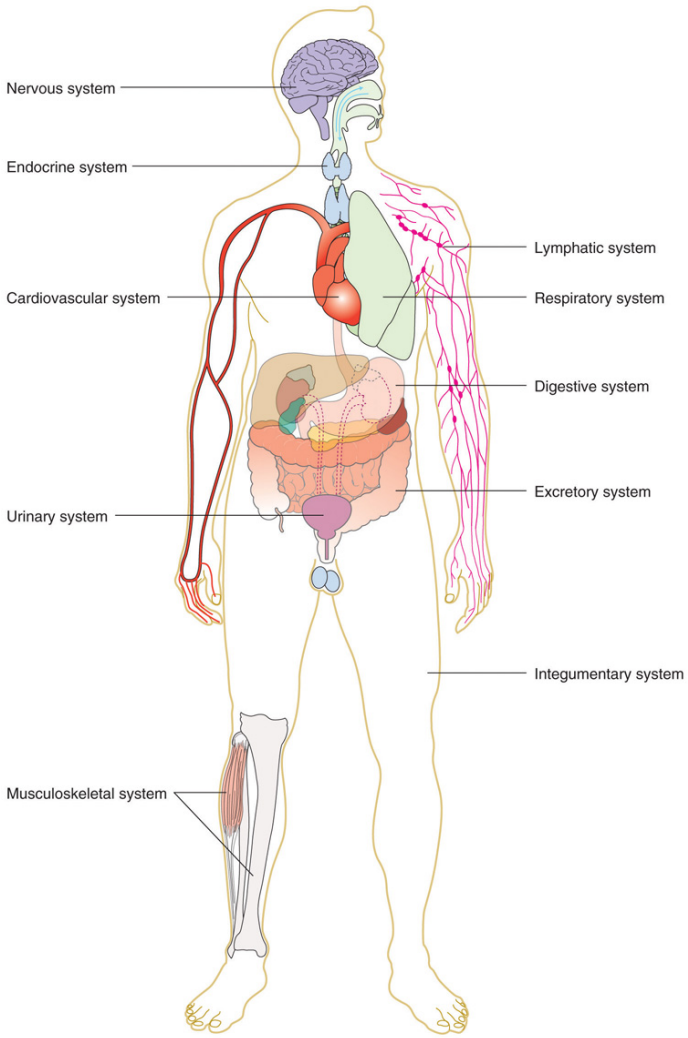


Figure 2.2.3: *Organ Systems in the Human Body © Networkgraphics*

An Organism Requires Energy and Nutrient Input

Energy is required in order to build molecules into larger macromolecules, and to turn macromolecules into organelles and cells, and then turn those into tissues, organs, and organ systems, and finally into an organism. Proper nutrition provides the necessary nutrients to make the energy that supports life's processes. Your body builds new macromolecules from the nutrients in food.

Nutrient and Energy Flow

Energy is stored in a nutrient's chemical bonds. Energy comes from sunlight, which plants then capture and, via photosynthesis, use it to transform carbon dioxide in the air into the molecule, glucose. When the glucose bonds are broken, energy is released. Bacteria, plants, and animals (including humans) harvest the energy in glucose via a biological process called cellular respiration.

In this process the chemical energy of glucose is transformed into cellular energy in the form of the molecule, adenosine triphosphate (ATP). Cellular respiration requires oxygen (aerobic) and it is provided as a waste product of photosynthesis. The waste products of cellular respiration are carbon dioxide (CO_2) and water, which plants use to conduct photosynthesis again. Thus, energy is constantly cycling between plants and animals. As energy is consumed nutrients are recycled within it.

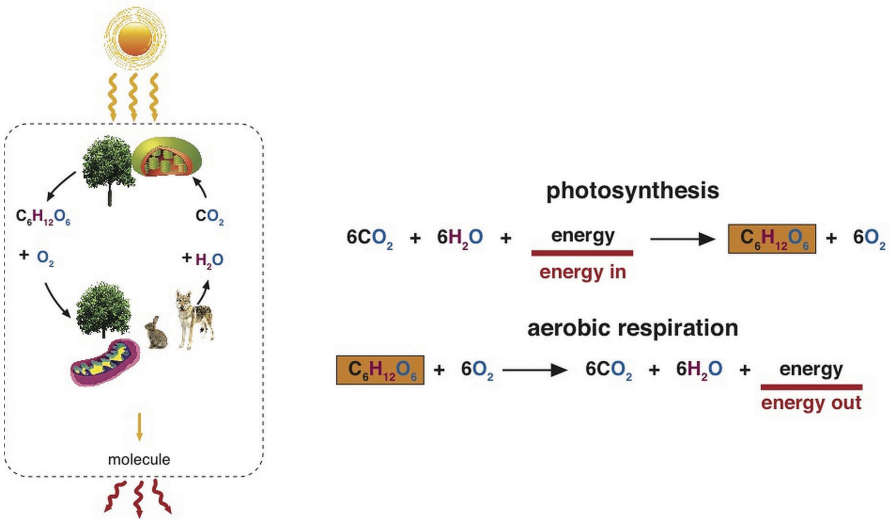


Figure 2.2.4: Plants harvest energy from the sun and capture it in the molecule, glucose. Humans harvest the energy in glucose and capture it into the molecule, ATP.

In this section, we have learned that all life is composed of cells capable of transforming small organic molecules into energy. How do complex organisms such as humans convert the large macromolecules in the foods that we eat into molecules that can be used by cells to make cellular energy? In the next section, we will discuss the physiological process of digestion to answer this question.

Key Takeaways

- The cell is the basic structural and functional unit of life. Cells are independent, single-celled organisms that take in nutrients, excrete wastes, detect and respond to their environment, move, breathe, grow, and reproduce. The macromolecules carbohydrates, proteins, lipids, and nucleic acids make up all of the structural and functional units of cells.
- In complex organisms, cells are organized into five levels so that an organism can conduct all basic processes associated with life.
- There are eleven organ systems in the human body that work together to support life, all of which require nutrient input.
- Energy is constantly cycling between plants and animals. As energy is consumed nutrients are recycled within it.

Discussion Starter

1. Discuss the importance of organization in the human body. If the body becomes disorganized by a disease or disorder what happens to its function? Can you think of a good example (what about leg fracture and movement)?

2.2: The Basic Structural and Functional Unit of Life- The Cell is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

2.3: Digestion and Absorption

Learning Objectives

- Sketch and label the major organs of the digestive system and state their functions.

Digestion begins even before you put food into your mouth. When you feel hungry, your body sends a message to your brain that it is time to eat. Sights and smells influence your body's preparedness for food. Smelling food sends a message to your brain. Your brain then tells the mouth to get ready, and you start to salivate in preparation for a delicious meal.

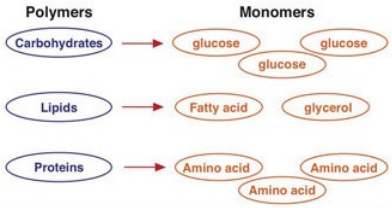


Figure 2.3.1: The Digestion Process. Digestion converts the food we eat into smaller particles, which will be processed into energy or used as building blocks.

Once you have eaten, your digestive system (Figure 2.3.1) breaks down the food into smaller components. Another word for the breakdown of complex molecules into smaller, simpler molecules is "catabolism". To do this, catabolism functions on two levels, mechanical and chemical. Once the smaller particles have been broken down, they will be absorbed into the blood and delivered to cells throughout the body for energy or for building blocks needed for cells to function. The digestive system is one of the eleven organ systems of the human body and it is composed of several hollow tube-shaped organs including the mouth, pharynx, esophagus, stomach, small intestine, large intestine (or colon), rectum, and anus. It is lined with mucosal tissue that secretes digestive juices (which aid in the breakdown of food) and mucus (which facilitates the propulsion of food through the tract). Smooth muscle tissue surrounds the digestive tract and its contraction produces waves, known as peristalsis, that propel food down the tract. Nutrients as well as some non-nutrients are absorbed. Substances such as fiber get left behind and are appropriately excreted.

From the Mouth to the Stomach

There are four steps in the digestion process (Figure 2.3.2). The first step is ingestion, which is the collection of food into the digestive tract. It may seem a simple process, but ingestion involves smelling food, thinking about food, and the involuntary release of saliva, in the mouth to prepare for food entry. In the mouth, where the second step of digestion occurs, the mechanical and chemical breakdown of food begins. The chemical breakdown of food involves enzymes, which break apart the components in food. In the mouth, the enzyme amylase is secreted to begin breaking down complex carbohydrate. Mechanical breakdown starts with mastication (chewing) in the mouth. Teeth crush and grind large food particles, while saliva initiates the chemical breakdown of food and enables its movement downward. The slippery mass of partially broken-down food is called bolus, which moves down the digestive tract as you swallow. Swallowing may seem voluntary at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins.

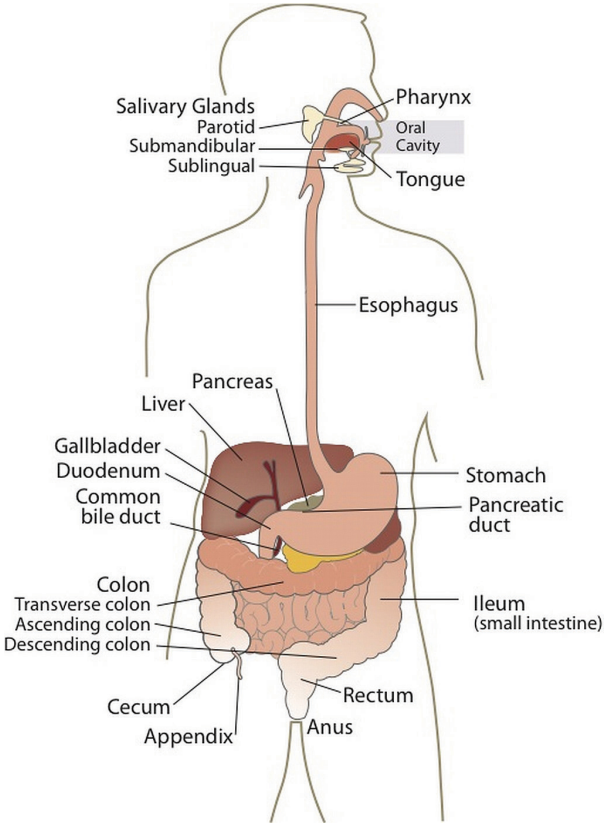


Figure 2.3.2: The Human Digestive System : © Networkgraphics

As you swallow, the bolus is pushed from the mouth through the pharynx and into a muscular tube called the esophagus. As it travels through the pharynx, a small flap called the epiglottis closes, to prevent choking by keeping food from going into the trachea. Peristaltic contractions in the esophagus propel the food down to the stomach. At the junction between the esophagus and stomach, there is a sphincter muscle that remains closed until the food bolus approaches. The pressure of the food bolus stimulates the lower esophageal sphincter to relax and open and food then moves from the esophagus into the stomach. The mechanical breakdown of food is accentuated by the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal. Solid food takes between four and eight seconds to travel down the esophagus, and liquids take about one second.

From the Stomach to the Small Intestine

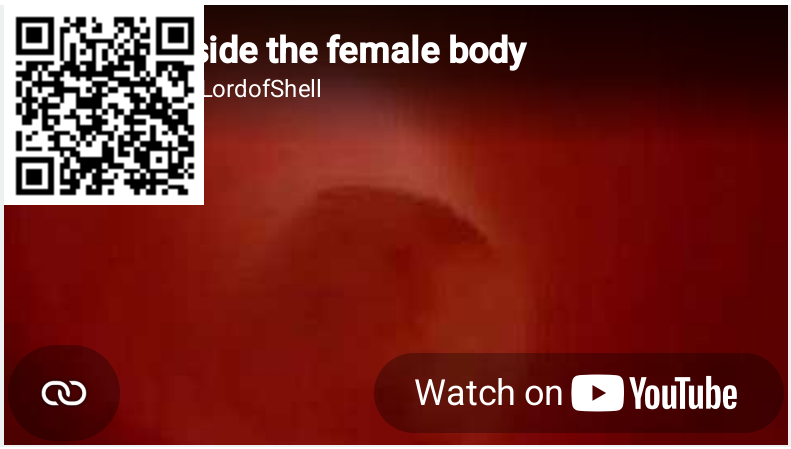
When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. Chyme is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. Cells in the stomach also secrete hydrochloric acid and the enzyme pepsin, that chemically breaks down protein into smaller molecules. A thick mucus coat lines the stomach to protect it from digesting itself. The stomach has three basic tasks:

1. To store food
2. To mechanically and chemically break down food
3. To empty partially broken-down food into the small intestine

The length of time food spends in the stomach varies by the macronutrient composition of the meal. A high-fat or high-protein meal takes longer to break down than one rich in carbohydrates. It usually takes a few hours after a meal to empty the stomach contents completely. The sphincter that allows chyme to pass into the small intestine is known as the pyloric sphincter.

Video 2.3.1: Digestion Video

This video shows the mechanical and chemical breakdown of food into chyme.



The small intestine is divided into three structural parts: the duodenum, the jejunum, and the ileum. Once the chyme enters the duodenum (the first segment of the small intestine), three accessory (or helper) organs: liver, pancreas, and gallbladder are stimulated to release juices that aid in digestion. The pancreas secretes up to 1.5 liters of pancreatic juice through a duct into the duodenum per day. This fluid consists mostly of water, but it also contains bicarbonate ions that neutralize the acidity of the stomach-derived chyme and enzymes that further break down proteins, carbohydrates, and lipids. The gallbladder secretes a much smaller amount of bile to help digest fats, also through a duct that leads to the duodenum. Bile is made in the liver and stored in the gallbladder. Bile's components act like detergents by surrounding fats similar to the way dish soap removes grease from a frying pan. This allows for the movement of fats in the watery environment of the small intestine. Two different types of muscular contractions, called peristalsis and segmentation, move and mix the food in various stages of digestion through the small intestine. Similar to what occurs in the esophagus and stomach, peristalsis is circular waves of smooth muscle contraction that propel food forward. Segmentation sloshes food back and forth in both directions promoting further mixing of the chyme. Almost all the components of food are completely broken down to their simplest unit within the first 25 centimeters of the small intestine. Instead of proteins, carbohydrates, and lipids, the chyme now consists of amino acids, monosaccharides, and emulsified fatty acids.

The next step of digestion (nutrient absorption) takes place in the remaining length of the small intestine, or ileum (> 5 meters).

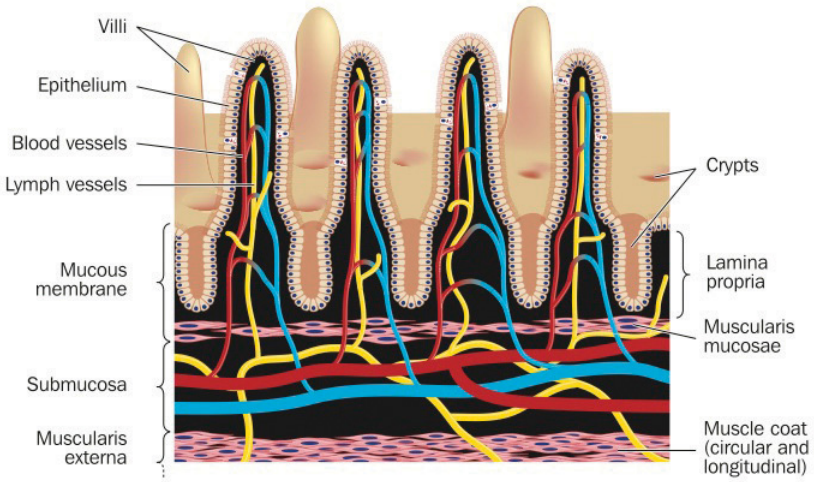


Figure 2.3.3: The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvilli. © Shutterstock

The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The surface area of the small intestine increases by multiple levels of folding. The internal tissue of the small intestine is covered in villi, which are tiny finger-like projections that are covered with even smaller projections, called microvilli (Figure 2.3.3). The digested nutrients pass through the absorptive cells of the intestine via diffusion or special transport proteins. Amino acids, minerals, alcohol, water soluble vitamins, and monosaccharides (sugars like glucose) are

transported from the intestinal cells into capillaries, but the much larger emulsified fatty acids, fat-soluble vitamins, and other lipids are transported first through lymphatic vessels, which soon meet up with blood vessels.

From the Small Intestine to the Large Intestine

The process of digestion is fairly efficient. Any food that is still incompletely broken down (usually less than ten percent of food consumed) and the food's indigestible fiber content moves from the small intestine to the large intestine (colon) through a connecting valve, ileoceceal sphincter. The main task of the large intestine is to reabsorb water. Remember, water is present not only in solid foods but also the stomach releases a few hundred milliliters of gastric juice and the pancreas adds approximately another 500 milliliters during the digestion of the meal. For the body to conserve water, it is important that the water is reabsorbed. In the large intestine, no further chemical or mechanical breakdown of food takes place, unless it is accomplished by the bacteria that inhabit this portion of the digestive tract. The number of bacteria residing in the large intestine is estimated to be greater than $10^{(14)}$, which is more than the total number of cells in the human body ($10^{(13)}$). This may seem rather unpleasant, but the great majority of bacteria in the large intestine are harmless and some are even beneficial. The bacteria synthesize the essential nutrient, vitamin K, short chain fatty acids, which are essential for our health, from the undigested fiber. Also, minerals, such as sodium and potassium, are absorbed.

Kefir

There has been significant talk about pre- and probiotic foods in the mainstream media. The World Health Organization defines probiotics as live bacteria that confer beneficial health effects on their host. They are sometimes called "friendly bacteria." The most common bacteria labeled as probiotic is lactic acid bacteria (lactobacilli). They are added as live cultures to certain fermented foods such as yogurt. Prebiotics are indigestible foods, primarily soluble fibers, that stimulate the growth of certain strains of bacteria in the large intestine and provide health benefits to the host. Examples of prebiotics would be inulin, soluble fiber and resistant starch. A review article in the June 2008 issue of the *Journal of Nutrition* concludes that there is a scientific consensus that probiotics ward off viral-induced diarrhea and reduce the symptoms of lactose intolerance.Farnworth, E. R. "The Evidence to Support Health Claims for Probiotics." *J Nutr* 138, no. 6 (2008): 1250S–4S. http://jn.nutrition.org/content/138/6/1250S.long. Expert nutritionists agree that more health benefits of pre- and probiotics will likely reach a scientific consensus. As the fields of pre- and probiotic manufacturing and their clinical study progress, more information on proper dosing and what exact strains of bacteria are potentially "friendly" will become available.



Figure 2.3.4: Kefir, a dairy product fermented with probiotic bacteria, can make a pleasant tasting milkshake. (CC BY-SA 3.0; Quijote)

You may be interested in trying some of these foods in your diet. A simple food to try is kefir. Several websites provide good recipes, including www.kefir.net/recipes.htm.

From the Large Intestine to the Anus

After a few hours in the stomach, plus three to six hours in the small intestine, and about sixteen hours in the large intestine, the digestion process enters step four, which is the elimination of indigestible food as feces. Feces contain indigestible food and gut bacteria (almost 50 percent of content). It is stored in the rectum until it is expelled through the anus via defecation.

Video 2.3.2: The Stages of Digestion

This video reviews the sequence of events during food digestion.



Processes of Digestion

Digestion involves two processes - physical and chemical. During the physical process, the food is mixed and moved throughout the gastrointestinal tract. This process is also referred to as motility and the partially digested food is propelled by the wave-like action called peristalsis. Ring-like muscular valves called sphincters prevent the back flow of partially digested food and digestive juices. There are sphincters between the esophagus and stomach (esophageal sphincter), between the stomach and small intestine (pyloric sphincter) and small intestine and colon (ileocecal sphincter).

The chemical process of digestion involves the release of water, acid, bicarbonate and enzymes to be mixed with the food to further break it down into smaller subunits. Chemical breakdown starts in the mouth where enzymes break down complex carbohydrate. In the stomach, water and acid are released to begin the breakdown of protein. A mucus lining protects the stomach from the corrosive acid. The mixture, also known as chyme, enters the small intestine where bicarbonate is introduced to neutralize the acid and enzymes are added to break chemical bonds. Most small intestine digestive enzymes are produced in the pancreas and small intestine.

Regulation of Digestion

Our nervous system and hormones control digestion. The nervous system consists of the central nervous system, and the peripheral nervous system. Our brain and spinal cord make up the central nervous system while the peripheral system lies outside the skull and vertebral column. There are two components to the peripheral system: the somatic system that supplies the skin and muscle, and the autonomic system which supplies smooth muscle, cardiac muscle, and glands. The autonomic system has two divisions: the parasympathetic (PSNS or PNS) and sympathetic system (SNS). The PSNS supplies signals to maintain normal function and conserve body processes. The SNS provides signals to accelerate the process. Our gastrointestinal tract receives signals from the central and autonomic systems as well as sends signals to these systems.

https://www.youtube.com/watch?v=hWks2wS56Qs

Hormones are also involved in regulating digestion. Your digestive tract secretes hormones to control the release of digestive enzymes and juices. Here is a table of some hormones.

Table 2.3.1: Hormones involved in digestion.

Hormone	Origin	Stimulus	Action
Gastrin	Stomach	Food, especially proteins, caffeine, spices, alcohol	Stimulates stomach acids and enzymes
Cholecystokinin (CCK)	Small Intestine	Fat and protein	Stimulates pancreas and liver secretions (enzymes and bile) for protein and fat digestion

Hormone	Origin	Stimulus	Action
Secretin	Small Intestine	Acid (from stomach) in small intestine	Secretes bicarbonate to neutralize acid
Gastric inhibitory protein (GIP)	Small Intestine	Fat and protein	Inhibits gastric motility and secretion of gastric juices

Our appetite and hunger are controlled by a complex process that involves many signals. Here is a brief overview of that process.

https://www.youtube.com/watch?v=bQT17Mifh94

Key Takeaways

- The breakdown of complex macromolecules in foods to simple absorbable components is accomplished by the digestive system. These components are processed by cells throughout the body into energy or are used as building blocks.
- The digestive system is composed of the mouth, pharynx, esophagus, stomach, small intestine, large intestine (or colon), rectum, and anus. There are four steps in the digestion process: ingestion, the mechanical and chemical breakdown of food, nutrient absorption, and elimination of indigestible food.
- The mechanical breakdown of food occurs via muscular contractions called peristalsis and segmentation. Enzymes secreted by the salivary glands, stomach, pancreas, and small intestine accomplishes the chemical breakdown of food. Additionally, bile emulsifies fats.

Discussion Starter

1. Decide whether you want to consume pre- and probiotic foods to benefit your health. Visit the websites below to help in your decision-making process. Defend your decision scientifically.

   http://www.health.harvard.edu/fhg/updates/update0905c.shtml

   nccam.nih.gov/research/results/spotlight/110508.htm

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2.4: Nutrients Are Essential for Organ Function

Learning Objectives

- Generalize how the body distributes nutrients to the rest of the body.
- Summarize the importance of adequate nutrition on other organ systems.

When the digestive system has broken down food to its nutrient components the body eagerly awaits delivery. The first stop of most absorbed nutrients is the liver. One of the liver's primary functions is to regulate metabolic homeostasis. Metabolic homeostasis may be defined as when the nutrients consumed and absorbed matches the energy required to carry out life's biological processes. Simply put, nutrient energy intake equals energy output. Through the body's network of blood vessels and veins, glucose and amino acids are directly transported from the small intestine to the liver. Lipids are transported to the liver by a more circuitous route involving the lymphatic system, which contains vessels similar to the circulatory system that transport white blood cells called lymph.

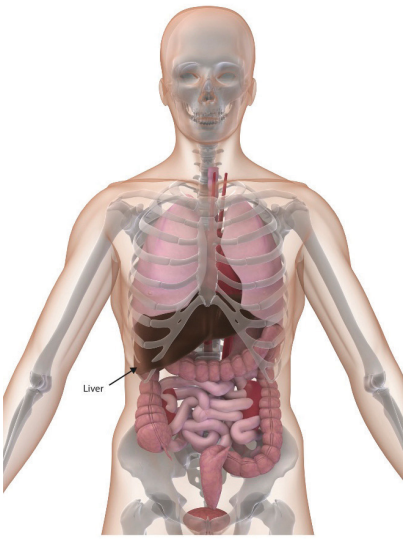


Figure 2.4.1: The liver is the checkpoint for metabolic activity. © Shutterstock

Maintaining the body's energy status quo is crucial because when metabolic homeostasis is disturbed by an eating disorder or disease, bodily function suffers. This will be discussed in more depth in the last section of this chapter. The liver is the only organ in the human body that is capable of exporting nutrients for energy production to other tissues. Therefore, when a person is in between meals (fasted state) the liver exports nutrients and when a person has just eaten (fed state) the liver stores nutrients within itself. Nutrient levels and the hormones that respond to their levels in the blood provide the input so that the liver can distinguish between the fasted and fed states and distribute nutrients appropriately.

All eleven organ systems in the human body require nutrient input to perform their specific biological functions. No energy in means no work output. Overall health and the ability to carry out all of life's basic processes are fueled by nutrients. Without them organ systems would fail, humans would not reproduce, and the race would disappear. In this section, we will discuss some of the critical nutrients that support specific organ system functions.

The Circulatory System (also known as part of the Cardiovascular System)

The circulatory system, which is part of the "cardiovascular" system, is one of the eleven organ systems of the human body. Its main function is to transport nutrients to cells and wastes from cells (Figure 3.4.1). This system consists of the heart, blood, and blood vessels. The heart pumps the blood, and the blood is the transportation fluid. The transportation route to all tissues is a highly intricate blood-vessel network, comprised of arteries, veins, and capillaries. Nutrients absorbed in the small intestine travel mainly to the liver through the hepatic portal vein. From the liver, nutrients travel upward through the inferior vena cava blood vessel to the heart. The heart forcefully pumps the nutrient-rich blood first to the lungs to pick up some oxygen and then to all other cells in the body. Arteries become smaller and smaller on their way to cells so that by the time blood reaches a cell, the artery's diameter is

extremely small and the vessel is now called a capillary. The reduced diameter of the blood vessel substantially slows the speed of blood flow. This dramatic reduction in blood flow gives cells time to harvest the nutrients in blood and exchange metabolic wastes.

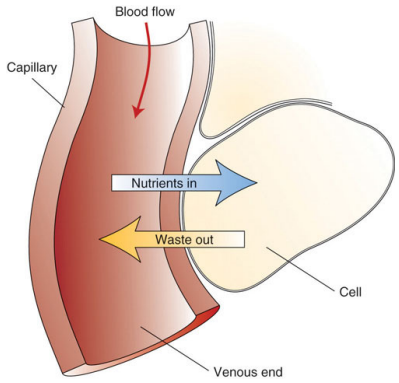


Figure 2.4.2: The Circulatory System: The circulatory system transports nutrients to all cells and carries wastes out.

The Central Nervous System

The human brain (which weighs only about 3 pounds, or 1,300 kilograms) is estimated to contain over one hundred billion neurons. Neurons form the core of the central nervous system, which consists of the brain, spinal cord, and other nerve bundles in the body. The main function of the central nervous system is to sense changes in the external environment and create a reaction to them. For instance, if your finger comes into contact with a thorn on a rose bush, a sensory neuron transmits a signal from your finger up through the spinal cord and into the brain. Another neuron in the brain sends a signal that travels back to the muscles in your hand and stimulates muscles to contract and you jerk your finger away. All of this happens within a tenth of a second. All nerve impulses travel by the movement of charged sodium, potassium, calcium, and chloride atoms. These are some of the essential minerals in our diets—essential because they are absolutely required for central nervous system function. Nerves communicate with each other via chemicals built from amino acids called neurotransmitters. Eating adequate protein from a variety of sources will ensure the body gets all of the different amino acids that are so important for central nervous system function.

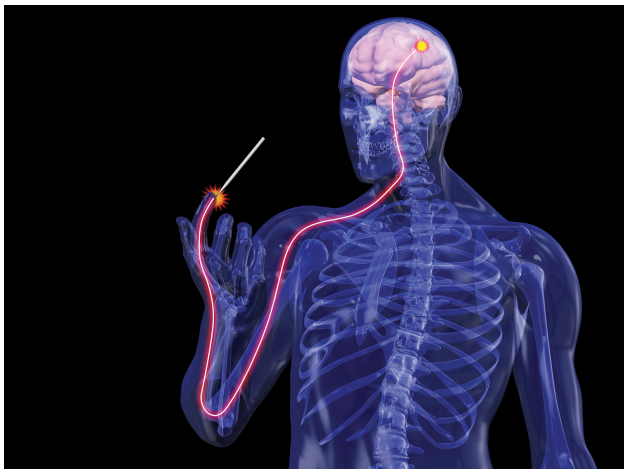


Figure 2.4.3: The brain has been compared to a central computer that controls all body functions. It relays messages to and from various body parts at lightning speed within a vast communication network of cells. © Shutterstock

Every day the brain uses over 20 percent of the energy obtained from nutrients. Its main fuel is glucose and only in extreme starvation will it use anything else (ketones). For acute mental alertness and clear thinking, glucose must be systematically delivered to your brain. This does not mean that sucking down a can of sugary soda before your next exam is a good thing. Just as too much glucose is bad for other organs, such as the kidneys and pancreas, it also produces negative effects upon the brain. Excessive glucose levels in the blood can cause a loss of cognitive function and chronically high blood-glucose levels can damage brain cells. The brain's cognitive functions include language processing, learning, perceiving, and thinking. Recent scientific studies demonstrate that having continuously high blood-glucose levels substantially elevates the risk of developing Alzheimer's disease, which is the greatest cause of age-related cognitive decline.

The good news is that much research is directed toward determining the best diets and foods that slow cognitive decline and maximize brain health. A study in the June 2010 issue of the *Archives of Neurology* reports that people over age sixty-five who adhered to diets that consisted of higher intakes of nuts, fish, poultry, tomatoes, cruciferous vegetables, fruits, salad dressing, and dark green, and leafy vegetables, as well as a lower intake of high-fat dairy products, red meat, organ meat, and butter, had a much reduced risk for Alzheimer's disease.Gu, Y., PhD et al. "Food Combination and Alzheimer Disease Risk: A Protective Diet." *Arch Neurol* 67, no. 6 (2010): 699–706. doi: 10./1001/archneurol.2010.84. Other scientific studies provide supporting evidence that foods rich in omega-3 fatty acids and/or antioxidants provide the brain with protection against Alzheimer's disease. One potential "brain food" is the blueberry. The protective effects of blueberries upon the brain are linked to their high content of anthocyanins, which are potent antioxidants and reduce inflammation. A small study published in the April 2010 issue of the *Journal of Agricultural and Food Chemistry* found that elderly people who consumed blueberry juice every day for twelve weeks had improved learning and memorization skills in comparison to other subjects given a placebo drink.Krikorian, R. et al. "Blueberry Supplementation Improves Memory in Older Adults." *J Agric Food Chem* 58, no. 7 (2010): 3996–4000. doi: 10.1021/jf9029332. More clinical trials are evaluating the effects of blueberries and other foods that benefit the brain and preserve its function as we age.

The Muscular System

The muscular system allows the body to move voluntarily, but it also controls involuntary movements of other organ systems such as heartbeat in the circulatory system and peristaltic waves in the digestive system. It consists of over six hundred skeletal muscles, as well as the heart muscle, the smooth muscles that surround your entire alimentary canal, and all your arterial blood vessels. Muscle contraction relies on energy delivery to the muscle. Each movement uses up cellular energy and without an adequate energy supply, muscle function suffers. Muscle, like the liver, can store the energy from glucose in the large polymeric molecule glycogen. But unlike the liver, muscles use up all of their own stored energy and do not export it to other organs in the body. When muscle energy stores are diminished, muscle contraction weakens. However, muscle is not as susceptible to low levels of blood glucose as the brain because it will readily use alternate fuels, such as fatty acids and protein to produce cellular energy.

"Hitting the Wall" or "Bonking"

If you are familiar with endurance sports, you may have heard of "hitting the wall" or "bonking." These colloquial terms refer to the extreme fatigue that sets in after about 120 minutes of performing an endurance sport, such as marathon running or long-distance cycling. The physiology underlying "hitting the wall" means that muscles have used up all their stored glycogen and are therefore dependent on other nutrients to support their energy needs. Fatty acids are transported from fat-storing cells to the muscle to rectify the nutrient deficit. However, fatty acids take more time to convert to energy than glucose, thus decreasing performance levels. To avoid "hitting the wall" or "bonking," endurance athletes load up on carbohydrates a few days before the event. This will maximize an athlete's amount of glycogen stored in their liver and muscle tissues. It is important not to assume that carbohydrate loading works for everyone. Without accompanied endurance training you will not increase the amount of stored glucose. If you plan on running a five-mile race for fun with your friend and decide to eat a large amount of carbohydrates in the form of a big spaghetti dinner the night before, the excess carbohydrates will be stored fat. Another way for athletes to avoid "hitting the wall" is to consume carbohydrate-containing drinks and foods during an endurance event. In fact, throughout the Tour de France—a twenty-two-day, twenty-four-hundred-mile race—the average cyclist consumes greater than 60 grams of carbohydrates per hour.



Figure 2.4.4: In order to avoid “hitting the wall,” athletes consume large amounts of carbohydrates before and during events to ensure enough glucose is available for optimal performance, especially during endurance activities such as cycling. © Shutterstock

The Endocrine System

The functions of the endocrine system are intricately connected to the body’s nutrition. This organ system is responsible for regulating appetite, nutrient absorption, nutrient storage, and nutrient usage, in addition to other functions, such as reproduction. The glands in the endocrine system are the pituitary, thyroid, parathyroid, adrenals, thymus, pineal, pancreas, ovaries, and testes. The glands secrete hormones, which are biological molecules that regulate cellular processes in other target tissues, so they require transportation by the circulatory system. Adequate nutrition is critical for the functioning of all the glands in the endocrine system. A protein deficiency impairs gonadal-hormone release, preventing reproduction. Athletic teenage girls with very little body fat often do not menstruate. Children who are malnourished usually do not produce enough growth hormone and fail to reach normal height for their age group. Probably the most popularized connection between nutrition and the functions of the endocrine system is that unhealthy dietary patterns are linked to obesity and the development of Type 2 diabetes. The Centers for Disease Control and Prevention (CDC) estimates that twenty-six million Americans have Type 2 diabetes as of 2011. This is 8.3 percent of the US population. The maps in Note 3.35 show the percentage of adults who are obese, and those with diagnosed Type 2 diabetes within all American counties. You can see that those counties with the highest incidence of obesity also have the highest incidence of Type 2 diabetes.

Video 2.4.1: Obesity and Type 2 Diabetes

Watch the National Health video to see the relationship between the rise in obesity and the rise in Type 2 diabetes.



What is the causal relationship between overnutrition and Type 2 diabetes? The prevailing theory is that the overconsumption of high-fat and high-sugar foods causes changes in muscle, fat, and liver cells that leads to a diminished response from the pancreatic hormone insulin. These cells are called “insulin-resistant.” Insulin is released after a meal and instructs the liver and other tissues to take up glucose and fatty acids that are circulating in the blood. When cells are resistant to insulin they do not take up enough

glucose and fatty acids and so glucose and fatty acids remain at high concentrations in the blood. The continuously high amounts of glucose and fatty acids in the blood impair the release of insulin from the pancreas, further exacerbating the situation. The chronic elevation of glucose and fatty acids in the blood also causes damage to other tissues over time, so that people who have Type 2 diabetes are at increased risk for cardiovascular disease, kidney disease, nerve damage, and eye disease.

Tools for Change

Do your part to slow the rising tide of obesity and Type 2 diabetes in this country. On the individual level, improve your own family's diet; at the local community level, support the development of more nutritious school lunch programs; and at the national level, support your nation's nutrition goals. Visit the CDC Diabetes Public Health Resource website at http://www.cdc.gov/diabetes/. It provides information on education resources, projects, and programs, and spotlights news on diabetes and obesity. The CDC also has a new workplace program called CDC's LEAN *Works!* (LEAN: Leading Employees to Activity and Nutrition). The program provides free web-based resources with the mission of designing worksites that prevent obesity. See http://www.cdc.gov/leanworks/ for more details.

The Immune System

The immune system is comprised of several types of white blood cells that circulate in the blood and lymph. Their jobs are to seek, recruit, attack, and destroy foreign invaders, such as bacteria and viruses. Other less realized components of the immune system are the skin (which acts as a barricade), mucus (which traps and entangles microorganisms), and even the bacteria in the large intestine (which prevent the colonization of bad bacteria in the gut). Immune system functions are completely dependent on dietary nutrients. In fact, malnutrition is the leading cause of immune-system deficiency worldwide. When immune system functions are inadequate there is a marked increase in the chance of getting an infection. Children in many poor, developing countries have protein- and/or energy-deficient diets that are causative of two different syndromes, kwashiorkor and marasmus. These children often die from infections that their bodies could normally have fought off, but because their protein and/or energy intake is so low, the immune system cannot perform its functions.

Other nutrients, such as zinc, selenium, copper, folate, and vitamins A, B_6, C, D, and E, all provide benefits to immune system function. Deficiencies in these nutrients can cause an increased risk of infection and death. Zinc deficiency results in suppression of the immune system's barrier functions by damaging skin cells; it is also associated with a decrease in the number of circulating white blood cells. A review of several studies in the journal *Pediatrics* concluded that zinc supplements administered to children under age five for longer than three months significantly reduces the incidence and severity of diarrhea and respiratory illnesses.Aggarwal R., MD, DM, J. Sentz, MPH and M. A. Miller, MD. "Role of Zinc Administration in Prevention of Childhood Diarrhea and Respiratory Illnesses: A Meta-Analysis." *Pediatrics* 119, no. 6 (2007): 1120–30. doi: 10.1542/peds.2006–3481. Zinc supplementation has also been found to be therapeutically beneficial for the treatment of leprosy, tuberculosis, pneumonia, and the common cold. Equally important to remember is that multiple studies show that it is best to obtain your minerals and vitamins from eating a variety of healthy foods.

Tools for Change

To ensure that your diet includes zinc-friendly foods, try these foods high in zinc and other immune-system friendly nutrients: oysters, poultry, baked beans, chick peas, cashews, sesame seeds, peanuts, whole grains, and zinc-fortified cereals.



Figure 2.4.5: These are just some of the foods that are high in zinc.

Just as undernutrition compromises immune system health, so does overnutrition. People who are obese are at increased risk for developing immune system disorders such as asthma, rheumatoid arthritis, and some cancers. Both the quality and quantity of fat affect immune system function. High intakes of saturated and trans fats negatively affect the immune system, whereas increasing your intake of omega-3 fatty acids, found in salmon and other oily fish, decreases inflammatory responses. High intakes of omega-3 fatty acids are linked to a reduction in the risk of developing certain autoimmune disorders, such as rheumatoid arthritis, and are used as part of a comprehensive treatment for rheumatoid arthritis.

Key Takeaways

- Metabolic homeostasis occurs when the amount of nutrients consumed matches the energy required to carry out life's biological processes.
- The circulatory system transports nutrients to cells and transports wastes from them.
- The essential minerals sodium, potassium, calcium, and chloride, and the macronutrients protein and carbohydrates are required for central nervous system function. Fat is also critical for central nervous system function (see the Discussion Starter below).
- Without energy from nutrients, muscles cannot contract.
- Undernutrition and overnutrition compromise endocrine and immune system functions. Type 2 diabetes, increased rates of infection, and inflammatory disorders are symptoms of an imbalance in the diet.

Interactive 2.1

Take a look at the PowerPoint presentation prepared by the CDC that captures the concurrent rises of obesity and Type 2 diabetes in this country. Click on "Maps of Trends in Diabetes and Obesity." www.cdc.gov/diabetes/statistics/diabetes_slides.htm

Discussion Starter

1. Find out how fat supports brain function and protects nerves by visiting the Franklin Institute Resources for Science Learning website.

   www.fi.edu/learn/brain/fats.html

   Now look at the websites below to see how too much of the wrong kind of fats may be bad for the brain, while other types of fat are good for the brain.

   http://archneur.ama-assn.org/cgi/content/full/60/2/194

   http://www.sciencedaily.com/releases/2007/12/071210163251.htm

   http://www.webmd.com/alzheimers/news/20070418/omeg-3-fatty-acid-slows-alzheimers

   After viewing all of the videos, discuss the importance of "good fats" in the diet for optimizing brain function and preventing diseases such as Alzheimer's.

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2.5: Energy and Calories

Learning Objectives

- Estimate your total daily caloric /energy needs based upon your physical activity level.

Energy is essential to life. You must eat to have energy. You must go to bed at a decent time, so that when you wake up in the morning, you will not be too tired and you will have sufficient energy for the next day's activities. Energy is also everywhere in our environment: sunlight, wind, water, plants, and animals. All living things use energy every day. Energy can be defined as the quantity of work a particular system can perform, whether it be a growing child's body or a train transporting passengers from one place to another. Energy also helps us perform daily functions and tasks such as breathing, walking up a flight of steps, and studying for a test.

Energy is classified as either potential or kinetic. Potential energy is stored energy, or energy waiting to happen. Kinetic energy is energy in motion. To illustrate this, think of an Olympic swimmer standing at the pool's edge awaiting the sound of the whistle to begin the race. While he waits for the signal, he has potential energy. When the whistle sounds and he dives into the pool and begins to swim, his energy is kinetic (in motion).

Some basic forms of energy are:

1. **Thermal (heat) energy.** We can say that a cup of hot tea has thermal energy. Thermal energy is defined as the collective, microscopic, kinetic, and potential energy of the molecules within matter. In a cup of tea, the molecules have kinetic energy because they are moving and oscillating, but they also possess potential energy due to their shared attraction to each other.
2. **Chemical energy.** In your body, blood sugar (glucose) possesses chemical energy. When glucose reacts chemically with oxgen, energy is released from the glucose. Once the energy is released, your muscles will utilize it to produce mechanical force and heat.
3. **Electrochemical energy.** In the body, electrical impulses travel to and from the brain encoded as nerve impulses. Once the brain receives an electrical impulse it causes the release of a messenger chemical (glutamate, for example). This in turn facilitates electrical impulses as they move from one neuron to another.

The Calorie Is a Unit of Energy

The amount of energy in nutrients can be quantified into specific units that can be measured. The unit of measurement that defines the energy contained in a energy-yielding nutrient is called a calorie. A calorie is the amount of energy in the form of heat that is required to heat one gram of water one degree Celsius. To measure the number of calories in a particular food substance, a certain amount of food is burned in a device called a calorimeter. As the food burns, heat is created. The heat dissipates to the surrounding water while a thermometer detects the change in temperature of the water. You can even perform calorimetry at home with a more basic device. However, it is not likely that you will use this device to measure calorie content in the foods that you eat since mathematical formulas have been developed to estimate caloric content.

Estimating Caloric Content

The energy contained in energy-yielding nutrients differs because the energy-yielding nutrients are composed of different types of chemical bonds. A carbohydrate or a protein yields 4 kilocalories per gram, whereas a lipid yields 9 kilocalories per gram. A kilocalorie (Calorie) is the amount of heat generated by a particular macronutrient that raises the temperature of 1 kilogram of water 1 degree Celsius. A kilocalorie of energy performs one thousand times more work than a calorie. On the Nutrition Facts panel, the calories within a particular food are expressed as kilocalories, which is commonly denoted as "Calories" with a capital "C" (1 kcal = 1 Calorie = 1,000 calories).

Calculating the number of Calories in commercially prepared food is made fairly easy since the total number of Calories in a serving of a particular food is listed on the Nutrition Facts panel. If you wanted to know the number of Calories in the breakfast you consumed this morning just add up the number of Calories in each food. For example, if you ate one serving of yogurt that contained 150 Calories, on which you sprinkled one half of a cup of low-fat granola cereal that contained 209 Calories, and drank a glass of orange juice that contained 100 Calories, the total number of Calories you consumed at breakfast is 150 + 209 + 100 = 459 Calories. If you do not have a Nutrition Facts panel for a certain food, such as a half cup of blueberries, and want to find out the amount of Calories it contains, go to MyFood-a-pedia, a website maintained by the USDA.

Interactive 2.2

Try using "Fooducate" which will give each food a letter grade (A, B, C, D or F) for how healthy it is! Just type any food into the search box at the top. For example, Fig Newton Cookies get a C+.

Fooducate

Estimating the Amount of Energy from Each Macronutrient

Also listed on the Nutrition Facts panel are the amounts of total fat, total carbohydrate, and protein in grams. To calculate the contribution of each macronutrient to the total kilocalories in a serving, multiply the number of grams by the number of kilocalories yielded per gram of nutrient. For instance, from the Nutrition Facts panel for yogurt given in Figure 2.7, the protein content in one serving is 7 grams. Protein yields 4 kilocalories per gram. The number of kilocalories from protein is calculated by using the following equation:

of grams of protein × 4 kilocalories/gram of protein 7 grams × 4 kilocalories/gram = 28 kilocalories

(# kilocalories from protein ÷ total kilocalories per serving) × 100 (28 ÷ 150) × 100 = 18.7 percent

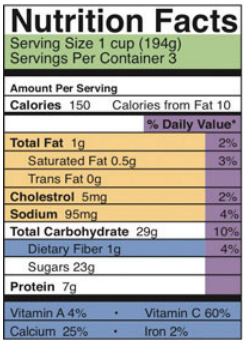


Figure 2.5.1: *A Nutrition Facts Panel for Yogurt: Because the total number of kilocalories in each serving of yogurt is 150, the percent of energy obtained from protein is calculated by using the following equation:*

Key Takeaways

- Energy is vital to life and is categorized into two types—kinetic and potential. There are also different forms of energy such as thermal, chemical, and electrochemical.
- Calories are a measurement of a specific quantity of energy contained in foods. The number of calories contained in a commercially prepared food is listed on the Nutrition Facts panel.

Discussion Starter

1. Estimate the total number of kilocalories that you have eaten so far today. What percentage of the kilocalories you consumed was obtained from carbohydrates? Protein? Fat?

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2.6: Gastrointestinal Tract and Your Health

Learning Objectives

- Interpret why certain disorders and diseases, such as gastroesophageal reflux disease (GERD), celiac disease, and irritable bowel syndrome compromise overall health.

When nutrients and energy are in short supply, cells, tissues, organs, and organ systems do not function properly. Unbalanced diets can cause diseases and, conversely, certain illnesses and diseases can cause an inadequate intake and absorption of nutrients, simulating the health consequences of an unbalanced diet. Overeating high-fat foods and nutrient-poor foods can lead to obesity and exacerbate the symptoms of gastroesophageal reflux disease (GERD) and irritable bowel syndrome (IBS). Many diseases and illnesses, such as celiac disease, interfere with the body getting its nutritional requirements. A host of other conditions and illnesses, such as food allergies, cancer, stomach ulcers, Crohn's disease, and kidney and liver disease, also can impair the process of digestion and/or negatively affect nutrient balance and decrease overall health.

Gastroesophageal Reflux Disease

Gastroesophageal reflux disease (GERD) is a persistent form of acid reflux that occurs more than two times per week. Acid reflux occurs when the acidic contents of the stomach leak backward into the esophagus and cause irritation. It is estimated that GERD affects 25 to 35 percent of the US population. An analysis of several studies published in the August 2005 issue of *Annals of Internal Medicine* concludes that GERD is much more prevalent in people who are obese.Hampel, H. MD, PhD, N. S. Abraham, MD, MSc(Epi) and H. B. El-Serag, MD, MPH. "Meta-Analysis: Obesity and the Risk of Gastroesophageal Reflux Disease and Its Complications." *Ann Intern Med* 143, no. 3 (2005): 199–211. http://www.ncbi.nlm.nih.gov/pubmed/16061918 While the links between obesity and GERD are not completely known, they likely include that excess body fat puts pressure on the stomach, overeating increases pressure in the stomach, and fatty foods are triggers for GERD symptoms. The most common GERD symptom is heartburn, but people with GERD may also experience regurgitation (flow of the stomach's acidic contents into the mouth), frequent coughing, and trouble swallowing. Approximately 35 percent of children born in the United States have GERD. In babies, the symptoms are more difficult to distinguish from what babies do normally. The symptoms are spitting up more than normal, incessant crying, refusal to eat, burping, and coughing. Most babies outgrow GERD before their first birthday but a small percentage do not.

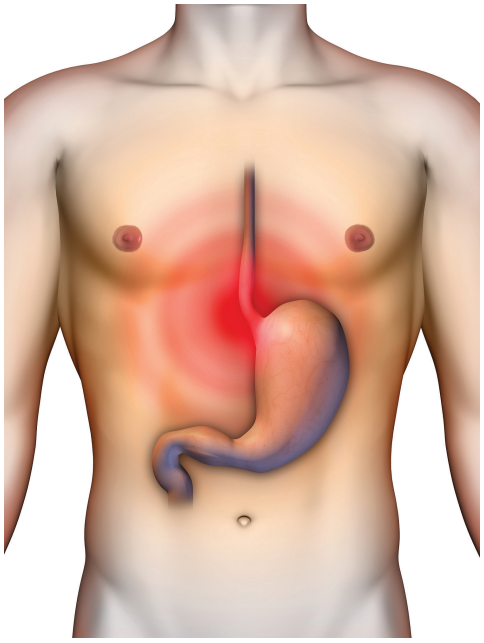


Figure 2.6.1: Heartburn is a burning sensation that radiates throughout the chest. © Shutterstock

Additional Facts about GERD

There are other causative factors of GERD that may be separate from or intertwined with obesity. The sphincter that separates the stomach's internal contents from the esophagus often does not function properly and acidic gastric contents seep upward. Sometimes the peristaltic contractions of the esophagus are also sluggish and compromise the clearance of acidic contents. In addition to having an unbalanced, high-fat diet, some people with GERD are sensitive to particular foods—chocolate, garlic, spicy foods, fried foods, and tomato-based foods—which worsen symptoms. Drinks containing alcohol or caffeine may also worsen GERD symptoms. GERD is diagnosed most often by a history of the frequency of recurring symptoms. A more proper diagnosis can be made when a doctor inserts a small device into the lower esophagus that measures the acidity of the contents during one's daily activities. Sometimes a doctor may use an endoscope, which is a long tube with a camera at the end, to view the tissue in the esophagus. About 50 percent of people with GERD have inflamed tissues in the esophagus. A condition known as Barrett's esophagus may develop over time in some people who have GERD. Barrett's esophagus refers to a structural difference in the tissue of the esophagus, which is caused by recurrent tissue damage. It occurs in 5 to 15 percent of patients diagnosed with GERD and less than 1 percent of these patients may develop cancer of the esophagus, a highly lethal cancer.

The first approach to GERD treatment is dietary and lifestyle modifications. Suggestions are to reduce weight if you are overweight or obese, avoid foods that worsen GERD symptoms, eat smaller meals, stop smoking, and remain upright for at least three hours after a meal. There is some evidence that sleeping on a bed with the head raised at least six inches helps lessen the symptoms of GERD. People with GERD may not take in the nutrients they need because of the pain and discomfort associated with eating. As a result, GERD can be caused by an unbalanced diet and its symptoms can lead to a worsening of nutrient inadequacy, a viscious cycle that further compromises health. Many medications are available to treat GERD, including antacids, histamine2 (H2) blockers, and proton-pump inhibitors. Some evidence from scientific studies indicates that medications used to treat GERD may accentuate certain nutrient deficiencies, namely zinc and magnesium. When these treatment approaches do not work surgery is an option. The most common surgery involves reinforcing the sphincter that serves as a barrier between the stomach and esophagus.

Ulcers

Ulcers occur when the top layer of the cells in the stomach, duodenum, and/or colon erode and expose the lower cell layer to the luminal contents. The number one cause of ulcers is the bacteria, *Helicobacter pylori* (*H. pylori*), which degrades the protective layer. Chronic use of anti-inflammatories can also erode the protective layer of the stomach and or small intestine, and cause ulcers. Ulcers are not caused by stress or smoking but these can make an ulcer worse. Avoiding coffee, caffeinated beverages like coffee, drinking alcohol, and foods that exacerbate the condition can help improve ulcers. Prescribed medicine is the best treatment.

Diverticulitis

Sometimes small pouches form in the colon wall at weakened spots. These are called diverticula and become inflamed from bacteria and irritants. There is a low incidence of diverticulitis in people who eat more fiber.

Inflammatory Bowel Disease (IBD)

The cause of inflammatory bowel disease is unknown. Crohn's disease and chronic ulcerative colitis are the most common types of IBD.

Irritable Bowel Syndome (IBS)

Irritable bowel syndrome (IBS) is characterized by muscle spasms in the colon that result in abdominal pain, bloating, constipation, and/or diarrhea. Interestingly, IBS produces no permanent structural damage to the large intestine as often happens to patients who have Crohn's disease or inflammatory bowel disease. It is estimated that one in five Americans displays symptoms of IBS. The disorder is more prevalent in women than men. Two primary factors that contribute to IBS are an unbalanced diet and stress. There is no specific test to diagnose IBS, but other conditions that have similar symptoms (such as celiac disease) must be ruled out. This involves stool tests, blood tests, and having a colonoscopy (which involves the insertion of a flexible tube with a tiny camera on the end through the anus so the doctor can see the colon tissues).

Symptoms of IBS significantly decrease a person's quality of life as they are present for at least twelve consecutive or nonconsecutive weeks in a year. Large meals and foods high in fat and added sugars, or those that contain wheat, rye, barley, peppermint, and chocolate intensify or bring about symptoms of IBS. Additionally, beverages containing caffeine or alcohol may worsen IBS. Stress and depression compound the severity and frequency of IBS symptoms. As with GERD, the first treatment approaches for IBS are diet and lifestyle modifications. People with IBS are often told to keep a daily food journal to help identify

and eliminate foods that cause the most problems. Other recommendations are to eat slower, add more fiber to the diet, drink more water, and to exercise. There are some medications (many of which can be purchased over-the-counter) to treat IBS and the resulting diarrhea or constipation. Sometimes antidepressants and drugs to relax the colon are prescribed.

Celiac Disease

Celiac disease is an autoimmune disorder affecting between 0.5 and 1.0 percent of Americans—that is, one in every one- to two-hundred people. It is caused by an abnormal immune reaction of small intestine cells to a type of protein, called gluten. Gluten forms in the presence of water and is composed of two protein parts, glutenin and gliadin. Glutenin and gliadin are found in grains that are commonly used to make bread, such as wheat, rye, and barley. When bread is made, yeast eats the flour and makes a waste product, carbon dioxide, which forms bubbles in the dough. As the dough is kneaded, gluten forms and stretches. The carbon dioxide gas bubbles infiltrate the stretchy gluten, giving bread its porosity and tenderness. For those who are sensitive to gluten, it is good to know that corn, millet, buckwheat, and oats do not contain the proteins that make gluten. However, some people who have celiac disease also may have a response to products containing oats. This is most likely the result of cross-contamination of grains during harvest, storage, packaging, and processing.

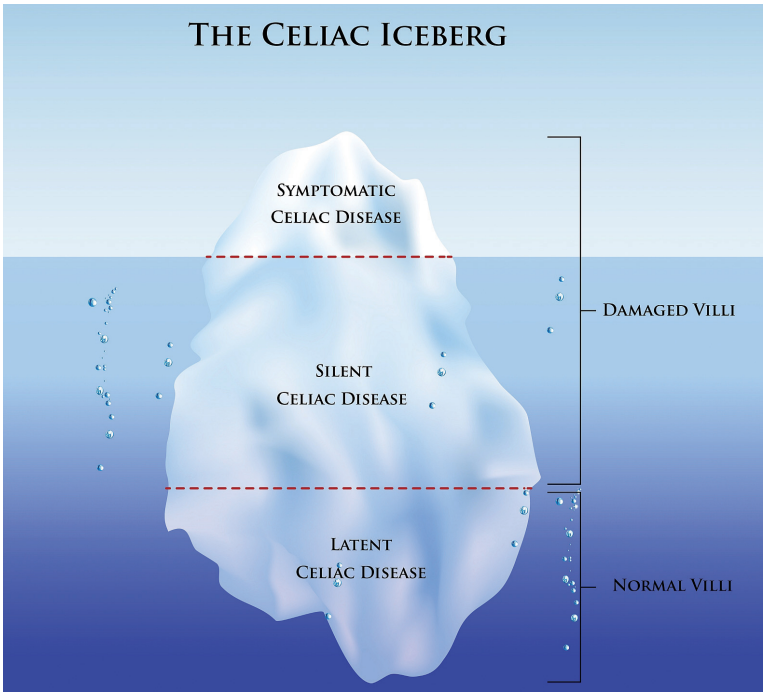


Figure 2.6.2: Celiac: Not everyone with celiac is diagnosed—many have “silent” or “latent” celiac disease. © Shutterstock

Celiac disease is most common in people of European descent and is rare in people of African American, Japanese, and Chinese descent. It is much more prevalent in women and in people with Type 1 diabetes, autoimmune thyroid disease, and Down and Turner syndromes. Symptoms can range from mild to severe and can include pale, fatty, loose stools, gastrointestinal upset, abdominal pain, weight loss and, in children, a failure to grow and thrive. The symptoms can appear in infancy or much later in life, even by age seventy. Celiac disease is not always diagnosed because the symptoms may be mild. A large number of people have what is referred to as “silent” or “latent” celiac disease (Figure 3.6.1).

Celiac disease diagnosis requires a blood test and a biopsy of the small intestine. Because celiac disease is an autoimmune disease, antibodies produced by white blood cells circulate in the body and can be detected in the blood. When gluten-containing foods are consumed the antibodies attack cells lining the small intestine leading to a destruction of the small villi projections. This tissue damage can be detected with a biopsy, a procedure that removes a portion of tissue from the damaged organ. Villi destruction is what causes many of the symptoms of celiac disease. The destruction of the absorptive surface of the small intestine also results in the malabsorption of nutrients, so that while people with this disease may eat enough, nutrients do not make it to the bloodstream because absorption is reduced. The effects of nutrient malabsorption are most apparent in children and the elderly as they are especially susceptible to nutrient deficiencies. Over time these nutrient deficiencies can cause health problems. Poor absorption of iron and folic acid can cause anemia, which is a decrease in red blood cells. Anemia impairs oxygen transport to all cells in the body. Calcium and vitamin D deficiences can lead to osteoporosis, a disease in which bones become brittle.

If you think you or someone close to you may have celiac disease, do not despair; it is a very treatable disease. Once diagnosed, a person follows a gluten-free diet for life. This requires dedication and careful detective work to seek out foods with hidden gluten, but some stores carry gluten-free foods. After eliminating gluten from the diet, the tissues of the small intestine rapidly repair themselves and heal in less than six months.

Gallstones

The gallbladder is a where bile is stored and bile is important for the digestion of fat. Sometimes pieces of solid matter form in the gallbladder and this material is called gallstones. Gallstones are mainly formed from cholesterol. If these "stones" block the ball duct or prevent the flow of bile into the small intestine, fat in your diet will not be absorbed.

Lactose Intolerance

Lactose intolerance is common and is estimated to occur in 70% of the population. It occurs when the enzyme lactase is missing, low, or ineffective at digesting the carbohydrate lactose. Bacteria then ferment the lactose causing bloating and discomfort. Lactose intolerance increases with age and people who experience this condition must avoid foods that contain lactose. Such foods would be milk and milk-based products. Several dairy products treated with lactase to remove lactose are available on the market as well as a variety of fermented products like yogurt and kefir. Each person is different so you will have to experiment to see which products you can tolerate and how much of that product.

Constipation

Constipation occurs when your bowel movements are infrequent and difficult, and there are many reasons why it occurs. These include but are not limited to some medications, changes in your usual diet or activities, eating a lot of dairy products, eating disorders, irritable bowel syndrome, not being active, not enough water or fiber in your diet, overuse of laxatives, stress, and atonic colon (weakened muscles). Treatment involves listening to defecation signals, high fluid, high fiber diet (as long as the cause is not spastic colon), and exercise. Including more whole grains, fruits and vegetables in your diet is a good way to prevent constipation. When adding more fiber to your diet, add more water too.

Hemorrhoids

Hemorrhoids occur when the veins in your lower rectum and/or anus become swollen. This condition occurs when you don't eat enough fiber, push too hard during defecation, stand or sit too long, labor during childbirth, lift too heavy a weight, or are overweight or obese. Avoiding the cause of the hemorrhoid is the best way to prevent their reoccurrence.

Diarrhea

Diarrhea is watery stools caused by reduced water absorption or reversed water transport, and shortened transit time through the gut. It is common and generally will resolve in a few days but one should be careful not to become dehydrated. There are many reasons why diarrhea occurs including food poisoning, infections, IBS, lactose intolerance, and allergies to cow's milk. The best treatment is bowel rest coupled with fluid and electrolyte replacement.

Food Allergies

Paying attention to the way individuals react to various foods is essential in determining what foods may specifically affect a person adversely. Food allergies are one of the many ways in which different body make-ups affect nutritional concerns. Although an estimated twelve million Americans have food allergies, there are likely many more people who say they have food allergies than actually do. This is because food sensitization is different from a medically-determined food allergy. When someone has a food allergy, the immune system mistakenly attacks a certain kind of food (usually the protein component of a food), such as peanuts, as if it were a threat and IgE antibodies are produced. Doctors sometimes test for food allergies by using skin-prick tests or blood tests to look for the presence of IgE antibodies. However, these types of tests are not always reliable as they can sometimes yield a false positive result. By far, the most valuable tests for determining a food allergy is the Double Blind Placebo Controlled Food Challenge (DBPCFC), which involves administering the food orally and then denoting the signs and symptoms of the allergic response.



Figure 2.6.3: *Many people with food allergies experience skin rashes after eating an allergenic food. © Shutterstock*

Food allergy symptoms usually develop within a few minutes to two hours after a person has eaten a food to which they are allergic. These symptoms can range from the annoying to the potentially fatal, and include:

- A tingling mouth
- Swelling tongue and/or throat
- Difficulty breathing
- Hives
- Stomach cramps
- Diarrhea
- Vomiting
- Drop in blood pressure
- Loss of consciousness
- Death

There are no clear treatments for food allergies. Epinephrine is sometimes used to control severe reactions, and individuals with known and dangerous allergies may get prescriptions for self-injectable devices. The only certain way to avoid allergic reactions to food is to avoid the foods that cause them. Beyond avoidance, this can mean reading food labels carefully, or even calling manufacturers for product information.

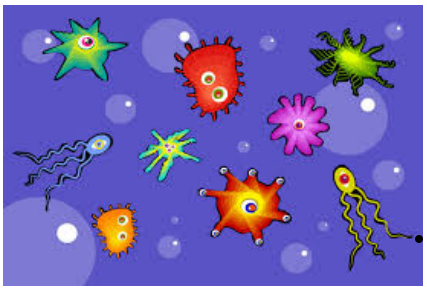
Ninety percent of food allergies are caused by these eight foods:

1. Milk
2. Eggs
3. Peanuts
4. Tree nuts
5. Fish
6. Shellfish
7. Wheat
8. Soy

The prevalence of food allergies is a complex and growing problem. In response to this situation, the National Institute of Allergy and Infectious Diseases (NIAID) collaborated with thirty-four professional organizations, federal agencies, and patient-advocacy groups to develop a comprehensive guide to diagnosing and managing food allergies and treating acute food allergy reactions. The guide defines various food allergies, allergens, and reactions, provides comprehensive information on the prevalence of different food allergies, tracks the history of food allergies, and reviews medical management techniques for people with food allergies.

Gut Microbiota

Our body is covered with small microorganisms we cannot see. Within our gut, it is estimated that there are 100 trillion bacteria, which 10 times more cells than we have in our body. Most bacteria do not cause us harm and, in fact, have a symbiotic relationship that keeps us healthy; for example, they produce vitamin B_6, vitamin B_{12}, biotin, vitamin K, and short chain fatty acids. Recent studies have suggested a link between several chronic diseases (cancer, obesity, heart disease, depression, and autism, to name a few) and the microbes that reside in our gut. Diet plays a role in prominent role in determining the specific microbial communities



found in our intestinal track. Prebiotic foods contain undigested material, like fiber, that our gut microbes digest while probiotic foods contain live bacteria.

https://www.youtube.com/watch?v=QE9QWFg-XNs

Figure 2.6.4: Cartoon of different types of bacteria.

Key Takeaways

Unbalanced diets can cause diseases and, conversely, certain disorders and diseases can cause an inadequate intake and absorption of nutrients simulating the health consequences of an unbalanced diet.

- Unbalanced, high-fat diets can exacerbate the symptoms of GERD and IBS.
- Celiac disease and anorexia can lead to nutritional deficiencies, which compromise the functioning of the organ systems and decrease health.
- Food allergies affect roughly twelve million Americans, with symptoms that range from mild to deadly. Proper diagnosis leads to better management of food allergies and sensitivities.

Discussion Starter

1. The next time you visit the grocery store, be a “gluten detective” and use the ingredients list to identify all the foods you might normally purchase that contain gluten. Discuss how you can use food labels to avoid products containing gluten.

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2.E: Exercises

It's Your Turn

1. After watching the video on GERD, list the potential consequences of GERD.

   Understanding GERD (GERD #1)

   (click to see video)

Expand Your Knowledge

1. Find out how fat supports brain function and protects nerves by visiting the following website: www.fi.edu/learn/brain/fats.html. Now look at these other websites to see how too much of the wrong kind of fats may be bad for the brain, while other types of fat are good for the brain.

   http://archneur.ama-assn.org/cgi/content/full/60/2/194

   http://www.webmd.com/alzheimers/news/20070418/omeg-3-fatty-acid-slows-alzheimers.

   Discuss how a balanced fat intake that contains "good fats" helps optimize brain function and prevent diseases such as Alzheimer's.

2. Estimate the total number of kilocalories that you have eaten so far today. What percentage of the kilocalories you consumed was obtained from carbohydrates, protein, and fat? Compare the percentage of calories from carbohydrates, protein, and fat that you consumed to their Acceptable Macronutrient Distribution Ranges.
3. On your next trip to the grocery store, pretend you have a child with a peanut allergy and determine which foods you need to avoid purchasing to prevent your child from having an allergic response.

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3: Carbohydrates

In this Chapter we explore the many types of carbohydrates, including their functions. We also take a look at diabetes and at sugar substitutes.

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3.1: Introduction to Carbohydrates

You likely eat grains everyday—cereal, a sandwich, pasta, or your favorite rice dish. Whole grains are vital to a healthful diet. In addition to fiber, whole grains offer other slow-releasing carbohydrates, antioxidants, vitamins, and minerals, all of which are needed for good health. Maybe you are on a diet and have been told to limit or restrict your carbohydrate intake. How much is too much and which carbohydrates are better for you? Can you promote a healthy weight with a balanced intake of whole grains? Before we answer these questions, let's examine in brief the history of grain.

Video 3.1.1

Watch the History of Bread, part one, from The History Channel. To further satiate your interest go on to watch the other five parts, available on YouTube.

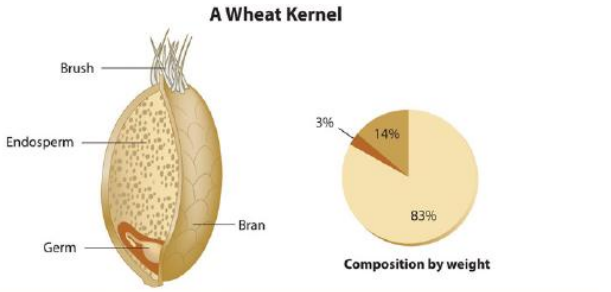


In ancient times whole grains were cracked open using quern stones that required hours of hand labor. As technology slowly advanced, the quern stone was modified into the millstone. It wasn't until the advent of water wheels that human labor to produce grains was reduced. About 2,500 years ago the Romans started milling flour by turning one millstone wheel against another that did not move. The turning was done by animals, slaves, and later by waterwheels. The process of milling breaks the hard outer bran coat of the wheat seeds. The bran and germ, which contain the majority of fiber, vitamins, and minerals, are removed by sifting. In the earliest days, the whitest flour was chosen to make bread for the wealthy, and the coarsest was given to the poor. One's economic status was depicted by the color of bread they ate. Wheat was the grain of choice for many cultures, as it not only produced white flour but also contained gluten which gives wheat bread its elasticity and lightness in texture. The word "flour" comes from a French word meaning "blossom" and is metaphoric for the finest part of the meal. Bakers highly prized their art and it was kept from the masses. In fact the baker's mark was one of the first trademarks.



Figure 3.1.1: The *2015 Dietary Guidelines* recommends that whole grains over refined grains. What percentage of your diet is whole grain? © Thinkstock

In America, Oliver Evans built the first flour mill, which was powered by a watermill. It used a series of elevators that moved grain through the mill, cleaning it first, then grinding and sifting it. Today, modern milling produces three types of flour; whole meal containing 100 percent of the grain, with nothing added or removed; brown flour, containing 85 percent of the original grain with some bran and germ and white flour, containing 75 percent of the wheat grain with the most bran and germ removed. The vast majority of flour milled and used in foods and cooking in America is white flour. The modern milling process of preparing white flour removes between 50 and 85 percent of B vitamins, vitamin E, calcium, iron, potassium, chromium, phosphorus, zinc, magnesium manganese, and cobalt.



	Carb/g	Protein/g	Fat/g	Fiber/g	Iron (% daily req.)	Others
Bran	63	16	3	43	59	vitamin Bs
Endosperm	79	7	0	4	7	
Germ	52	23	10	14	35	vitamin Bs omega-3/6 lipids

Nutritional value (per 100g)

Figure 3.1.2: *Wheat kernel anatomy and composition.*

In the early nineteenth century several diseases stemming from vitamin and mineral deficiencies, such as pellagra (niacin, B_3), beriberi (thiamine, B_1), and anemia (iron), plagued many inhabitants of the nation. One of the first public health campaigns was to improve the health of Americans by enriching flour, a dietary staple. The B vitamins, niacin, thiamine, riboflavin, and folate were added along with iron to combat dietary deficiencies and proved a successful strategy to improve public health. However, enriched flour contains only 6 percent or less of the recommended daily intake of the vitamins and minerals it "replaces." Overwhelming scientific evidence now shows that diets containing high amounts of whole grains rather than refined white flour decrease weight gain and the risk for many chronic diseases, including certain types of cancer and diabetes. Whole grains contain a whole nutrient package that is not replaced by enriched flour. Consumers are becoming more aware of the many health benefits of whole grains. However, the food industry has created a puzzle for consumers in determining if a product is made from 100 percent whole grains. "Whole wheat" does not always mean the product is made with 100 percent whole grains, and brown breads are not always healthier than white as the color may come from added caramel. The Food and Drug Administration (FDA) has provided the food industry with specifics on how to label whole-grain foods—to label it as made from 100 percent whole grains. The best method to ensure the product is made from 100 percent whole grains is to check the ingredient list. One-hundred percent whole-grain products

list whole grains or whole-wheat flour most often as the first ingredient and do not contain wheat flour, white flour, yellow corn flour, semolina flour, degerminated flour, or durum flour. In America, whole-grain choices are improving, but progress still needs to be made on reducing the added sugar content of many industrially prepared breads, assuring added fiber comes from good sources, eliminating ambiguous labels and claims on packaging, and reducing the costs of whole-grain breads, which still exceed that of white bread.

You Decide

What 100 percent whole-grain products can you include in your diet to improve health, prevent disease, and be tastefully satisfied?

As you read on, you will learn the different types of carbohydrates, their essential roles in the body, the potential health consequences and benefits of diets rich in particular carbohydrates, and the many foods available that are rich in carbohydrates as well as nutritious and satisfying. After reading this chapter, you will be better equipped to decide the best way to get your nutritional punch from various carbohydrates in your diet.

“If thou tastest a crust of bread, thou tastest all the stars and all the heavens.”

Robert Browning, English poet, and playwright (May 1812–December 1889)

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3.2: A Closer Look at Carbohydrates

Learning Objectives

- Describe some of the distinguishing features of carbohydrates.
- Describe the differences between fast-releasing and slow-releasing carbohydrates.
- What Exactly Are Carbohydrates and How Many Types Are There?

Carbohydrates are the perfect nutrient to meet your body's nutritional needs. They nourish your brain and nervous system, provide energy to all of your cells (and within proper caloric limits), and help keep your body fit and lean. Specifically, digestible carbohydrates provide bulk in foods, vitamins, and minerals, while indigestible carbohydrates provide a good amount of fiber with a host of other health benefits.

Plants synthesize the fast-releasing carbohydrate, glucose, from carbon dioxide in the air and water, and by harnessing the sun's energy. Recall that plants convert the energy in sunlight to chemical energy in the molecule, glucose. Plants use glucose to make other larger, more slow-releasing carbohydrates. When we eat plants we harvest the energy of glucose to support life's processes.

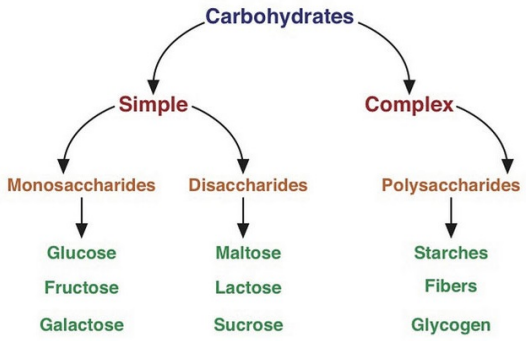


Figure 3.2.1: Carbohydrate Classification Scheme. Carbohydrates are broken down into the subgroups "fast-releasing" and "slow-releasing" carbohydrates. These subgroups are further categorized into mono-, di-, and polysaccharides.

Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Basically, they are hydrated carbons. The word "carbo" means carbon and "hydrate" means water. Glucose (also called dextrose), the most abundant carbohydrate in the human body, has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. The chemical formula for glucose is written as $C_6H_{12}O_6$. Synonymous with the term carbohydrate is the Greek word "saccharide," which means sugar. The simplest unit of a carbohydrate is a monosaccharide. Carbohydrates are broadly classified into two subgroups, "fast-releasing" and "slow-releasing." Fast-releasing carbohydrates are further grouped into the monosaccharides and disaccharides. Slow-releasing carbohydrates are long chains of monosaccharides. (Figure 3.2.1).

Fast-Releasing Carbohydrates

Fast-releasing carbohydrates are also known more simply as "sugars." Fast-releasing carbohydrates are grouped as either monosaccharides or disaccharides. Monosaccharides include glucose, fructose, and galactose, and the disaccharides include, lactose, maltose, and sucrose.

Monosaccharides

For all organisms from bacteria to plants to animals, glucose is the preferred fuel source. The brain is completely dependent on glucose as its energy source (except during extreme starvation conditions). The monosaccharide galactose differs from glucose only in that a hydroxyl (−OH) group faces in a different direction on the number four carbon (Figure 3.2.2). This small structural alteration causes galactose to be less stable than glucose. As a result, the liver rapidly converts it to glucose. Most absorbed galactose is utilized for energy production in cells after its conversion to glucose. (Galactose is one of two simple sugars that are bound together to make up the sugar found in milk. It is later freed during the digestion process.)

Fructose also has the same chemical formula as glucose but differs in its chemical structure, as the ring structure contains only five carbons and not six (Figure 4.2.2). Fructose, in contrast to glucose, is not an energy source for other cells in the body. Mostly found

in fruits, honey, and sugarcane, fructose is one of the most common monosaccharides in nature. It is also found in soft drinks, cereals, and other products sweetened with high fructose corn syrup.

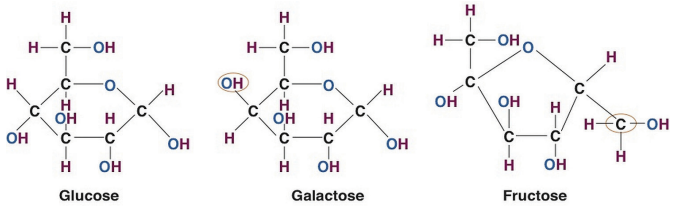


Figure 3.2.2: Structures of the Three Most Common Monosaccharides: Glucose, Galactose, and Fructose. Red circles indicate the structural differences between the three.

Less common monosaccharides are the pentoses, which have only five carbons and not six. The pentoses are abundant in the nucleic acids RNA and DNA, and also as components of fiber.

Lastly, there are the sugar alcohols, which are industrially synthesized derivatives of monosaccharides. Some examples of sugar alcohols are sorbitol, xylitol, and glycerol. (Xylitol is similar in sweetness to table sugar.) Sugar alcohols are often used in place of table sugar to sweeten foods as they are incompletely digested and absorbed, and therefore less caloric. The bacteria in your mouth opposes them, hence sugar alcohols do not cause tooth decay. Interestingly, the sensation of “coolness” that occurs when chewing gum that contains sugar alcohols comes from them dissolving in the mouth, a chemical reaction that requires heat from the inside of the mouth.

Disaccharides

Disaccharides are composed of pairs of two monosaccharides linked together. Disaccharides include sucrose, lactose, and maltose. All of the disaccharides contain at least one glucose molecule.

Sucrose, which contains both glucose and fructose molecules, is otherwise known as table sugar. Sucrose is also found in many fruits and vegetables, and at high concentrations in sugar beets and sugar cane, which are used to make table sugar. Lactose, which is commonly known as milk sugar, is composed of one glucose unit and one galactose unit. Lactose is prevalent in dairy products such as milk, yogurt, and cheese. Maltose consists of two glucose molecules bonded together. It is a common breakdown product of plant starches and is rarely found in foods as a disaccharide. It is formed because of the germination of grains.

Oligosaccharides

Oligosaccharides is a complex sugar that has three to ten monosaccharide molecules hooked in a chain. Examples are raffinose and stachyose which are found in some sports drinks and are a chain of glucose molecules. Raffinose and stachyose are digested and the resulting glucose is absorbed. Beans also contain raffinose and stachyose.

Slow-Releasing Carbohydrates

Slow-releasing carbohydrates are polysaccharides, long chains of monosaccharides that may be branched or not branched. There are two main groups of polysaccharides: starches and fibers.

Starches

Starch molecules (the carbohydrate storage form in plants) are found in abundance in grains, legumes, and root vegetables, such as potatoes. Amylose, a plant starch, is a linear chain containing hundreds of glucose units. Amylopectin, another plant starch, is a branched chain containing thousands of glucose units. These large starch molecules form crystals and are the energy-storing molecules of plants. These two starch molecules (amylose and amylopectin) are contained together in foods, but the smaller one, amylose, is more abundant. Eating raw foods containing starches provides very little energy as the digestive system has a hard time breaking them down. Cooking breaks down the crystal structure of starches, making them much easier to break down in the human body. The starches that remain intact throughout digestion are called resistant starches. Bacteria in the gut can break some of these down and may benefit gastrointestinal health. Isolated and modified starches are used widely in the food industry and during cooking as food thickeners.

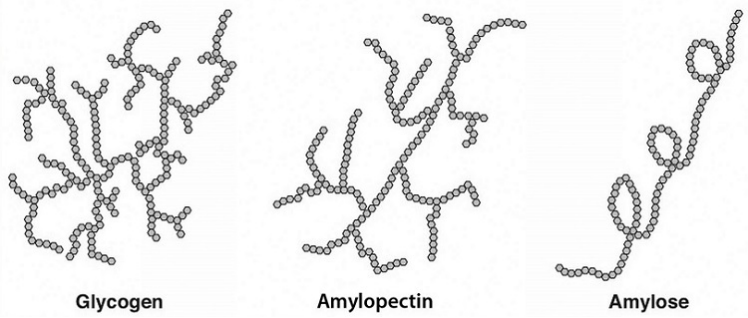


Figure 3.2.3: Structures of the Plant Starches and Glycogen

Humans and animals store glucose energy from starches in the form of the very large molecule, glycogen. It has many branches that allow it to break down quickly when energy is needed by cells in the body. It is predominantly found in liver and muscle tissue in animals.

Dietary Fibers

Dietary fibers are polysaccharides that are highly branched and cross-linked. Some dietary fibers are pectin, gums, cellulose, and lignin. Humans do not produce the enzymes that can break down dietary fiber; however, bacteria in the large intestine (colon) do. Dietary fibers are very beneficial to our health. The Dietary Guidelines Advisory Committee states that there is enough scientific evidence to support that diets high in fiber reduce the risk for obesity and diabetes, which are primary risk factors for cardiovascular disease.US Department of Agriculture. “Part D. Section 5: Carbohydrates.” In Report of the DGAC on the Dietary Guidelines for Americans, 2010. Accessed September 30, 2011. www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/D-5-Carbohydrates.pdf.

Dietary fiber is categorized as either water-soluble or insoluble. Soluble fibers dissolve and swell in water. Classes of soluble fibers are pectins, gums, mucilage and some hemicelluloses. Examples of soluble fibers you may see on ingredient lists are inulin, pectin, and guar gum while food sources are peas, beans, oats, barley, and rye.

Cellulose, hemicellulose, psyllium, and lignin are insoluble fibers and a few dietary sources of these fibers are whole-grain foods, flax, cauliflower, and avocados. Cellulose is the most abundant fiber in plants, making up the cell walls and providing structure.

Soluble fibers are more easily accessible to bacterial enzymes in the large intestine so they can be broken down to a greater extent than insoluble fibers, but even some breakdown of cellulose and other insoluble fibers occurs.

The last class of fiber is functional fiber. Functional fibers have been added to foods and have been shown to provide health benefits to humans. Functional fibers may be extracted from plants and purified or synthetically made. An example of a functional fiber is psyllium-seed husk. Scientific studies show that consuming psyllium-seed husk reduces blood-cholesterol levels and this health claim has been approved by the FDA. Total dietary fiber intake is the sum of dietary fiber and functional fiber consumed.

Dietary recommendations for dietary fiber are 25-35 g/day for adults and for children, 5 g + the child's age/day. A variety of fiber sources should be consumed with the focus on whole grain, not refined. Excessive intake of fiber, > 60 g/day, can cause intestinal blockage, bind minerals, and cause intestinal gas or cramping.

Key Takeaways

- Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Carbohydrates are broadly classified into two subgroups, fast-releasing, and slow-releasing carbohydrates.
- Fast-releasing carbohydrates are sugars and they include the monosaccharides and disaccharides. Slow-releasing carbohydrates include the polysaccharides, amylose, amylopectin, glycogen, dietary fiber, and functional fiber.
- Glucose is the most important monosaccharide in human nutrition. Many other monosaccharides and disaccharides become glucose in the body.
- Fiber-rich foods are scientifically proven to reduce the risk of obesity and diabetes. Functional fibers are added to foods because they are proven to have added health benefits.

Discussion Starters

1. What do you eat most of: fast-releasing carbohydrates, starches, or fiber?
2. Bring in the packages for the breads you eat and compare the different ingredients lists with your classmates. Are they labeled well? Do they contain any health claims? Are they made from 100 percent whole grain? Do they contain added sugars? For more help on defining products made with whole grains, visit the website of the Whole Grains Council. http://www.wholegrainscouncil.org/whole-grains-101/definition-of-whole-grains

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3.3: Digestion and Absorption of Carbohydrates

Learning Objectives

- Discuss how carbohydrates are digested and absorbed in the human body.

Sweetness is one of the five basic taste sensations of foods and beverages and is sensed by protein receptors in cells of the taste buds. Fast-releasing carbohydrates stimulate the sweetness taste sensation, which is the most sensitive of all taste sensations. Even extremely low concentrations of sugars in foods will stimulate the sweetness taste sensation. Sweetness varies between the different carbohydrate types—some are much sweeter than others. Fructose is the top naturally occurring sugar in sweetness value.



Figure 3.3.1: Blueberry pancakes. *Whole grains provide satisfaction from the beginning to the end of the digestion process. (CC-SA-BY-2.0;* jeffreyw)

See Table 3.3.1 for sweetness comparisons among different naturally-occurring carbohydrates. Sweetness is a pleasurable sensation and some people enjoy the taste more than others. In a colloquial sense, we identify such people as having a “sweet tooth.” This does not mean that the less-sweet whole grains containing more starches and fiber are less satisfying. Whole grains take longer to chew and get sweeter the more you chew them. Additionally, once in the stomach, whole-grain foods take longer to digest and keep you full longer. Remember too that they contain fiber which makes elimination much smoother. Whole-grain foods satisfy the body the entire way through the digestive tract and provide the nutrients that also better satisfy the body’s functional needs.

Table 3.3.1: Sweetness Comparison of Carbohydrates

Carbohydrate	Sweetness (percentage of sucrose)
Sucrose	100
Glucose	74
Galactose	33
Fructose	173
Maltose	33
Lactose	16
Starch	0
Fiber	0

Source: Carter, J. Stein. “Carbohydrates.” © 1996 by J. Stein Carter. All rights reserved. www.biology.clc.uc.edu/courses/bio104/carbohydrates.htm.

From the Mouth to the Stomach

The mechanical and chemical digestion of carbohydrates begins in the mouth. Chewing, also known as mastication, crumbles the carbohydrate foods into smaller and smaller pieces. The salivary glands in the oral cavity secrete saliva that coats the food particles. Saliva contains the enzyme, salivary amylase. This enzyme breaks the bonds between the monomeric sugar units of disaccharides, oligosaccharides, and starches. The salivary amylase breaks down amylose and amylopectin into smaller chains of glucose, called

dextrins and maltose. The increased concentration of maltose in the mouth that results from the mechanical and chemical breakdown of starches in whole grains is what enhances their sweetness. Only about five percent of starches are broken down in the mouth. (This is a good thing as more glucose in the mouth would lead to more tooth decay.) When carbohydrates reach the stomach no further chemical breakdown occurs because the amylase enzyme does not function in the acidic conditions of the stomach. But the mechanical breakdown is ongoing—the strong peristaltic contractions of the stomach mix the carbohydrates into the more uniform mixture of chyme.

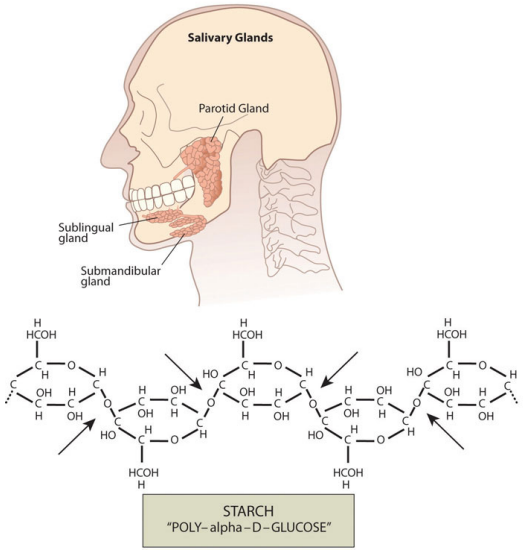


Figure 3.3.2: Salivary glands secrete salivary amylase, which begins the chemical breakdown of carbohydrates by breaking the bonds between monomeric sugar units.

From the Stomach to the Small Intestine

The chyme is gradually expelled into the upper part of the small intestine. Upon entry of the chyme into the small intestine, the pancreas releases pancreatic juice through a duct. This pancreatic juice contains the enzyme, pancreatic amylase, which starts again the breakdown of dextrins into shorter and shorter carbohydrate chains. Additionally, enzymes are secreted by the intestinal cells that line the villi. These enzymes, known collectively as disaccharides, are sucrase, maltase, and lactase. Sucrase breaks sucrose into glucose and fructose molecules. Maltase breaks the bond between the two glucose units of maltose, and lactase breaks the bond between galactose and glucose. Once carbohydrates are chemically broken down into single sugar units they are then transported into the inside of intestinal cells.

When people do not have enough of the enzyme lactase, lactose is not sufficiently broken down resulting in a condition called lactose intolerance. The undigested lactose moves to the large intestine where bacteria are able to digest it. The bacterial digestion of lactose produces gases leading to symptoms of diarrhea, bloating, and abdominal cramps. Lactose intolerance usually occurs in adults and is associated with race. The National Digestive Diseases Information Clearing House states that African Americans, Hispanic Americans, American Indians, and Asian Americans have much higher incidences of lactose intolerance while those of northern European descent have the least.National Digestive Diseases Information Clearing House. "Lactose Intolerance." Last updated April 23, 2012. digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/. Most people with lactose intolerance can tolerate some amount of dairy products in their diet. The severity of the symptoms depends on how much lactose is consumed and the degree of lactase deficiency.

Absorption: Going to the Blood Stream

The cells in the small intestine have membranes that contain many transport proteins in order to get the monosaccharides and other nutrients into the blood where they can be distributed to the rest of the body. Fructose is absorbed by facilitated diffusion while glucose and galactose are actively transported. The first organ to receive glucose, fructose, and galactose is the liver. The liver takes them up and converts galactose to glucose, breaks fructose into even smaller carbon-containing units, and either stores glucose as glycogen or exports it back to the blood. How much glucose the liver exports to the blood is under hormonal control and you will soon discover that even the glucose itself regulates its concentrations in the blood.

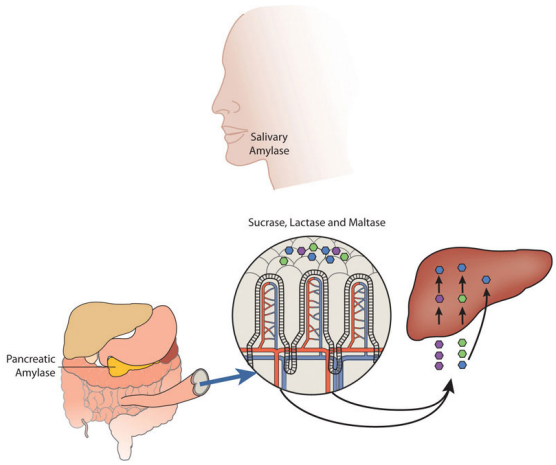


Figure 3.3.3: Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver.

Maintaining Blood Glucose Levels: The Pancreas and Liver

Glucose levels in the blood are tightly controlled, as having either too much or too little glucose in the blood can have health consequences. Glucose regulates its levels in the blood via a process called negative feedback. An everyday example of negative feedback is in your oven because it contains a thermostat. When you set the temperature to cook a delicious homemade noodle casserole at 375°F the thermostat senses the temperature and sends an electrical signal to turn the elements on and heat up the oven. When the temperature reaches 375°F the thermostat senses the temperature and sends a signal to turn the element off. Similarly, your body senses blood glucose levels and maintains the glucose "temperature" in the target range. The glucose thermostat is located within the cells of the pancreas. After eating a meal containing carbohydrates glucose levels rise in the blood.

Insulin-secreting cells in the pancreas (pancreatic beta cells) sense the increase in blood glucose and release the hormonal message, insulin, into the blood. Insulin sends a signal to the body's cells to remove glucose from the blood by transporting it into cells and within the cell to use glucose to make energy or for building macromolecules. In the case of muscle tissue and the liver, insulin sends the biological message to store glucose away as glycogen. The presence of insulin in the blood signifies to the body that it has just been fed and to use the fuel. Insulin has an opposing hormone called glucagon. As the time after a meal lengthens, glucose levels decrease in the blood. Glucagon-secreting cells in the pancreas (pancreatic alpha-cells) sense the drop in blood glucose and, in response, release the hormone glucagon into the blood. Glucagon communicates to the cells in the body to stop using glucose. More specifically, it signals the liver to break down glycogen and release the stored glucose into the blood, so blood glucose levels stay within the target range and all cells get the fuel the need to function properly.

Epinephrine or adrenaline is released in response to stress or exercise. It causes the breakdown of glycogen, or glycogenolysis, which releases glucose and increases blood glucose levels.

Our bodies work hard to maintain blood glucose in a specific range, 80-120 mg/dL. During fasting, blood glucose can fall below 80, so the body has several mechanisms to bring the blood sugar back to an acceptable level. The hormone glucagon is released from the pancreas and causes the breakdown of liver glycogen and the release of glucose. If the fasting lasts longer, early starvation (1-3 days), protein is broken down to release gluconeogenic amino acids. These travel to the liver and are converted to glucose. If starvation continues (>3 days), protein catabolism slows and fatty acids are released to provide ketones as the source of energy. The brain and other body cells use ketones as their main energy source in an effort to conserve glucose and muscle mass.

Leftover Carbohydrates: The Large Intestine

Almost all of the carbohydrates, except for dietary fiber and resistant starches, are efficiently digested and absorbed into the body. Some of the remaining indigestible carbohydrates are broken down by enzymes released by bacteria in the large intestine. The products of bacterial digestion of these slow-releasing carbohydrates are short-chain fatty acids and some gases. The short-chain fatty acids are either used by the bacteria to make energy and grow, are eliminated in the feces, or are absorbed into cells of the colon, with a small amount being transported to the liver. Colonic cells use the short-chain fatty acids to support some of their functions. The liver can also metabolize the short-chain fatty acids into cellular energy. The yield of energy from dietary fiber is about 2 kilocalories per gram for humans but is highly dependent upon the fiber type, with soluble fibers and resistant starches yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other

carbohydrate types (simple sugars, many starches) the rise in blood glucose after eating them is less, and slower. These physiological attributes of high-fiber foods (i.e. whole grains) are linked to a decrease in weight gain and reduced risk of chronic diseases, such as Type 2 diabetes and cardiovascular disease.

A Carbohydrate Feast



Figure 3.3.4: Thanksgiving dinner: A feast of high-carbohydrate foods. © Shutterstock

It's Thanksgiving and you have just consumed turkey with mashed potatoes, stuffing smothered in gravy, green beans topped with crispy fried onions, a hot roll dripping with butter, and cranberry sauce. Less than an hour later you top it all off with a slice of pumpkin pie and then lie down on the couch to watch the football game. What happens in your body after digesting and absorbing the whopping amount of nutrients in this Thanksgiving feast? The "hormone of plenty," insulin, answers the nutrient call. Insulin sends out the physiological message that glucose and everything else is in abundant supply in the blood, so cells absorb and then use or store it. The result of this hormone message is the maximization of glycogen stores and all the excess glucose, protein, and lipids are stored as fat.

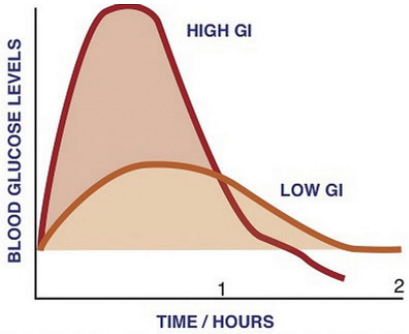


Figure 3.3.5: The glycemic index measures the effects of foods on blood-glucose levels.

A typical American Thanksgiving meal contains many foods that are dense in carbohydrates, with the majority of those being simple sugars and starches. These types of carbohydrate foods are rapidly digested and absorbed. Blood glucose levels rise quickly causing a spike in insulin levels. Contrastingly, foods containing high amounts of fiber are like time-release capsules of sugar. A measurement of the effects of a carbohydrate-containing food on blood-glucose levels is called the glycemic response (Figure 3.4).

Glycemic Index

The glycemic responses of various foods have been measured and then ranked in comparison to a reference food, usually, a slice of white bread (50 g) or just straight glucose, to create a numeric value called the glycemic index (GI). Foods that have a low GI do not raise blood-glucose levels as fast as foods that have a higher GI. A diet of low-GI foods has been shown in epidemiological and clinical trial studies to increase weight loss and reduce the risk of obesity, Type 2 diabetes, and cardiovascular disease.Brand-

Miller, J., PhD, et al. “Dietary Glycemic Index: Health Implications.” J Am Coll Nutr 28, no. 4, supplement (2009): 446S–49S. http://www.jacn.org/content/28/4_Supplement_1/446S.long.

Table 3.3.2: The Glycemic Index: Foods in Comparison to Glucose

Foods	GI Value
Low GI Foods (< 55)	
Apple	44
Pear	38
Banana (under-ripe)	51
Grapefruit	25
Barley	25
Navy beans	38
Green peas	48
Oat bran (Quaker Oats)	50
Spaghetti (whole wheat)	37
Mashed sweet potatoes	54
Baked beans	48
Butter beans	44
Banana bread	47
Bread (sourdough)	52
Soy milk	31
Skim milk	32
Whole milk	27
Yogurt (sweetened)	33
Yogurt (plain, artificial sweetener)	14
Medium GI Foods (56–69)	
Apricots	57
Cantaloupe	65
Mashed potatoes	70
Whole-wheat pita bread	57
Whole-wheat bread	69
Couscous	65
Brown rice	55
Cheese pizza	60
Rye bread	65
Hamburger bun	61
Black bean soup	64

Foods	GI Value
Macaroni and cheese	64
Coca-Cola	63
High GI Foods (70 and higher)	
Dates	103
Banana (over-ripe)	82
Parsnips	97
Corn chips	72
Pretzels	83
White bread	70
White rice	72
Spaghetti (durum flour)	78
White rice (instant)	87
French baguette	95
Bagel	72
Bread stuffing	74
Cheerios	74
Cream of wheat	71
Raisin Bran	73
Fruit roll-up	99
Gatorade	78

Source: University of Sydney. Glycemic Index Database. © 2011 The University of Sydney, all rights reserved. http://www.glycemicindex.com/.

The carbohydrate type within a food affects the GI, but so does its fat and fiber content (which reduce the GI). Increased fat and fiber in foods increases the time required for digestion and delays the rate of gastric emptying into the small intestine. Processing and cooking additionally affect a food's GI by increasing their digestibility. Advancements in the technologies of food processing and the high consumer demand for convenient, precooked foods in the United States have created foods that are digested and absorbed more rapidly, independent of the fiber content. Modern breakfast cereals, breads, pastas, and many prepared foods have a high GI. In contrast, most raw foods have a lower GI. (However, the more ripened a fruit or vegetable is, the higher its GI.) Table 3.2 provides the GI for various foods. The GI can be used as a guide for choosing healthier carbohydrate choices but has some limitations. One is that the GI does not take into account the amount of carbohydrates in a portion of food, only the type of carbohydrate. Another is that combining low- and high-GI foods changes the GI for the meal. Also, some nutrient-dense foods have higher GIs than less nutritious food. (For instance, oatmeal has a higher GI than chocolate because the fat content of chocolate is higher.) Lastly, meats and fats do not have a GI since they do not contain carbohydrates.

Interactive 3.3.1: Balancing the Thanksgiving Feast

Visit this online database of glycemic indices of foods. http://www.gilisting.com/

To balance the high-GI foods on the Thanksgiving table with low-GI foods, follow some of these suggestions:

- Serve a winter fruit salad.
- Leave the skins on the potatoes. The skin contains fiber and adds texture to mashed potatoes. Do not use instant potatoes.

- Instead of canned green beans with cream of mushroom soup and fried onions for a side dish, combine butter beans and green peas for a colorful, low-GI food.
- Make your stuffing with whole-grain bread and add mushrooms and extra celery and onions.
- Try a new low-sugar pumpkin pie recipe and make the crust from whole-grain flour.
- Offer homemade banana bread for dessert.

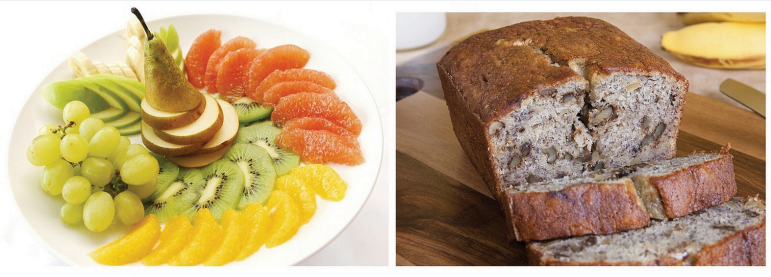


Figure 3.3.6: *Balance the high-GI foods at the Thanksgiving table with low-GI foods. © Shutterstock*

Key Takeaways

- Carbohydrate digestion begins in the mouth with the mechanical action of chewing and the chemical action of salivary amylase. Carbohydrates are not chemically broken down in the stomach, but rather in the small intestine. Pancreatic amylase and the disaccharidases finish the chemical breakdown of digestible carbohydrates.
- The monosaccharides are absorbed into the bloodstream and delivered to the liver.
- Some of the indigestible carbohydrates are digested by bacteria in the large intestine.
- Glucose itself participates in regulating its levels in the blood. Not all carbohydrates have the same effect on blood-glucose levels. The glycemic response is a measurement of the effects of a carbohydrate-containing food on blood-glucose levels.

Discussion Starters

1. Experience the taste sensations of different carbohydrates. What are some foods that satisfy your sweetness sensation?
2. Even though fiber contains calories, albeit less than half of other carbohydrates, why do we generally discount its caloric contribution from our diets?
3. How long a person feels full after eating a carbohydrate-rich meal depends on the type of carbohydrate consumed and what other nutrients are in the meal. Conduct an experiment and determine how long you feel full after eating a candy bar; after eating a slice of whole-grain bread; after eating an apple; and after eating a potato. Compare your results with your classmates and discuss why some of these carbohydrate foods make you feel full longer than others.

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3.4: The Functions of Carbohydrates in the Body

Learning Objectives

- List four primary functions of carbohydrates in the human body

There are five primary functions of carbohydrates in the human body. They are energy production, energy storage, building macromolecules, sparing protein, and assisting in lipid metabolism.

Energy Production

The primary role of carbohydrates is to supply energy to all cells in the body. Many cells prefer glucose as a source of energy versus other compounds like fatty acids. Some cells, such as red blood cells, are only able to produce cellular energy from glucose. The brain is also highly sensitive to low blood-glucose levels because it uses *only* glucose to produce energy and function (unless under extreme starvation conditions). About 70 percent of the glucose entering the body from digestion is redistributed (by the liver) back into the blood for use by other tissues. Cells that require energy remove the glucose from the blood with a transport protein in their membranes. The energy from glucose comes from the chemical bonds between the carbon atoms. Sunlight energy was required to produce these high-energy bonds in the process of photosynthesis. Cells in our bodies break these bonds and capture the energy to perform cellular respiration. Cellular respiration is basically a controlled burning of glucose versus an uncontrolled burning. A cell uses many chemical reactions in multiple enzymatic steps to slow the release of energy (no explosion) and more efficiently capture the energy held within the chemical bonds in glucose.

The first stage in the breakdown of glucose is called glycolysis, which occurs in an intricate series of ten enzymatic-reaction steps. The second stage of glucose breakdown occurs in the energy factory organelles, called mitochondria. One carbon atom and two oxygen atoms are removed, yielding more energy. The energy from these carbon bonds is carried to another area of the mitochondria, making the cellular energy available in a form cells can use.

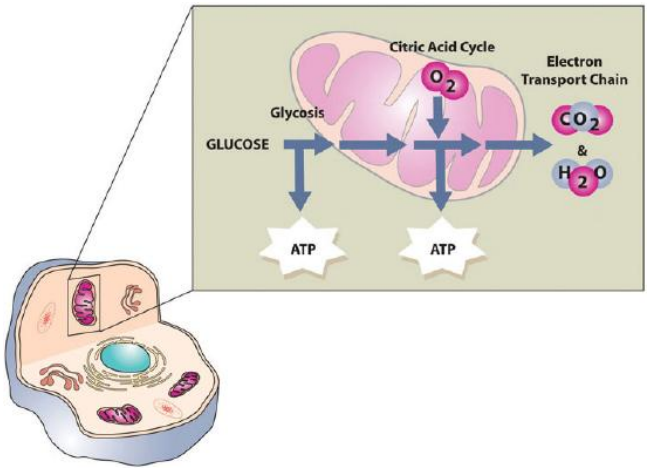


Figure 3.4.1: *Cellular respiration is the process by which energy is captured from glucose.*

Energy Storage

If the body already has enough energy to support its functions, the excess glucose is stored as glycogen (the majority of which is stored in the muscle and liver). A molecule of glycogen may contain in excess of fifty thousand single glucose units and is highly branched, allowing for the rapid dissemination of glucose when it is needed to make cellular energy (Figure 3.4.2).

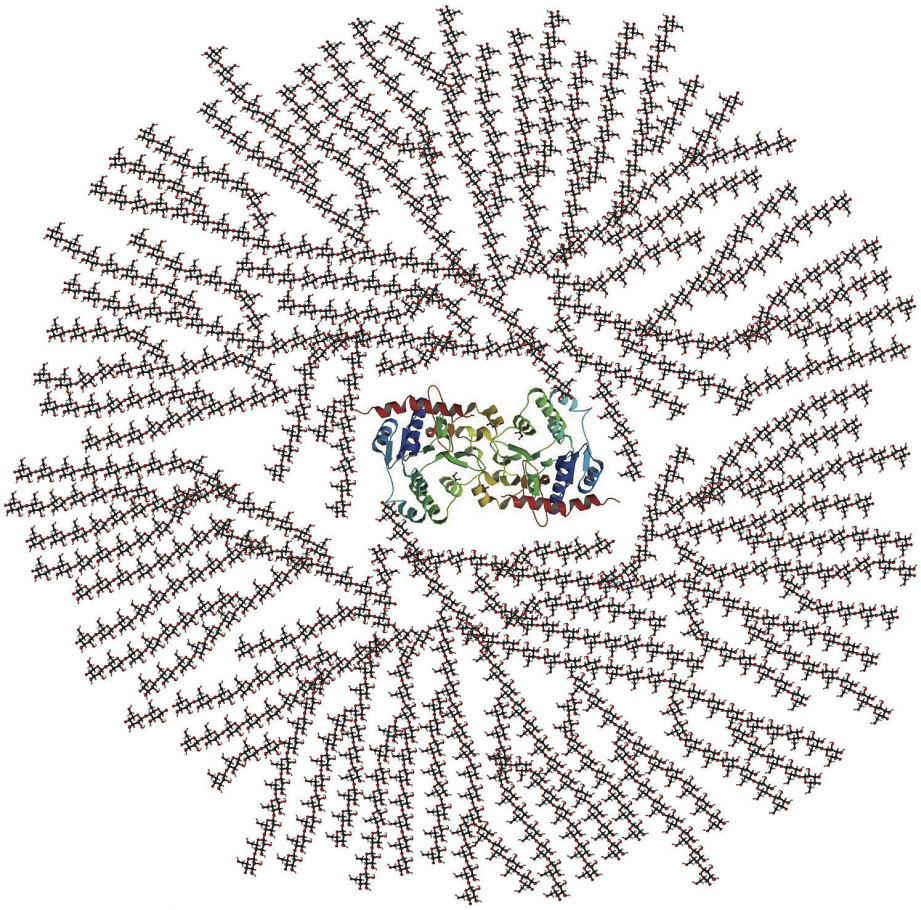


Figure 3.4.2: The structure of glycogen enables its rapid mobilization into free glucose to power cells.

The amount of glycogen in the body at any one time is equivalent to about 4,000 kilocalories—3,000 in muscle tissue and 1,000 in the liver. Prolonged muscle use (such as exercise for longer than a few hours) can deplete the glycogen energy reserve. This is referred to as “hitting the wall” or “bonking” and is characterized by fatigue and a decrease in exercise performance. The weakening of muscles sets in because it takes longer to transform the chemical energy in fatty acids and proteins to usable energy than glucose. After prolonged exercise, glycogen is gone and muscles must rely more on lipids and proteins as an energy source. Athletes can increase their glycogen reserve modestly by reducing training intensity and increasing their carbohydrate intake to between 60 and 70 percent of total calories three to five days prior to an event. People who are not hardcore training and choose to run a 5-kilometer race for fun do not need to consume a big plate of pasta prior to a race since without long-term intense training the adaptation of increased muscle glycogen will not happen.

The liver, like muscle, can store glucose energy as a glycogen, but in contrast to muscle tissue it will sacrifice its stored glucose energy to other tissues in the body when blood glucose is low. Approximately one-quarter of total body glycogen content is in the liver (which is equivalent to about a four-hour supply of glucose) but this is highly dependent on activity level. The liver uses this glycogen reserve as a way to keep blood-glucose levels within a narrow range between meal times. When the liver’s glycogen supply is exhausted, glucose is made from amino acids obtained from the destruction of proteins in order to maintain metabolic homeostasis.

Building Macromolecules

Although most absorbed glucose is used to make energy, some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP (Figure 3.4.3). Glucose is additionally utilized to make the molecule NADPH, which is important for protection against oxidative stress and is used in many other chemical reactions in the body. If all of the energy, glycogen-storing capacity, and building needs of the body are met, excess glucose can be used to make fat. This is why a diet too high in carbohydrates and calories can add on the fat pounds—a topic that will be discussed shortly.

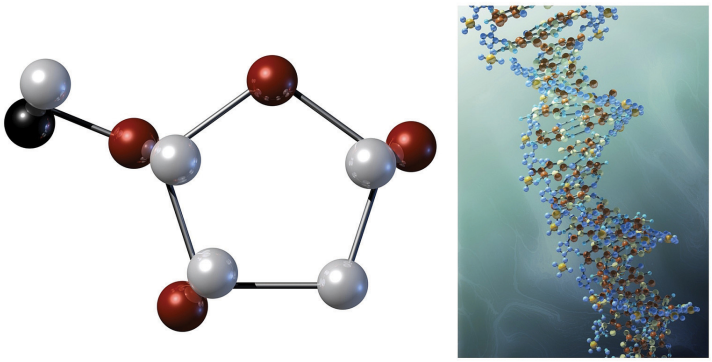


Figure 3.4.3: The sugar molecule deoxyribose is used to build the backbone of DNA.© Shutterstock

Sparing Protein

In a situation where there is not enough glucose to meet the body's needs, glucose is synthesized from amino acids. Because there is no storage molecule of amino acids, this process requires the destruction of proteins, primarily from muscle tissue. The presence of adequate glucose basically spares the breakdown of proteins from being used to make glucose needed by the body.

Lipid Metabolism

As blood-glucose levels rise, the use of lipids as an energy source is inhibited. Thus, glucose additionally has a "fat-sparing" effect. This is because an increase in blood glucose stimulates release of the hormone insulin, which tells cells to use glucose (instead of lipids) to make energy. Adequate glucose levels in the blood also prevent the development of ketosis. Ketosis is a metabolic condition resulting from an elevation of ketone bodies in the blood. Ketone bodies are an alternative energy source that cells can use when glucose supply is insufficient, such as during fasting. Ketone bodies are acidic and high elevations in the blood can cause it to become too acidic. This is rare in healthy adults, but can occur in alcoholics, people who are malnourished, and in individuals who have Type 1 diabetes. The minimum amount of carbohydrate in the diet required to inhibit ketosis in adults is 50 grams per day.

Carbohydrates are critical to support life's most basic function—the production of energy. Without energy none of the other life processes are performed. Although our bodies can synthesize glucose it comes at the cost of protein destruction. As with all nutrients though, carbohydrates are to be consumed in moderation as having too much or too little in the diet may lead to health problems.

Key Takeaways

- The four primary functions of carbohydrates in the body are to provide energy, store energy, build macromolecules, and spare protein and fat for other uses.
- Glucose energy is stored as glycogen, with the majority of it in the muscle and liver. The liver uses its glycogen reserve as a way to keep blood-glucose levels within a narrow range between meal times. Some glucose is also used as building blocks of important macromolecules, such as RNA, DNA, and ATP.
- The presence of adequate glucose in the body spares the breakdown of proteins from being used to make glucose needed by the body.

Discussion Starters

1. Discuss two reasons it is essential to include carbohydrates in your diet.
2. Why is it necessary for the body to spare protein?

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3.5: Looking Closely at Diabetes

Learning Objectives

- Summarize the long-term health implications and the dietary approaches to living with Type 1 and Type 2 diabetes.

Diabetes is one of the top three diseases in America. It affects millions of people and causes tens of thousands of deaths each year. Diabetes is a metabolic disease of insulin deficiency and glucose over-sufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person's risk for developing diabetes. One sure way to decrease your chances of getting diabetes is to maintain an optimal body weight by adhering to a diet that is balanced in carbohydrate, fat, and protein intake. There are three different types of diabetes: Type 1 diabetes, Type 2 diabetes, and gestational diabetes.

Type 1 Diabetes

Type 1 diabetes is a metabolic disease in which insulin-secreting cells in the pancreas are killed by an abnormal response of the immune system, causing a lack of insulin in the body. Its onset typically occurs before the age of thirty. The only way to prevent the deadly symptoms of this disease is to inject insulin under the skin. Before this treatment was discovered, people with Type 1 diabetes died rapidly after disease onset. Death was the result of extremely high blood-glucose levels affecting brain function and leading to coma and death. Up until 1921, patients with Type 1 diabetes, the majority of them children, spent their last days in a ward where they lapsed into a coma awaiting death. One of the most inspiring acts in medical history is that of the scientists who discovered, isolated, and purified insulin and then went on to find out that it relieved the symptoms of Type 1 diabetes, first in dogs and then in humans. Frederick Banting, Charles Best, and James Collip went into a hospital ward in Toronto, Canada and injected comatose children with insulin. Before they completed their rounds children were already awakening to the cheers of their families.

A person with Type 1 diabetes usually has a rapid onset of symptoms that include hunger, excessive thirst and urination, and rapid weight loss. Because the main function of glucose is to provide energy for the body, when insulin is no longer present there is no message sent to cells to take up glucose from the blood. Instead, cells use fat and proteins to make energy, resulting in weight loss. If Type 1 diabetes goes untreated individuals with the disease will develop a life-threatening condition called ketoacidosis. This condition occurs when the body uses fats and not glucose to make energy, resulting in a build-up of ketone bodies in the blood. It is a severe form of ketosis with symptoms of vomiting, dehydration, rapid breathing, and confusion and eventually coma and death. Upon insulin injection these severe symptoms are treated and death is avoided. Unfortunately, while insulin injection prevents death, it is not considered a cure. People who have this disease must adhere to a strict diet to prevent the development of serious complications. Type 1 diabetics are advised to consume a diet low in the types of carbohydrates that rapidly spike glucose levels (high-GI foods), to count the carbohydrates they eat, to consume healthy-carbohydrate foods, and to eat small meals frequently. These guidelines are aimed at preventing large fluctuations in blood glucose. Frequent exercise also helps manage blood-glucose levels. Type 1 diabetes accounts for between 5 and 10 percent of diabetes cases.

Type 2 Diabetes

The other 90 to 95 percent of diabetes cases are Type 2 diabetes. Type 2 diabetes is defined as a metabolic disease of insulin insufficiency, but it is also caused by muscle, liver, and fat cells no longer responding to the insulin in the body (Figure 3.5.1). In brief, cells in the body have become resistant to insulin and no longer receive the full physiological message of insulin to take up glucose from the blood. Thus, similar to patients with Type 1 diabetes, those with Type 2 diabetes also have high blood-glucose levels.

For Type 2 diabetics, the onset of symptoms is more gradual and less noticeable than for Type 1 diabetics. The symptoms are increased thirst and urination, unexplained weight loss, and hunger. The first stage of Type 2 diabetes is characterized by high glucose and insulin levels. This is because the insulin-secreting cells in the pancreas attempt to compensate for insulin resistance by making more insulin. In the second stage of Type 2 diabetes, the insulin-secreting cells in the pancreas become exhausted and die. At this point, Type 2 diabetics also have to be treated with insulin injections. Healthcare providers is to prevent the second stage from happening. As with Type 1 diabetes, chronically high-glucose levels cause big detriments to health over time, so another goal for patients with Type 2 diabetes is to properly manage their blood-glucose levels. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.

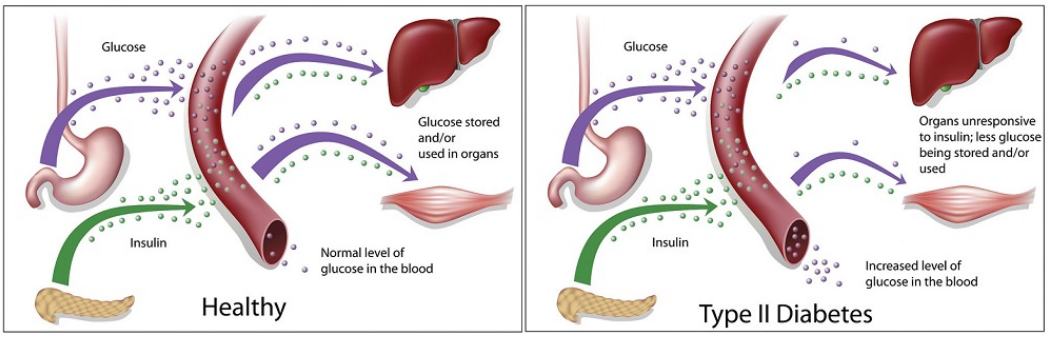


Figure 3.5.1: Type 2 diabetes is a metabolic disease characterized by high blood-glucose levels. © Shutterstock

The Centers for Disease Control Prevention (CDC) estimates that as of 2010, 25.8 million Americans have diabetes, which is 8.3 percent of the population. Centers for Disease Control and Prevention. “Diabetes Research and Statistics.” Accessed September 30, 2011. www.cdc.gov/diabetes/consumer/research.htm. In 2007 the cost of diabetes to the United States was estimated at $174 billion.Centers for Disease Control and Prevention. “CDC Statements on Diabetes Issues.” Accessed September 30, 2011. www.cdc.gov/diabetes/news/docs/dpp.htm. The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity in this country. Genetics, environment, nutrition, and lifestyle all play a role in determining a person’s risk for Type 2 diabetes. We have the power to change some of the determinants of disease, but not others. The Diabetes Prevention Trial that studied lifestyle and drug interventions in more than three thousand participants who were at high risk for Type 2 diabetes found that intensive lifestyle intervention reduced the chances of getting Type 2 diabetes by 58 %. Knowler, W. C. et al. “Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin.” N Engl J Med 346, no. 6 (2002): 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512.

Video 3.5.1: Do You Have High Blood Sugar?

A more in-depth view of blood sugar and your health.



Having more than one risk factor for Type 2 diabetes substantially increases a person’s chances for developing the disease. Metabolic syndrome refers to a medical condition in which people have three or more risk factors for Type 2 diabetes and cardiovascular disease (Figure 3.5.2). According to the International Diabetes Federation (IDF) people are diagnosed with this syndrome if they have central (abdominal) obesity and any two of the following health parameters: triglycerides greater than 150 mg/dL; high density lipoproteins (HDL) lower than 40 mg/dL; systolic blood pressure above 100 mmHg, or diastolic above 85 mmHg; fasting blood-glucose levels greater than 100 mg/dL.International Diabetes Federation. “The IDF Consensus Worldwide Definition of the Metabolic Syndrome.” Accessed September 30, 2011. www.idf.org/webdata/docs/IDF_Meta_def_final.pdf.

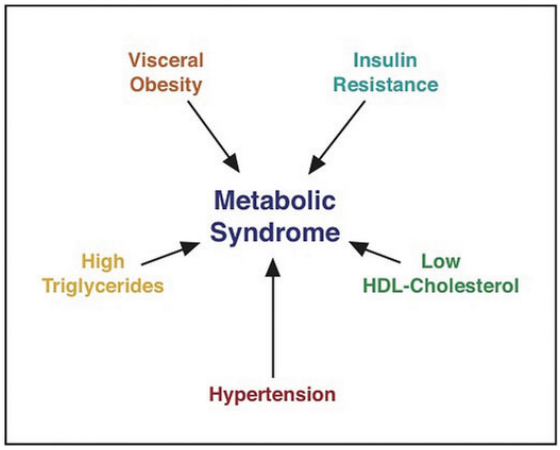


Figure 3.5.2: *Metabolic Syndrome: A Combination of Risk Factors Increasing the Chances for Chronic Disease*

The IDF estimates that between 20 and 25 percent of adults worldwide have metabolic syndrome. Studies vary, but people with metabolic syndrome have between a 9 and 30 times greater chance of developing Type 2 diabetes than those who do not have the syndrome.International Diabetes Federation. "The IDF Consensus Worldwide Definition of the Metabolic Syndrome." Accessed September 30, 2011. www.idf.org/webdata/docs/IDF_Meta_def_final.pdf.

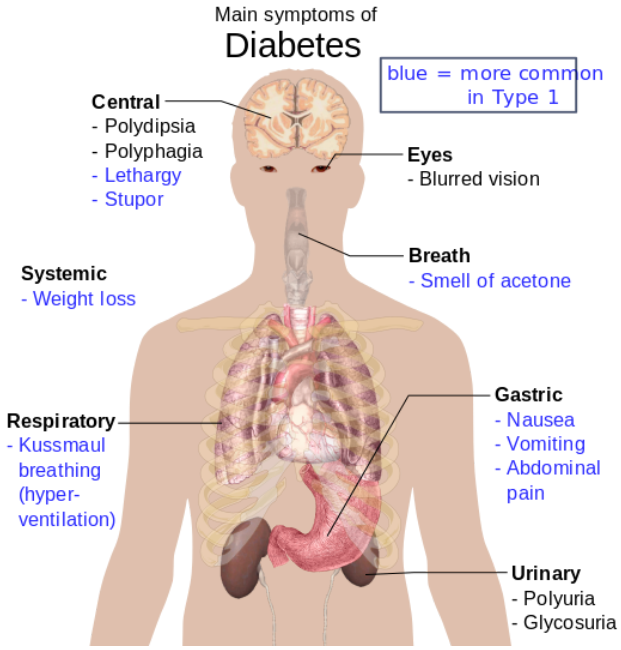


Figure 3.5.3: Overview of the most significant possible symptoms of diabetes. (Public domain; Mikael Häggström)

Gestational Diabetes

During pregnancy, some women develop gestational diabetes. Gestational diabetes is characterized by high blood-glucose levels and insulin resistance. The exact cause is not known but does involve the effects of pregnancy hormones on how cells respond to insulin (like Type II diabetes). Gestational diabetes can cause pregnancy complications and it is common practice for healthcare practitioners to screen pregnant women for this metabolic disorder. The disorder normally ceases when the pregnancy is over, but the National Diabetes Information Clearing House notes that women who had gestational diabetes have between a 40 and 60 percent likelihood of developing Type 2 diabetes within the next ten years. National Diabetes Information Clearing House. "Diabetes Overview." Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/. Gestational diabetes not only affects the health of a pregnant woman but also is associated with an increased risk of obesity and Type 2 diabetes in her child.

Prediabetes

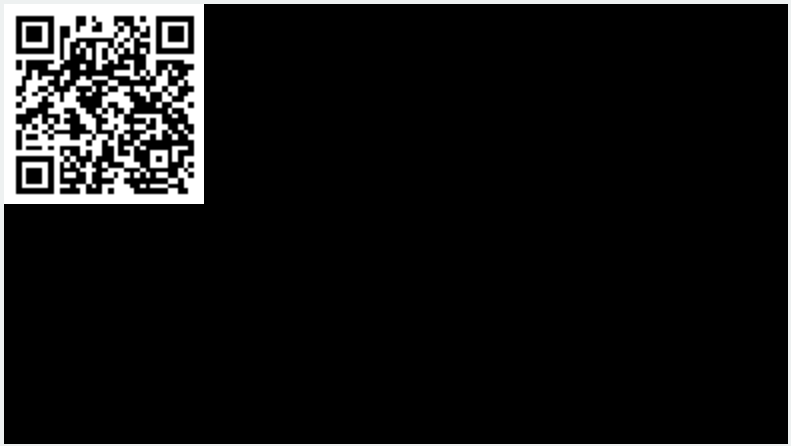
As the term infers, prediabetes is a metabolic condition in which people have moderately high glucose levels, but do not meet the criteria for diagnosis as a diabetic. Over seventy-nine million Americans are prediabetic and at increased risk for Type 2 diabetes and cardiovascular disease. National Diabetes Information Clearing House. “Diabetes Overview.” Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/. The National Diabetes Information Clearing House reports that 35 percent of adults aged twenty and older, and 50 percent of those over the age of sixty-five have prediabetes.National Diabetes Information Clearing House. “Diabetes Overview.” Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/.

Long-Term Health Consequences of Diabetes

The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood accompanied by other metabolic abnormalities such as high blood-lipid levels. People with diabetes are between two and four times more likely to die from cardiovascular disease. Diabetes is the number one cause of new cases of blindness, lower-limb amputations, and kidney failure. Many people with diabetes develop peripheral neuropathy, characterized by muscle weakness, loss of feeling and pain in the lower extremities. More recently, there is scientific evidence to suggest people with diabetes are also at increased risk for Alzheimer’s disease.

Video 3.5.2: Diabetes and Associated Complications

Watch this video to learn more about the whole-body complications associated with diabetes.



Diabetes Treatment

Keeping blood-glucose levels in the target range (70–130 mg/dL before a meal) requires careful monitoring of blood-glucose levels with a blood-glucose meter, strict adherence to a healthy diet, and increased physical activity. Type 1 diabetics begin insulin injections as soon as they are diagnosed. Type 2 diabetics may require oral medications and insulin injections to maintain blood-glucose levels in the target range. The symptoms of high blood glucose, also called hyperglycemia, are difficult to recognize, diminish in the course of diabetes, and are mostly not apparent until levels become very high. The symptoms are increased thirst and frequent urination. Having too low blood glucose levels, known as hypoglycemia, is also detrimental to health. Hypoglycemia is more common in Type 1 diabetics and is most often caused by injecting too much insulin or injecting it at the wrong time. The symptoms of hypoglycemia are more acute including shakiness, sweating, nausea, hunger, clamminess, fatigue, confusion, irritability, stupor, seizures, and coma. Hypoglycemia can be rapidly and simply treated by eating foods containing about ten to twenty grams of fast-releasing carbohydrates. If symptoms are severe a person is either treated by emergency care providers with an intravenous solution of glucose or given an injection of glucagon, which mobilizes glucose from glycogen in the liver. Some people who are not diabetic may experience reactive hypoglycemia. This is a condition in which people are sensitive to the intake of sugars, refined starches, and high GI foods. Individuals with reactive hypoglycemia have some symptoms of hypoglycemia. Symptoms are caused by a higher than normal increase in blood-insulin levels. This rapidly decreases blood-glucose levels to a level below what is required for proper brain function.



Insulin Syringe and Pen. (CC-SA-BY-3.0; BruceBlaus)

The major determinants of Type 2 diabetes that can be changed are overnutrition and a sedentary lifestyle. Therefore, reversing or improving these factors by lifestyle interventions markedly improve the overall health of Type 2 diabetics and lower blood-glucose levels. In fact, it has been shown that when people are overweight, losing as little as nine pounds (four kilograms) decreases blood-glucose levels in Type 2 diabetics. The Diabetes Prevention Trial demonstrated that by adhering to a diet containing between 1,200 and 1,800 kilocalories per day with a dietary fat intake goal of less than 25 percent and increasing physical activity to at least 150 minutes per week, people at high risk for Type 2 diabetes achieved a weight loss of 7 percent and significantly decreased their chances of developing Type 2 diabetes.Knowler, W. C. et al. "Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin." N Engl J Med 346, no. 6 (2002): 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512.

The American Diabetes Association (ADA) has a website that provides information and tips for helping diabetics answer the question, "What Can I Eat" (see Note 4.34). In regard to carbohydrates, the ADA recommends diabetics keep track of the carbohydrates they eat and set a limit. These dietary practices will help keep blood-glucose levels in the target range.

Interactive 3.5.1

The ADA has a website containing great information and tips on how to eat a healthy diet that helps keep blood-glucose levels in the target range. Visit it to learn more about how to prevent serious complications of this disease.

http://www.diabetes.org/food-and-fitness/food/what-can-i-eat/?utm_source=WWW&utm_medium=DropDownFF&utm_content=WhatCanIEat&utm_campaign=CON

An unfortunate problem is that most diabetics do not adhere to the lifestyle interventions long-term. This is partly because of individual disinclination but is also because health insurance companies do not provide continued financial support for dietary guidance and because primary care physicians do not prescribe dietary guidance from a dietitian. This shifts the way diabetes is treated away from lifestyle intervention toward medications, as the goal still remains to manage blood-glucose levels. Numerous oral medications are available on the market and are often prescribed to Type 2 diabetics in combination.

Reactive (postprandial) Hypoglycemia

We have been discussing diabetes which is a disease characterized by high blood glucose. Below normal levels of blood glucose are dangerous too. Reactive hypoglycemia can occur 2-5 hours after eating and is characterized by fatigue, weakness, dizziness, irritability, tachycardia, anxiety, sweating, trembling, hunger and/or headaches. Treatment is small, frequent meals and reduced intake of carbohydrates.

Key Takeaways

- Diabetes is a disease of insulin deficiency and glucose over sufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person's risk for developing diabetes.
- Type 1 diabetes was once a death sentence, but now can be treated with insulin injections. However, insulin injections do not cure the disease, and diabetics can suffer many disease complications. Diabetes complications can be relieved by strictly managing blood-glucose levels, adhering to a healthy diet, and increasing physical activity.
- The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.

- The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood and other metabolic abnormalities such as high blood-lipid levels.

Discussion Starters

1. If you owned a grocery store what are some practices you could introduce to combat the epidemic of Type 2 diabetes in this country?
2. What are some options for you to intervene in your lifestyle and decrease your risk for Type 2 diabetes?

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3.6: Health Consequences and Benefits of High-Carbohydrate Diets

Learning Objectives

- Identify the health benefits of eating a diet rich in whole grains.

Can America blame its obesity epidemic on the higher consumption of added sugars and refined grains? This is a hotly debated topic by both the scientific community and the general public. In this section, we will give a brief overview of the scientific evidence.

Added Sugars

The Food and Nutrition Board of the Institute of Medicine (IOM) defines added sugars as "sugars and syrups that are added to foods during processing or preparation." The IOM goes on to state, "Major sources of added sugars include soft drinks, sports drinks, cakes, cookies, pies, fruitades, fruit punch, dairy desserts, and candy." Processed foods, even microwaveable dinners, also contain added sugars. Added sugars do not include sugars that occur naturally in whole foods (such as an apple), but do include natural sugars such as brown sugar, corn syrup, dextrose, fructose, fruit juice concentrates, maple syrup, sucrose, and raw sugar that are then added to create other foods (such as cookies).

Currently, nutrition labels do not distinguish between added and naturally occurring sugars and give only the total sugar content, making it difficult for consumers to determine their consumption of added sugars. Results from a survey of forty-two thousand Americans reports that in 2008 the average intake of added sugars is 15 percent of total calories, a drop from 18 percent of total calories in 2000.Welsh J. A. et al. "Consumption of Added Sugars Is Decreasing in the United States." *Am J Clin Nutr* 94, no. 3 (2011): 726–34. http://www.ncbi.nlm.nih.gov/pubmed/21753067. This is still above the recommended intake of less than 10 percent of total calories. The US Department of Agriculture (USDA) reports that sugar consumption in the American diet in 2008 was, on average, 28 teaspoons per day (Figure3.6.1).

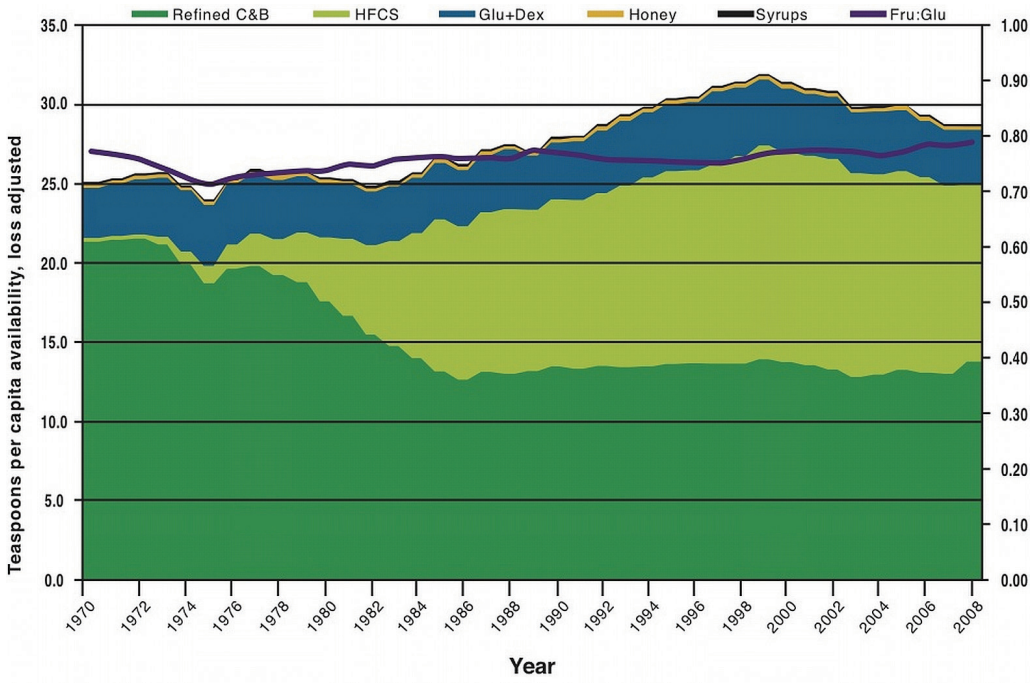


Figure 3.6.1: *Sugar Consumption (in Teaspoons) from Various Sources*

Obesity, Diabetes, and Heart Disease and Their Hypothesized Link to Excessive Sugar and Refined Carbohydrate Consumption

To understand the magnitude of the health problem in the United States consider this—in the United States approximately 130 million adults are overweight, and 30 percent of them are considered obese. The obesity epidemic has reached young adults and children and will markedly affect the prevalence of serious health consequences in adulthood. Health consequences linked to being overweight or obese include Type 2 diabetes, cardiovascular disease, arthritis, depression, and some cancers. An infatuation with

sugary foods and refined grains likely contributes to the epidemic proportion of people who are overweight or obese in this country, but so do the consumption of high-calorie foods that contain too much saturated fat and the sedentary lifestyle of most Americans. There is much disagreement over whether high-carbohydrate diets increase weight-gain and disease risk, especially when calories are not significantly higher between compared diets. Many scientific studies demonstrate positive correlations between diets high in added sugars with weight gain and disease risk, but some others do not show a significant relationship. In regard to refined grains, there are no studies that show consumption of refined grains increases weight gain or disease risk. What is clear, however, is that getting more of your carbohydrates from dietary sources containing whole grains instead of refined grains stimulates weight loss and reduces disease risk.

A major source of added sugars in the American diet is soft drinks. There is consistent scientific evidence that consuming sugary soft drinks increases weight gain and disease risk. An analysis of over thirty studies in the *American Journal of Clinical Nutrition* concluded that there is much evidence to indicate higher consumption of sugar-sweetened beverages is linked with weight gain and obesity.Malik, V. S., M. B. Schulze, and F. B. Hu. "Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review." *Am J Clin Nutr* 84, no. 2 (2006): 274–88. http://www.ajcn.org/content/84/2/274.long. A study at the Harvard School of Public Health linked the consumption of sugary soft drinks to an increased risk for heart disease.Harvard School of Public Health. "Public Health Takes Aim at Sugar and Salt." Accessed September 30, 2011. www.hsph.harvard.edu/news/hphr/fall-2009/sugar-and-salt.html. While the sugar and refined grains and weight debate rages on, the results of all of these studies has led some public health organizations like the American Heart Association (AHA) to recommend even a lower intake of sugar per day (fewer than 9 teaspoons per day for men and fewer than 6 teaspoons for women) than what used to be deemed acceptable. After its 2010 scientific conference on added sugars, the AHA made the following related dietary recommendations:

- First, know the number of total calories you should eat each day.
- Consume an overall healthy diet and get the most nutrients for the calories, using foods high in added sugars as discretionary calories (those left over after getting all recommended nutrients subtracted from the calories used).
- Lower sugar intake, especially when the sugars in foods, such as in sugary drinks, candies, cakes, and cookies, are not tied to positive nutrients.
- Focus on calories in certain food categories such as beverages and confections, and encourage consumption of positive nutrients and foods such as cereals and low-fat or fat-free dairy products.Van Horn, L. et al. "Added Sugars and Health." Research reviewed at the AHA Added Sugars Conference, 2010. *Circulation* 122 (2010): 2470–90. doi: 10.1161/CIR.0b013e3181ffdcb0.

The Most Notorious Sugar

Before high-fructose corn syrup (HCFS) was marketed as the best food and beverage sweetener, sucrose (table sugar) was the number-one sweetener in America. (Recall that sucrose, or table sugar, is a disaccharide consisting of one glucose unit and one fructose unit.) HFCS also contains the simple sugars fructose and glucose, but with fructose at a slightly higher concentration. In the production of HFCS, corn starch is broken down to glucose and fructose, and some of the glucose is then converted to fructose. Fructose is sweeter than glucose; hence many food manufacturers choose to sweeten foods with HFCS. HFCS is used as a sweetener for carbonated beverages, condiments, cereals, and a great variety of other processed foods.

Some scientists, public health personnel, and healthcare providers believe that fructose is the cause of the obesity epidemic and its associated health consequences. The majority of their evidence stems from the observation that since the early 1970s the number of overweight or obese Americans has dramatically increased and so has the consumption of foods containing HFCS. However, as discussed, so has the consumption of added sugars in general. Animal studies that fuel the fructose opponents show fructose is not used to produce energy in the body; instead, it is mostly converted to fat in the liver—potentially contributing to insulin resistance and the development of Type 2 diabetes. Additionally, fructose does not stimulate the release of certain appetite-suppressing hormones, like insulin, as glucose does. Thus, a diet high in fructose could potentially stimulate fat deposition and weight gain.

In human studies, excessive fructose intake has sometimes been associated with weight gain, but results are inconsistent. Moderate fructose intake is not associated with weight gain at all. Moreover, other studies show that some fructose in the diet actually improves glucose metabolism especially in people with Type 2 diabetes.Elliott, S. S. et al. "Fructose, Weight Gain, and the Insulin Resistance Syndrome." *Am J Clin Nutr* 76, no. 5 (2002): 911–22. http://www.ajcn.org/content/76/5/911.full. In fact, people with diabetes were once advised to use fructose as an alternative sweetener to table sugar. Overall, there is no good evidence that moderate fructose consumption contributes to weight gain and chronic disease. At this time conclusive evidence is not available on whether fructose is any worse than any other added sugar in increasing the risk for obesity, Type 2 diabetes, and cardiovascular disease.

Interactive 3.6.1

The USDA is in the process of developing a database on the added sugars in many different foods and has made the information accessible. You might be frightened by what you discover when perusing it. For instance, one 6-ounce container (170 grams) of flavored yogurt contains 20 grams (5 teaspoons) of added sugars.

www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/Add_Sug/addsug01.pdf

Oral Disease

Oral health refers not only to healthy teeth and gums, but also to the health of all the supporting tissues in the mouth such as ligaments, nerves, jawbone, chewing muscles, and salivary glands. Over ten years ago the Surgeon General produced its first report dedicated to oral health, stating that oral health and health, in general, are not separate entities. Surgeon General. "National Call to Action to Promote Oral Health." Accessed September 30, 2011. ttp://www.surgeongeneral.gov/library...ltoaction.html. Instead, oral health is an integral part of overall health and well-being. Soft drinks, sports drinks, candies, desserts, and fruit juices are the main sources of "fermentable sugars" in the American diet. (Fermentable sugars are those that are easily metabolized by bacteria in a process known as fermentation. Glucose, fructose, and maltose are three examples.) Bacteria that inhabit the mouth metabolize fermentable sugars and starches in refined grains to acids that erode tooth enamel and deeper bone tissues. The acid creates holes (cavities) in the teeth that can be extremely painful (Figure 3.6.2). Gums are also damaged by bacteria produced by acids, leading to gingivitis (characterized by inflamed and bleeding gums). Saliva is actually a natural mouthwash that neutralizes the acids and aids in building up teeth that have been damaged.



Figure 3.6.2: *Gingivitis. One way to prevent gingivitis and subsequent tooth decay is to lower consumption of sugary drinks.Gingivitis before (top) and after (bottom) a thorough mechanical debridement of the teeth. (Public domain).*

According to Healthy People 2010, 23 percent of US children have cavities by the age of four, and by second grade, one-half of all children in this country have at least one cavity. Continuing MCH Education in Oral Health. "Oral Health and Health Care." Accessed September 30, 2011. http://ccnmtl.columbia.edu/projects/otm/index.html. Cavities are an epidemic health problem in the United States and are associated with poor diet, but other contributors include poor dental hygiene and the inaccessibility to regular oral health care. A review in *Academic Pediatrics* reports that "frequent consumption of fast-releasing carbohydrates, primarily in the form of dietary sugars, is significantly associated with increased dental caries risk."Mobley C., PhD, et al. "The Contribution of Dietary Factors to Dental Caries and Disparities in Caries." Acad Pediatr 9, no. 6 (2009): 410–14. doi: 10.1016/j.acap.2009.09.008. In regards to sugary soft drinks, the American Dental Association says that drinking sugary soft drinks increases the risk of decay formation (American Dental Association. "Diet and Oral Health." Accessed September 30, 2011. www.ada.org/2984.aspx#eatoothdecay).

Interactive 3.6.2

The Harvard School of Public Health *Nutrition Source* has developed a guide called "How Sweet Is It?" that notes the calories and sugar contents of many popular beverages. Visit the site to determine drinks that are better for your oral and overall health.

www.hsph.harvard.edu/nutritionsource/files/how-sweet-is-it-color.pdf

Tools for Change

Save your teeth and gums and choose to drink a beverage that does not contain excess added sugars. An idea: brew some raspberry tea, add some sparkling mineral water, a raspberry or two, some ice, and a mint leaf. Then sit back and refresh.

Do Low-Carbohydrate Diets Affect Health?

Since the early 1990s, marketers of low-carbohydrate diets have bombarded us with the idea that eating fewer carbohydrates promotes weight loss and that these diets are superior to others in their effects on weight loss and overall health. The most famous of these low-carbohydrate diets is the Atkin's diet. Others include the "South Beach" diet, the "Zone" diet, and the "Earth" diet. Despite the claims these diets make, there is little scientific evidence to support that low-carbohydrate diets are significantly better than other diets in promoting long-term weight loss. A study in *The Nutritional Journal* concluded that all diets, (independent of carbohydrate, fat, and protein content) that incorporated an exercise regimen significantly decreased weight and waist circumference in obese women (Kerksick, C. M. et al. "Changes in Weight Loss, Body Composition, and Cardiovascular Disease Risk after Altering Macronutrient Distributions During a Regular Exercise Program in Obese Women." *J Nutr* 9, no. 59 (2010). doi: 10.1186/1475-2891-9-59). Some studies do provide evidence that in comparison to other diets, low-carbohydrate diets improve insulin levels and other risk factors for Type 2 diabetes and cardiovascular disease. The overall scientific consensus is that consuming fewer calories in a balanced diet will promote health and stimulate weight loss, with significantly better results achieved when combined with regular exercise.

Health Benefits of Whole Grains in the Diet

While excessive consumption of fast-releasing carbohydrates is potentially bad for your health, consuming more slow-releasing carbohydrates is extremely beneficial to health. There is a wealth of scientific evidence supporting that replacing refined grains with whole grains decreases the risk for obesity, Type 2 diabetes, and cardiovascular disease. Whole grains are great dietary sources of fiber, vitamins, minerals, healthy fats, and a vast amount of beneficial plant chemicals, all of which contribute to the effects of whole grains on health. Americans typically do not consume the recommended amount of whole grains, which is 50 percent or more of grains from whole grains (Figure 3.6.3).

Diets high in whole grains have repeatedly been shown to decrease weight. A large group of studies all support that consuming more than two servings of whole grains per day reduces one's chances of getting Type 2 diabetes by 21 percent (de Munter, J. S. L. et al. "Whole Grain, Bran, and Germ Intake and Risk of Type 2 Diabetes: A Prospective Cohort Study and Systematic Review." PLoS Medicine, no. 8 (2007): e261. doi: 10.1371/journal.med.0040261). The Nurses' Health Study found that women who consumed two to three servings of whole grain products daily were 30 percent less likely to have a heart attack (Liu, S. et al. "Whole-Grain Consumption and Risk of Coronary Heart Disease: Results from the Nurses' Health Study." *Am J Clin Nutr* 70, no. 3 (1999): 412–19. http://www.ajcn.org/content/70/3/412.long). The AHA makes the following statements on whole grains:

- "Dietary fiber from whole grains, as part of an overall healthy diet, helps reduce blood cholesterol levels and may lower risk of heart disease."
- "Fiber-containing foods, such as whole grains, help provide a feeling of fullness with fewer calories and may help with weight management."American Heart Association ("Whole Grains and Fiber." Accessed September 30, 2011. http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Whole-Grains-and-Fiber_UCM_303249_Article.jsp).

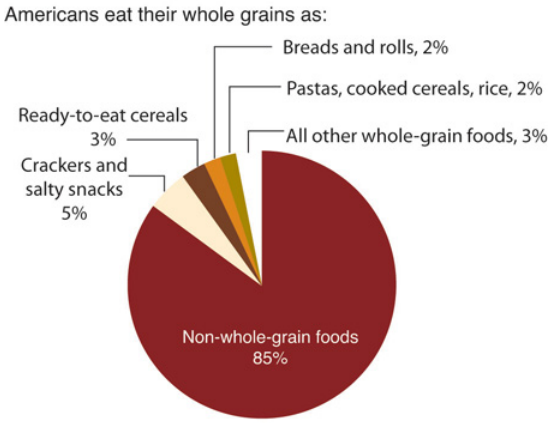


Figure 3.6.3: *Grain Consumption Statistics in America. Source: Economic Research Service. http://www.ers.usda.gov/data-products/commodity-consumption-by-population-characteristics/documentation.aspx.*

Colon Health

A substantial health benefit of whole grain foods is that fiber actively supports digestion and optimizes colon health. (This can be more specifically attributed to the insoluble fiber content of whole grains.) There is good evidence supporting that insoluble fiber prevents the irritating problem of constipation and the development of diverticulosis and diverticulitis. Diverticulosis is a benign condition characterized by out-pocketings of the colon. Diverticulitis occurs when the out-pocketings in the lining of the colon become inflamed. Interestingly, diverticulitis did not make its medical debut until the early 1900s, and in 1971 was defined as a deficiency of whole-grain fiber. According to the National Digestive Diseases Information Clearinghouse, 10 percent of Americans over the age of forty have diverticulosis, and 50 percent of people over the age of sixty have the disorder.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. “Diverticulosis and Diverticulitis.” *NIH Publication No. 08-1163* (July 2008). digestive.niddk.nih.gov/ddiseases/pubs/diverticulosis/. Ten to 25 percent of people who have diverticulosis go on to develop diverticulitis.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. “Diverticulosis and Diverticulitis.” *NIH Publication No. 08-1163* (July 2008). Symptoms include lower abdominal pain, nausea, and alternating between constipation and diarrhea.

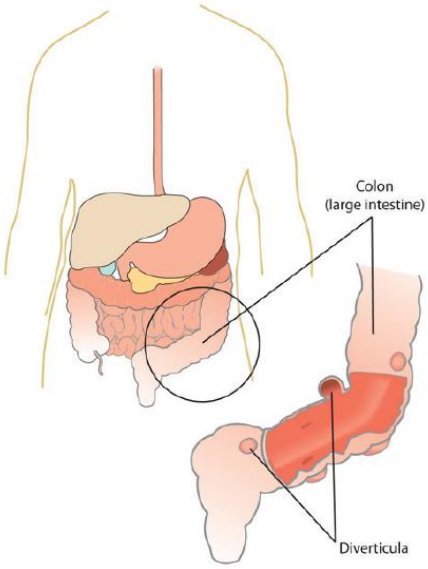


Figure 3.6.4: *Diverticulitis: A Disease of Fiber Deficiency*

The chances of developing diverticulosis can be reduced with fiber intake because of what the breakdown products of the fiber do for the colon. The bacterial breakdown of fiber in the large intestine releases short-chain fatty acids. These molecules have been

found to nourish colonic cells, inhibit colonic inflammation, and stimulate the immune system (thereby providing protection of the colon from harmful substances). Additionally, the bacterial indigestible fiber, mostly insoluble, increases stool bulk and softness increasing transit time in the large intestine and facilitating feces elimination. One phenomenon of consuming foods high in fiber is increased gas, since the byproducts of bacterial digestion of fiber are gases.

Some studies have found a link between high dietary-fiber intake and a decreased risk for colon cancer. However an analysis of several studies, published in the *Journal of the American Medical Association* in 2005, did not find that dietary-fiber intake was associated with a reduction in colon cancer risk.Park, Y. et al. “Dietary Fiber Intake and Risk of Colorectal Cancer.” *JAMA* 294, no. 22 (2005): 2849–57. doi: 10.1001/jama.294.22.2849. There is some evidence that specific fiber types (such as inulin) may protect against colon cancer, but more studies are needed to conclusively determine how certain fiber types (and at what dose) inhibit colon cancer development.

Key Takeaways

- Whole grain dietary sources stimulate weight loss and reduce disease risk. Excessive high fructose consumption has been shown to cause weight gain. A primary source of added sugars in the American diet is sugary soft drinks.
- While excessive consumption of some fast-releasing carbohydrates and refined grains is potentially bad for your health, consuming whole grains made up of nutrient-dense slow-releasing carbohydrates is extremely beneficial to health.

Discussion Starters

1. Have a debate in your classroom on the USDA restriction on the sale of carbonated beverages in schools. Find out more information about this topic by reading “Soft Drinks and School-Age Children: Trends, Effects, Solutions,” developed by the North Carolina School Nutrition Action Committee.

   nepc.colorado.edu/files/CERU-0203-41-OWI.pdf

2. Learn about the “Australian Paradox:” How decreased sugar consumption paralleled increased rates of overweight and obese people. Read the study and have a classroom debate over the weight of evidence that supports that diets high in added sugars actually increase weight gain.

   http://www.mdpi.com/2072-6643/3/4/491/pdf

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3.7: Carbohydrates and Personal Diet Choices

Learning Objectives

- Define the Acceptable Macronutrient Distribution Range for carbohydrates, the Adequate Intake for fiber, and recommended intake of added sugars.
- List five foods that are good sources of slow-releasing carbohydrates.
- Identify three to five foods high in fiber and carbohydrates from whole, unrefined sources.

In this chapter, you learned what carbohydrates are, the different types of carbohydrates in your diet, and that excess consumption of some types of carbohydrates cause disease while others decrease disease risk. Now that we know the benefits of eating the right carbohydrate, we will examine exactly how much should be eaten to promote health and prevent disease.

How Many Carbohydrates Does a Person Need?

The Food and Nutrition Board of IOM has set the Recommended Dietary Allowance (RDA) of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates is between 45 and 65 percent. This means that on a 2,000 kilocalorie diet, a person should consume between 225 and 325 grams of carbohydrate each day. According to the IOM, not more than 25 percent of total calories consumed should come from added sugars. The World Health Organization and the AHA recommend much lower intakes of added sugars—10 percent or less of total calories consumed. The IOM has also set Adequate Intakes for dietary fiber, which are 38 and 25 grams for men and women, respectively. The recommendations for dietary fiber are based upon the intake levels known to prevent heart disease.

Table 3.7.1: Dietary Reference Intakes for Carbohydrates and Fiber

Carbohydrate Type	RDA (g/day)	AMDR (% calories)
Total Carbohydrates	130	45–65
Added Sugars		< 25
Fiber	38 (men),* 25 (women)*	
* denotes Adequate Intake		

When Carbohydrate Intake is Inadequate

Inadequate intake of carbohydrate lowers blood glucose. To maintain blood glucose, the liver breaks down glycogen to release glucose and liver glycogen stores can become depleted. Also, certain amino acids are released from muscle protein and used to make glucose. This process is called catabolism. Finally, fat is mobilized from fat stores and the released fatty acids are converted to ketones in the liver and used as an energy source. This is not the body's preferred energy source.

Low Carbohydrate Diets

Some weight loss diets, for example, Atkins, South Beach, and Sugar Busters, recommend a low carbohydrate intake. Since carbohydrate is low one of the other macronutrients is excessive, usually protein. Generally, these diets are also low in calories too and this promotes the weight loss, not the reduced carbohydrate content. Side effects of these diets include halitosis (bad breath), constipation fatigue, nausea, dizziness and bone loss.

Dietary Sources of Carbohydrates

Carbohydrates are contained in all five food groups: grains, fruits, vegetables, meats, and beans (only in some processed meats and beans), and dairy products. Fast-releasing carbohydrates are more prevalent in fruits, fruit juices, and dairy products, while slow-releasing carbohydrates are more plentiful in starchy vegetables, beans, and whole grains. Fast-releasing carbohydrates are also found in large amounts in processed foods, soft drinks, and sweets. On average, a serving of fruits, whole grains, or starches contains 15 grams of carbohydrates. A serving of dairy contains about 12 grams of carbohydrates, and a serving of vegetables contains about 5 grams of carbohydrates. Table 3.7.2 gives the specific amounts of carbohydrates, fiber, and added sugar of various foods.

Table 3.7.2: Carbohydrates in Foods (grams/serving)

Foods	Total Carbohydrates	Sugars	Fiber	Added Sugars
Apple	19 (1 medium)	19.00	4.4	0
Banana	27 (1 medium)	14.40	3.1	0
Lentils	40 (1 c.)	3.50	16.0	0
Snap beans	8.7 (1 c.)	1.60	4.0	0
Green pepper	5.5 (1 medium)	2.90	2.0	0
Corn tortilla	10.7 (1)	0.20	1.5	0
Bread, wheat bran	17.2 (1 slice)	3.50	1.4	3.4
Bread, rye	15.5 (1 slice)	1.20	1.9	1.0
Bagel (plain)	53 (1 medium)	5.30	2.3	4.8
Brownie	36 (1 square)	20.50	1.2	20.0
Oatmeal cookie	22.3 (1 oz.)	12.00	2.0	7.7
Cornflakes	23 (1 c.)	1.50	0.3	1.5
Pretzels	47 (10 twists)	1.30	1.7	0
Popcorn (homemade)	58 (100 g)	0.50	10.0	0
Skim milk	12 (1 c.)	12.00	0	0
Cream (half and half)	0.65 (1 Tbs.)	0.02	0	0
Cream substitute	1.0 (1 tsp.)	1.00	0	1.0
Cheddar cheese	1.3 (1 slice)	0.50	0	0
Yogurt (with fruit)	32.3 (6 oz.)	32.30	0	19.4
Caesar dressing	2.8 (1 Tbs.)	2.80	0	2.4

Sources: US Department of Agriculture. National Nutrient Database for Standard Reference. Last modified December 7, 2011. http://www.nal.usda.gov/fnic/foodcomp/search/, and US Department of Agriculture. "Database for the Added Sugars Content of Selected Foods." February 2006. http://www.nal.usda.gov/fnic/foodcomp/search/.

It's the Whole Nutrient Package

In choosing dietary sources of carbohydrates the best ones are those that are nutrient dense, meaning they contain more essential nutrients per calorie of energy. In general, nutrient-dense carbohydrates are minimally processed and include whole-grain breads and cereals, low-fat dairy products, fruits, vegetables, and beans. In contrast, empty-calorie carbohydrate foods are highly processed and often contain added sugars and fats. Soft drinks, cakes, cookies, and candy are examples of empty-calorie carbohydrates. They are sometimes referred to as 'bad carbohydrates,' as they are known to cause health problems when consumed in excess.

Interactive 3.7.1

This interactive USDA tool allows you to enter the foods and serving size of what you're eating and find out the whole nutrient package.

http://www.ars.usda.gov/Services/docs.htm?docid=17032

Understanding Carbohydrates from Product Information

While nutrition facts labels aid in determining the amount of carbohydrates you eat, they do not help in determining whether a food is refined or not. The ingredients list provides some help in this regard. It identifies all of the food's ingredients in order of concentration, with the most concentrated ingredient first. When choosing between two breads, pick the one that lists whole wheat (not wheat flour) as the first ingredient, and avoid those with other flour ingredients, such as white flour or corn flour. (Enriched wheat flour refers to white flour with added vitamins.) Eat less of products that list HFCS and other sugars such as sucrose, honey, dextrose, and cane sugar in the first five ingredients. If you want to eat less processed foods then, in general, stay away from products with long ingredient lists. On the front of food and beverages the manufacturers may include claims such as "sugar-free," "reduced sugar," "high fiber," etc.. The Nutrition and Labeling Act of 1990 has defined for the food industry and consumers what these labels mean (Table 4.7.3).

Table 3.7.3: Food Labels Pertaining to Carbohydrates

Label	Meaning
Sugar-free	Contains less than 0.5 grams of sugar per serving
Reduced sugar	Contains 25 percent less sugar than similar product
Less sugar	Contains 25 percent less sugar than similar product, and was not altered by processing to become so
No sugars added	No sugars added during processing
High fiber	Contains at least 20 percent of daily value of fiber in each serving
A good source of fiber	Contains between 10 and 19 percent of the daily value of fiber per serving
More fiber	Contains 10 percent or more of the daily value of fiber per serving

Source: US Food and Drug Administration. "Appendix A: Definitions of Nutrient Claims." *Guidance for Industry: A Food Labeling Guide*. September 1994. Last revised October 2009. www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

In addition, the FDA permits foods that contain whole oats (which contain soluble fiber) to make the health claim on the package that the food reduces the risk of coronary heart disease. The FDA no longer permits Cheerios to make the claim that by eating their cereal "you can lower your cholesterol four percent in six weeks."

The Bottom Line

Read the labels and ingredient lists of foods to determine your carbohydrate intake and know the types of carbohydrate you consume.

Personal Choices

Carbohydrates are in most foods so you have a great variety of choices with which to meet the carbohydrates recommendations for a healthy diet. The *2010 Dietary Guidelines* recommends eating more unrefined carbohydrates and more fiber, and reducing consumption of foods that are high in added sugars. To accomplish these recommendations use some or all of the following suggestions:

- Get more daily carbohydrate servings from whole grains by eating a whole-grain cereal for breakfast, using whole-grain bread to make a sandwich for lunch, and eating a serving of beans and/or nuts with dinner.
- Make sure to get at least three servings (or more) of all the grains you eat as whole grains every day. A serving of whole grains is equal to one slice of whole-wheat bread, one ounce of whole-grain cereal, and one-half cup of cooked cereal, brown rice, or whole-wheat pasta.
- Food products made with cornmeal use the whole grain so choose tortillas, corn cereals, and corn breads with cornmeal listed as the first ingredient.
- When baking, substitute whole-wheat flour or other whole-grain flour for some of the refined white flour.

- If you like bread at dinner, choose a whole-grain muffin over a Kaiser roll or baguette.
- Add beans, nuts, or seeds to salad—they add texture and taste.
- Choose whole-grain pastas and brown rice, cook al dente, and add some beans and vegetables in equal portions.
- Change it up a bit and experience the taste and satisfaction of other whole grains such as barley, quinoa, and bulgur.
- Eat snacks high in fiber, such as almonds, pistachios, raisins, and air-popped popcorn.
- Add an artichoke and green peas to your dinner plate more often.
- Calm your "sweet tooth" by eating fruits, such as berries or an apple.
- Replace sugary soft drinks with seltzer water, tea, or a small amount of 100 percent fruit juice added to water or soda water.

Key Takeaways

- The IOM has set the Recommended Dietary Allowance of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range for total carbohydrates is 45 to 65 percent.
- Carbohydrates are contained in all five food groups: grains, fruits, vegetables, meats and beans (only in some processed meats and beans), and dairy products.
- The *2010 Dietary Guidelines* recommends eating more slow-releasing carbohydrates and more fiber, and reducing consumption of foods that are high in added sugars. This involves choosing carbohydrate sources that are nutrient-dense, with more essential nutrients per calorie of energy.

Discussion Starters

1. Are you getting the recommended amount of dietary fiber in your diet?
2. Visit the USDA "Database for the Added Sugars Content of Selected Foods" and find the added sugar contents of foods common in your diet. Discuss some of the "surprises" that you discover with your classmates.

   www.nal.usda.gov/fnic/foodcomp/Data/add_sug/addsug01.pdf

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3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

Learning Objectives

- Discuss the usefulness (or lack thereof) of consuming foods containing sugar substitutes

In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes, including increased sweetness, viscosity, bulk, coating ability, solubility, consistency, texture, body, and browning capacity. The differences in chemical structure between the different carbohydrates confer their varied functional uses in foods. Starches, gums, and pectins are used as thickening agents in making jam, cakes, cookies, noodles, canned products, imitation cheeses, and a variety of other foods. Molecular gastronomists use slow-releasing carbohydrates, such as alginate, to give shape and texture to their fascinating food creations (Video 4.8.1). Adding fiber to foods increases bulk. Simple sugars are used not only for adding sweetness, but also to add texture, consistency, and browning. In ice cream, the combination of sucrose and corn syrup imparts sweetness as well as a glossy appearance and smooth texture. Added sugars include white, brown, and raw sugar, corn syrup, HFCS, malt and maple syrups, liquid fructose, honey, molasses, agave nectar, and crystal dextrose.

Video 3.8.1: Ferran Adrian Demonstrates Alginates

Watch this video to see how molecular gastronomist Ferran Adrian uses the polysaccharide alginate to give shape and texture to olive puree.



Due to the potential health consequences of consuming too many added sugars, sugar substitutes have replaced them in many foods and beverages. Sugar substitutes may be from natural sources or artificially made. Those that are artificially made are called artificial sweeteners and must be approved by the FDA for use in foods and beverages. The artificial sweeteners approved by the FDA are saccharin, aspartame, acesulfame potassium, neotame, and sucralose. Stevia is an example of a naturally derived sugar substitute. It comes from a plant commonly known as sugarleaf and does not require FDA approval. Sugar alcohols, such as xylitol, sorbitol, erythritol, and mannitol, are carbohydrates that occur naturally in some fruits and vegetables. However, they are industrially synthesized with yeast and other microbes for use as food additives.



Figure 3.8.1: *Pectin (a carbohydrate) is added to jam to give it its consistency. © Shutterstock*

The FDA requires that foods disclose the fact that they contain sugar alcohols, but does not require scientific testing of it. (Though many of them have undergone studies anyway.) In comparison to sucrose, artificial sweeteners are significantly sweeter (in fact, by several hundred times), but sugar alcohols are more often less sweet than sucrose (Table 3.8.1). Artificial sweeteners and Stevia are not digested or absorbed in significant amounts and therefore are not a significant source of calories in the diet. Sugar alcohols are somewhat digested and absorbed and, on average, contribute about half of the calories as sucrose (4 kilocalories/gram). These attributes make sugar substitutes attractive for many people—especially those who want to lose weight and/or better manage their blood-glucose levels.

Table 3.8.1: Sweetness Comparison of Sugar Substitutes

Sweetener	Trade Names	Times that of Sucrose
Acesulfame-K	“Sunette,” "Sweet One"	200.0
Aspartame	“NutraSweet,” “Equal”	180.0–220.0
Erythritol		1.0
Mannitol		0.5
Neotame		7,000.0–13,000.0
Saccharine	“Sweet-N-Lo," "SugarTwin"	600.0
Sorbitol		0.6
Stevia		250.0–300.0
Sucralose	“Splenda”	600.0
Xylitol		0.8

Sources: University of North Texas. “Sugar Substitutes.” Accessed November 6, 2012. dining.unt.edu/nutrition/nutrition_brochures/Sugar%20Substitutes.pdf, and Yale-New Haven Hospital. “Eat Any Sugar Alcohol Lately?” Accessed November 6, 2012. http://www.ynhh.org/about-us/sugar_alcohol.aspx.

Benefits of Sugar Substitutes

Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. Artificial sweeteners are basically nonnutrients though not all are completely calorie-free. However, because they are so intense in sweetness they are added in very small amounts to foods and beverages. Artificial sweeteners and sugar alcohols are not “fermentable sugars” and therefore they do not cause tooth decay. Chewing gum with artificial sweeteners is the only proven way that artificial sweeteners promote oral health. The American Dental Association (ADA) allows manufacturers of chewing gum to label packages with an ADA seal if they have convincing scientific evidence demonstrating their product either reduces plaque acids, cavities, gum disease, or promotes tooth remineralization.

There is limited scientific evidence that consuming products with artificial sweeteners decreases weight. In fact, some studies suggest the intense sweetness of these products increases appetite for sweet foods and may lead to increased weight gain. Also, there is very limited evidence that suggests artificial sweeteners lower blood-glucose levels. Additionally, many foods and beverages containing artificial sweeteners and sugar alcohols are still empty-calorie foods (i.e. chewing sugarless gum or drinking diet soda pop) are not going to better your blood-glucose levels or your health.

Health Concerns

The most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion. Since the introduction of sugar substitutes to the food and beverage markets, the public has expressed concern about their safety. The health concerns of sugar substitutes originally stemmed from scientific studies, which were misinterpreted by both scientists and the public.

In the early 1970s, scientific studies were published that demonstrated that high doses of saccharin caused bladder tumors in rats. This information fueled the still-ongoing debate of the health consequences of all artificial sweeteners. In actuality, the results from the early studies were completely irrelevant to humans. The large doses (2.5 percent of diet) of saccharine caused a pellet to form in the rat’s bladder. That pellet chronically irritated the bladder wall, eventually resulting in tumor development. Since this study, scientific investigation in rats, monkeys, and humans have not found any relationship between saccharin consumption and bladder cancer. In 2000, saccharin was removed from the US National Toxicology Program’s list of potential carcinogens.National Cancer Institute. “Artificial Sweeteners and Cancer.” Accessed September 30, 2011. http://www.cancer.gov/cancertopics/factsheet/Risk/artificial-sweeteners.

There have been health concerns over other artificial sweeteners, most notably aspartame (sold under the trade names of NutraSweet and Equal). The first misconception regarding aspartame was that it was linked with an increase in the incidence of brain tumors in the United States. It was subsequently discovered that the increase in brain tumors started eight years prior to the introduction of aspartame to the market. Today, aspartame is accused of causing brain damage, autism, emotional disorders, and a myriad of other disorders and diseases. Some even believe aspartame is part of a governmental conspiracy to make people dumber. The reality is there is no good scientific evidence backing any of these accusations, and that aspartame has been the most scientifically tested food additive. It is approved for use as an artificial sweetener in over ninety countries.

Aspartame is made by joining aspartic acid and phenylalanine to amino acids. When digested, it is broken down to aspartic acid, phenylalanine, and methanol. People who have the rare genetic disorder phenylketonuria (PKU) have to avoid products containing aspartame. Individuals who have PKU do not have a functional enzyme that converts phenylalanine to the amino acid tyrosine. This causes a build-up of phenylalanine and its metabolic products in the body. If PKU is not treated, the build-up of phenylalanine causes progressive brain damage and seizures. The FDA requires products that contain aspartame to state on the product label, “Phenylketonurics: Contains Phenylalanine.” For more details on sugar substitutes please refer to Table 3.8.2.

Table 3.8.2: Sweeteners

Sweeteners with Trade Name	Calories	Source/Origin	Consumer Recommendations	Controversial Issues	
Aspartame • NutraSweet • Equal	4 kcal/g	Composed of two amino acids (phenylalanine + aspartic acid) + methanol. Two hundred times sweeter than sucrose.	FDA set maximum Acceptable Daily Intakes (ADI): 50 mg/kg body weight = 16 12 oz. diet soft drinks for adults. ***Cannot be used in products requiring cooking.** People with PKU should not consume aspartame.	Children have potential to reach ADI if consuming many beverages, desserts, frozen desserts, and gums containing aspartame routinely.	Beverages, spreads.
Saccharin • Sweet ‘n’ Low	0 kcal/g	Discovered in 1878. The basic substance is benzoic sulfinide. Three hundred times sweeter than sucrose.	ADI: 5 mg/kg body weight. ***Can be used in cooking.**	1970s, high doses of saccharin associated with bladder cancer in laboratory animals. In 1977, FDA proposed banning saccharin from use in food • protest launched by consumer & interest groups • warning label listed on products about saccharin and cancer risk in animals until 2001 when studies concluded that it did not cause cancer in humans	General p and bevera Sold as S States; al pharmaceu
Acesulfame K • Sunnette • Sweet One	0 kcal/g	Discovered in 1967. Composed of an organic salt, potassium (K). The structure is very similar to saccharin. It passes through the body unchanged which means it does not provide energy. Two hundred times sweeter than sucrose.	ADI: 15 mg/kg body weight. The body cannot digest it. ***Can be used in cooking.**		Chewing g nondairy instant tea
Cyclamates • Sugar Twin (Canada only)	0 kcal/g	Thirty times sweeter than sucrose. Discovered in 1937.	No ADI available.	1949, cyclamate approved by FDA for use. Cyclamate was classified as GRAS (Generally Recognized As Safe) until 1970 when it was removed from GRAS status and banned from use in all food and beverage products within the United States on the basis of one study that indicated it caused bladder cancer in rats. Approval still pending for use in the United States since the ban. Canada and other countries use this type of sweetener.	Recommer sugar for d
Sucralose • Splenda	One Splenda packet contains 3.31 calories = 1g	First discovered in 1976. Approved for use in 1998 in the United States and in 1991 in Canada. Derived from sucrose in which three of its hydroxyl (OH) groups are replaced by chlorine (Cl−). Six hundred times sweeter than sugar.	ADI: 5 mg/kg body weight. ***Can be used in cooking.**		General pu beverages, desserts, dietary recommen sugar and

Sweeteners with Trade Name	Calories	Source/Origin	Consumer Recommendations	Controversial Issues	
Stevioside • Stevia • Sweet Leaf	N/A	Derived from stevia plant found in South America. *Stevia rebaudianan* leaves.	Classified as GRAS. Considered to be a dietary supplement and approved not as an additive, but as a dietary supplement.	Used sparingly, stevia may do little harm, but FDA could not approve the extensive use of this sweetener due to concerns regarding its effect on reproduction, cancer development, and energy metabolism.	Sold in h supplemen
Sucrose • Sugar	~4 kcal/g	Extracted from either sugar beets or sugar cane, which is then purified and crystallized.	It is illegal to sell true raw sugar in the United States because when raw it contains dirt and insect parts, as well as other byproducts. Raw sugar products sold in the United States have actually gone through more than half of the same steps in the refining process as table sugar.	Over-consumption has been linked to several health effects such as tooth decay or dental caries and contributes to increased risk for chronic diseases.	Biscuits, canes, ice preservativ
Honey	3 kcal/g	Made from sucrose. Contains nectar of flowering plants. Made by bees. Sucrose is fructose + glucose; however, honey contains more calories than sucrose because honey is denser.	*Considered safe for baking and cooking. Infants under twelve months old should not be given honey because their digestive tracts cannot handle the bacteria found in honey. Older children and adults are immune to these effects. Honey contains some harmful bacteria that can cause fatal food poisoning in infants.		Sweetener beverages beverages,
HFCS • high fructose corn syrup	Dry form: 4 kcal/g; Liquid form: 3 kcal/g	Corn is milled to produce corn starch, then the corn starch is further processed to yield corn syrup.		Controversial because it is found ubiquitously in processed food products, which could lead to over-consumption. Study results are varied regarding its role in chronic disease.	Soft drinks
Sugar Alcohols • Sorbitol • Xylitol • Mannitol	2–4 kcal/g. Not calorie free	Sugar alcohols. Sorbitol is derived from glucose.	Less likely to cause tooth decay than sucrose. Sugar alcohols have a laxative effect.	May cause diarrhea and gastrointestinal distress if consumed in large amounts.	Provide l following jellies, ch pharmaceu

Regulation

Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA. The FDA regulates artificial sweeteners along with other food additives, which number in the thousands. The FDA is responsible for determining whether a food additive presents "a reasonable certainty of no harm" to consumers when used as proposed. The FDA uses the best scientific evidence available to make the statement of no harm, but it does declare that science has its limits and that the "FDA can never be *absolutely* certain of the absence of any risk from the use of any substance."US Food and Drug Administration. "Food Ingredients and Colors." Accessed September 30, 2011. www.fda.gov/food/foodingredientspackaging/ucm094211.htm. The FDA additionally has established ADIs for artificial sweeteners. The ADIs are the maximum amount in milligrams per kilogram of body weight considered safe to consume daily (mg/kg bw/day) and incorporates a large safety factor. The following list contains the artificial sweeteners approved for use in foods and beverages in the United States, and their ADIs:

- **Acesulfame potassium (Sunett, Sweet One).** ADI = 15 mg/kg bw/day
- **Aspartame (Equal, NutraSweet).** ADI = 50 mg/kg bw/day
- **Neotame.** ADI = 18 mg/kg bw/day
- **Saccharin (SugarTwin, Sweet'N Low).** ADI = 5 mg/kg bw/day
- **Sucralose (Splenda).** ADI = 5 mg/kg bw/day

Carbohydrates in a Kernel

Referring back to the wheat kernel mentioned at the opening of this chapter, recall that all components of the wheat kernel are required in order to build an optimal healthy diet. The endosperm provides the carbohydrates, and the bran and germ contain the majority of protein, vitamins, minerals, and fiber. Eating foods made with whole grains provides a better nutritional punch for your health. Once whole grains are processed and refined, enrichment in only a few of these removed nutrients does not offset the gain from consuming whole-grain products. Other dietary sources of carbohydrates that maximize nutrient uptake are vegetables, fruits, beans, and low-fat dairy products. To avoid compromising your health, do not consume excessive amounts of carbohydrate foods that contain added sugars, or that are high in sodium and saturated fat. Processed foods contain all of these ingredients in an unwelcome nutrient package that negatively impacts health. Sugar substitutes provide one avenue of decreasing the intake of fast-releasing carbohydrates, but there are others. Know that consumer demand for healthy carbohydrate choices is on the rise, so in the future, you can expect decreased prices, more variety of whole-grain products, and less added sugars.

The Bottom Line

Choose more slow-releasing carbohydrates, eat more fiber, and reduce consumption of foods high in added sugars.

Key Takeaways

- In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes. The differences in chemical structure between the different carbohydrates confer their many different functional uses in foods.
- Due to the health consequences of consuming too many added sugars, sugar substitutes are widely used in many foods and beverages.
- Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. However, the most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion.
- Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA.

Discussion Starters

1. Conduct a taste test of sugar and its substitutes. What do your taste buds tell you? Do you prefer foods with sugar substitutes or the real thing?
2. Have a class discussion on the safety of aspartame. To fuel the debate, read the FDA's report and watch the reactionary video, "Aspartame, Brain Cancer, and the FDA Approval Process."

   www.fda.gov/Food/FoodIngredientsPackaging/FoodAdditives/ucm208580.htm

   Aspartame, Brain Cancer, and the FDA Approval Process

   (click to see video)

3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

3.E: Exercises

It's Your Turn

1. Learn more on glycolysis and cellular respiration by watching this video on YouTube, and describe in a short paragraph what happens in the body as it uses the process of glycolysis to fuel short bursts of activity.

   Glycolysis Cellular Respiration Overview

   (click to see video)
2. Conduct an experiment in the classroom that evaluates the sweetness and tastefulness of sugar substitutes. Try them in pure form by putting a small amount on your finger. Record the results from you and your classmates and make a sweetness and taste comparison chart.

Expand Your Knowledge

1. Design a Thanksgiving feast with at least ten items that help balance the GI of the meal.
2. Draw a flow chart that incorporates the concept of negative feedback in the regulation of blood glucose levels.
3. Visit the website of the CDC (apps.nccd.cdc.gov/DDTSTRS/default.aspx) and record the estimates of obesity, physical inactivity, and Type 2 diabetes in the county you live in. Make a list of five ways to curb the trends of obesity, physical inactivity, and Type 2 diabetes in your county.

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4: Lipids

In this chapter, we look at the types, structure, and roles of lipids, and we explain the different types of cholesterol in the blood. We also explore topics of interest such as omega-3 and omega-6 fatty acids and trans fats.

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4.1: Chapter Introduction

In the 1920s, anthropologist Vilhjalmur Stefansson lived with and studied a group of Inuit. The Inuit were fishers and hunters, primarily of sea mammals such as whales, walruses, and seals. They consumed a high-protein, high-fat diet. In fact, the Inuit consumed an average of 75 percent of their daily energy intake from fat. Patricia Gadsby, "*The Inuit Paradox," Discover*, 1 October 2004. http://discovermagazine.com/2004/oct/inuit-paradox/article_print. Stefansson's research focused on the fact that the Inuit diet had no adverse effects on either their health or his own.Lieb, C. W. "The Effects of an Exclusive Long-Continued Meat Diet." *JAMA* 87, no. 1 (1926): 25–26. doi:10.1001/jama.1926.02680010025006

Video 4.1.1: Why Omega-3 Fatty Acids Are Essential

Dr. Gerard L. Guillory reviews the benefits of omega-3 fatty acids in this video, as part of a "10 Steps to Better Health" series



These findings were supported by a later study in 1972, when the Greenland Inuit first caught the attention of Dr. H. O. Bang from Aalborg University in Denmark. He noted that although the Inuit consumed massive amounts of fatty ocean fish, which are packed with omega-3s, none of the Inuit tested showed signs of heart disease. In addition, there was significantly less evidence of joint disease and skin disease than found in Western countries. Further research led Bang and his associate, Dyerberg, to conclude that the omega-3 fatty acids (docosahexaenoic acid, or DHA, and eicosapentaenoic acid, or EPA) present in the diet offer significant health benefits:Bang, H.O. and J. Dyerberg. "Fatty Acid Composition of the Plasma Lipids in Greenland Eskimos." *Am J Clin Nutr* 28 (1975): 958–66.

- **Heart disease.** Further research supports Bang and Dyerberg's finding and shows DHA and EPA to be beneficial to heart health and human development. EPA and DHA tend to reduce blood pressure, prevent blood-clot formation (thereby reducing the risk of stroke), and protect against irregular heartbeats.
- **Inflammation and autoimmune diseases.** According to research published in the *Journal of the American College of Nutrition*, animal experiments and clinical intervention studies indicate that omega-3 fatty acids have anti-inflammatory properties.Sears, B. "Anti-Inflammatory Diets for Obesity and Diabetes." *J Am Coll Nutr* 21 (2008). The low incidence of autoimmune and inflammatory disorders such as psoriasis, asthma, and Type 1 diabetes and the complete absence of multiple sclerosis has been observed and studied in the Inuit population in Greenland.Brzezinski, A. "Review." *Gastroenterol Hepatol* 3, no. 10 (2007): 787–88. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3104160/. Subsequent studies concur with these findings and it is believed that omega-3 fats play an important role in the prevention and treatment of coronary artery disease, high blood pressure, arthritis, other inflammatory and autoimmune disorders, and cancer.Simopoulos, A. "Omega-3 Fatty Acids in Inflammation and Autoimmune Diseases." *J Am Coll Nutr* 21, no. 6 (2002): 495–505. http://www.jacn.org/content/21/6/495.full.
- **Brain health.** Omega-3 fats play an important role in maintaining mental health and are crucial for brain function. Omega-3 fatty acids may provide benefits such as expanding learning and memory capacities. Early evidence suggests that the consumption of omega-3 fats is essential for synaptic transmission in the brain. Furthermore, omega-3 fats seem to be most effective when obtained from foods rather than from supplements.

You Decide

What sources of omega-3 fatty acids would you include in your diet and why?

As you read further, you will learn the different types of fats, their essential roles in the body, and the potential health consequences and benefits of diets rich in particular lipids. You will be better equipped to decide the best way to get your nutritional punch from various fats in your diet.

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4.2: What Are Lipids?

Learning Objectives

- Explain the role of lipids in overall health.

Lipids are important fats that serve different roles in the human body. A common misconception is that fat is simply fattening. However, fat is probably the reason we are all here. Throughout history, there have been many instances when food was scarce. Our ability to store excess caloric energy as fat for future usage allowed us to continue as a species during these times of famine. So, normal fat reserves are a signal that metabolic processes are efficient and a person is healthy.

Lipids are a family of organic compounds that are mostly insoluble in water. Composed of fats and oils, lipids are molecules that yield high energy and have a chemical composition mainly of carbon, hydrogen, and oxygen. Lipids perform three primary biological functions within the body: they serve as structural components of cell membranes, function as energy storehouses, and function as important signaling molecules.

The three main types of lipids are triacylglycerols (also called triglycerides), phospholipids, and sterols. Triacylglycerols (also known as triglycerides) make up more than 95 percent of lipids in the diet and are commonly found in fried foods, vegetable oil, butter, whole milk, cheese, cream cheese, and some meats. Naturally occurring triacylglycerols are found in many foods, including avocados, olives, corn, and nuts. We commonly call the triacylglycerols in our food “fats” and “oils.” Fats are lipids that are solid at room temperature, whereas oils are liquid. As with most fats, triacylglycerols do not dissolve in water. The terms fats, oils, and triacylglycerols are discretionary and can be used interchangeably. In this chapter when we use the word fat, we are referring to triacylglycerols.

Phospholipids make up only about 2 percent of dietary lipids. They are water-soluble and are found in both plants and animals. Phospholipids are crucial for building the protective barrier, or membrane, around your body’s cells. In fact, phospholipids are synthesized in the body to form cell and organelle membranes. In blood and body fluids, phospholipids form structures in which fat is enclosed and transported throughout the bloodstream.

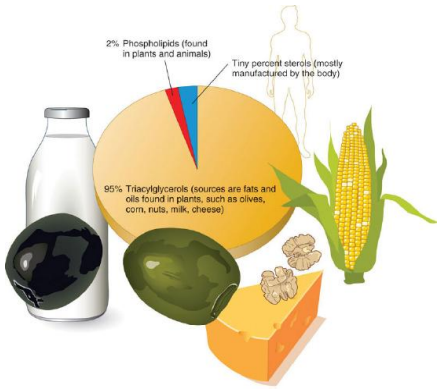


Figure 4.2.1: Types of Lipids

Sterols are the least common type of lipid. Cholesterol is perhaps the best well-known sterol. Though cholesterol has a notorious reputation, the body gets only a small amount of its cholesterol through food—the body produces most of it. Cholesterol is an important component of the cell membrane and is required for the synthesis of sex hormones, vitamin D, and bile salts.

Later in this chapter, we will examine each of these lipids in more detail and discover how their different structures function to keep your body working.

Functions of Lipids in the Body: Storing Energy

The excess energy from the food we eat is digested and incorporated into adipose tissue, or fatty tissue. Most of the energy required by the human body is provided by carbohydrates and lipids. As discussed in Chapter 3, glucose is stored in the body as glycogen. While glycogen provides a ready source of energy, lipids primarily function as an energy reserve. As you may recall, glycogen is quite bulky with heavy water content, thus the body cannot store too much for long. Alternatively, fats are packed together tightly without water and store far greater amounts of energy in a reduced space. A fat gram is densely concentrated with energy—it

contains more than double the amount of energy than a gram of carbohydrate. Energy is needed to power the muscles for all the physical work and play an average person or child engages in. For instance, the stored energy in muscles propels an athlete down the track, spurs a dancer's legs to showcase the latest fancy steps, and keeps all the moving parts of the body functioning smoothly.

Unlike other body cells that can store fat in limited supplies, fat cells are specialized for fat storage and are able to expand almost indefinitely in size. An overabundance of adipose tissue can result in undue stress on the body and can be detrimental to your health. A serious impact of excess fat is the accumulation of too much cholesterol in the arterial wall, which can thicken the walls of arteries and lead to cardiovascular disease. Thus, while some body fat is critical to our survival and good health, in large quantities it can be a deterrent to maintaining good health.

Functions of Lipids in the Body: Regulating and Signaling

Triacylglycerols control the body's internal climate, maintaining a constant temperature. Those who don't have enough fat in their bodies tend to feel cold sooner, are often fatigued and have pressure sores on their skin from fatty acid deficiency. Triacylglycerols also help the body produce and regulate hormones. For example, adipose tissue secretes the hormone leptin, which regulates appetite. In the reproductive system, fatty acids are required for proper reproductive health; women who lack proper amounts may stop menstruating and become infertile. Omega-3 and omega-6 essential fatty acids help regulate cholesterol and blood clotting and control inflammation in the joints, tissues, and bloodstream. Fats also play important functional roles in sustaining nerve impulse transmission, memory storage, and tissue structure. More specifically in the brain, lipids are focal to brain activity in structure and in function. They help form nerve cell membranes, insulate neurons, and facilitate the signaling of electrical impulses throughout the brain.



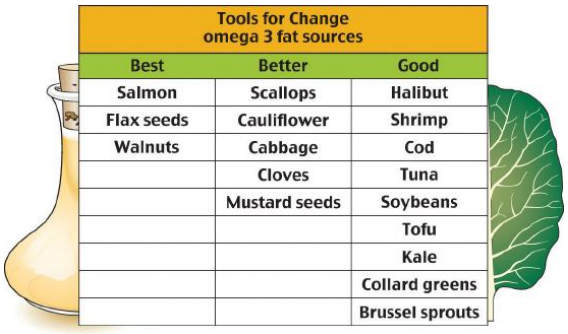
Figure 4.2.2: Lipids serve as signaling molecules; they are catalysts of electrical impulse activity within the brain. © Thinkstock

Functions of Lipids in the Body: Insulating and Protecting

Did you know that up to 30 percent of body weight is comprised of fat tissue? Some of this is made up of visceral fat or adipose tissue surrounding delicate organs. Vital organs such as the heart, kidneys, and liver are protected by visceral fat. The composition of the brain is outstandingly 60 percent fat, demonstrating the major structural role that fat serves within the body. You may be most familiar with subcutaneous fat, or fat underneath the skin. This blanket layer of tissue insulates the body from extreme temperatures and helps keep the internal climate under control. It pads our hands and buttocks and prevents friction, as these areas frequently come in contact with hard surfaces. It also gives the body the extra padding required when engaging in physically demanding activities such as ice- or roller skating, horseback riding, or snowboarding.

Functions of Lipids in the Body: Aiding Digestion and Increasing Bioavailability

The dietary fats in the foods we eat break down in our digestive systems and begin the transport of precious micronutrients. By carrying fat-soluble nutrients through the digestive process, intestinal absorption is improved. This improved absorption is also known as increased bioavailability. Fat-soluble nutrients are especially important for good health and exhibit a variety of functions. Vitamins A, D, E, and K—the fat-soluble vitamins—are mainly found in foods containing fat. Some fat-soluble vitamins (such as vitamin A) are also found in naturally fat-free foods such as green leafy vegetables, carrots, and broccoli. These vitamins are best absorbed when combined with foods containing fat. Fats also increase the bioavailability of compounds known as phytochemicals, which are plant constituents such as lycopene (found in tomatoes) and beta-carotene (found in carrots). Phytochemicals are believed to promote health and well-being. As a result, eating tomatoes with olive oil or salad dressing will facilitate lycopene absorption. Other essential nutrients, such as essential fatty acids, are constituents of the fats themselves and serve as building blocks of a cell.



Tools for Change omega 3 fat sources		
Best	Better	Good
Salmon	Scallops	Halibut
Flax seeds	Cauliflower	Shrimp
Walnuts	Cabbage	Cod
	Cloves	Tuna
	Mustard seeds	Soybeans
		Tofu
		Kale
		Collard greens
		Brussel sprouts

Figure 4.2.3: Food Sources of Fat-Soluble Vitamins

Note that removing the lipid elements from food also takes away the food's fat-soluble vitamin content. When products such as grain and dairy are processed, these essential nutrients are lost. Manufacturers replace these nutrients through a process called enrichment.

Tools for Change

Remember, fat-soluble nutrients require fat for effective absorption. For your next snack, look for foods that contain vitamins A, D, E, and K. Do these foods also contain fat that will help you absorb them? If not, think of ways to add a bit of healthy fat to aid in their absorption.

Role of Lipids in Food: High Energy Source

Fat-rich foods naturally have a high caloric density. Foods that are high in fat contain more calories than foods high in protein or carbohydrates. As a result, high-fat foods are a convenient source of energy. For example, 1 gram of fat or oil provides 9 kilocalories of energy, compared with 4 kilocalories found in 1 gram of carbohydrate or protein. Depending on the level of physical activity and on nutritional needs, fat requirements vary greatly from person to person. When energy needs are high, the body welcomes the high-caloric density of fats. For instance, infants and growing children require proper amounts of fat to support normal growth and development. If an infant or child is given a low-fat diet for an extended period, growth and development will not progress normally. Other individuals with high-energy needs are athletes, people who have physically demanding jobs, and those recuperating from illness.



Figure 4.2.4: Athletes have high-energy requirements. © Thinkstock

When the body has used all of its calories from carbohydrates (this can occur after just twenty minutes of exercise), it initiates fat usage. A professional swimmer must consume large amounts of food energy to meet the demands of swimming long distances, so eating fat-rich foods makes sense. In contrast, if a person who leads a sedentary lifestyle eats the same high-density fat foods, they will intake more fat calories than their body requires within just a few bites. Use caution—consumption of calories over and beyond energy requirements is a contributing factor to obesity.

Role of Lipids in Food: Smell and Taste

Fat contains dissolved compounds that contribute to mouth-watering aromas and flavors and increase palatability of food. Fat also adds texture to food. Baked foods are supple and moist. Frying foods locks in flavor and lessens cooking time. How long does it

take you to recall the smell of your favorite food cooking? What would a meal be without that savory aroma to delight your senses and heighten your preparedness for eating a meal?

Fat plays another valuable role in nutrition. Fat contributes to satiety, or the sensation of fullness. When fatty foods are swallowed the body responds by enabling the processes controlling digestion to retard the movement of food along the digestive tract, thus promoting an overall sense of fullness. Oftentimes before the feeling of fullness arrives, people overindulge in fat-rich foods, finding the delectable taste irresistible. Indeed, the very things that make fat-rich foods attractive also make them a hindrance to maintaining a healthful diet.

Tools for Change

While fats provide delicious smells, tastes, and textures to our foods, they also provide numerous calories. To allow your body to experience the satiety effect of the fat before you overindulge, try savoring rich foods. Eating slowly will allow you to both fully enjoy the experience and be sated with a smaller portion. Remember to take your time. Drink water in between bites or eat a lower fat food before and after a higher fat food. The lower-fat foods will provide bulk, but fewer calories.

Key Takeaways

- Lipids include triacylglycerols, phospholipids, and sterols.
- Triacylglycerols, the most common lipid, comprise most body fat and are described as fats and oils in food.
- Excess energy from food is stored as adipose tissue in the body.
- Fats are critical for maintaining body temperature, cushioning vital organs, regulating hormones, transmitting nerve impulses, and storing memory.
- Lipids transport fat-soluble nutrients and phytochemicals and promote bioavailability of these compounds.
- Fat is a convenient source of energy for people with high-energy requirements.
- Fat provides double the energy per gram than protein or carbohydrates, enhances the smell and flavor of food, and promotes satiety.

Discussion Starters

- Discuss the role of lipids in our diet and their critical functions in the body.
- Explain the importance of fats to the bioavailability of other nutrients.
- Discuss the role of fats as an energy source for the body.

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4.3: How Lipids Work

Learning Objectives

- Explain how the structure of each lipid impacts its function as it relates to health and disease.
- Compare and contrast the structure of the following types of fats: triacylglycerols (monounsaturated, polyunsaturated, omega-3, and omega-6), phospholipids, and sterols.
- Explain how the fatty acids you consume relate to the fatty-acid composition of your body fat.

Lipids are unique organic compounds, each serving key roles and performing specific functions within the body. As we discuss the various types of lipids (triacylglycerols, phospholipids, and sterols) in further detail, we will compare their structures and functions and examine their impact on human health.

Triacylglycerols Structure and Functions

Triacylglycerols are the main form of lipid found in the body and in the diet. Fatty acids and glycerol are the building blocks of triacylglycerols. Glycerol is a thick, smooth, syrupy compound that is often used in the food industry. To form a triacylglycerol, a glycerol molecule is joined by three fatty acid chains. Triacylglycerols contain varying mixtures of fatty acids.

Fatty Acids

Fatty acids determine if the compound is solid or liquid at room temperature. Fatty acids consist of a carboxylic acid (−OOH) group on one end of a carbon chain and a methyl group ($-CH_3$) on the other end. Fatty acids can differ from one another in two important ways—carbon chain length and degree of saturation.

It's All in the Chain

Fatty acids have different chain lengths and different compositions. Foods have fatty acids with chain lengths between four and twenty-four carbons and most of them contain an even number of carbon atoms. When the carbon chain length is shorter, the melting point of the fatty acid becomes lower—and the fatty acid becomes more liquid.

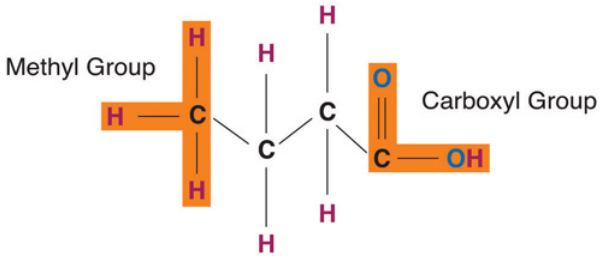


Figure 4.3.1: Structures of a Saturated, Monounsaturated, and Polyunsaturated Fat

Short-chain fatty acids (SCFAs) are 6 carbons or less in length. Medium-chain fatty acids (MCFAs) are eight to fourteen carbons in length while long chain fatty acids (LCFAS) are sixteen or more carbons.

Degrees of Saturation

Fatty acid chains are held together by carbon atoms that attach to each other and to hydrogen atoms. The term *saturation* refers to whether or not a fatty acid chain is filled (or "saturated") to capacity with hydrogen atoms. If each available carbon bond holds a hydrogen atom we call this a saturated fatty acid chain. All carbon atoms in such a fatty acid chain are bonded with single bonds. Sometimes the chain has a place where hydrogen atoms are missing. This is referred to as the point of unsaturation.

When one or more bonds between carbon atoms are a double bond (C=C), that fatty acid is called an unsaturated fatty acid, as it has one or more points of unsaturation. Any fatty acid that has only one double bond is a monounsaturated fatty acid, an example of which is olive oil (75 percent of its fat is monounsaturated). Monounsaturated fats help regulate blood cholesterol levels, thereby reducing the risk of heart disease and stroke. A polyunsaturated fatty acid is a fatty acid with two or more double bonds or two or more points of unsaturation. Soybean oil contains high amounts of polyunsaturated fatty acids. Both monounsaturated fats and polyunsaturated fats provide nutrition that is essential for normal cell development and healthy skin.

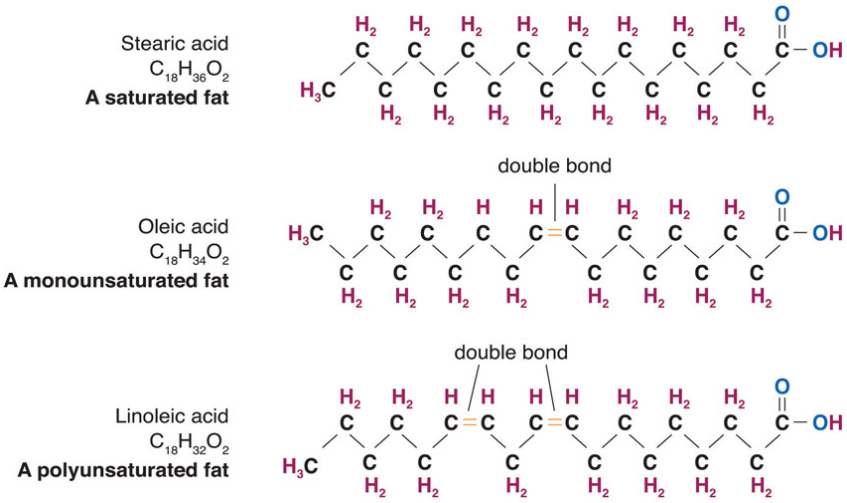


Figure 4.3.2: Chain structures of saturated fatty acids, monounsaturated, and polyunsaturated fatty acids

Foods that have a high percentage of saturated fatty acids tend to be solid at room temperature. Examples of these are fats found in chocolate (stearic acid, an eighteen-carbon saturated fatty acid is a primary component) and meat. Common saturated fatty acids are palmitic acid (16 carbon; palm kernel oil, coconut oil, and animal fat), stearic acid (18 carbon length; cocoa butter, animal fat), lauric acid (12 carbon length; coconut and palm kernel oil), and myristic acid (14 carbon length; butter fat, coconut oil).

Foods rich in unsaturated fatty acids, such as olive oil (oleic acid, an eighteen-carbon unsaturated fatty acid, is a major component) tend to be liquid at room temperature. Flaxseed oil is rich in alpha-linolenic acid, which is an unsaturated fatty acid and becomes a thin liquid at room temperature. Unsaturated fats have a lower temperature that they melt compared to saturated fats.

Knowing the connection between chain length, the degree of saturation and the state of the fatty acid (solid or liquid) is important for making food choices. If you decide to limit or redirect your intake of fat products, then choosing unsaturated fat is more beneficial than choosing a saturated fat. This choice is easy enough to make because unsaturated fats tend to be liquid at room temperature (for example, olive oil) whereas saturated fats tend to be solid at room temperature (for example, butter). Avocados are rich in unsaturated fats. Most vegetable and fish oils contain high quantities of polyunsaturated fats. Olive oil and canola oil are also rich in monounsaturated fats. Conversely, tropical oils are an exception to this rule in that they are liquid at room temperature yet high in saturated fat. Palm oil (often used in food processing) is highly saturated and has been proven to raise blood cholesterol. Shortening, margarine, and commercially prepared products (in general) report to use only vegetable-derived fats in their processing. But even so, much of the fat they use may be in the saturated and trans fat categories.

Cis or Trans Fatty Acids?

The introduction of a carbon double bond in a carbon chain, as in an unsaturated fatty acid, can result in different structures for the same fatty acid composition. When the hydrogen atoms are bonded to the same side of the carbon chain, it is called a cis fatty acid. Because the hydrogen atoms are on the same side, the carbon chain has a bent structure and melt at a lower temperature. Naturally occurring fatty acids usually have a cis configuration.

In a trans fatty acid, the hydrogen atoms are attached on opposite sides of the carbon chain. Unlike cis fatty acids, most trans fatty acids are not found naturally in foods, but are a result of a process called hydrogenation. Hydrogenation is the process of adding hydrogen to the carbon double bonds, thus making the fatty acid saturated (or less unsaturated, in the case of partial hydrogenation), the carbon chain straighter in shape, and increasing the melting point. This is how vegetable oils are converted into semisolid fats for use in the manufacturing process.

According to the ongoing Harvard Nurses Health Study, trans fatty acids have been associated with increased risk for coronary heart disease because of the way they negatively impact blood cholesterol levels.Harvard School of Public Health. “It’s Time to End the Low-Fat Myth.” Introduction to “Fats and Cholesterol: Out with the Bad, In with the Good” in *The Nutrition Source*. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/#references.

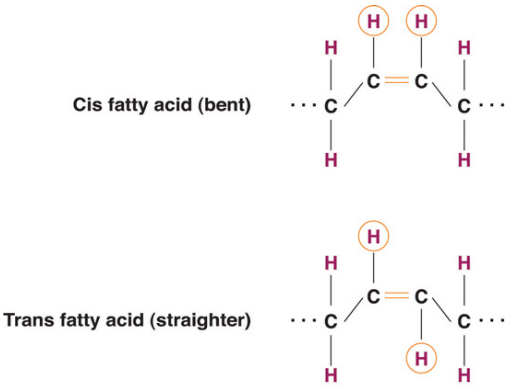


***Figure 4.3.3**: Cis and trans double bonds.*

Interestingly, some naturally occurring trans fats do not pose the same health risks as their artificially engineered counterparts. These trans fats are found in ruminant animals such as cows, sheep, and goats, resulting in trans fatty acids being present in our meat, milk, and other dairy product supply. Reports from the US Department of Agriculture (USDA) indicate that these trans fats comprise 15 to 20 percent of the total trans-fat intake in our diet. While we know that trans fats are not exactly harmless, it seems that any negative affect naturally occurring trans fats have are counteracted by the presence of other fatty acid molecules in these animal products, which work to promote human health.

Nonessential and Essential Fatty Acids

Fatty acids are vital for the normal operation of all body systems. The circulatory system, respiratory system, integumentary system, immune system, brain, and other organs require fatty acids for proper function. The body is capable of synthesizing most of the fatty acids it needs from food. These fatty acids are known as non-essential fatty acids. However, there are some fatty acids that the body cannot synthesize and these are called essential fatty acids. It is important to note that non-essential fatty acids don't mean unimportant; the classification is based solely on the ability of the body to synthesize the fatty acid. These fatty acids, alpha-linolenic acid, and linoleic acid are required in the diet. Without these fatty acids, infants fail to grow and have poor vision, the skin becomes scaly, reproductive processes fail, and one experiences poor immunity and susceptibility to infectious diseases.

Essential fatty acids must be obtained from food. They fall into two categories—omega-3 and omega-6. The 3 and 6 refer to the position of the first carbon double bond and the omega refers to the methyl end of the chain. Omega-3 and omega-6 fatty acids are precursors to important compounds called eicosanoids. Eicosanoids are powerful hormones that control many other hormones and important body functions, such as the central nervous system and the immune system. Eicosanoids derived from omega-6 fatty acids are known to increase blood pressure, immune response, and inflammation. In contrast, eicosanoids derived from omega-3 fatty acids are known to have heart-healthy effects. Given the contrasting effects of the omega-3 and omega-6 fatty acids, a proper dietary balance between the two must be achieved to ensure optimal health benefits.

Some linoleic acid (omega-6) is converted to arachidonic acid within our body .

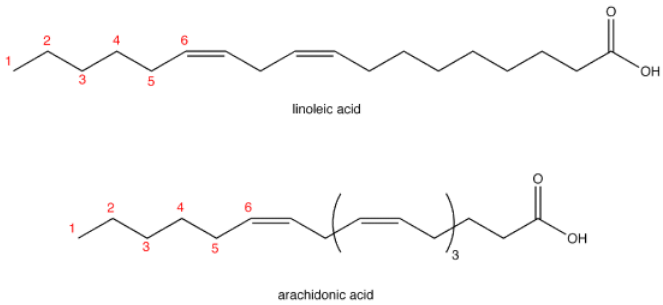


Figure 4.3.4: Omega-6 fatty acid showing first doubly bonded carbon atom from the methyl group is the sixth carbon atom.

A small percent, about 17%, of dietary alpha-linolenic acid is converted to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Omega-3 fatty acids are involved in regulating a variety of processes including blood pressure, muscle contractions, blood clotting, immune cell production and blood triglyceride.

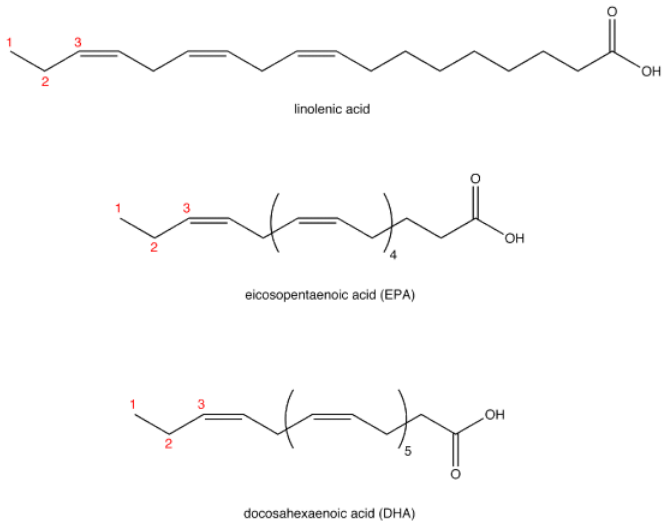


Figure 4.3.5*: Omega-3 fatty acids showing first doubly bonded carbon atom from the methyl group is the third carbon atom.*

Essential fatty acids play an important role in the life and death of cardiac cells, immune system function, and blood pressure regulation. Docosahexaenoic acid (DHA) is an omega-3 essential fatty acid shown to play important roles in synaptic transmission in the brain during fetal development.

Some excellent sources of omega-3 and omega-6 essential fatty acids are fish, flaxseed oil, hemp, walnuts, and leafy vegetables. Because these essential fatty acids are easily accessible, essential fatty acid deficiency is extremely rare.

Tools for Change

It is important to strike a proper balance between omega-3 and omega-6 fats in your diet. Research suggests that a diet that is too high in omega-6 fats distorts the balance of proinflammatory agents, promoting chronic inflammation and causing the potential for health problems such as asthma, arthritis, allergies, or diabetes. Omega-6 fats compete with omega-3 fats for enzymes and will actually replace omega-3 fats. The typical western diet is characterized by an excessive consumption of foods high in omega-6 fatty acids. To gain proper balance between the two, increase your omega-3 fat intake by eating more fatty fish or other sources of omega-3 fatty acids at least two times per week.

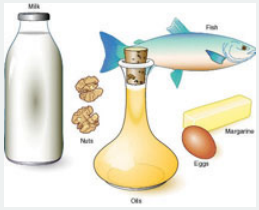


Figure 4.3.6: There are many sources of omega-3 foods.

Fatty-Acid Composition in the Diet and in the Body

The fatty-acid profile of the diet directly correlates to the tissue lipid profile of the body. It may not solely be the quantity of dietary fat that matters. More directly, the type of dietary fat ingested has been shown to affect body weight, composition, and metabolism. The fatty acids consumed are often incorporated into the triacylglycerols within the body. Evidence confirms that saturated fatty acids are linked to higher rates of weight retention when compared to other types of fatty acids. Alternatively, the fatty acids found in fish oil are proven to reduce the rate of weight gain as compared to other fatty acids.Mori, T. “Dietary fish oil upregulates intestinal lipid metabolism and reduces body weight gain in C57BL/6J mice.” *J Nutr*. 2007 Dec;137(12):2629-34. http://www.ncbi.nlm.nih.gov/pubmed/18029475

Phospholipids

Like triacylglycerols, phospholipids have a glycerol backbone. But unlike triacylglycerols, phospholipids are diglycerides (two fatty-acid molecules attached to the glycerol backbone) while their third fatty-acid chain has a phosphate group coupled with a nitrogen-containing group. This unique structure makes phospholipids water soluble. Phospholipids are what we call amphiphilic—

the fatty-acid sides are hydrophobic (dislike water) and the phosphate group is hydrophilic (likes water). Egg yolks, liver, soybeans, and peanuts are rich in phospholipids.

In the body, phospholipids bind together to form cell membranes. The amphiphilic nature of phospholipids governs their function as components of cell membranes. The phospholipids form a double layer in cell membranes, thus effectively protecting the inside of the cell from the outside environment while at the same time allowing for transport of fat and water through the membrane. Phospholipids are also important for maintaining the cell's integrity and regulation of immune, cardiovascular, and muscular systems.

Phospholipids are ideal emulsifiers that can keep oil and water mixed. Emulsions are mixtures of two liquids that do not mix. Without emulsifiers, the fat and water content would be separated within the food. Lecithin (phosphatidylcholine), found in egg yolk, honey, and mustard, is a popular food emulsifier. Mayonnaise demonstrates lecithin's ability to blend vinegar and oil to create the stable, spreadable condiment that so many enjoy. Food emulsifiers play an important role in making the appearance of food appetizing. Adding emulsifiers to sauces and creams not only enhances their appearance but also increases their freshness.

Lecithin's crucial role within the body is clear because it is present in every cell throughout the body; 28 percent of brain matter is composed of lecithin and 66 percent of the fat in the liver is lecithin. Many people attribute health-promoting properties to lecithins, such as its ability to lower blood cholesterol and aid with weight loss. There are several lecithin supplements on the market broadcasting these claims. However, as the body can make most phospholipids, it is not necessary to consume them in a pill. The body makes all of the lecithin that it needs.

Sterols

Sterols have a very different structure from triacylglycerols and phospholipids. Most sterols do not contain any fatty acids but rather multi-ring structures. They are complex molecules that contain interlinking rings of carbon atoms, with side chains of carbon, hydrogen, and oxygen attached. They may be a clear, waxy substance, soluble in lipid, and lipophilic (lipid friendly).

Cholesterol is the best-known sterol because of its role in heart disease. It forms a large part of the plaque that narrows the arteries in atherosclerosis. In stark contrast, cholesterol does have specific beneficial functions to perform in the body. Like phospholipids, cholesterol is present in all body cells as it is an important substance in cell membrane structure. Approximately 25 percent of the cholesterol in the body is localized in brain tissue. Cholesterol is used in the body to make a number of important things, including vitamin D, glucocorticoids, bile, and the sex hormones, progesterone, testosterone, and estrogens.

Although cholesterol is preceded by its infamous reputation, it is clearly a vital substance in the body that poses a concern only when there is an excess accumulation of it in the blood. Like lecithin, the body can synthesize cholesterol.

Phytosterols and phytostanols are two other forms of sterols found in our diet. You will find these in some plants and animals. Notably, the sterols found in plants resemble cholesterol in structure. However, plant sterols inhibit cholesterol absorption in the human body, which can contribute to lower cholesterol levels.

Key Takeaways

- Three fatty acids combine with one glycerol to make a triacylglycerol, the body's storage form of fat.
- The carbon chain of fatty acids can be saturated (filled with hydrogen), monounsaturated (with one point of unsaturation and possessing one carbon-carbon double bond), or polyunsaturated (with more than one point of unsaturation and possessing two or more double-carbon bonds)
- The structure and length of a fatty acid determines whether it is solid or liquid at room temperature.
- Essential fatty acids cannot be synthesized by the body and must be included in the diet. Omega-3 and omega-6 fatty acids have opposing functions and must be consumed in proper balance to promote health.
- Fatty acids in food influence the composition of fatty acids in the body.
- Phospholipids are diglycerides with a phosphate-nitrogen group in place of the third fatty-acid chain. They are ideal emulsifiers as they keep oil and water mixed.
- Sterols contain a multi-ring structure. Cholesterol serves important body functions such as vitamin D and hormone synthesis and is important in cell membrane and brain structure.

Discussion Starters

1. List the oils, snacks, spreads, or sauces in your home. Do they contain saturated or unsaturated fatty acids?

2. Name the characteristic that differentiates a triacylglycerol from a phospholipid. Describe the properties of phospholipids. Discuss their role in forming cell membranes. Explain their role as an emulsifier.
3. Think about your favorite restaurant and the food you like to order there. What type of fatty acids does a typical meal that you eat there have? Discuss the health benefits and possible drawbacks. What foods would you add to enhance your meal? What foods should you consider avoiding?

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4.4: Digestion and Absorption of Lipids

Learning Objectives

- Summarize the steps in lipid digestion and absorption.
- Explain how lipids are used for energy and stored in the body.

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-based, how does the body break down fat and make it available for the various functions it must perform in the human body?

From the Mouth to the Stomach

The first step in the digestion of triacylglycerols and phospholipids begins in the mouth as lipids encounter saliva. Next, the physical action of chewing coupled with the action of emulsifiers enables the digestive enzymes to do their tasks. The enzyme lingual lipase, along with a small amount of phospholipid as an emulsifier, initiates the process of digestion and starts the breakdown of triacylglycerides. These actions cause the fats to become more accessible to the digestive enzymes. As a result, the fats become tiny droplets and separate from the watery components.

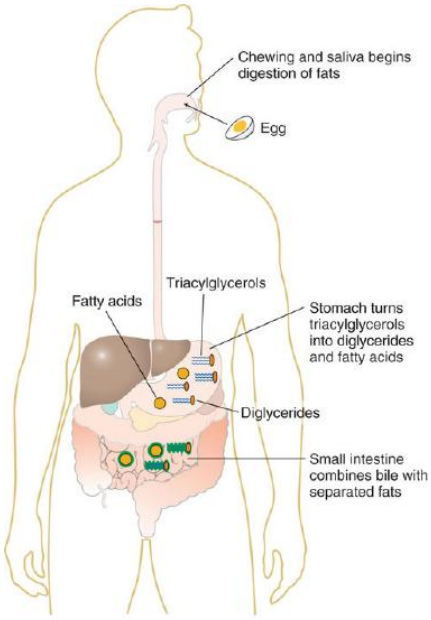


Figure 4.4.1: Lipid Digestion

In the stomach, gastric lipase starts to break down triacylglycerols into diglycerides and fatty acids. Within two to four hours after eating a meal, roughly 30 percent of the triacylglycerols are converted to diglycerides and fatty acids. The stomach's churning and contractions help to disperse the fat molecules, while the diglycerides derived in this process act as further emulsifiers. However, even amid all of this activity, very little fat digestion occurs in the stomach.

Going to the Bloodstream

As stomach contents enter the small intestine, the digestive system sets out to manage a small hurdle, namely, to combine the separated fats with its own watery fluids. The solution to this hurdle is bile. Bile contains bile salts, lecithin, and substances derived from cholesterol so it acts as an emulsifier. It attracts and holds on to fat while it is simultaneously attracted to and held on to by water. Emulsification increases the surface area of lipids over a thousand-fold, making them more accessible to the digestive enzymes.

Once the stomach contents have been emulsified, fat-breaking enzymes work on the triacylglycerols and diglycerides to severe fatty acids from their glycerol foundations. As pancreatic lipase enters the small intestine, it breaks down the fats into free fatty acids and monoglycerides. Yet again, another hurdle presents itself. How will the fats pass through the watery layer of mucus that coats the absorptive lining of the digestive tract? As before, the answer is bile. Bile salts envelop the fatty acids and

monoglycerides to form micelles. Micelles have a fatty acid core with a water-soluble exterior. This allows efficient transportation to the intestinal microvillus. Here, the fat components are released and disseminated into the cells of the digestive tract lining.

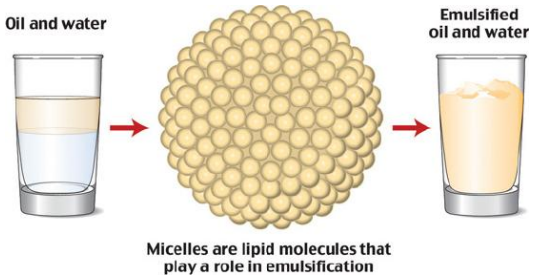


Figure 4.4.2: Fats can travel through the watery environment of the body due to the process of emulsification.

Just as lipids require special handling in the digestive tract to move within a water-based environment, they require similar handling to travel in the bloodstream. Inside the intestinal cells, the monoglycerides and fatty acids reassemble themselves into triacylglycerols. Triacylglycerols, cholesterol, and phospholipids form lipoproteins when joined with a protein carrier. Lipoproteins have an inner core that is primarily made up of triacylglycerols and cholesterol esters (a cholesterol ester is a cholesterol linked to a fatty acid). The outer envelope is made of phospholipids interspersed with proteins and cholesterol. Together they form a chylomicron, which is a large lipoprotein that now enters the lymphatic system, bypassing the liver, and will soon be released into the bloodstream via the jugular vein in the neck. Chylomicrons transport food fats perfectly through the body's water-based environment to specific destinations such as the liver and other body tissues. Entrance into the bloodstream can last up to 14 hours with the peak 30 to 3 hours post-meal.

Cholesterols are poorly absorbed when compared to phospholipids and triacylglycerols. Cholesterol absorption is aided by an increase in dietary fat components and is hindered by high fiber content. This is the reason that a high intake of fiber is recommended to decrease blood cholesterol. Foods high in fiber such as fresh fruits, vegetables, and oats can bind bile salts and cholesterol, preventing their absorption and carrying them out of the colon.

If fats are not absorbed properly as is seen in some medical conditions, a person's stool will contain high amounts of fat. If fat malabsorption persists the condition is known as steatorrhea. Steatorrhea can result from diseases that affect absorption, such as Crohn's disease and cystic fibrosis.

Brief Overview of Triacylglyceride Metabolism

Fat cells are located in special depots in your body and there are many different locations, for example, abdominal (belly fat) or the hips. Also, a small amount of fat is stored in skeletal muscle too. See Figure 4.4.3 to see an adipocyte in skeletal muscle.

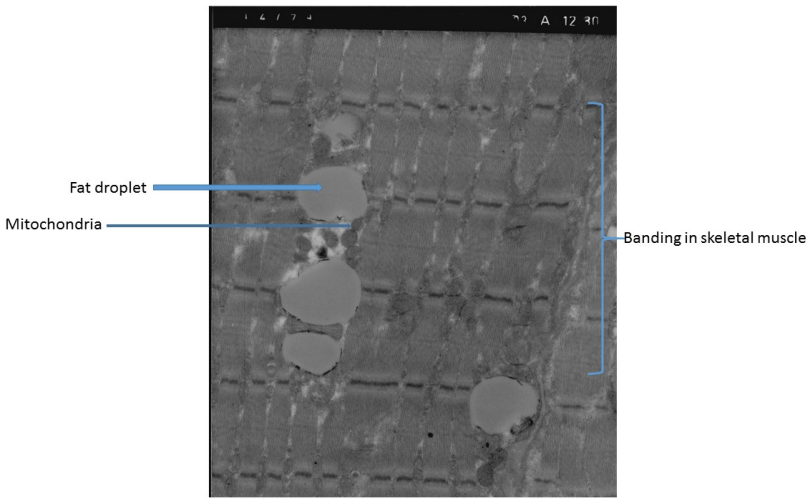


Figure 4.4.3: Adipocyte or fat cell within skeletal muscle.

Once stored in the adipocyte (fat cell), the fat will remain there until it is needed to produce energy. Lipolysis is the process by which the triacylglyceride is removed from the lipid droplet with the fat cells, broken into 3 fatty acids and glycerol. The glycerol is

secreted from the cells along with some but not all of the fatty acids. These are transported to the liver where the glycerol may be converted to glucose. The fatty acids may be converted to ketones or transported to other cells and burn to produce ATP.

The Truth about Storing and Using Body Fat

Before the prepackaged food industry, fitness centers, and weight-loss programs, our ancestors worked hard to even locate a meal. They made plans, not for losing those last ten pounds to fit into a bathing suit for vacation, but rather for finding food. Today, this is why we can go long periods without eating, whether we are sick with a vanished appetite, our physical activity level has increased, or there is simply no food available. Our bodies reserve fuel for a rainy day.

One way the body stores fat involves the body transforms carbohydrates into glycogen that is in turn stored in the muscles for energy. When the muscles reach their capacity for glycogen storage, the excess is returned to the liver, where it is converted into triacylglycerols and then stored as fat.

In a similar manner, much of the triacylglycerols the body receives from food is transported to fat storehouses within the body if not used for producing energy. The chylomicrons are responsible for shuttling the triacylglycerols to various locations such as the muscles, breasts, external layers under the skin, and internal fat layers of the abdomen, thighs, and buttocks where they are stored by the body in adipose tissue for future use. How is this accomplished? Recall that chylomicrons are large lipoproteins that contain a triacylglycerol and fatty-acid core. Capillary walls contain an enzyme called lipoprotein-lipase that dismantles the triacylglycerols in the lipoproteins into fatty acids and glycerol, thus enabling these to enter into the adipose cells. Once inside the adipose cells, the fatty acids and glycerol are reassembled into triacylglycerols and stored for later use. Muscle cells may also take up the fatty acids and use them for muscular work and for generating energy. When a person's energy requirements exceed the amount of available fuel presented from a recent meal or extended physical activity has exhausted glycogen energy reserves, fat reserves are retrieved for energy utilization.

As the body calls for additional energy, the adipose tissue responds by dismantling its triacylglycerols and dispensing glycerol and fatty acids directly into the blood. Upon receipt of these substances, the energy-hungry cells break them down further into tiny fragments. These fragments go through a series of chemical reactions that yield energy, carbon dioxide, and water.

Key Takeaways

- In the stomach fat is separated from other food substances. In the small intestines, bile emulsifies fats while enzymes digest them. The intestinal cells absorb the fats.
- Long-chain fatty acids form a large lipoprotein structure called a chylomicron that transports fats through the lymph system.
- Chylomicrons are formed in the intestinal cells and carry lipids from the digestive tract into circulation.
- Short- and medium-fatty chains can be absorbed directly into the bloodstream via the portal system from the intestinal microvillus because they are water-soluble.
- Cholesterol absorption is hindered by foods high in fiber.
- When energy supplies are low the body utilizes its stored fat reserves for energy.

Discussion Starters

- Explain the role of emulsifiers in fat digestion.
- Name the part of the digestive system where most fat digestion and absorption occurs.
- Describe the role of bile salts in the digestion of triacylglycerols and phospholipids.
- Define chylomicron.
- Explain how fiber-rich foods affect cholesterol absorption.
- Discuss the body's processes for using energy.

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4.5: Understanding Blood Cholesterol

Learning Objectives

- Compare and contrast the roles of LDLs and HDLs in your body.
- Explain the purpose of a blood lipid profile and identify healthy ranges.

You may have heard of the abbreviations LDL and HDL with respect to heart health. These abbreviations refer to low-density lipoprotein (LDL) and high-density lipoprotein (HDL), respectively. Lipoproteins are characterized by size, density, and composition. As the size of the lipoprotein increases, the density decreases. This means that HDL is smaller than LDL. Why are they referred to as “good” and “bad” cholesterol? What should you know about these lipoproteins? This section will help you answer these questions.

Short chain fatty acids and medium chain fatty acids can be carried in the bloodstream attached to the protein, albumin. Long chain fatty acids are much less water soluble so require special transport within lipoproteins. After a meal, during digestion and absorption, long chain fatty acids are packaged into chylomicrons and transported throughout the body in these micelles.

Cholesterol is found only in animal products. Also, our body makes cholesterol because it is important for the synthesis of bile and hormones. The amount of cholesterol synthesized is related to the amount found in the blood. This is also influenced by the amount of cholesterol in your diet.

Major Lipoproteins

Recall that chylomicrons are transporters of fats throughout the watery environment within the body. After about ten hours of circulating throughout the body, chylomicrons gradually release their triacylglycerols into cells until all that is left of their composition is cholesterol-rich remnants. These remnants are used as raw materials by the liver to formulate specific lipoproteins. Following is a list of the various lipoproteins and their functions:

- VLDLs. Very low-density lipoproteins are made in the liver from remnants of chylomicrons and transport triacylglycerols from the liver to various tissues in the body. As the VLDLs travel through the circulatory system, the lipoprotein lipase strips the VLDL of triacylglycerols. As triacylglycerol removal persists, the VLDLs become intermediate-density lipoproteins.
- IDLs. Intermediate-density lipoproteins transport a variety of fats and cholesterol in the bloodstream and are a little under half triacylglycerol in composition. While traveling in the bloodstream, cholesterol is gained from other lipoproteins while circulating enzymes strip its phospholipid component. When IDLs return to the liver, they are transformed into low-density lipoprotein.
- LDLs. As low-density lipoproteins are commonly known as the “bad cholesterol” it is imperative that we understand their function in the body so as to make healthy dietary and lifestyle choices. LDLs carry cholesterol and other lipids. They are comprised of very small amounts of triacylglycerols, and house over 50 percent cholesterol and cholesterol esters. LDL is developing as the lipid is removed from VLDL by the body's cells. How does the body receive the lipids contained therein? As the LDLs deliver cholesterol and other lipids to the cells, each cell’s surface has receptor systems specifically designed to bind with LDLs. Circulating LDLs in the bloodstream bind to these LDL receptors and are consumed. Once inside the cell, the LDL is taken apart and its cholesterol is released. In liver cells these receptor systems aid in controlling blood cholesterol levels as they bind the LDLs. A deficiency of these LDL binding mechanisms will leave a high quantity of cholesterol traveling in the bloodstream, which can lead to heart disease or atherosclerosis. Diets rich in saturated fats will prohibit the LDL receptors. Thus, LDL receptors are critical for regulating cholesterol levels.
- HDLs. High-density lipoproteins are responsible for carrying cholesterol out of the bloodstream and into the liver, where it is either reused or removed from the body with bile. HDLs have a very large protein composition coupled with low cholesterol content (20 to 30 percent) compared to the other lipoproteins. Hence, these high-density lipoproteins are commonly called “good cholesterol.”

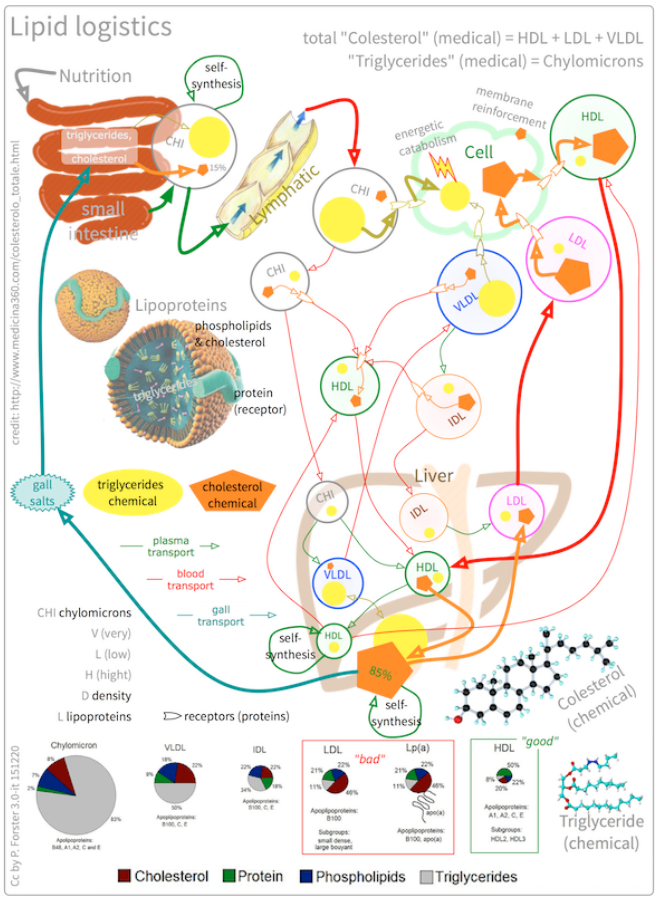


Figure 4.5.1 Formation of the major lipoproteins.

Contrasting LDL and HDL

Heart attack and atherosclerosis are conditions often caused by cholesterol that has accumulated and thickened in the walls of arteries. HDLs and LDLs are directly connected to these life-threatening ailments. By comparing and contrasting the roles each of these lipoproteins serves in the health of heart and blood vessels, you will be able to construct and evaluate a plan of action for your personal health. Consider the following lipoprotein facts:

- **LDL/HDL composition**. LDL is approximately 25 percent protein and 75 percent cholesterol and other fats. LDL is bigger (yet lighter) and richer in cholesterol than HDL. HDL is 50 percent protein and 50 percent cholesterol and other fats. HDL is smaller, more dense, and richer in protein.
- **LDL/HDL function**. LDLs carry cholesterol into cells for normal usage, but LDLs can also deposit cholesterol into the walls of blood vessels, which can lead to harmful disease. HDLs scavenge excess cholesterol from the cells, tissues, and blood vessels and deliver these back to the liver, where these are either reused or excreted.
- **LDL/HDL and inflammation**. LDLs carry lipids that are proinflammatory and may contribute to heart disease. HDLs transport lipids that are anti-inflammatory and may reduce the occurrence of heart disease.
- **LDL/HDL warnings**. High LDL values warn of increased health risks for heart disease, while high HDL values indicate a reduced risk for heart disease.
- **Oxidized LDL**. LDLs become more dangerous when oxidized. Oxidation is defined as the loss of electrons between two substances via a chemical reaction. If an LDL oxidation occurs, the oxidized LDL is left unstable. Oxidized LDL can speed up the process of plaque formation in the arteries. It is believed to hasten the deposition of cholesterol into the arterial walls and to induce a chronic inflammatory effect throughout the body's vast network of vessels. This activity promotes atherosclerosis and significantly increases risks for heart attack or stroke.

Blood Cholesterol Recommendations

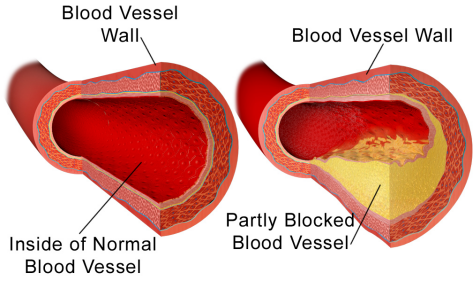
For healthy total blood cholesterol, the desired range you would want to maintain is under 200 mg/dL. More specifically, when looking at individual lipid profiles, a low amount of LDL and a high amount of HDL prevents excess buildup of cholesterol in the arteries and wards off potential health hazards. An LDL level of less than 100 milligrams per deciliter is ideal while an LDL level above 160 milligrams per deciliter would be considered high. In contrast, a low value of HDL is a telltale sign that a person is living with major risks for disease. Values of less than 40 milligrams per deciliter for men and 50 milligrams per deciliter for women mark a risk factor for developing heart disease. In short, elevated LDL blood lipid profiles indicate an increased risk of heart attack, while elevated HDL blood lipid profiles indicate a reduced risk. An excellent resource for more

information is the following guide from the National Cholesterol Education Program: ATP III Guidelines At-A-Glance Quick Desk Reference - National Heart, Lung, and Blood Institute

The University of Maryland Medical Center reports that omega-3 fatty acids promote lower total cholesterol and lower triacylglycerols in people with high cholesterol.University of Maryland Medical Center. “Omega-3 fatty acids.” http://www.umm.edu/altmed/articles/omega-3-000316.htm It is suggested that people consume omega-3 fatty acids such as alpha-linolenic acid in their diets regularly. Polyunsaturated fatty acids are especially beneficial to consume because they both lower LDL and elevate HDL, thus contributing to healthy blood cholesterol levels. The study also reveals that saturated and trans fatty acids serve as catalysts for the increase of LDL cholesterol. Additionally, trans fatty acids lower HDL levels, which can impact negatively on total blood cholesterol.

Cardiovascular Disease

According to the Centers for Disease Control and Prevention (CDC), heart disease is the leading cause of death in the United States (Centers for Disease Control and Prevention. “Leading Causes of Death.” Last updated September 6, 2011. http://www.cdc.gov/nchs/fastats/lcod.htm). The disease generally starts with arteriosclerosis, or a thickening, loss of elasticity, and calcification of the arterial walls. Atherosclerosis is a type of arteriosclerosis often defined as a "hardening of the arteries." It is a chronic condition so common that most people show signs of it by the time they turn thirty. Arteries start to narrow and harden when fats accumulate along their inner walls and form plaques. A plaque is made of fat, cholesterol, calcium, and other substances found in blood.



Normal and Partly Blocked Blood Vessel

Figure 4.5.2: Illustration comparing a normal blood vessel and partially blocked vessel due to atherosclerotic plaque build-up. Plaque formation along arterial walls impedes blood flow and can create a thrombus, or stationary blood clot. from BruceBlaus (via Wikipedia). For a video of the process click here.

Plaque formation causes arteries to narrow and harden, which elevates blood pressure because the vessels can’t expand effectively to accommodate blood pulses. Higher blood pressure strains the heart and causes more damage. Arterial walls can become so weakened due to high blood pressure that they balloon and form what is known as an aneurysm. If the aneurysm bursts, it becomes a life-threatening event. The plaques themselves can also rupture due to a spike in blood pressure or a tremor along an arterial wall, and the body responds to this perceived injury by forming blood clots. These clots are serious health threats, whether they are stationary (a thrombus) or moving (an embolus). A stable clot can slowly kill off surrounding tissue by restricting oxygen (called ischemia) to the area, or grow so big that it blocks blood circulation and causes thrombosis. When a moving clot becomes stuck in an artery too small for its passage, it cuts off blood flow and causes cell death. This is referred to as an embolism. Blood clots in heart and brain arteries can cause heart attacks or strokes, respectively.

Table 4.5.1: The Risk Factors for Cardiovascular Disease

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases for men at forty-five, and for women at fifty-five. • **Sex.** Men have a higher risk than women, though the risk for women steeply rises after menopause. • **Family history.** The more family members who have heart disease, the greater the risk.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of atherosclerosis. • **Obesity.** Excess weight worsens other risk factors. • **Diabetes.** This condition is associated with an increased risk of heart disease. Both types have certain risk factors in common, including obesity and high blood pressure. • **Physical inactivity.** Lack of exercise is associated with heart disease. • **Cholesterol levels.** High levels of blood cholesterol can increase the risk. A high level of low-density lipoprotein (LDL), or the “bad” cholesterol, is a common contributing factor. However, a low level of high-density lipoprotein (HDL), or “good” cholesterol, can also promote atherosclerosis. • **Stress**. Excess stress is a risk factor for heart disease. • **Hypertension**. High blood pressure left untreated can cause heart disease.

Steps to Reducing the Risk of Cardiovascular Disease

Diet and nutrition can play a significant role in reducing the risk of cardiovascular disease. It is helpful to lower sodium intake, increase consumption of dietary fiber, and limit consumption of saturated fat which promotes plaque formation. In addition, it is important to replace refined starches and added sugar, which can boost triglycerides, with whole grains, fruits, and vegetables. Eating foods rich in omega-3 fatty acids, especially fish, using alcohol in moderation, and opting for low or no-fat dairy products can all help reduce your cardiovascular disease risk. Emphasizing vegetable-based sources of protein, such as beans and legumes, can be beneficial, as well as consuming more soy products. It is also important to maintain a healthy weight, manage cholesterol levels, and avoid smoking or chewing tobacco.

Your total fat intake should be less than 35% of your total energy intake and that fat should be distributed 1/3 saturated, 1/3 monounsaturated, and 1/3 polyunsaturated fat. Here are suggestions on ways to reduce your saturated fat intake: 1) reduce your animal fat intake by selecting lean cuts of meat, trimming the fat, removing the skin and/or baking and broiling instead of frying; 2) drink fat-free or 1% milk, and 3) reduce your intake of coconut and palm oils which are rich in saturated fat. You will find these fats in commercial baked goods. Also, replace your saturated fat intake with monounsaturated fat such as canola oil, olive oil and/or nuts. Polyunsaturated fats should comprise 1/3 of your dietary fat intake. You find these fats in vegetable oil and fish oil. Finally, reduce your intake of trans fatty acids which are found in hydrogenated or partially hydrogenated vegetable oil, deep fried foods, hard margarine and commercial baked goods.

Tools for Change

Being conscious of the need to reduce cholesterol means limiting the consumption of saturated fats and trans fats. Remember that saturated fats found in some meat, whole-fat dairy products, and tropical oils elevate your total cholesterol. Trans fats, such as the ones often found in margarines, processed cookies, pastries, crackers, fried foods, and snack foods also elevate your cholesterol levels. Read and select from the following suggestions as you plan ahead:

Soluble fiber reduces cholesterol absorption in the bloodstream. Try eating more oatmeal, oat bran, kidney beans, apples, pears, citrus fruits, barley, and prunes.

Fatty fish are heart-healthy due to high levels of omega-3 fatty acids that reduce inflammation and lower cholesterol levels. Consume mackerel, lake trout, herring, sardines, tuna, salmon, and halibut. Grilling or baking is best to avoid unhealthy trans fats that could be added from frying oil.

Walnuts, almonds, peanuts, hazelnuts, pecans, some pine nuts, and pistachios all contain high levels of unsaturated fatty acids that aid in lowering LDL. Make sure the nuts are raw and unsalted. Avoid sugary or salty nuts. One ounce each day is a good amount.

Olive oil contains a strong mix of antioxidants and monounsaturated fat, and may lower LDL while leaving HDL intact. Two tablespoons per day in place of less healthy saturated fats may contribute to these heart-healthy effects without adding extra calories. Extra virgin olive oil promises a greater effect, as the oil is minimally processed and contains more heart-healthy antioxidants.

Testing Your Lipid Profile

The danger of consuming foods rich in cholesterol and saturated and trans fats cannot be overemphasized. Regular testing can provide the foreknowledge necessary to take action to help prevent any life-threatening events.

Current guidelines recommend testing for anyone over age twenty. If there is a family history of high cholesterol, your healthcare provider may suggest a test sooner than this. Testing calls for a blood sample to be drawn after nine to twelve hours of fasting for an accurate reading. (By this time, most of the fats ingested from the previous meal have circulated through the body and the concentration of lipoproteins in the blood will have stabilized.)

According to the National Institutes of Health (NIH), the following total cholesterol values are used to target treatment:National Heart, Lung, and Blood Institute, National Institutes of Health. “High Blood Cholesterol: What You Need to Know.” NIH Publication No. 05-3290. (Revised June 2005). Section 2.01. www.nhlbi.nih.gov/health/public/heart/chol/wyntk.htm.

- Desirable. Under 200 milligrams per deciliter
- Borderline high. 200–239 milligrams per deciliter
- High risk. 240 milligrams per deciliter and up

According to the NIH, the following desired values are used to measure an overall lipid profile:

- LDL. Less than 160 milligrams per deciliter (if you have heart disease or diabetes, less than 100 milligrams per deciliter)
- HDL. Greater than 40–60 milligrams per deciliter
- Triacylglycerols. 10–150 milligrams per deciliter
- VLDL. 2–38 milligrams per deciliter



***Video 4.5.1**: Understanding Cholesterol (www.youtube.com/v/hjv5OnbcjE8)*

Key Takeaways

- Some of the major lipoproteins are VLDL, IDL, LDL, and HDL.
- VLDL delivers triacylglycerols and other lipids to the body's tissues and slowly becomes IDL. The liver uses IDL to create LDL, the main transporter of cholesterol.
- LDL, or "bad" cholesterol, has low protein composition and high cholesterol content. High levels of LDL have been shown to increase the risks for heart disease.
- HDL or "good'' cholesterol has a larger proportion of protein and a small cholesterol composition. HDL scavenges excess cholesterol and returns it to the liver for reuse or disposal. A high level of HDL reduces the risk for heart disease.
- It is important to maintain a healthy lipid profile with values as recommended by the NIH in order to minimize the risk of heart disease. Consuming omega-3 fatty acids can help maintain a healthy blood lipid profile.

Discussion Starters

1. Summarize the roles of LDL and HDL. Explain why LDL is termed "bad" cholesterol and why HDL is termed "good" cholesterol.
2. Explain oxidation and how it affects LDL and contributes to heart disease.
3. Describe the procedure and blood test for testing your lipid profile.
4. Recall the desired lipid values set out by the NIH. Identify the desired total cholesterol, LDL, HDL, VLDL, and triacylglycerol values.
5. How has learning this information affected your motivation to eat a more healthy diet?

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4.6: Balancing Your Diet with Lipids

Learning Objectives

- Describe the current recommended intake levels for lipids.
- Recognize sources of saturated and unsaturated fats, essential fatty acids, and trans fats.
- Discuss the functions of essential fatty acids, such as omega-3, and where to find them in foods.

You may reason that if some fats are healthier than other fats, why not consume as much healthy fat as desired? Remember, everything in moderation. As we review the established guidelines for daily fat intake, the importance of balancing fat consumption with proper fat sources will be explained.

Recommended Fat Intake

The acceptable macronutrient distribution range (AMDR) from the Dietary Reference Intake Committee for adult fat consumption is as follows:Institute of Medicine. "Dietary Reference Intakes: Macronutrients." Accessed October 5, 2012. www.iom.edu/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI _Macronutrients.pdf

- Fat calories should be limited to 20–35 percent of total calories with most fats coming from polyunsaturated and monounsaturated fats, such as those found in fish, nuts, and vegetable oils.
- Consume fewer than 10 percent of calories from saturated fats. Some studies suggest that lowering the saturated fat content to less than 7 percent can further reduce the risk of heart disease.
- Keep the consumption of trans fats (any food label that reads hydrogenated or partially hydrogenated oil) to a minimum, less than 1 percent of calories.
- Think lean and low-fat when selecting meat, poultry, milk, and milk products.

The current AMDR for child and adolescent fat consumption (for children over four) are as follows:

- For children between ages four and eighteen years, between 25 and 35 percent of caloric intake should be from fat.
- For all age groups, most fats should come from polyunsaturated and monounsaturated fats such as fish, nuts, and vegetable oils.

Identifying Sources of Fat

Population-based studies of American diets have shown that intake of saturated fat is more excessive than the intake of trans fat and cholesterol. Saturated fat is a prominent source of fat for most people as it is so easily found in animal fats, tropical oils such as coconut and palm oil, and full-fat dairy products. Oftentimes the fat in the diet of an average young person comes from foods such as cheese, pizza, cookies, chips, desserts, and animal meats such as chicken, burgers, sausages, and hot dogs. To aim for healthier dietary choices, the American Heart Association (AHA) recommends choosing lean meats and vegetable alternatives, choosing dairy products with low-fat content, and minimizing the intake of trans fats. The AHA guidelines also recommend consuming fish, especially oily fish, at least twice per week.American Heart Association. "Frequently Asked Questions About Fish." www.heart.org/HEARTORG/General/Frequently-Asked-Questions-About-Fish _UCM_306451_Article.jsp. These more appropriate dietary choices will allow for enjoyment of a wide variety of foods while providing the body with the recommended levels of fat from healthier sources. Evaluate the following sources of fat in your overall dietary pattern:

- **Monounsaturated fat.** This type of fat is found in plant oils. Common sources are nuts (almonds, cashews, pecans, peanuts, and walnuts) and nut products, avocados, extra virgin olive oil, sesame oil, high oleic safflower oil, sunflower oil, and canola oil.
- **Polyunsaturated fat.** This type of fat is found mainly in plant-based foods, oils, and fish. Common sources are nuts (walnuts, hazel nuts, pecans, almonds, and peanuts), soybean oil, corn oil, safflower oil, flaxseed oil, canola oil, and fish (trout, herring, and salmon).
- **Saturated fat.** This fat is found in animal products, dairy products (e.g. butter, cream), palm and coconut oils, and cocoa butter. Limit these products to less than 10 percent of your overall dietary fat consumption.
- **Trans fatty acids.** Stick margarines, fast foods, commercial baked goods, and some snack foods contain trans fats. Limit your consumption of these products to keep trans fats to less than 1 percent of your fat consumption.
- **Omega-3 fatty acids (alpha-linolenic acid).** Good sources of these are canola oil, flaxseed oil, soybean oil, olive oil, nuts, seeds, whole grains, legumes, and green leafy vegetables.

- **DHA and EPA.** Good sources of these are cod liver oil and fish such as tuna, herring, mackerel, salmon, and trout.
- **Omega-6 fatty acids (linoleic acid).** Eggs, poultry, most vegetable oils, wheat germ oil, whole grains, baked goods, and cereals contain these fatty acids. Omega-6 fatty acids are present abundantly in nuts and seeds such as flaxseeds, sunflower seeds, sesame seeds, and watermelon seeds.



Figure 4.6.1: Enjoy a delicious vegetable burger as an alternative to a traditional beef hamburger with French fries. (CC-SA_BY-2.0; divinemisscopa)

Omega-3 and Omega-6 Fatty Acids

Recall that the body requires fatty acids and is adept at synthesizing the majority of these from fat, protein, and carbohydrate. However, when we say *essential* fatty acid we are referring to the two fatty acids that the body cannot create on its own, namely, alpha-linolenic acid and linoleic acid.

- **Omega-3 Fatty Acids.** At the helm of the omega-3 fatty acid family is alpha-linolenic acid. From this fatty acid, the body can make eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Linolenic acid is found in nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed. EPA and DHA are found abundantly in fatty fish.
- **Omega-6 Fatty Acids.** At the helm of the omega-6 fatty acid family is linoleic acid. Like linolenic acid, the body uses linoleic acid to make other important substances such as arachidonic acid (ARA) that is used to make eicosanoids. Recall that eicosanoids perform critical roles in the body as they affect a broad spectrum of functions. The word *eicosanoid* originates from the Greek word *eicosa*, meaning twenty because this hormone is derived from ARA that is twenty carbon atoms in length. Eicosanoids affect the synthesis of all other body hormones and control all body systems, such as the central nervous system and the immune system. Among the many functions eicosanoids serve in the body, their primary function is to regulate inflammation. Without these hormones, the body would not be able to heal wounds, fight infections, or fight off illness each time a foreign germ presented itself. Eicosanoids work together with the body's immune and inflammation processes to play a major role in several important body functions, such as circulation, respiration, and muscle movement.

Attain the Omega-3 and Omega-6 Balance

As our food choices evolve, the sources of omega-6 fatty acids in our diets are increasing at a much faster rate than sources of omega-3 fatty acids. Omega-3s are plentiful in diets of nonprocessed foods where grazing animals and foraging chickens roam free, eating grass, clover, alfalfa, and grass-dwelling insects. In contrast, today's western diets are bombarded with sources of omega-6. For example, we have oils derived from seeds and nuts and from the meat of animals that are fed grain. Vegetable oils used in fast-food preparations, most snack-foods, cookies, crackers, and sweet treats are also loaded with omega-6 fatty acids. Also, our bodies synthesize eicosanoids from omega-6 fatty acids and these tend to increase inflammation, blood clotting, and cell proliferation, while the hormones synthesized from omega-3 fatty acids have just the opposite effect.

While omega-6 fatty acids are essential, they can be harmful when they are out of balance with omega-3 fatty acids. Omega-6 fats are required only in small quantities. Researchers believe that when omega-6 fats are out of balance with omega-3 fats in the diet they diminish the effects of omega-3 fats and their benefits. This imbalance may elevate the risks for allergies, arthritis, asthma, coronary heart disease, diabetes, and many types of cancer, autoimmunity, and neurodegenerative diseases, all of which are believed to originate from some form of inflammation in the body. The recommendations for the ratio of omega-3 to omega-6 fatty acids vary from 5:1 to 10:1.

What does this mean for you? If your diet is low in omega-3 fats to begin with, then most of your essential fatty acids are from omega-6s. Stop. Do not set up a proinflammatory environment. Attaining proper balance between omega-3 fatty acids and omega-6 fatty acids means learning to make healthy choices and replacing bad fats with good ones that promote health and well-being.

Key Takeaways

- The recommended fat intake for adults is 20–35 percent of your total caloric intake. Saturated fat must be less than 10 percent of your total caloric intake, and lowering this to 7 percent can further reduce the risks for heart disease. Trans fat should be less than 1 percent of total caloric intake.
- Nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed are excellent sources of monounsaturated and polyunsaturated fats.
- The polyunsaturated fatty acids linolenic and linoleic acids are used by the body to make substances that carry out many vital functions in the body.
- The omega-3 fatty-acid family includes alpha-linolenic acid, EPA, and DHA. The omega-6 fatty-acid family includes linoleic acid and ARA. DHA and ARA play crucial roles in brain and eye development. EPA and DHA found in fatty fish play important roles in inflammation reduction and disease prevention.
- Many people consume too many omega-6 fatty acids and not enough omega-3 fatty acids. Omega-3 fats and omega-6 fats are precursors to hormones that have opposing properties. A proper balance between both must be obtained to avoid health problems.

Discussion Starters

1. State the recommended intake of total fat, as well as saturated versus unsaturated fat, in the diet.
2. List sources of monounsaturated and polyunsaturated fats.
3. Summarize the important functions of essential fatty acids in the human body.
4. Explain why it is necessary to maintain a proper balance between omega-3 fat and omega-6 fat intake.
5. Record a food diary for one week. What foods do you most often consume? What type of fat dominates your diet? How can you alter your eating habits to promote better health? Outline steps you can take to replace saturated and trans fat in your diet.

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4.7: Lipids and the Food Industry

Learning Objectives

- Discuss reasons oils are hydrogenated and describe this process.
- Describe the health effects of trans fats.

What is the first thing that comes to mind when you read ingredients such as “partially hydrogenated oil” and “hydrogenated oil” on a food label? Do you think of heart disease, heart health, or atherosclerosis? Most people probably do not. As we uncover what hydrogenation is and why manufacturers use it, you will be better equipped to adhere to healthier dietary choices and promote your heart health.

Hydrogenation: The Good Gone Bad?

Figure 4.71 The fatty acid, oleic acid, in its cis and trans form.

Food manufacturers are aware that fatty acids are susceptible to attack by oxygen molecules because their points of unsaturation render them vulnerable in this regard. When oxygen molecules attack these points of unsaturation the modified fatty acid becomes oxidized. The oxidation of fatty acids makes the oil rancid and gives the food prepared with it an unappetizing taste. Because oils can undergo oxidation when stored in open containers, they must be stored in airtight containers and possibly be refrigerated to minimize damage from oxidation. Hydrogenation poses a solution that food manufacturers prefer.

When lipids are subjected to hydrogenation, the molecular structure of the fat is altered. Hydrogenation is the process of adding hydrogen to unsaturated fatty-acid chains, so that the hydrogen atoms are connected to the points of saturation and results in a more saturated fatty acid. Liquid oils that once contained more unsaturated fatty acids become semisolid or solid (upon complete hydrogenation) and behave like saturated fats. Oils initially contain polyunsaturated fatty acids. When the process of hydrogenation is not complete, for example, not all carbon double bonds have been saturated the end result is a partially hydrogenated oil. The resulting oil is not fully solid. Total hydrogenation makes the oil very hard and virtually unusable. Some newer products are now using fully hydrogenated oil combined with nonhydrogenated vegetable oils to create a usable fat.

Manufacturers favor hydrogenation as a way to prevent oxidation of oils and ensure longer shelf life. Partially hydrogenated vegetable oils are used in the fast food and processed food industries because they impart the desired texture and crispness to baked and fried foods. Partially hydrogenated vegetable oils are more resistant to breakdown from extremely hot cooking temperatures. Because hydrogenated oils have a high smoking point they are very well suited for frying. In addition, processed vegetable oils are cheaper than fats obtained from animal sources, making them a popular choice for the food industry.

Trans fatty acids occur in small amounts in nature, mostly in dairy products. However, the trans fats that are used by the food industry are produced from the hydrogenation process. Trans fats are a result of the partial hydrogenation of unsaturated fatty acids, which cause them to have a trans configuration, rather than the naturally occurring cis configuration.

Health Implications of Trans Fats

No trans fats! Zero trans fats! We see these advertisements on a regular basis. So widespread is the concern over the issue that restaurants, food manufacturers, and even fast-food establishments proudly tout either the absence or the reduction of these fats within their products. Amid the growing awareness that trans fats may not be good for you, let’s get right to the heart of the matter. Why are trans fats so bad?

Processing naturally occurring fats to modify their texture from liquid to semisolid and solid forms results in the development of trans fats, which have been linked to an increased risk for heart disease. Trans fats are used in many processed foods such as cookies, cakes, chips, doughnuts, and snack foods to give them their crispy texture and increased shelf life. However, because trans fats can behave like saturated fats, the body processes them as if they were saturated fats. Consuming large amounts of trans fats has been associated with tissue inflammation throughout the body, insulin resistance in some people, weight gain, and digestive troubles. In addition, the hydrogenation process robs the person of the benefits of consuming the original oil because hydrogenation destroys omega-3 and omega-6 fatty acids. The AHA states that, like saturated fats, trans fats raise LDL “bad cholesterol,” but unlike saturated fats, trans fats lower HDL “good cholesterol.” The AHA advises limiting trans-fat consumption to less than 1 percent.

How can you benefit from this information? When selecting your foods, steer clear of anything that says “hydrogenated,” “fractionally hydrogenated,” or “partially hydrogenated,” and read food labels in the following categories carefully:

- cookies, crackers, cakes, muffins, pie crusts, pizza dough, and breads
- stick margarines and vegetable shortening
- premixed cake mixes, pancake mixes, and drink mixes
- fried foods and hard taco shells
- snack foods (such as chips), candy, and frozen dinners

Choose brands that don’t use trans fats and that are low in saturated fats.

Dietary-Fat Substitutes

In response to the rising awareness and concern over the consumption of trans fat, various fat replacers have been developed. Fat substitutes aim to mimic the richness, taste, and smooth feel of fat without the same caloric content as fat.

Fat substitutes can also be made from proteins (for example, egg whites and milk whey). However, these are not very stable and are affected by changes in temperature; hence, their usefulness is somewhat limited. You will find these incorporated into foods that are not cooked such as ice cream, dairy products, mayonnaise, salad dressings, baked goods, and spreads.

Olestra or Olean is a fat-based fat replacer in which fatty acids have been attached to the sucrose molecule. This complex is not sweet and contains zero calories because it cannot be digested by our enzymes for absorption into our body. This makes it a better fat substitute for using in cooked products like chips and crackers. It can cause diarrhea and fecal leakage from the anal. As well, fat-soluble nutrients and phytochemicals can bond to it causing these to be unavailable for absorption.

Salatrim is another fat-based fat replacer and is composed of short and long chain fatty acids. It contains 5 calories per g which is less than the 9 calories per gram fats have, and you will find Salatrim in confections, dairy products, and baked goods.

The carbohydrate-based replacers tend to bind water and thus dilute calories. These are modified starch, maltodextrins, fruit purees, and pastes. All contain 1-4 calories per gram, so these products may contain less fat but are not always calorie-reduced. Be sure to read the package label. Examples of foods that contain these fat-replacers in baked goods, candy, dairy products, butter-flavored sprinkles.

Gels, gums, oat fiber (Oatrim: Beta-Trim, TrimChoice) polydextrose, hulls of corn, oats, and rice (Z-Trim) are examples of fiber-based fat replacers. These contain 0-4 calories per gram, so products that contain these are calorically reduced (remember fat has 9 calories per gram). People who eat products containing these fat replacers may experience the same problems associated with carbohydrate-based fat replacers.

Tools for Change

One classic cinnamon roll can have 5 grams of trans fat, which is quite high for a single snack. Foods such as pastries, frozen bakery goods, cookies, chips, popcorn, and crackers contain trans fat and often have their nutrient contents listed for a very small serving size—much smaller than what people normally consume—which can easily lead you to eat many “servings.” Labeling laws allow foods containing trans fat to be labeled “trans-fat free” if there are fewer than 0.5 grams per serving. This makes it possible to eat too much trans fat when you think you’re not eating any at all because it is labeled trans-fat free.

Always review the label for trans fat per serving. Check the ingredient list, especially the first three to four ingredients, for telltale signs of hydrogenated fat such as partially or fractionated hydrogenated oil. The higher up the words “partially hydrogenated oil” are on the list of ingredients, the more trans fat the product contains.

Measure out one serving and eat one serving only. An even better choice would be to eat a fruit or vegetable. There are no trans fats and the serving size is more reasonable for similar calories. Fruits and vegetables are packed with water, fiber, and many vitamins, minerals, phytonutrients, and antioxidants. At restaurants be aware that phrases such as “cooked in vegetable oil” might mean hydrogenated vegetable oil, and therefore trans fat.

Key Takeaways

- Hydrogenation is the process of adding hydrogen to the points of unsaturation in unsaturated fatty acid chains. The resulting oil is very hard and unusable. Partial hydrogenation is the process of adding hydrogen to some of the points of unsaturation in unsaturated fatty acid chains. This produces oils that are more spreadable and usable in food products.

- Food manufacturers favor the use of hydrogenated oils because they do not succumb to oxidative damage, they increase the shelf life of food products, and they have a high smoking point.
- Fat replacers mimic fat but do not have the same chemical configuration as fat. Therefore the body does not process these the same way it would a naturally occurring fat. Fat substitutes such as Olestra have produced symptoms of fat malabsorption in some people.

Discussion Starters

1. Describe how trans fatty acids are created. Explain the drawbacks of consuming this type of fat and its impact on human health.
2. Make a list of the foods in your kitchen. Read each food label. List all of the food items that contain trans fat. Recall the recommendation that trans fat be less that 1 percent of your fat intake. About what percentage of your diet is currently trans fat? Do you see a need to adjust your trans fat intake?

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4.8: Lipids and Disease

Learning Objectives

- Describe how saturated fat and cholesterol intake can impact health.

Because heart disease, cancer, and stroke are the three leading causes of death in the United States, it is critical to address dietary and lifestyle choices that will ultimately decrease risk factors for these diseases. According to the US Department of Health and Human Services (HHS), the following risk factors are controllable: high blood pressure, high cholesterol, cigarette smoking, diabetes, poor diet, physical inactivity, being overweight, and obesity.

In light of that, we present the following informational tips to help you define, evaluate, and implement healthy dietary choices to last a lifetime. The amount and the type of fat that composes a person's dietary profile will have a profound effect upon the way fat and cholesterol is metabolized in the body.

Watch Out for Saturated Fat and Cholesterol

In proper amounts, cholesterol is a compound used by the body to sustain many important body functions. In excess, cholesterol is harmful if it accumulates in the structures of the body's vast network of blood vessels. High blood LDL and low blood HDL are major indicators of blood cholesterol risk. The largest influence on blood cholesterol levels rests in the mix of saturated fat and trans fat in the diet. According to the Harvard School of Public Health, for every extra 2 percent of calories from trans fat consumed per day—about the amount found in a midsize order of French fries at a fast-food establishment—the risk of coronary heart disease increases by 23 percent.Harvard School of Public Health. "Fats and Cholesterol: Out with the Bad, In with the Good." Section 2.02. http://www.hsph.harvard.edu/nutritionsource/what-should-you -eat/fats-full-story/. A buildup of cholesterol in the blood can lead to brittle blood vessels and a blockage of blood flow to the affected area.

How saturated is the fat in your diet? Is it really necessary to eat saturated fat when the body makes all the saturated fat that it needs? Saturated fats should fall into the "bad" category—the body does not demand this kind of fat and it is proven to be a forerunner of cardiovascular disease. In the United States and other developed countries, populations acquire their saturated fat content mostly from meat, seafood, poultry (with skin consumed), and whole-milk dairy products (cheese, milk, and ice cream). Some plant foods are also high in saturated fats, including coconut oil, palm oil, and palm kernel oil.

Food Cholesterol's Effect on Blood Cholesterol

Dietary cholesterol does have a small impact on overall blood cholesterol levels, but not as much as some people may think. The average American female consumes 237 milligrams of dietary cholesterol per day and for males the figure is slightly higher—about 358 milligrams. The USDA dietary guidelines suggest a daily limit intake of cholesterol not to exceed 300 milligrams for healthy people and 200 milligrams for those who may be suffering from high cholesterol. Most people display little response to normal dietary cholesterol intake as the body responds by halting its own synthesis of the substance in favor of using the cholesterol obtained through food. Genetic factors may also influence the way a person's body modifies cholesterol.

A Prelude to Disease

If left unchecked, improper dietary fat consumption can lead down a path to severe health problems. An increased level of lipids, triacylglycerols, and cholesterol in the blood is called hyperlipidemia. Hyperlipidemia is inclusive of several conditions but more commonly refers to high cholesterol and triacylglycerol levels. When blood lipid levels are high, any number of adverse health problems may ensue. Consider the following:

- **Cardiovascular disease**. According to the AHA, cardiovascular disease encompasses a variety of problems, many of which are related to the process of atherosclerosis. Over time the arteries thicken and harden with plaque buildup, causing restricted or at times low or no blood flow to selected areas of the body.
- **Heart attack**. A heart attack happens when blood flow to a section of the heart is cut off due to a blood clot. Many have survived heart attacks and go on to return to their lives and enjoy many more years of life on this earth. However, dietary and lifestyle changes must be implemented to prevent further attacks.
- **Ischemic stroke**. The most common type of stroke in the United States, ischemic stroke, occurs when a blood vessel in the brain or leading to the brain becomes blocked, again usually from a blood clot. If part of the brain suffers lack of blood flow and/or oxygen for three minutes or longer, brain cells will start to die.

- **Congestive heart failure**. Sometimes referred to as heart failure, this condition indicates that the heart is not pumping blood as well as it should. The heart is still working but it is not meeting the body's demand for blood and oxygen. If left unchecked, it can progress to further levels of malfunction.
- **Arrhythmia**. This is an abnormal rhythm of the heart. The heart may beat above one hundred beats per minute (known as tachycardia) or below sixty beats per minute (known as bradychardia), or the beats are not regular. The heart may not be able to pump enough volume of blood to meet the body's needs.
- **Heart valve problems**. Stenosis is a condition wherein the heart valves become compromised in their ability to open wide enough to allow proper blood flow. When the heart valves do not close tightly and blood begins to leak between chambers, this is called regurgitation. When valves bulge or prolapse back into the upper chamber, this condition is called mitral valve prolapse.
- **Obesity**. Obesity is defined as the excessive accumulation of body fat. According to US Surgeon General Richard Carmona, obesity is the fastest growing cause of death in America. The HHS reports that the number of adolescents who are overweight has tripled since 1980 and the prevalence of the disease among younger children has doubled.US Department of Health and Human Services. "Childhood Obesity." Accessed October 5, 2012. http://aspe.hhs.gov/health/reports/child_obesity/. Obesity has been linked to increased risks of developing diabetes and heart disease. To help combat this problem important dietary changes are necessary. Reducing the type and amount of carbohydrates and sugar consumed daily is critical. Limiting the intake of saturated fats and trans fats, increasing physical activity, and eating fewer calories are all equally important in this fight against obesity.



Figure 4.8.1: *A 4-ml sample of hyperlipidemic blood with lipids separated into the top fraction (Sample is in an EDTA collection tube.). This is a standard EDTA (cell count) tube, as may be used to obtain a full blood count or iron studies. The tube was set upright for four hours - it was not centrifuged. This sample was not analyzed; however, a similar sample showed a serum triglyceride of over 130mmol/L (over 5000mg/dl), and an LDL over 40mmol/L (over 1540mg/dl). (public domain) from Carmen Crisp-Obenhaus.*

What You Can Do

Remember that saturated fats are found in large amounts in foods of animal origin. They should be limited within the diet. Polyunsaturated fats are generally obtained from nonanimal sources. While they are beneficial for lowering bad cholesterol they also lower good cholesterol. They are better for you than saturated fats but are not to be consumed in excess. Monounsaturated fats are of plant origin and are found in most nuts, seeds, seed oils, olive oil, canola oil, and legumes. Monounsaturated fats are excellent because they not only lower bad cholesterol, but also they elevate the good cholesterol. Replace current dietary fats with an increased intake of monounsaturated fats.

Choose whole-grain and high-fiber foods. Reduced risk for cardiovascular disease has been associated with diets that are high in whole grains and fiber. Fiber also slows down cholesterol absorption. The AHA recommends that at least half of daily grain intake should originate from whole grains. The Adequate Intake value for fiber is 14 grams per 1,000 kilocalories. These amounts are based upon the amount of fiber that has been shown to reduce cardiovascular risk.

Do not be sedentary. Get more exercise on a regular basis. Increasing your energy expenditure by just twenty minutes of physical activity at least three times per week will improve your overall health. Physical exercise can help you manage or prevent high blood pressure and blood cholesterol levels. Regular activity raises HDL while at the same time decreases triacylglycerols and

plaque buildup in the arteries. Calories are burned consistently, making it easier to lose and manage weight. Circulation will improve, the body will be better oxygenated, and the heart and blood vessels will function more efficiently.

Key Takeaways

- Food cholesterol does not affect blood cholesterol as much as some people think. The main causes of unfavorable blood cholesterol values come from an overconsumption of saturated fats and trans fats.
- An increased intake of lipids is associated with heart disease, obesity, cardiovascular disease, and other problems.
- Making dietary choices that limit the intake of saturated and trans fats to the recommended levels, replacing saturated and trans fats with monounsaturated and polyunsaturated fats, increasing physical activity, and cessation of smoking can reduce the risk of developing heart disease and other ailments.

Discussion Starters

1. Explain why saturated fats and trans fats contribute to unfavorable blood cholesterol levels.
2. Discuss some of the diseases that can result from an unhealthy lipid profile for an extended period of time.
3. List the types of fat that will help you achieve a healthy blood lipid profile. List the sources of these fats.
4. Evaluate your personal dietary and lifestyle habits. Identify key areas where you need to improve. Construct an overall plan of diet and lifestyle choices that you implement to help you reach healthy goals.

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4.9: A Personal Choice about Lipids

Learning Objectives

- Discuss ways to decrease saturated fat and cholesterol intake and increase unsaturated fat intake in your diet.

A Guide to Making Sense of Dietary Fat

On your next trip to the grocery store prepare yourself to read all food labels carefully and to seriously consider everything that goes into your shopping cart. Create a shopping list and divide your list into columns for "Best," "Better," "Good," "Least Desirable," and "Infrequent Foods." As you refine your sense of dietary fat, here are key points to bear in mind:

Shopping for groceries. Don't be bombarded with gratuitous grams of saturated fats and empty grams of trans fats. Read and decipher food labels carefully so that you know exactly what types of fat a food item contains and how much fat it will contribute to your overall fat intake. For snacks and daily eating, gravitate toward foods that are lowest in or absent of harmful trans fats. Restrict other foods to occasional usage based upon their fat content. For example, if selecting prepared foods, choose the ones without high-fat sauces in favor of adding your own flavorings. If selecting precooked meats, avoid those that are fried, coated, or prepared in high-fat sauces. A popular and healthy precooked meat food choice is the rotisserie chicken that most supermarkets carry. When selecting meats be aware of the need to compare different cuts—notice their fat content, color, and marbling. Higher-fat meats tend to have whiter fat marbled throughout. Choose lean cuts and white meat as these are lower in saturated fat. Always choose plenty of fresh fruits, vegetables, nuts, and seeds, as their phytosterols are a good competitor for cholesterol. Keep a collection of nuts in your freezer that can be added to your salads, stir-fry, one-dish foods, soups, desserts, and yogurts.

Appearance. Saturated and trans fats are not good for you and must be placed in your "Least Desirable" column because they increase cholesterol levels and put you at risk for heart disease. Monounsaturated and polyunsaturated fats are better choices to replace these undesirable fats. The key in identifying the "Best" or "Better" fats from the "Least Desirable" fats while you shop is based upon appearance. When choosing fats remember that saturated fats and trans fats are solid at room temperature; think of butter. Monounsaturated and polyunsaturated fats are liquid at room temperature; think of vegetable oil.

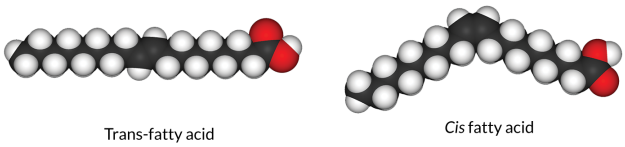


Figure 4.9.1: When a lipid molecule is unhydrogenated, the double bonds between the carbons keep it kinky and a liquid at room temperature. If that fat realigns into the trans formation, it gets straighter, forming up into a solid.

Note: Trans Fats

Stay away from trans fats. There is no amount of trans fats that are good for human health. Try to eliminate as much of these fats as possible from your food selections. Avoid commercially baked goods and fast foods. Make these your "Infrequent Foods."

Choose unsaturated fats. Fatty fish, walnuts, flaxseeds, flaxseed oil, and canola oil all have good health benefits and should be on the "Best," "Better," and "Good" fat lists. They each provide essential omega-3 fatty acids necessary for overall body health. To derive the most benefit from including these foods, do not add them to an existing diet full of fat. Use these to replace the "Least Desirable" fats that are being removed from the diet. Be careful of exposing fats and oils to heat, light, and oxygen as they can be easily damaged. Exercise caution when heating oils. Polyunsaturated fats are the most fragile and lose beneficial properties when exposed to heat. For proper storage and freshness, place your oils in opaque containers and keep refrigerated. Do not use any oil if it has a bitter smell or taste.

Limit saturated fat intake. Reduce red meat consumption, processed meats, and whole-fat dairy products. A good replacement for red meat could be beans (black beans are very high in protein), nuts, poultry, and fish whenever possible. To reduce full-fat dairy items try their low-fat or nonfat counterparts such as mozzarella cheese.

Low fat does not equal healthy. Remember, a fat-free label does not provide you with a license to consume all the calories you desire. There will be consequences to your weight and your overall health. Common replacements for fat in many fat-free foods are

refined carbohydrates, sugar, and calories. Too much of these ingredients can also cause health problems. Choose and consume wisely.

Tools for Change

As a delicious alternative to red meat, try preparing and eating at least one meal each week using beans. For interesting ideas and tips, visit http://www.swbeans.com.

Helpful Suggestions

Keep the following in mind as you strive toward a healthier diet:

- **A "better-fat" diet will successfully support weight loss**. With the obesity rates in the United States more than tripling since 1980, it is interesting to note that this figure has presented itself and increased at a time when "low fat" advertising runs rampant throughout the food supply. While cutting "Least Desirable" fat calories are vital to weight loss, remember that "Better" fats are filling and just a handful of nuts can curb an appetite to prevent overeating.
- **Consume omega-3 fats each day**. For optimal health and disease prevention include a moderate serving of fish, walnuts, ground flaxseeds, flaxseed oil, or soybean oil in your diet every day.
- **Limit cholesterol-rich foods**. The following foods should be limited from the diet in order to reduce blood cholesterol: chicken livers, beef, pork, fast foods, pastries, butter, cheese, and ice cream.
- **How much saturated fat is too much?** Your goal is to keep your intake of saturated fat to no more than 10 percent of your total dietary calories on a daily basis. Thus, it is important to learn to reduce the intake of foods high in saturated fat. High-fat foods can be consumed but they must fall within the overall goal for a person's fat allowance for the day.
- **Home cooking**. Limit the use of saturated fats in home preparation of meals. Instead of butter try spreads made from unsaturated oils such as canola or olive oils and the use of cooking sprays. Couple this with the use of herbs and spices to add flavor. Avoid using high-fat meat gravies, cheese, and cream sauces. Limit adding extras to foods such as butter on a baked potato. Use nonfat sour cream instead. Grill, bake, stir-fry, roast, or bake your foods. Never fry in solid fats such as butter or shortening. Marinate foods to be grilled in fruit juices and herbs. Instead of relying upon commercial salad dressings, learn to make your own top-quality dressing from cold-pressed olive oil, flaxseed oil, or sesame oil.

Make sure the fat is flavorful. Adding flavor to food is what makes the eating experience enjoyable. Why not choose unsaturated fats and oils that have strong flavors? In this way you will add good flavor to your meals but use less fat in the process. Some examples are sesame oil, peanut oil, and peanut butter. Replace less flavorful cheeses with small amounts of strongly flavored cheeses such as romano, parmesan, and asiago.

Now that you have gained a wealth of information and food for thought to enable you to make changes to your dietary pattern we hope that your desire to pursue a healthier lifestyle has been solidified. While we realize that making grand strides in this direction may be awkward at first, even the smallest of accomplishments can produce noticeable results that will spur you on and perhaps spark the interest of friends and family to join you in this health crusade.

Becoming aware of the need to limit your total fat intake will facilitate your ability to make better choices. In turn, making better dietary choices requires gaining knowledge. As you understand that your food choices not only impact your personal physical health but also the delicate balance of our ecosystem, we are confident that you will successfully adapt to the dynamics of the ever-changing global food supply. Remember, the food choices you make today will benefit you tomorrow and into the years to come.

Key Takeaways

- To reduce saturated fat in your diet, eat less red and processed meat and more fish and chicken. Choose lean cuts of meat and white meat portions. Bake, broil, or grill instead of fry. Avoid deep-fried foods, cheeses, and creamy cheese sauces. Remove the skin from chicken and remove as much fat from meat as possible. Choose low-fat milk and lower fat cheeses, such as mozzarella, where possible. Use liquid vegetable oils such as olive oil or canola oil instead of shortening or butter.
- In order to reduce blood cholesterol, restrict the consumption of eggs, chicken livers, beef, pork, shrimp, crustaceans, fast foods, pastries, butter, cheese, and ice cream.
- To gain the most benefit from reducing your saturated fat intake, substitute unsaturated fats in the place of saturated fats and trans fats. Do not add unsaturated fats to an already fatty diet. Fill your plate with plant-based foods and use the foods containing fat more as an accompaniment.

Discussion Starters

1. Think of at least three ways to reduce, substitute, and eliminate from your diet foods that are higher in less-desirable fat. List some foods that you will add to your diet that will add bulk and help satisfy your need to eat, but do not contain the calories in fat-rich foods.
2. Make a list of your favorite snack foods. Then make a listing of the fat content in each. Decide what snack foods you should reduce or eliminate from your diet. Think of at least two replacement foods for these snacks. Tell what benefit these replacement foods will have on your overall health.
3. Make a list of all the common foods you eat that contain trans fats. Looking ahead, develop a plan of action for you to slowly eliminate as much of these fats from your diet as possible. What substitutes will you add in their place? How will you cut out trans fats from your diet?

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4.E: Exercises

It's Your Turn

1. Provide examples of three foods that are rich in unsaturated fats.
2. Assume you are reluctant to eat fish. Name three other sources of omega-3 fats.
3. Your friend tends to feel cold a lot of the time, is often tired, and has developed sores on her skin. Based on the content in this chapter, identify a nutritional reason for this condition.
4. Explain the role of lipids in your overall health.

Apply It

1. Make a chart of the three main types of lipids, their specific functions in the body, and where they are found.
2. Diagram the steps in lipid digestion and absorption.
3. Create a blood lipid profile with healthy ranges.

Expand Your Knowledge

1. You're making a concerted effort to begin eating more foods that will promote good health. Turn your attention to omega-3 fatty acids. What will you incorporate into your diet?
2. Obesity rates in the United States have more than tripled since 1980. At the same time, "low fat" advertising is all over the news. How would you explain this?
3. Review and analyze the Cholesterol Risk Chart on the following site: heartriskonline.com/CholesterolChart.htm. Check with three members of your family or close friends. Where do they "fit" into this chart?

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5: Proteins

In this chapter, we cover the structure and roles of protein, and explore the consequences of getting too little or too much protein in your diet. Tips for getting the right amount and quality of protein, as well as a look at special populations, such as the elderly and athletes, are also covered.

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5.1: Chapter Introduction

Big Idea

Protein is best used for vital body functions—eat just enough for your lifestyle needs.

Some dieters use protein bars as a prime part of their diet, with the hopes of slimming their waistlines. Exercise cafes serve protein shakes to many of their patrons, who drink them for building muscle and enhancing exercise recovery. Some people have stopped eating meat and feel the need to use protein supplements to ensure they are getting their required protein intake each day. After all, protein is a vital constituent of all organs in the body and is required to synthesize hormones, enzymes, and a variety of molecules.



Figure 5.1.1 Is protein supplement consumption a healthy way to supply your body with this vital macronutrient? Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement. (CC-SA-BY 3.0; Sandstein).

It is no wonder that so many people are preoccupied with optimizing their dietary protein intake. Dieters, athletes, physically active people, and vegetarians may worry that they lack protein in their diet and that they need to consume more from protein bars, shakes, or supplements to perform better and optimize health. This chapter will help address these concerns. First, let us take a look at vegetarian diets.

There are different types of vegetarians, but a common theme is that vegetarians do not eat meat. Four common forms of vegetarianism are:

1. **Lacto-ovo vegetarian.** This is the most common form. This type of vegetarian eats eggs and dairy.
2. **Lacto-vegetarian.** This type of vegetarian eats dairy products but not eggs.
3. **Ovo-vegetarian.** This type of vegetarian eats eggs but not dairy products.
4. **Vegan.** This type of vegetarian does not eat dairy, eggs, or any type of animal product or by-product.

People choose a vegetarian diet for various reasons, including religious doctrines, health concerns, ecological and animal welfare concerns, or simply because they dislike the taste of meat. Vegetarianism has been practiced for centuries. In the fourth century BC, great thinkers such as Pythagoras and Plato promoted vegetarian diets in their natural philosophies. Ancient Olympians were placed on vegetarian diets one month prior to the Olympic Games.

Gladiators were tough men who fought violently against each other during games sponsored by the Roman Empire's upper-class political rulers. In 1993, archeologists uncovered a gladiator burial ground not far from the Temple of Artemis. To their surprise, forensic analysis of the gladiators' bones revealed that they consumed a vegetarian diet. This information matches other historical accounts that gladiators ate a diet rich in barley and dried fruits. Hulled barley is a very nutritious whole grain; it is a complete protein source, containing more than 20 grams of protein and all nine essential amino acids in a one-cup serving.

Although the great philosophers, ancient Olympic athletes, and Roman gladiators saw vegetarianism as a means of maintaining optimal health, it took a while for the vegetarian dietary pattern to catch on in America. In 1987, John Robbins wrote *Diet for a New America* and popularized the vegan diet first introduced by Jay Dinshah in the United States in 1960. In the early 1990s, Dr. John McDougall wrote a series of books that promoted vegan dietary regimens to ward off chronic disease. Also during the 1990s, scientific evidence accumulated that supported that diets consisting of too much red meat were linked to chronic disease. This prompted many health organizations, such as the Academy of Nutrition and Dietetics (AND) and the American Heart Association (AHA), to issue statements endorsing the health benefits of vegetarian diets. These statements can be read at www.eatright.org/about/content.aspx?id=8357 and bit.ly/O2VQkC.

The US federal government was unable to ignore the health benefits of plant-based diets any longer, and consequently released the *2010 Dietary Guidelines* in which Americans were challenged to eat a more plant-based diet. Moreover, the *Dietary Guidelines* Advisory Committee stated, “In prospective studies of adults, compared to nonvegetarian eating patterns, vegetarian-style eating patterns have been associated with improved health outcomes—lower levels of obesity, a reduced risk of cardiovascular disease, and lower total mortality.”

You Decide

What are the best sources of protein and how much protein do I need to eat to have a healthy diet?

Whether you choose to consume protein from animal- or plant-derived products, an important factor to consider is the entire nutrient package of the food. What other fats, nutrients, additives, or preservatives come with the protein source? Red meat is a popular choice for protein, but it contains high amounts of saturated fat. Fish is another good protein choice, and it provides much less saturated fat than other meats, in addition to more healthy fats. Some plant-based sources of protein contain high amounts of protein per serving with just under one gram of less desirable fat in addition to good amounts of healthy fats. As you read through this chapter you will learn how to choose the best protein sources to support your health.

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5.2: Defining Protein

Learning Objectives

- Categorize the different types of amino acids.
- Describe how protein differs in structure from carbohydrates and lipids.

Protein makes up approximately 20 percent of the human body and is present in every single cell. The word protein is a Greek word, meaning “of utmost importance.” Proteins are called the workhorses of life as they provide the body with structure and perform a vast array of functions. You can stand, walk, run, skate, swim, and more because of your protein-rich muscles. Protein is necessary for proper immune system function, digestion, and hair and nail growth, and is involved in numerous other body functions. In fact, it is estimated that more than one hundred thousand different proteins exist within the human body. In this chapter, you will learn about the components of protein, the important roles that protein serves within the body, how the body uses protein, the risks and consequences associated with too much or too little protein, and where to find healthy sources of it in your diet.



Figure 5.2.1 Your protein-rich muscles allow for body strength and movement, which enable you to enjoy many activities. Australia v Japan on 24 March 2012 at Hawker International Softball Centre. (CC-SA-BY 3.0; LauraHale)

What Is Protein?

Proteins, simply put, are macromolecules composed of amino acids. Amino acids are commonly called protein’s building blocks. Proteins are crucial for the nourishment, renewal, and continuance of life. Proteins contain the elements carbon, hydrogen, and oxygen just as carbohydrates and lipids do, but proteins are the only macronutrient that contains nitrogen. Nitrogen makes up approximately 16% of the weight of an amino acid. In each amino acid, the elements are arranged into a specific conformation around a carbon center. Each amino acid consists of a central carbon atom connected to a side chain, a hydrogen, a nitrogen-containing *amino* group, a carboxylic *acid* group—hence the name “amino acid.” Amino acids differ from each other by which specific side chain is bonded to the carbon center.

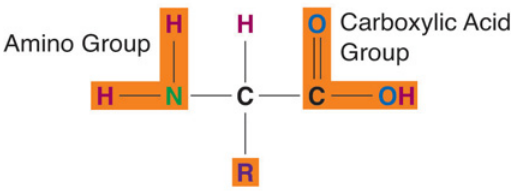


Figure 5.2.2: *Amino Acid Structure*

Amino acids contain four elements. The arrangement of elements around the carbon center is the same for all amino acids. Only the side chain (R) differs.

It's All in the Side Chain

The side chain of an amino acid, sometimes called the "R" group determines the name of the amino acid. It can be as simple as one hydrogen bonded to the carbon center, or as complex as a six-carbon ring bonded to the carbon center. Although each side chain of the twenty amino acids is unique, there are some chemical likenesses among them. Therefore, they can be classified into four different groups (Figure 5.2.2). These are nonpolar, polar, acidic, and basic.

- **Nonpolar amino acids.** Nonpolar amino acids include alanine (Ala), leucine (Leu), isoleucine (Ile), proline (Pro), tryptophan (Trp), valine (Val), phenylalanine (Phe), and methionine (Met). The side chains of these amino acids are long carbon chains or carbon rings, making them bulky. They are hydrophobic, meaning they repel water.
- **Polar amino acids.** Polar amino acids are glycine (Gly), serine (Ser), threonine (Thr), cysteine (Cys), tyrosine (Tyr), asparagine (Asn), and glutamine (Gln). The side chains of polar amino acids make them hydrophilic, meaning they are water-soluble.
- **Acidic amino acids.** Acidic amino acids are negatively charged, hydrophilic amino acids and include aspartic acid (Asp) and glutamic acid (Glu).
- **Basic amino acids.** Basic amino acids are positively charged, hydrophilic amino acids and include lysine (Lys), arginine (Arg), and histidine (His).

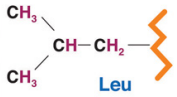
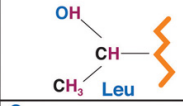
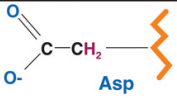
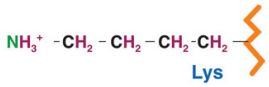
Group	Characteristics	Name	Example (-Rx)
non-polar	hydrophobic	Ala, Val, Leu, Ile, Pro, Phe Trp, Met	
polar	hydrophilic (non-charged)	Gly, Ser, Thr, Cys, Tyr, Asn Gln	
acidic	negatively charged	Asp, Glu	
basic	positively charged	Lys, Arg, His	
		Total = 20	

Figure 5.2.3: Amino acids are classified into four groups. These are nonpolar, polar, acidic, and basic.

Essential and Nonessential Amino Acids

Amino acids are further classified based on nutritional aspects. Recall that there are twenty different amino acids, and we require all of them to make the many different proteins found throughout the body (Table 6.1). Eleven of these are called nonessential amino acids because the body can synthesize them. However, nine of the amino acids are called essential amino acids because we cannot synthesize them either at all or in sufficient amounts. These must be obtained from the diet. Sometimes during infancy, growth, and in diseased states, the body cannot synthesize enough of some of the nonessential amino acids and more of them are required in the diet. These types of amino acids are called conditionally essential amino acids. The nutritional value of a protein is dependent on what amino acids it contains and in what quantities.

Table 5.2.1: Essential and Nonessential Amino Acids

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine*
Leucine	Asparagine
*Conditionally essential	

Essential	Nonessential
Lysine	Aspartic acid
Methionine	Cysteine*
Phenylalanine	Glutamic acid
Threonine	Glutamine*
Tryptophan	Glycine*
Valine	Proline*
	Serine
	Tyrosine*
*Conditionally essential	

The Many Different Types of Proteins

As discussed, there are over one hundred thousand different proteins in the human body. Different proteins are produced because there are twenty types of naturally occurring amino acids that are combined in unique sequences. Additionally, proteins come in many different sizes. Two amino acids bond together are called a dipeptide while ten or more amino acids bound together are called a polypeptide. The hormone insulin, which regulates blood glucose, is composed of only fifty-one amino acids; whereas collagen, a protein that acts like glue between cells consists of more than one thousand amino acids. Titin is the largest known protein. It accounts for the elasticity of muscles, and consists of more than twenty-five thousand amino acids! The abundant variations of proteins are due to the unending number of amino acid sequences that can be formed. To compare how so many different proteins can be designed from only twenty amino acids, think about music. All of the music that exists in the world has been derived from a basic set of seven notes C, D, E, F, G, A, B and variations thereof. As a result, there is a vast array of music and songs all composed of specific sequences from these basic musical notes. Similarly, the twenty amino acids can be linked together in an extraordinary number of sequences, much more than are possible for the seven musical notes to create songs. As a result, there are enormous variations and potential amino acid sequences that can be created. For example, if an amino acid sequence for a protein is 104 amino acids long the possible combinations of amino acid sequences is equal to 20^{104}, which is 2 followed by 135 zeros!

Building Proteins with Amino Acids

The building of a protein consists of a complex series of chemical reactions that can be summarized into three basic steps: transcription, translation, and protein folding (Figure 6.3). The first step in constructing a protein is the transcription (copying) of the genetic information in double-stranded deoxyribonucleic acid (DNA) into the single-stranded, messenger macromolecule ribonucleic acid (RNA). RNA is chemically similar to DNA, but has two differences; one is that its backbone uses the sugar ribose and not deoxyribose; and two, it contains the nucleotide base uracil, and not thymidine. The RNA that is transcribed from a given piece of DNA contains the same information as that DNA, but it is now in a form that can be read by the cellular protein manufacturer known as the ribosome. Next, the RNA instructs the cells to gather all the necessary amino acids and add them to the growing protein chain in a very specific order. This process is referred to as translation. The decoding of genetic information to synthesize a protein is the central foundation of modern biology.

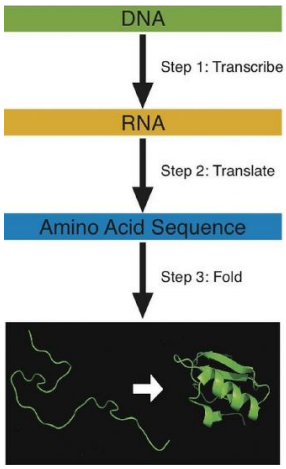


Figure 5.2.4: Building a protein involves three steps: transcription, translation, and folding.

During translation, each amino acid is connected to the next amino acid by a special chemical bond called a peptide bond (Figure 6.4). The peptide bond forms between the carboxylic acid group of one amino acid and the amino group of another, releasing a molecule of water. The third step in protein production involves folding it into its correct shape. Specific amino acid sequences contain all the information necessary to spontaneously fold into a particular shape. A change in the amino acid sequence will cause a change in protein shape. Each protein in the human body differs in its amino acid sequence and consequently, its shape. The newly synthesized protein is structured to perform a particular function in a cell. A protein made with an incorrectly placed amino acid may not function properly and this can sometimes cause disease.

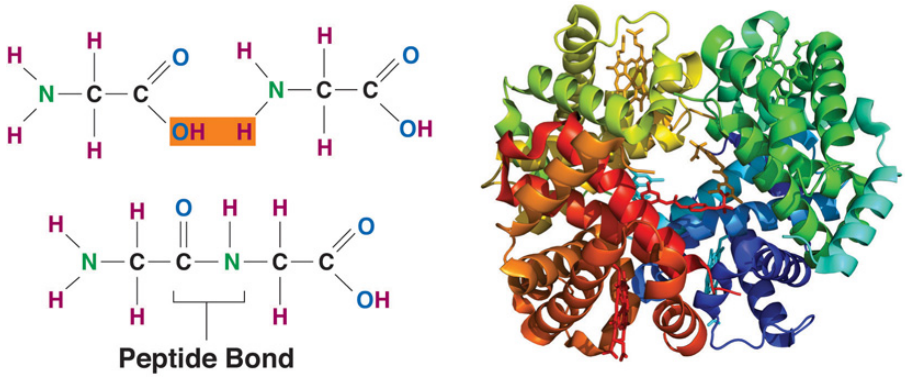


Figure 5.2.5: Connecting amino acids with peptide bonds builds proteins. In the process of translation, amino acids are sequentially strung along in a chain in a specific sequence that spontaneously folds into the correct protein shape.

Protein Organization

The structure and function of proteins are determined by their amino acid sequence. Protein's structure enables it to perform a variety of functions. Proteins are similar to carbohydrates and lipids in that they are polymers of simple repeating units; however, proteins are much more structurally complex. In contrast to carbohydrates, which have identical repeating units, proteins are made up of amino acids that are different from one another. Furthermore, a protein is organized into four different structural levels (Figure 6.5). The first level is the one-dimensional sequence of amino acids that are held together by peptide bonds. Carbohydrates and lipids also are one-dimensional sequences of their respective monomers, which may be branched, coiled, fibrous, or globular, but their conformation is much more random and is not organized by their sequence of monomers. In contrast, the two-dimensional level of protein structure is dependent on the chemical interactions between amino acids, which cause the protein to fold into a specific shape, such as a helix (like a coiled spring) or sheet. The third level of protein structure is three-dimensional. As the different side chains of amino acids chemically interact, they either repel or attract each other, resulting in the coiled structure. Thus, the specific sequence of amino acids in a protein directs the protein to fold into a specific, organized shape. The fourth level of structure (also known as its "quaternary" structure) is achieved when protein fragments called peptides combine to make one larger functional protein. The protein hemoglobin is an example of a protein that has quaternary structure. It is composed of four peptides that bond together to form a functional oxygen carrier. A protein's structure also influences its nutritional quality. Large fibrous protein structures are more difficult to digest than smaller proteins and some, such as keratin, are indigestible. Because

digestion of some fibrous proteins is incomplete, not all of the amino acids are absorbed and available for the body to utilize, thereby decreasing their nutritional value.

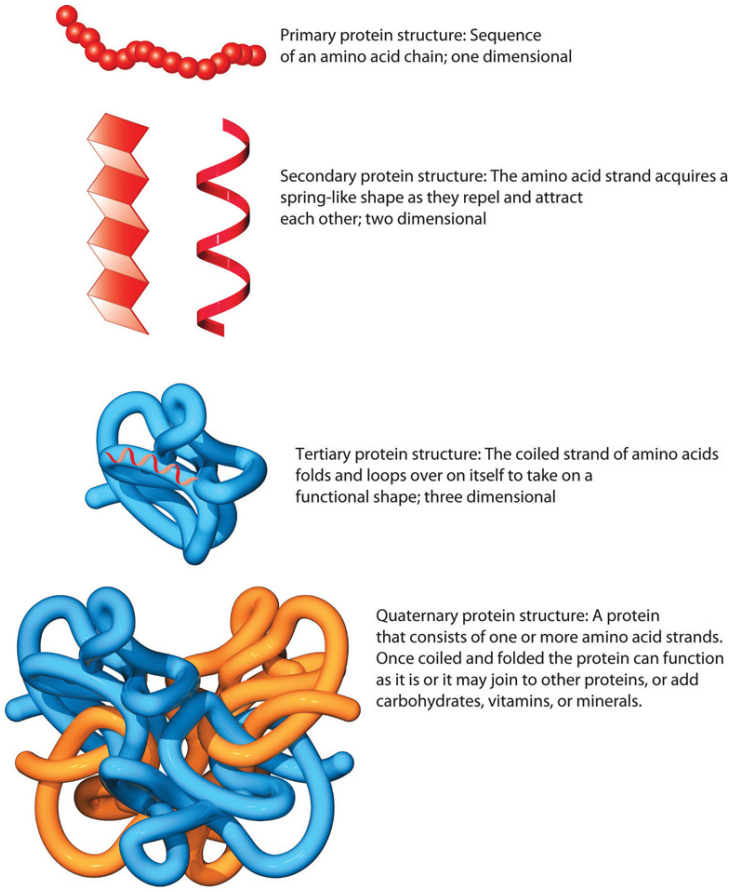
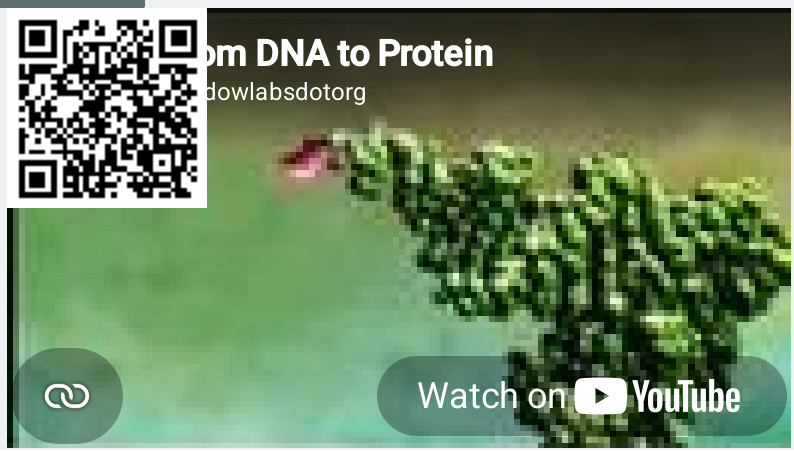


Figure 5.2.6: A protein has four different structural levels.

Video 5.1: From DNA to Protein



See the process of building a protein in real time in this animation. (click to see video)

Key Takeaways

- Amino acids differ chemically in the molecular composition of their side chains, but they do have some similarities. They are grouped into four different types: nonpolar, polar, acidic, and basic.
- Amino acids are also categorized based upon their nutritional aspects. Some are nonessential in the diet because the body can synthesize them, and some are essential in the diet because the body cannot make them.

- Proteins are polymers of amino acid monomers held together by peptide bonds. They are built in three steps; transcription, translation, and folding.
- Proteins have up to four different levels of structure, making them much more complex than carbohydrates or lipids.

Discussion Starters

1. There are over four thousand diseases caused by incorrectly built protein. Find out more about how one incorrectly placed amino acid causes the disease sickle cell anemia by watching this animation.

   http://www.dnalc.org/resources/3d/17-sickle-cell.html.

2. Why do you think protein-building diseases are rare? In every cell in your body over ten million ribosomes are at work constructing millions of proteins every minute. What can you say about the body's amazing track record in correctly building proteins?

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5.3: The Role of Proteins in Foods- Cooking and Denaturation

Learning Objectives

- Explain the process of denaturation and its consequences. Give an example.

In addition to having many vital functions within the body, proteins perform different roles in our foods by adding certain functional qualities to them. Protein provides food with structure and texture and enables water retention. For example, proteins foam when agitated. (Picture whisking egg whites to make angel food cake. The foam bubbles are what give the angel food cake its airy texture.) Yogurt is another good example of proteins providing texture. Milk proteins called caseins coagulate, increasing yogurt's thickness. Cooked proteins add some color to foods as the amino group binds with carbohydrates and produces a brown pigment. Eggs are between 10 and 15 percent protein by weight. Most cake recipes use eggs because the egg proteins help bind all the other ingredients together into a uniform cake batter. The proteins aggregate into a network during mixing and baking that gives cake structure.



Figure 5.3.1: Protein gives structure and texture to cakes. A layered pound cake, with alternating interstitial spaces filled with raspberry jam and lemon curd, finished with buttercream frosting. Image use with permission (Public domain; Scheinwerfermann).

Protein Denaturation: Unraveling the Fold

When a cake is baked, the proteins are denatured. Denaturation refers to the physical changes that take place in a protein exposed to abnormal conditions in the environment. Heat, acid, high salt concentrations, alcohol, and mechanical agitation can cause proteins to denature. When a protein denatures, its complicated folded structure unravels, and it becomes just a long strand of amino acids again. Weak chemical forces that hold tertiary and secondary protein structures together are broken when a protein is exposed to unnatural conditions. Because proteins' function is dependent on their shape, denatured proteins are no longer functional. During cooking the applied heat causes proteins to vibrate. This destroys the weak bonds holding proteins in their complex shape (though this does not happen to the stronger peptide bonds). The unraveled protein strands then stick together, forming an aggregate (or network).

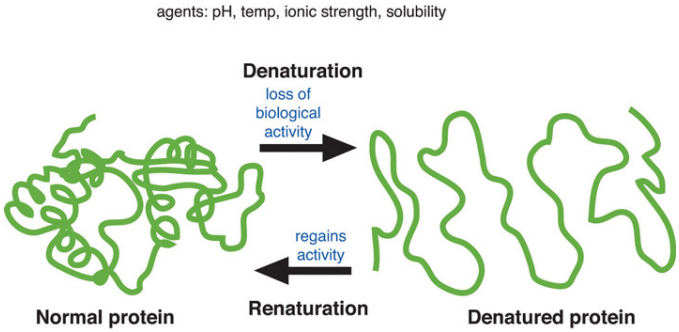


Figure 5.3.2: When a protein is exposed to a different environment, such as increased temperature, it unfolds into a single strand of amino acids.

Interactive 5.3.1: Denaturing of Egg Proteins

View this animation of egg proteins denaturing.
http://www.sumanasinc.com/webcontent/animations/content/proteinstructure.html

Key Takeaways

- Proteins provide food not only with nutrition, but also with structure and texture.
- When a protein denatures, its complicated structure unfolds into a strand of amino acids.

Discussion Starters

1. Gelatin is a mixture of collagen proteins. How does gelatin add texture and structure to foods? Conduct an experiment by making some Jell-O™ using different methods of denaturation and discuss what happens to the texture and structure.
    1. Make the first batch of Jell-O™ following the directions. Does it set?
    2. Next, make up the Jell-O™, but replace hot water with cold. Does it set?
    3. Instead of adding hot water, add 2 teaspoons of salt and only cold water. Does it set?
    4. Take the first batch (that is now set) and either whisk it by hand or use an electric mixer. What happens?
2. If pouring salt on a live slug produces a puddle of goo, how is it possible to cook snails with salt and get a delicious dish?

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5.4: Protein Digestion, Absorption and Metabolism

Learning Objectives

- Discuss how proteins are digested and absorbed by our bodies.

How do the proteins from foods, denatured or not, get processed into amino acids that cells can use to make new proteins? When you eat food the body's digestive system breaks down the protein into the individual amino acids, which are absorbed and used by cells to build other proteins and a few other macromolecules, such as DNA. Let's follow the specific path that proteins take down the gastrointestinal tract and into the circulatory system. Eggs are a good dietary source of protein and will be used as our example to describe the path of proteins in the processes of digestion and absorption. One egg, whether raw, hard-boiled, scrambled, or fried, supplies about six grams of protein.



Figure 5.4.1: The egg is a good dietary source of protein. White, speckled (red), and brown chicken eggs. (CC-SA-BY 3.0; Timothy Titus)

From the Mouth to the Stomach

Unless you are eating it raw, the first step in egg digestion (or any other protein food) involves chewing. The teeth begin the mechanical breakdown of the large egg pieces into smaller pieces that can be swallowed. The salivary glands provide some saliva to aid swallowing and the passage of the partially mashed egg through the esophagus. The mashed egg pieces enter the stomach through the esophageal sphincter. The stomach releases gastric juices containing hydrochloric acid and the enzyme, pepsin, which initiate the breakdown of the protein. The acidity of the stomach facilitates the unfolding of the proteins that still retain part of their three-dimensional structure after cooking and helps break down the protein aggregates formed during cooking. Pepsin, which is secreted by the cells that line the stomach, dismantles the protein chains into smaller and smaller fragments. Egg proteins are large globular molecules and their chemical breakdown requires time and mixing. The powerful mechanical stomach contractions churn the partially digested protein into a more uniform mixture called chyme. Protein digestion in the stomach takes a longer time than carbohydrate digestion, but a shorter time than fat digestion. Eating a high-protein meal increases the amount of time required to sufficiently break down the meal in the stomach. Food remains in the stomach longer, making you feel full longer.

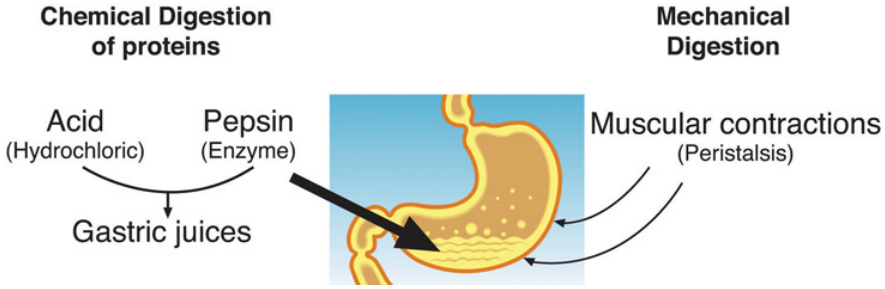


Figure 5.4.2: Protein digestion requires the chemical actions of gastric juice and the mechanical actions of the stomach.

From the Stomach to the Small Intestine

The stomach empties the chyme containing the broken down egg pieces into the small intestine, where the majority of protein digestion occurs. The pancreas secretes digestive juice that contains more enzymes that further break down the protein fragments.

The two major pancreatic enzymes that digest proteins are chymotrypsin and trypsin. The cells that line the small intestine release additional enzymes that finally break apart the smaller protein fragments into the individual amino acids. The muscle contractions of the small intestine mix and propel the digested proteins to the absorption sites. The goal of the digestive process is to break the protein into dipeptides and amino acids for absorption.

In the lower parts of the small intestine, the amino acids are transported from the intestinal lumen through the intestinal cells to the blood. This movement of individual amino acids requires special transport proteins and the cellular energy molecule, adenosine triphosphate (ATP). Once the amino acids are in the blood, they are transported to the liver. As with other macronutrients, the liver is the checkpoint for amino acid distribution and any further breakdown of amino acids, which is very minimal. Recall that amino acids contain nitrogen, so further catabolism of amino acids releases nitrogen-containing ammonia. Because ammonia is toxic, the liver transforms it into urea, which is then transported to the kidney and excreted in the urine. Urea is a molecule that contains two nitrogens and is highly soluble in water. This makes it a good choice for transporting excess nitrogen out of the body. Because amino acids are building blocks that the body reserves in order to synthesize other proteins, more than 90 percent of the protein ingested does not get broken down further than the amino acid monomers.

Very little protein makes it to the large intestine if you are not eating excessive amounts. If you have smelly flatulence, this may be a sign you are eating too much protein because the excess is making it to the colon where you gut microbes are digesting it and producing smelly gas.

Protein Absorption

In adults, essentially all protein is absorbed as tripeptides, dipeptides or amino acids and this process occurs in the duodenum or proximal jejunum of the small intestine. The peptides and/or amino acids pass through the interstitial brush border by facilitative diffusion or active transport. Active transport sodium and ATP to actively transport the molecule through the cell membrane. The R group determines the type of transporter used. Once passed through the membrane, the amino acids or peptides are released into the intestinal blood stream and are transported to the liver by the hepatic (liver) portal vein. This is known as the enterohepatic circulation.

In the liver, 50-65% remain and are used to synthesize protein, nitrogen containing compounds and form purine/pyrimidine bases. In some cases, they may be converted to energy. The liver regulates the amino acid levels in the blood. The amino acids that do not stay in the liver, pass through and are transported to the rest of the body to be taken up and utilized by other cells. Most branch chain amino acids pass through the liver.

Nitrogen Metabolism Overview

Amino acids are unique because they contain nitrogen. Several things can happen to the nitrogen. First, it can remain on the molecule and be incorporated into the product that cell is making, for example, a polypeptide. The nitrogen may be transaminated, in other words, the amine group (NH_2) is transferred to another carbon skeleton to form a new amino acid. An example would be the transfer of the amine from the non-essential amino acid, alanine, to alpha-ketoglutaric acid to make glutamic acid, another non-essential amino acid. The water-soluble vitamin B_6 is needed for this process.

The amine group may be removed from the amino acid in a process known as deamination. This process is used for the excretion of the nitrogen, and the carbon skeleton is used to produce energy. Again, vitamin B_6 is needed for this process.

The nitrogen removed from amino acids is excreted via several different routes. The most familiar path is urine where most of the nitrogen is in the form of urea. Nitrogen is also excreted in the feces, skin, hair, and nails. In skin, hair, and nails the nitrogen is bound to protein as this is the building block of each.

Amino Acids Are Recycled

Just as some plastics can be recycled to make new products, amino acids are recycled to make new proteins. All cells in the body continually break down proteins and build new ones, a process referred to as protein turnover. Every day over 250 grams of protein in your body are dismantled and 250 grams of new protein are built. To form these new proteins, amino acids from food and those from protein destruction are placed into a “pool.” Though it is not a literal pool, when an amino acid is required to build another protein it can be acquired from the additional amino acids that exist within the body. Amino acids are used not only to build proteins, but also to build other biological molecules containing nitrogen, such as DNA and RNA, and to some extent to produce energy. It is critical to maintaining amino acid levels within this cellular pool by consuming high-quality proteins in the diet, or the amino acids needed for building new proteins will be obtained by increasing protein destruction from other tissues within the body,

especially muscle. This amino acid pool is less than one percent of total body protein content. Thus, the body does not store protein as it does with carbohydrates (as glycogen in the muscles and liver) and lipids (as triglycerides in adipose tissue).

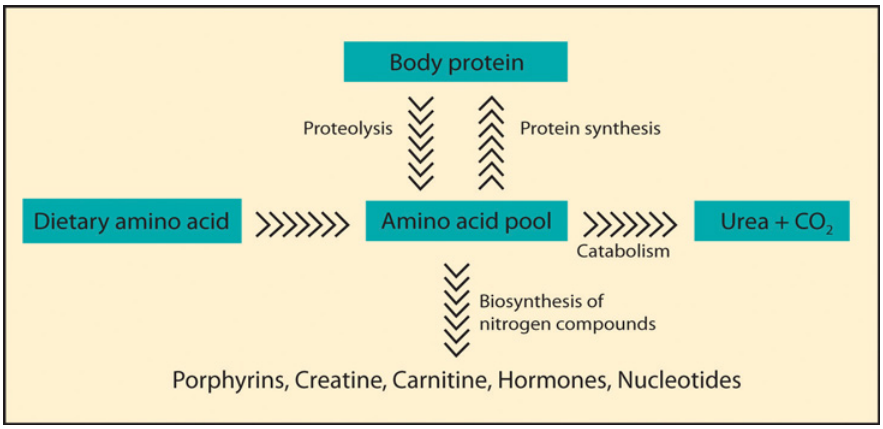


Figure 5.4.3: Amino acids in the cellular pool come from dietary protein and from the destruction of cellular proteins. The amino acids in this pool need to be replenished because amino acids are outsourced to make new proteins, energy, and other biological molecules.

Key Takeaways

- Mechanical digestion of protein begins in the mouth and continues in the stomach and small intestine.
- Chemical digestion of protein begins in the stomach and ends in the small intestine.
- The body recycles amino acids to make more proteins.

Discussion Starters

1. The next time you eat an egg, imagine it moving down the gastrointestinal tract and visualize what is happening to the proteins it contains. Does the amount of work required to digest a protein seem to be too much? How much energy does it take just to digest protein?
2. Why is it important to recycle amino acids?

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5.5: Protein's Functions in the Body

Learning Objectives

- List protein's functions in the body.

Proteins are the "workhorses" of the body and participate in many bodily functions. As you may recall, proteins come in all sizes and shapes and each is specifically structured for its particular function.

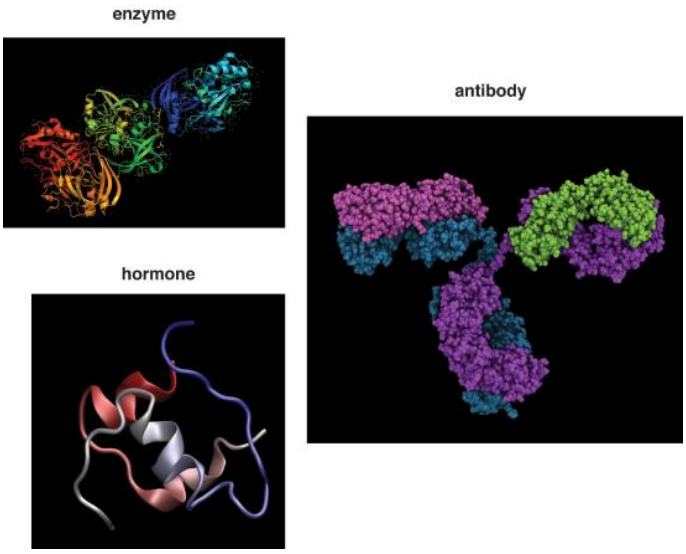


Figure 5.5.1: Proteins come in all sizes and shapes.

Structure and Motion

More than one hundred different structural proteins have been discovered in the human body, but the most abundant by far is collagen, which makes up about 6 percent of total body weight. Collagen makes up 30 percent of bone tissue and comprises large amounts of tendons, ligaments, cartilage, skin, and muscle. **Collagen** is a strong, fibrous protein made up of mostly glycine and proline amino acids. Within its quaternary structure three protein strands twist around each other like a rope and then these collagen ropes overlap with others. This highly ordered structure is even stronger than steel fibers of the same size. Collagen makes bones strong, but flexible. Collagen fibers in the skin's dermis provide it with structure, and the accompanying **elastin** protein fibrils make it flexible. Pinch the skin on your hand and then let go; the collagen and elastin proteins in the skin allow it to go back to its original shape. Smooth-muscle cells that secrete collagen and elastin proteins surround blood vessels, providing the vessels with structure and the ability to stretch back after blood is pumped through them. Another strong, fibrous protein is **keratin**, which is what skin, hair, and nails are made of.

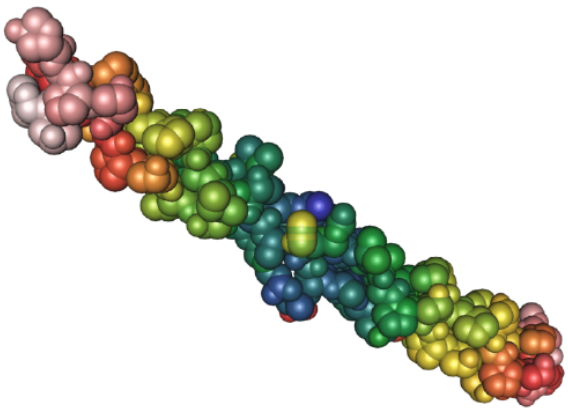


Figure 5.5.2: *Collagen: A strong protein made up of three intertwined peptides. (CC-SA-By; Nevit Dilmen).*

The closely packed collagen fibrils in tendons and ligaments allow for synchronous mechanical movements of bones and muscle and the ability of these tissues to spring back after a movement is complete. Move your fingers and watch the synchrony of your knuckle movements. In order to move, muscles must contract. The contractile parts of muscles are the proteins **actin** and **myosin**. When these proteins are stimulated by a nerve impulse they slide across each other, causing a shortening of the muscle cell. Upon stimulation, multiple muscle cells shorten at the same time, resulting in muscle contraction.

Video 5.5.1: Muscle Contraction: The Sliding Filament Model

Watch this video to see actin and myosin in action. (click to see video)

Enzymes

Although proteins are found in the greatest amounts in connective tissues such as bone, their most extraordinary function is as enzymes. Enzymes are proteins that conduct specific chemical reactions. An enzyme's job is to provide a site for a chemical reaction and to lower the amount of energy and time it takes for that chemical reaction to happen (this is known as "catalysis"). On average, more than one hundred chemical reactions occur in cells every single second and most of them require enzymes. The liver alone contains over one thousand enzyme systems. Enzymes are specific and will use only particular substrates that fit into their active site, similar to the way a lock can be opened only with a specific key. Nearly every chemical reaction requires a specific enzyme. Fortunately, an enzyme can fulfill its role as a catalyst over and over again, although eventually it is destroyed and rebuilt. All bodily functions, including the breakdown of nutrients in the stomach and small intestine, the transformation of nutrients into molecules a cell can use, and building all macromolecules, including protein itself, involve enzymes.

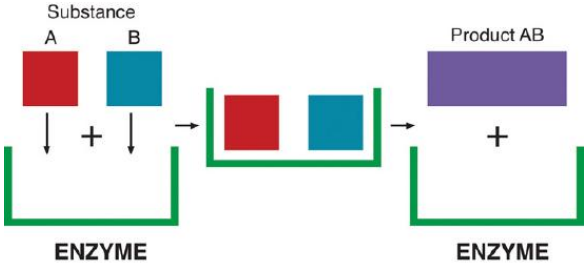


Figure 5.5.3: Enzymes are proteins. An enzyme's job is to provide a site for substances to chemically react and form a product and decrease the amount of energy and time it takes for this to happen.

Video 5.5.2: Enzyme

Watch this animation of an enzyme at work. (click to see video)

Hormones

Proteins are responsible for hormone synthesis. Recall that hormones are the chemical messages produced by the endocrine glands. When an endocrine gland is stimulated, it releases a hormone. The hormone is then transported in the blood to its target cell, where it communicates a message to initiate a specific reaction or cellular process. For instance, after you eat a meal, your blood glucose levels rise. In response to the increased blood glucose, the pancreas releases the hormone insulin. Insulin tells the cells of the body that glucose is available and to take it up from the blood and store it or use it for making energy or building macromolecules. A major function of hormones is to turn enzymes on and off, so some proteins can even regulate the actions of other proteins. While not all hormones are made from proteins, many of them are.

Fluid and Acid-Base Balance

Proper protein intake enables the basic biological processes of the body to maintain the status quo in a changing environment. Fluid balance refers to maintaining the distribution of water in the body. If too much water in the blood suddenly moves into a tissue, the results are swelling and, potentially, cell death. Water always flows from an area of high concentration to one of a low concentration. As a result, water moves toward areas that have higher concentrations of other solutes, such as proteins and glucose. To keep the water evenly distributed between blood and cells, proteins continuously circulate at high concentrations in the blood. The most abundant protein in blood is the butterfly-shaped protein known as **albumin**. Albumin's presence in the blood makes the

protein concentration in the blood similar to that in cells. Therefore, fluid exchange between the blood and cells is not in the extreme, but rather is minimized to preserve the status quo.

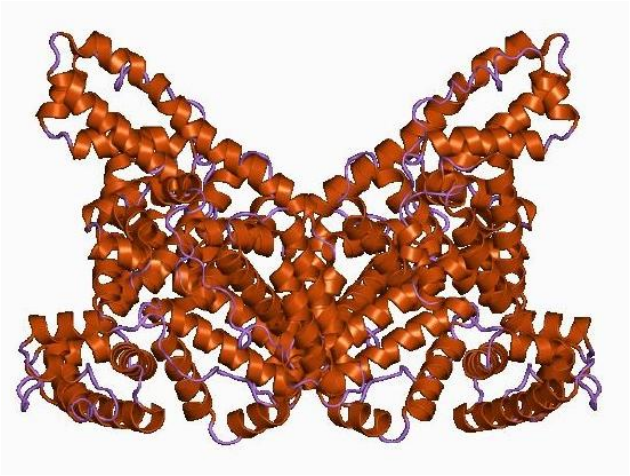


Figure 5.5.4: The butterfly-shaped protein, albumin, has many functions in the body including maintaining fluid and acid-base balance and transporting molecules. Cartoon representation of the molecular structure of protein registered with 1ao6 code. (Public Domain; Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute).

Protein is also essential in maintaining proper pH balance (the measure of how acidic or basic a substance is) in the blood. Blood pH is maintained between 7.35 and 7.45, which is slightly basic. Even a slight change in blood pH can affect body functions. Recall that acidic conditions can cause protein denaturation, which stops proteins from functioning. The body has several systems that hold the blood pH within the normal range to prevent this from happening. One of these is the circulating albumin. Albumin is slightly acidic, and because it is negatively charged it balances the many positively charged molecules, such as hydrogen protons (H^+), calcium, potassium, and magnesium which are also circulating in the blood. Albumin acts as a buffer against abrupt changes in the concentrations of these molecules, thereby balancing blood pH and maintaining the status quo. The protein hemoglobin also participates in acid-base balance by binding hydrogen protons.

Transport

Albumin and hemoglobin also play a role in molecular transport. Albumin chemically binds to hormones, fatty acids, some vitamins, essential minerals, and drugs, and transports them throughout the circulatory system. Each red blood cell contains millions of hemoglobin molecules that bind oxygen in the lungs and transport it to all the tissues in the body. A cell's plasma membrane is usually not permeable to large polar molecules, so to get the required nutrients and molecules into the cell many transport proteins exist in the cell membrane. Some of these proteins are channels that allow particular molecules to move in and out of cells. Others act as one-way taxis and require energy to function (Figure 5.5.5).

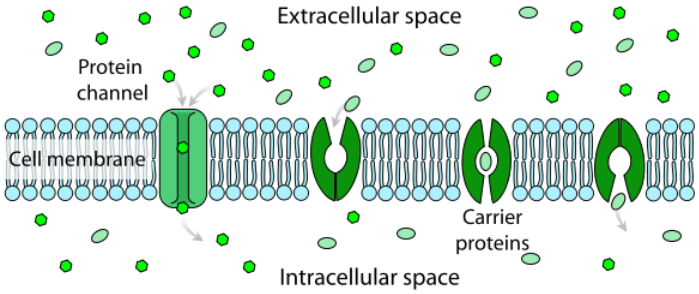


Figure 5.5.5: Molecules move in and out of cells through transport proteins, which are either channels or carriers. Facilitated diffusion in the cell membrane, showing ion channels (left) and carrier proteins (three on the right). (Public Domain; LadyofHats).

Protection

Earlier we discussed that the strong collagen fibers in skin provide it with structure and support. The skin's dense network of collagen fibers also serves as a barricade against harmful substances. The immune system's attack and destroy functions are dependent on enzymes and antibodies, which are also proteins. An enzyme called **lysozyme** is secreted in the saliva and attacks the walls of bacteria, causing them to rupture. Certain proteins circulating in the blood can be directed to build a molecular knife that

stabs the cellular membranes of foreign invaders. The antibodies secreted by the white blood cells survey the entire circulatory system looking for harmful bacteria and viruses to surround and destroy. Antibodies also trigger other factors in the immune system to seek and destroy unwanted intruders.

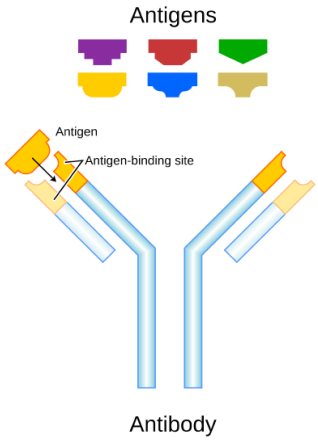


Figure 5.5.6: Proteins play a role in protecting the body against unwanted intruders. Antibodies surround and attack an influenza virus via "antigens" on their surface. Each antibody binds to a specific antigen; an interaction similar to a lock and key. (Public Domain; Fvasconcellos and USA government).

Video 5.5.4: Specific Immunity: Antibodies

Watch this to observe how antibodies protect against foreign intruders.(click to see video)

Wound Healing and Tissue Regeneration

Proteins are involved in all aspects of wound healing, a process that takes place in three phases: inflammatory, proliferative, and remodeling. For example, if you were sewing and pricked your finger with a needle, your flesh would turn red and become inflamed. Within a few seconds, bleeding would stop. The healing process begins with proteins such as bradykinin, which dilate blood vessels at the site of injury. An additional protein called fibrin helps to secure platelets that form a clot to stop the bleeding. Next, in the proliferative phase, cells move in and mend the injured tissue by installing newly made collagen fibers. The collagen fibers help pull the wound edges together. In the remodeling phase, more collagen is deposited, forming a scar. Scar tissue is only about 80 percent as functional as normal uninjured tissue. If a diet is insufficient in protein, the process of wound healing is markedly slowed.

While wound healing takes place only after an injury is sustained, a different process called tissue regeneration is ongoing in the body. The main difference between wound healing and tissue regeneration is in the process of regenerating an exact structural and functional copy of the lost tissue. Thus, old, dying tissue is not replaced with scar tissue but with brand new, fully functional tissue. Some cells (such as skin, hair, nails, and intestinal cells) have a very high rate of regeneration, while others, (such as heart-muscle cells and nerve cells) do not regenerate at any appreciable levels. Tissue regeneration is the creation of new cells (cell division), which requires many different proteins including enzymes that synthesize RNA and proteins, transport proteins, hormones, and collagen. In a hair follicle, cells divide and a hair grows in length. Hair growth averages 1 centimeter per month and fingernails about 1 centimeter every one hundred days. The cells lining the intestine regenerate every three to five days. Protein-inadequate diets impair tissue regeneration, causing many health problems including impairment of nutrient digestion and absorption and, most visibly, hair and nail growth.

Energy Production

Some of the amino acids in proteins can be disassembled and used to make energy. Only about 10 percent of dietary proteins are catabolized each day to make cellular energy. The liver is able to break down amino acids to the carbon skeleton, which can then be fed into the citric acid cycle. This is similar to the way that glucose is used to make ATP. If a person’s diet does not contain enough carbohydrates and fats their body will use more amino acids to make energy, which compromises the synthesis of new proteins and destroys muscle proteins. Alternatively, if a person’s diet contains more protein than the body needs, the extra amino acids will be broken down and transformed into fat.

Key Takeaways

- The many shapes and sizes of proteins allow them to perform a vast array of functions, including acting as enzymes and hormones, providing for fluid and acid-base balance, transport, protection, wound healing and tissue regeneration, and energy production.
- Without adequate intake of protein containing all the essential amino acids, all protein functions will be impaired.

Discussion Starter

1. Given protein's critical roles in the immune system, what do you think might occur more frequently in a person whose diet is protein deficient?

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5.6: Diseases Involving Proteins

Learning Objectives

- Identify the potential health risks associated with abnormal protein levels in the diet.

As you may recall, moderation refers to having the proper amount of a nutrient—having neither too little nor too much. A healthy diet incorporates all nutrients in moderation. Low protein intake has several health consequences, and a severe lack of protein in the diet eventually causes death. Although severe protein deficiency is a rare occurrence in children and adults in the United States, it is estimated that more than half of the elderly in nursing homes are protein-deficient. The Acceptable Macronutrient Distribution Range (AMDR) for protein for adults is between 10 and 35 percent of kilocalories, which is a fairly wide range. The percent of protein in the diet that is associated with malnutrition and its health consequences is less than 10 percent, but this is often accompanied by deficiencies in calories and other micronutrients. There is some scientific evidence that shows that people with diets low in animal protein (< 8 percent of caloric intake), who get adequate protein from plant-based foods instead, may actually have improved health and increased longevity. On the other hand, diets rich in animal-derived protein (> 30 percent of caloric intake) are associated with increased early mortality, kidney and liver malfunction, cardiovascular disease, colon cancer, and osteoporosis. In this section we will discuss the health consequences of protein intake that is either too low to support life's processes or too high, thereby increasing the risk of chronic disease. In the last section of this chapter, we will discuss in more detail the personal choices you can make to optimize your health by consuming the right amount of high-quality protein.

Health Consequences of Protein Deficiency

Although severe protein deficiency is rare in the developed world, it is a leading cause of death in children in many poor, underdeveloped countries. There are two main syndromes associated with protein deficiencies: Kwashiorkor and Marasmus. Kwashiorkor affects millions of children worldwide. When it was first described in 1935, more than 90 percent of children with Kwashiorkor died. Although the associated mortality is slightly lower now, most children still die after the initiation of treatment. The name Kwashiorkor comes from a language in Ghana and means, "rejected one." The syndrome was named because it occurred most commonly in children who had recently been weaned from the breast, usually because another child had just been born. Subsequently, the child was fed watery porridge made from low-protein grains, which accounts for the low protein intake. Kwashiorkor is characterized by swelling (edema) of the feet and abdomen, poor skin health, growth retardation, low muscle mass, and liver malfunction. Recall that one of protein's functional roles in the body is fluid balance. Diets extremely low in protein do not provide enough amino acids for the synthesis of albumin. One of the functions of albumin is to hold water in the blood vessels, so having lower concentrations of blood albumin results in water moving out of the blood vessels and into tissues, causing swelling. The primary symptoms of Kwashiorkor include not only swelling, but also diarrhea, fatigue, peeling skin, and irritability. Severe protein deficiency in addition to other micronutrient deficiencies, such as folate (vitamin B_9), iodine, iron, and vitamin C all contribute to the many health manifestations of this syndrome.



Figure 5.6.1: Kwashiorkor is a disease brought on by a severe dietary protein deficiency. Symptoms include edema of legs and feet, light-colored, thinning hair, anemia, a pot-belly, and shiny skin. (Public domain; Centers for Disease Control and Prevention).

Children and adults with marasmus neither have enough protein in their diets nor do they take in enough calories often referred to as protein-energy malnutrition. Marasmus affects mostly children below the age of one in poor countries. Body weights of children with Marasmus may be up to 80 percent less than that of a normal child of the same age. Marasmus is a Greek word, meaning "starvation." The syndrome affects more than fifty million children under age five worldwide. It is characterized by an extremely emaciated appearance, poor skin health, and growth retardation. The symptoms are acute fatigue, hunger, and diarrhea.

Kwashiorkor and marasmus often coexist as a combined syndrome termed marasmic kwashiorkor. Children with the combined syndrome have variable amounts of edema and the characterizations and symptoms of marasmus. Although organ system function is compromised by undernutrition, the ultimate cause of death is usually an infection. Undernutrition is intricately linked with suppression of the immune system at multiple levels, so undernourished children commonly die from severe diarrhea and/or pneumonia resulting from bacterial or viral infection (Figure 6.7). The United Nations Children's Fund (UNICEF), the most prominent agency with the mission of changing the world to improve children's lives, reports that undernutrition causes at least one-third of deaths of young children. As of 2008, the prevalence of children under age five who were underweight was 26 percent. The percentage of underweight children has declined less than 5 percent in the last eighteen years despite the Millennium Development Goal of halving the proportion of people who suffer from hunger by the year 2015.

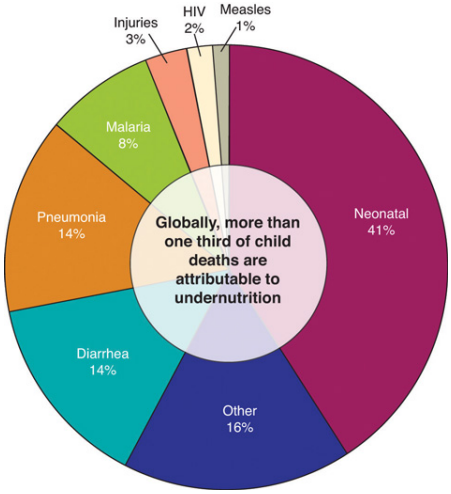


Figure 5.6.2: Causes of death for children under the age of five, worldwide.

Interactive 5.6.1

If you are interested in finding out more about world hunger and what is being done about it, visit the UNICEF website. http://www.childinfo.org/index.html

Health Consequences of Too Much Protein in the Diet

An explicit definition of a high-protein diet has not yet been developed by the Food and Nutrition Board of the Institute of Medicine (IOM), but typically diets high in protein are considered as those that derive more than 30 percent of calories from protein. Many people follow high-protein diets because marketers tout protein's ability to stimulate weight loss. It is true that following high-protein diets increases weight loss in some people. However, the number of individuals that remain on this type of diet is low and many people who try the diet and stop regain the weight they had lost. Additionally, there is a scientific hypothesis that there may be health consequences of remaining on high-protein diets for the long-term, but clinical trials are ongoing or scheduled to examine this hypothesis further. As the high-protein diet trend arose so did the intensely debated issue of whether there are any health consequences of eating too much protein. Observational studies conducted in the general population suggest diets high in animal protein, specifically those in which the primary protein source is red meat, are linked to a higher risk for kidney stones, kidney disease, liver malfunction, colorectal cancer, and osteoporosis. However, diets that include lots of red meat are also high in saturated fat and cholesterol and sometimes linked to unhealthy lifestyles, so it is difficult to conclude that the high protein content is the culprit.

High protein diets appear to only increase the progression of kidney disease and liver malfunction in people who already have kidney or liver malfunction, and not to *cause* these problems. However, the prevalence of kidney disorders is relatively high and underdiagnosed. In regard to colon cancer, an assessment of more than ten studies performed around the world published in the

June 2011 issue of *PLoS* purports that a high intake of red meat and processed meat is associated with a significant increase in colon cancer risk.Chan, D. S., et al. “Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective Studies.” *PLoS One* 6, no. 6 (2011): e20456. doi: 10.1371/journal.pone.0020456. Although there are a few ideas, the exact mechanism of how proteins, specifically those in red and processed meats, causes colon cancer is not known and requires further study.

Some scientists hypothesize that high-protein diets may accelerate bone-tissue loss because under some conditions the acids in protein block absorption of calcium in the gut, and, once in the blood, amino acids promote calcium loss from bone; however, even these effects have not been consistently observed in scientific studies. Results from the Nurse’s Health Study suggest that women who eat more than 95 grams of protein each day have a 20 percent higher risk for a wrist fracture (Harvard School of Public Health. “Protein: The Bottom Line.” *The Nutrition Source*. © 2012 The President and Fellows of Harvard University. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein/ and Barzel, U. S. and L. K. Massey. “Excess Dietary Protein Can Adversely Affect Bone.” *J Nutr* 128, no. 6 (June 1, 1998): 1051–53. http://jn.nutrition.org/content/128/6/1051.long). Other studies have not produced consistent results. The scientific data on high protein diets and increased risk for osteoporosis remain highly controversial and more research is needed to come to any conclusions about the association between the two (St. Jeor, S. T. et al. “Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association.” *Circulation* 104 (2001): 1869–74.)

High-protein diets can restrict other essential nutrients. The AHA states that “High-protein diets are not recommended because they restrict healthful foods that provide essential nutrients and do not provide the variety of foods needed to adequately meet nutritional needs. Individuals who follow these diets are therefore at risk for compromised vitamin and mineral intake, as well as potential cardiac, renal, bone, and liver abnormalities overall (”St. Jeor, S. T. et al. “Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association.” *Circulation* 104 (2001): 1869–74).

As with any nutrient, protein must be eaten in proper amounts. Moderation and variety are key strategies to achieving a healthy diet and need to be considered when optimizing protein intake. While the scientific community continues its debate about the particulars regarding the health consequences of too much protein in the diet, you may be wondering just how much protein you should consume to be healthy. Read on to find out more about calculating your dietary protein recommendations, dietary protein sources, and personal choices about protein.

Key Takeaways

- Protein deficiency syndromes are a leading cause of death in children under the age of five in poor, underdeveloped countries. Protein deficiency can cause swelling, fatigue, skin problems, irritability, muscle wasting, and eventual death from infection.
- The long-term health consequences of high-protein diets have not been adequately studied.

Discussion Starter

1. What are some diet changes you can make that are better, more sustainable, and easier to follow for the rest of your life than a high-protein diet?

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5.7: Proteins, Diet, and Personal Choices

Learning Objectives

- Calculate your Recommended Dietary Allowance for protein.
- Plan a one-day diet for each of the following: vegetarian, lacto-ovo vegetarian, and vegan. For each, calculate nutrient intake, then assess for adequacy, balance, and variety.
- Decide whether to take protein or amino acid supplements based on nutrition science studies.

We have discussed what proteins are, how they are made, how they are digested and absorbed, the many functions of proteins in the body, and the consequences of having too little or too much protein in the diet. This section will provide you with information on how to determine the recommended amount of protein for you, and your many choices in designing an optimal diet with high-quality protein sources.

How Much Protein Does a Person Need in Their Diet?

The recommendations set by the IOM for the Recommended Daily Allowance (RDA) and AMDR for protein for different age groups are listed in Table 5.7.1. A Tolerable Upper Intake Limit for protein has not been set, but it is recommended that you not exceed the upper end of the AMDR.

Table 5.7.1: Dietary Reference Intakes for Protein

Age Group	RDA (g/day)	AMDR (% calories)
Infants (0–6 mo)	9.1*	Not determined
Infants (7–12 mo)	11.0	Not determined
Children (1–3)	13.0	5–20
Children (4–8)	19.0	10–30
Children (9–13)	34.0	10–30
Males (14–18)	52.0	10–30
Females (14–18)	46.0	10–30
Adult Males (19+)	56.0	10–35
Adult Females (19+)	46.0	10–35
* Denotes Adequate Intake		

Source: Institute of Medicine. “Dietary Reference Intakes: Macronutrients.” *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* September 5, 2002.

Protein Input = Protein Used by the Body + Protein Excreted

The appropriate amount of protein in a person’s diet is that which maintains a balance between what is taken in and what is used. The RDAs for protein were determined by assessing **nitrogen balance**. Nitrogen is one of the four basic elements contained in all amino acids. When proteins are broken down and amino acids are catabolized, nitrogen is released. Remember that when the liver breaks down amino acids, it produces ammonia, which is rapidly converted to non-toxic, nitrogen-containing urea, which is then transported to the kidneys for excretion. Most nitrogen is lost as urea in the urine, but urea is also excreted in the feces. Proteins are also lost in sweat and as hair and nails grow. The RDA, therefore, is the amount of protein a person should consume in their diet to balance the amount of protein used up and lost from the body. For healthy adults, this amount of protein was determined to be 0.8 grams of protein per kilogram of body weight. You can calculate your exact recommended protein intake per day based on your weight by using the following equation:

$$(\text{Weight in lbs.} \div 2.2\ \text{kg/lb}) \times 0.8\ \text{g/kg}$$

Note that if a person is overweight, the amount of dietary protein recommended can be overestimated.

The IOM used data from multiple studies that determined nitrogen balance in people of different age groups to calculate the RDA for protein. A person is said to be in nitrogen balance when the nitrogen input equals the amount of nitrogen used and excreted. A person is in negative nitrogen balance when the amount of excreted nitrogen is greater than that consumed, meaning that the body is breaking down more protein to meet its demands. This state of imbalance can occur in people who have certain diseases, such as cancer or muscular dystrophy. Someone who has a low-protein diet may also be in negative nitrogen balance as they are taking in less protein than what they actually need. Positive nitrogen balance occurs when a person excretes less nitrogen than what is taken in by the diet, such as during child growth or pregnancy. At these times the body requires more protein to build new tissues, so more of what gets consumed gets used up and less nitrogen is excreted. A person healing from a severe wound may also be in positive nitrogen balance because protein is being used up to repair tissues.

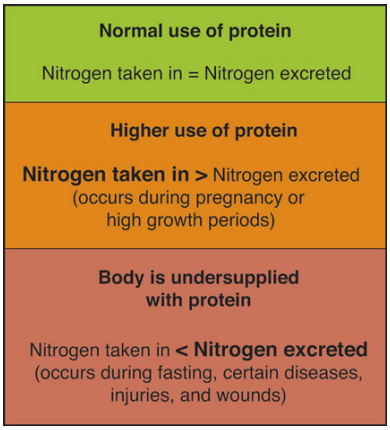


Figure 5.7.1: Nitrogen Balance

Dietary Sources of Protein

The protein food group consists of foods made from meat, seafood, poultry, eggs, soy, beans, peas, and seeds. According to the Harvard School of Public Health, “animal protein and vegetable protein probably have the same effects on health. It’s the protein package that’s likely to make a difference (”Harvard School of Public Health. “Protein: The Bottom Line.” *The Nutrition Source*. © 2012 The President and Fellows of Harvard University. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein/). Simply put, different protein sources differ in their additional components, so it is necessary to pay attention to the whole nutrient “package.” Protein-rich animal-based foods commonly have high amounts of B vitamins, vitamin E, iron, magnesium, and zinc. Seafood often contains healthy fats, and plant sources of protein contain a high amount of fiber. Some animal-based protein-rich foods have an unhealthy amount of saturated fat and cholesterol. When choosing your dietary sources of protein, take note of the other nutrients and also the nonnutrients, such as cholesterol, dyes, and preservatives, in order to make good selections that will benefit your health. For instance, a hamburger patty made from 80 percent lean meat contains 22 grams of protein, 5.7 grams of saturated fat, and 77 milligrams of cholesterol. A burger made from 95 percent lean meat also contains 22 grams of protein but has 2.3 grams of saturated fat and 60 milligrams of cholesterol. A cup of boiled soybeans contains 29 grams of protein, 2.2 grams of saturated fat, and no cholesterol. For more comparisons of protein-rich foods, see Table 5.7.2. To find out the complete nutrient package of different foods, visit the US Department of Agriculture (USDA) website listed below.

Table 5.7.2: Sources of Dietary Protein

Food	Protein Content (g)	Saturated Fat (g)	Cholesterol (mg)	Calories
Hamburger patty 3 oz. (80% lean)	22.0	5.7	77	230
Hamburger patty 3 oz. (95% lean)	22.0	2.3	60	139
Top sirloin 3 oz.	25.8	2.0	76	158
Beef chuck 3 oz. (lean, trimmed)	22.2	1.8	51	135
Pork loin 3 oz.	24.3	3.0	69	178

Food	Protein Content (g)	Saturated Fat (g)	Cholesterol (mg)	Calories
Pork ribs (country style, 1 piece)	56.4	22.2	222	790
Chicken breast (roasted, 1 c.)	43.4	1.4	119	231
Chicken thigh (roasted, 1 thigh)	13.5	1.6	49	109
Chicken leg (roasted, 1 leg)	29.6	4.2	105	264
Salmon 3 oz.	18.8	2.1	54	175
Tilapia 3 oz.	22.2	0.8	48	109
Halibut 3 oz.	22.7	0.4	35	119
Shrimp 3 oz.	17.8	0.2	166	84
Shrimp (breaded, fried, 6–8 pcs.)	18.9	5.4	200	454
Tuna 3 oz. (canned)	21.7	0.2	26	99
Soybeans 1 c. (boiled)	29.0	2.2	0	298
Lentils 1 c. (boiled)	17.9	0.1	0	226
Kidney beans 1 c. (canned)	13.5	0.2	0	215
Sunflower seeds 1 c.	9.6	2.0	0	269

Interactive 5.7.1

This interactive USDA tool allows you to enter the foods you eat (with serving size) and find out the whole nutrient package. http://www.ars.usda.gov/Services/docs.htm?docid=17032

The USDA provides some tips for choosing your dietary protein sources. Their motto is, “Go Lean with Protein”. The overall suggestion is to eat a variety of protein-rich foods to benefit health. The USDA recommends lean meats, such as round steaks, top sirloin, extra lean ground beef, pork loin, and skinless chicken. Additionally, a person should consume 8 ounces of cooked seafood every week (typically as two 4-ounce servings) to assure they are getting the healthy omega-3 fatty acids that have been linked to a lower risk for heart disease. Another tip is choosing to eat beans, peas, or soy products as a main dish. Some of the menu choices include chili with kidney and pinto beans, hummus on pita bread, and black bean enchiladas. You could also enjoy nuts in a variety of ways. You can put them on a salad, in a stir-fry, or use them as a topping for steamed vegetables in place of meat or cheese. If you do not eat meat, the USDA has much more information on how to get all the protein you need from a plant-based diet. When choosing the best protein-rich foods to eat, pay attention to the whole nutrient package and remember to select from a variety of protein sources to get all the other essential micronutrients.

Interactive 5.7.2

The USDA manages the website choosemyplate.gov. The site provides a lot of tips and information about protein-rich foods. www.choosemyplate.gov/food-groups/protein-foods.html

Tools for Change

Try some new, healthy, protein-rich food recipes by visiting the Harvard School of Public Health website, http://hvrd.me/OJRkpV. You will find recipes for foods such as spicy lemongrass tofu with Asian basil, fish Creole, and spicy chicken kebabs.

Protein Quality

While protein is contained in a wide variety of foods, it differs in quality. High-quality protein contains all the essential amino acids in the proportions needed by the human body. The amino acid profile of different foods is, therefore, one component of protein quality. Foods that contain some of the essential amino acids are called incomplete protein sources, while those that contain all nine essential amino acids are called complete protein sources, or high-quality protein sources. Foods that are complete protein sources include animal foods such as milk, cheese, eggs, fish, poultry, and meat, and a few plant foods, such as soy and quinoa (Figure 5.7.2). The only animal-based protein that is not complete is gelatin, which consists of the protein, collagen.



Figure 5.7.2: Complete and Incomplete Protein Sources. Examples of complete protein sources include soy, dairy products, meat, and seafood. Examples of incomplete protein sources include legumes and corn. © Shutterstock

Most plant-based foods are deficient in at least one essential amino acid and therefore are incomplete protein sources. For example, grains are usually deficient in the amino acid lysine, and legumes do not contain methionine or tryptophan. Because grains and legumes are not deficient in the same amino acids they can complement each other in a diet. Incomplete protein foods are called **complementary foods** because when consumed in tandem they contain all nine essential amino acids at adequate levels. Some examples of complementary protein foods are given in Table 5.7.4. Complementary protein sources do not have to be consumed at the same time—as long as they are consumed within the same day, you will meet your protein needs.

Tools for Change

Explore some ethnic grocery markets to find new high-protein foods for your diet and/or experiment with the much cheaper plant-based protein sources. SeeTable 5.7.4 for complementing protein sources the vegan way.

Table 5.7.3: Complementing Protein Sources the Vegan Way

Foods	Lacking Amino Acids	Complementary Food	Complementary Menu
Legumes	Methionine, tryptophan	Grains, nuts, and seeds	Hummus and whole-wheat pita
Grains	Lysine, isoleucine, threonine	Legumes	Cornbread and kidney bean chili
Nuts and seeds	Lysine, isoleucine	Legumes	Stir-fried tofu with cashews

The second component of protein quality is digestibility, as not all protein sources are equally digested. In general, animal-based proteins are completely broken down during the process of digestion, whereas plant-based proteins are not. This is because some proteins are contained in the plant's fibrous cell walls and these pass through the digestive tract unabsorbed by the body.

Protein Digestibility Corrected Amino Acid Score (PDCAAS)

The PDCAAS is a method adopted by the US Food and Drug Administration (FDA) to determine a food's protein quality. It is calculated using a formula that incorporates the total amount of amino acids in the food and the amount of protein in the food that is actually digested by humans. The food's protein quality is then ranked against the foods highest in protein quality. Milk protein, egg whites, whey, and soy all have a ranking of one, the highest ranking. Other foods' ranks are listed in Table 5.7.5.

Table 5.7.4: PDCAAS of Various Foods

Food	PDCAAS*
Milk protein	1.00
Egg white	1.00
Whey	1.00
Soy protein	1.00
Beef	0.92
Soybeans	0.91
Chickpeas	0.78
Fruits	0.76
Vegetables	0.73
Legumes	0.70
Cereals	0.59
Whole wheat	0.42
*1 is the highest rank, 0 is the lowest	

Protein Needs: Special Considerations

Some groups may need to examine how to meet their protein needs more closely than others. We will take a closer look at the special protein considerations for vegetarians, the elderly, and athletes.

Vegetarians and Vegans

Vegan eat no animal products while vegetarian diets may include a variety of different animal products. Here are the different types:

- Vegan - no animal products
- Lacto-vegetarian - milk products are consumed
- Ovo-vegetarian - egg products are consumed
- Lacto-ovo-vegetarian - milk and egg product are consumed
- Pesco-vegetarian - fish is allowed
- Pseudo-vegetarian - consumes dairy products, eggs, chicken, and fish, but does not consume other animal flesh
- Semi-vegetarian; flexitarian; partial vegetarian - plant-based diet with the occasional inclusion of animal meat
- Macrobiotic diet - only brown rice, water and herbal tea (this diet is deficient in many nutrients)
- Fruitarian - raw or dried fruit, seeds, nuts, honey and vegetable oil (this diet can be deficient in nutrients)

Many different cultures practice vegetarianism. Examples are shown in this table.

Table 5.7.5: Examples of Cultures that practice vegetarianism.

Culture	Food
Indian (Asian)	Dhal (lentils) and rice

Mexican	Rice and beans
South East US	Black-eyed peas and corn
South East Asia	Tofu (soybean protein) and rice
United States	Peanut butter and bread

People who follow variations of the vegetarian diet and consume eggs and/or dairy products can easily meet their protein requirements by consuming adequate amounts of these foods. Vegetarians and vegans can also attain their recommended protein intakes if they give a little more attention to high-quality plant-based protein sources. However, when following a vegetarian diet, the amino acid lysine can be challenging to acquire. Grains, nuts, and seeds are lysine-poor foods, but tofu, soy, quinoa, and pistachios are all good sources of lysine. Following a vegetarian diet and getting the recommended protein intake is also made a little more difficult because the digestibility of plant-based protein sources is lower than the digestibility of animal-based protein.

To begin planning a more plant-based diet, start by finding out which types of food you want to eat and in what amounts you should eat them to ensure that you get the protein you need. The Dietary Guidelines Advisory Committee (DGAC) has analyzed how three different, plant-based dietary patterns can meet the recommended dietary guidelines for all nutrients (Jacobs, D. R. et al. "Food, Plant Food, and Vegetarian Diets in the US Dietary Guidelines: Conclusions of an Expert Panel." *Am J Clin Nutr* 89, no. 5 (2009). http://ajcn.nutrition.org/content/89/5/1549S.short). The diets are defined in the following manner:

- **Plant-based.** Fifty percent of protein is obtained from plant foods.
- **Lacto-ovo vegetarian.** All animal products except eggs and dairy are eliminated.
- **Vegan.** All animal products are eliminated.

Table 5.7.6: Percentage of "Meat and Beans Group" Components in the USDA Base Diet, and Three Vegetarian Variations

Food Category	Base USDA (%)	Plant-Based (%)	Lacto-Ovo Vegetarian (%)	Vegan (%)
Meats	44.6	10.5	0	0
Poultry	27.9	8.0	0	0
Fish (high omega-3)	2.2	3.0	0	0
Fish (low omega-3)	7.1	10.0	0	0
Eggs	7.9	7.6	10.0	0
Soy products	0.9	15.0	30.0	25.0
Nuts and seeds	9.4	20.9	35.0	40.0
Dry beans and peas	n/a*	25.0	25.0	35.0
Total	100.0	100.0	100.0	100.0

*The dry beans and peas are in the vegetable food group of the base diet. Source: US Department of Agriculture. Appendix E-3.3, *"Vegetarian Food Patterns: Food Pattern Modeling Analysis."* In *2010 Dietary Guidelines for Americans*.

These diets are analyzed and compared to the more common dietary pattern of Americans, which is referred to as the USDA Base Diet. Tables 5.7.6 and 5.7.7 can be used to help determine what percentage of certain foods to eat when following a different dietary pattern. The percentages of foods in the different groups are the proportions consumed by the population, so that, on average, Americans obtain 44.6 percent of their foods in the meat and beans group from meats. If you choose to follow a lacto-ovo vegetarian diet, the meats, poultry, and fish can be replaced by consuming a higher percentage of soy products, nuts, seeds, dry beans, and peas. As an aside, the DGAC notes that these dietary patterns may not exactly align with the typical diet patterns of people in the United States. However, they do say that they can be adapted as a guide to developing a more plant-based diet that does not significantly affect nutrient adequacy.

Table 5.7.7: Proportions of Milk Products and Calcium-Fortified Soy Products in the Base USDA Patterns and Three Vegetarian Variations

Food Category	Base USDA (%)	Plant-based (%)	Lacto-ovo vegetarian (%)	Vegan (%)
Fluid milk	54.6	54.6	54.6	0
Yogurt	1.6	1.6	1.6	0
Cheese	42.7	42.7	42.7	0
Soy milk (w/ calcium)	1.1	1.1	1.1	67.0
Rice milk (w/ calcium)	0	0	0	16.0
Tofu (w/ calcium)	0	0	0	15.0
Soy yogurt	0	0	0	2.0
Total	100.0	100.0	100.0	100.0

Source: US Department of Agriculture. Appendix E-3.3, *"Vegetarian Food Patterns: Food Pattern Modeling Analysis."* In *2010 Dietary Guidelines for Americans*. www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/AppendixE-3-3-Vegetarian.pdf#xml=http://65.216.150.153/texis/search/p...ead=500&rdepth =0&sufs=2&order=r&cq=&id=4d9cfcc17.

From these analysis, the DGAC concluded that the plant-based, lacto-ovo vegetarian, and vegan diets do not significantly affect nutrient adequacy. Additionally, the DGAC states that people who choose to obtain proteins solely from plants should include foods fortified with vitamins B_{12}, D, and calcium. Other nutrients of concern may be omega-3 fatty acids and choline. Two large observational studies with thousands of participants demonstrated that in comparison to regular meat-eaters, people who followed a vegetarian diet had a significantly decreased risk of dying from heart disease or cancer.Lindbloom, E. "Long-Term Benefits of a Vegetarian Diet." *Am Fam Physician* 79, no. 7 (April 1, 2009): 541–42. www.aafp.org/afp/2009/0401/p541.html.

Interactive 5.7.3

To read the full report on the nutrient adequacy of plant-based, lacto-ovo vegetarian, and vegan diets, go to the link to the *Dietary Guidelines* below, which takes you directly to Appendix E-3.3. In addition to the information in Tables 5.7.6 and 5.7.7, this document provides details on the actual amounts in ounces and cups of various food groups required to eat each day in order to meet the dietary guidelines. 1.usa.gov/ML3M8D

Tools for Change

Make a sustainable choice to go meatless more than once a week. To get some ideas on how to expand your dietary choices, visit the Eating Well website, which has a twenty-eight-day vegetarian meal plan that meets the US dietary guidelines. http://www.eatingwell.com/nutrition_health/weight_loss_diet_plans/diet_meal_plans /vegetarian_meal_plan

The Elderly

As we age, muscle mass gradually declines. This is a process referred to as sarcopenia. A person is sarcopenic when their amount of muscle tissue is significantly lower than the average value for a healthy person of the same age. A significantly lower muscle mass is associated with weakness, movement disorders, and a generally poor quality of life. It is estimated that about half the US population of men and women above the age of eighty are sarcopenic. A review published in the September 2010 issue of *Clinical Intervention in Aging* demonstrates that higher intakes (1.2 to 1.5 grams per kilogram of weight per day) of high-quality protein may prevent aging adults from becoming sarcopenic.Waters, D. L. et al. "Advantages of Dietary, Exercise-Related, and Therapeutic Interventions to Prevent and Treat Sarcopenia in Adult Patients: An Update." *Clin Interv Aging* 5 (September 7, 2010): 259–70. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2938033/?tool=pubmed Currently, the RDA for protein for elderly persons is the same as that for the rest of the adult population, but several clinical trials are ongoing and are focused on determining the amount of protein in the diet that prevents the significant loss of muscle mass specifically in older adults.

Athletes

Muscle tissue is rich in protein composition and has a very high turnover rate. During exercise, especially when it is performed for longer than two to three hours, muscle tissue is broken down and some of the amino acids are catabolized to fuel muscle contraction. To avert excessive borrowing of amino acids from muscle tissue to synthesize energy during prolonged exercise, protein needs to be obtained from the diet. Intense exercise, such as strength training, stresses muscle tissue so that afterward, the body adapts by building bigger, stronger, and healthier muscle tissue. The body requires protein post exercise to accomplish this. The IOM does not set different RDAs for protein intakes for athletes, but the AND, the American College of Sports Medicine, and Dietitians of Canada have the following position statements:

- "Nitrogen balance studies suggest that dietary protein intake necessary to support nitrogen balance in endurance athletes ranges from 1.2 to 1.4 grams per kilogram of body weight per day."
- "Recommended protein intakes for strength-trained athletes range from approximately 1.2 to 1.7grams per kilogram of weight per day."American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada. "Joint Position Statement: Nutrition and Athletic Performance." *Med Sci Sports Exerc* 41, no. 3 (March 2009). doi: 10.1249/MSS.0b013e31890eb86.



Figure 5.7.3: When the body is subjected to intensive strength-training, muscles adapt to the stress placed upon it by becoming bigger and stronger. Image of the Mr. Universe competition Dec. 2. (Public Domain)

An endurance athlete who weighs 170 pounds should take in 93 to 108 grams of protein per day ((170 ÷ 2.2) × 1.2 and (170 ÷ 2.2) × 1.4). On a 3,000-kilocalorie diet, that amount is between 12 and 14 percent of total kilocalories and within the AMDR. There is general scientific agreement that endurance and strength athletes should consume protein from high-quality sources, such as dairy, eggs, lean meats, or soy; however eating an excessive amount of protein at one time does not further stimulate muscle protein synthesis. Nutrition experts also recommend that athletes consume some protein within one hour after exercise to enhance muscle tissue repair during the recovery phase, but some carbohydrates and water should be consumed as well. The recommended ratio from nutrition experts for exercise-recovery foods is 4 grams of carbohydrates to 1 gram of protein.

Table 5.7.8: Snacks for Exercise Recovery

Foods	Protein (g)	Carbohydrates (g)	Calories
Whole grain cereal with nonfat milk	14	53	260
Medium banana with nonfat milk	10	39	191
Power bar	10	43	250

In response to hard training, a person's body also adapts by becoming more efficient in metabolizing nutrient fuels both for energy production and building macromolecules. However, this raises another question: if athletes are more efficient at using protein, is it necessary to take in more protein from dietary sources than the average person? There are two scientific schools of thought on this matter. One side believes athletes need more protein and the other thinks the protein requirements of athletes are the same as for nonathletes. There is scientific evidence to support both sides of this debate. The consensus of both sides is that few people

exercise at the intensity that makes this debate relevant. It is good to remember that the increased protein intake recommended by the AND, American College of Sports Medicine, and Dietitians of Canada still lies within the AMDR for protein.

Interactive 5.7.4

Visit “Nutrition 101, Eating for Exercise and Sports.” This USDA site contains a wealth of nutritional information for active people. 1.usa.gov/ML3RJj

Protein Supplements

Protein supplements include powders made from compounds such as whey or soy and amino acids that either come as a powder or in capsules. We have noted that the protein requirements for most people, even those that are active, is not high. Is taking protein supplements ever justified, then? Neither protein nor amino acid supplements have been scientifically proven to improve exercise performance or increase strength. In addition, the average American already consumes more protein than is required. Despite these facts, many highly physically active individuals use protein or amino acid supplements. According to the AND, American College of Sports Medicine, and Dietitians of Canada, “the current evidence indicates that protein and amino acid supplements are no more or no less effective than food when energy is adequate for gaining lean body mass (”American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada. “Joint Position Statement: Nutrition and Athletic Performance.” *Med Sci Sports Exerc* 41, no. 3 (March 2009). doi: 10.1249/MSS.0b013e31890eb86). Branched-chain amino acids, such as leucine, are often touted as a way to build muscle tissue and enhance athletic performance. Despite these marketing claims, a review in the June 2005 issue of *The Journal of Nutrition* shows that most studies that evaluated a variety of exercise types failed to show any performance-enhancing effects of taking branched-chain amino acids (Gleeson, M. “Interrelationship between Physical Activity and Branched-Chain Amino Acids.” *J Nutr* 135, no. 6, supplement (June 1, 2005): 1591S–5S. http://jn.nutrition.org/content/135/6/1591S.long). Moreover, the author of this review claims that high-quality protein foods are a better and cheaper source of branched-chain amino acids and says that a chicken breast (100 grams) contains the equivalent of seven times the amount of branched-chain amino acids as one supplement tablet. This means if you are interested in enhancing exercise performance or building muscle, you do not need to support the $20 billion supplement industry. Whole foods also provide other nutrients that supplements do not contain.

Although the evidence for protein and amino acid supplements impacting athletic performance is lacking, there is some scientific evidence that supports consuming high-quality dairy proteins, such as casein and whey, and soy proteins positively influence muscle recovery in response to hard training. If you choose to buy a bucket of whey protein, use it to make a protein shake after an intense workout and do not add more than what is required to obtain 20 to 25 grams of protein. As always, choosing high-quality protein foods will help you build muscle and not empty your wallet as much as buying supplements. Moreover, relying on supplements for extra protein instead of food will not provide you with any of the other essential nutrients. The bottom line is that whether you are an endurance athlete or strength athlete, or just someone who takes Zumba classes, there is very little need to put your money into commercially sold protein and amino acid supplements. The evidence to show that they are superior to regular food in enhancing exercise performance is not sufficient.



Figure 5.7.4: Make a shake and use the AMDRs for macronutrients as a guide when filling up the blender. (CC-SA-BY 3.0; Sigurdas)

What about the numerous protein shakes and protein bars on the market? Are they a good source of dietary protein? Do they help you build muscle or lose weight as marketers claim? These are not such a bad idea for an endurance or strength athlete who has little time to fix a nutritious exercise-recovery snack. However, before you ingest any supplement, do your homework. Read the label, be selective, and don't use them to replace meals, but rather as exercise-recovery snacks now and then. Some protein bars have a high amount of carbohydrates from added sugars and are not actually the best source of protein, especially if you are not an athlete. Protein bars are nutritionally designed to restore carbohydrates and protein after endurance or strength training; therefore they are not good meal replacements. If you want a low-cost alternative after an intense workout, make yourself a peanut butter sandwich on whole-grain bread and add some sliced banana for less than fifty cents. Supermarket and health-food-store shelves offer an extraordinary number of high-protein shake mixes. While the carbohydrate count is lower now in some of these products than a few years ago, they still contain added fats and sugars. They also cost, on average, more than two dollars per can. If you want more nutritional bang for your buck, make your own shakes from whole foods. Use the AMDRs for macronutrients as a guide to fill up the blender. Your homemade shake can now replace some of the whole foods on your breakfast, lunch, or dinner plate. Unless you are an endurance or strength athlete and consume commercially sold protein bars and shakes only post exercise, these products are not a good dietary source of protein.

Proteins in a Nutshell

Proteins are long chains of amino acids folded into precise structures that determine their functions, which are in the tens of thousands. They are the primary construction materials of the body serving as building blocks for bone, skin, hair, muscle, hormones, and antibodies. Without them, we cannot break down or build macromolecules, grow, or heal from a wound. Eat proteins in moderation, at least 10 percent of the calories you take in and not more than 35 percent. Too little protein impairs bodily functions and too much can lead to chronic disease. Proteins are in a variety of foods. More complete sources are in animal-based foods, but choose those low in saturated fat and cholesterol. Some plant-based foods are also complete protein sources and don't add much to your saturated fat or cholesterol intake. Incomplete protein sources can easily be combined in the daily diet and provide all of the essential amino acids at adequate levels. Growing children and the elderly need to ensure they get enough protein in their diet to help build and maintain muscle strength. Even if you're a hardcore athlete, get your proteins from nutrient-dense foods as you need more than just protein to power up for an event.



Figure 5.7.5: Many Olympic athletes have adopted a vegetarian diet which, when implemented effectively, supports a very active and athletic lifestyle. The finish of a women's 100 m race. (CC-SA-BY 3.0; Wikipedia/flickr)

Nuts are one nutrient-dense food with a whole lot of protein. One ounce of pistachios, which is about fifty nuts, has the same amount of protein as an egg and contains a lot of vitamins, minerals, healthy polyunsaturated fats, and antioxidants. Moreover, the FDA says that eating one ounce of nuts per day can lower your risk for heart disease. Can you be a hardcore athlete and a vegetarian? Many Olympians are vegetarians: figure skater Charlene Wong, sprinter Leroy Burrell, hurdler Edwin Moses, and Carl Lewis, who won ten medals (nine of them gold) in track and field. The analysis of vegetarian diets by the DGAC did not find that they were inadequate in any nutrients, but did state that people who obtain proteins solely from plants should make sure they consume foods with vitamin B_{12}, vitamin D, calcium, omega-3 fatty acids, and choline. Iron and zinc may also be of concern, especially for female athletes. Being a vegetarian athlete requires that you pay more attention to what you eat, however, this is also a true statement for all athletes. For an exhaustive list that provides the protein, calcium, cholesterol, fat, and fiber content, as well as the number of calories, of numerous foods, go to the website, http://www.soystache.com/protein.htm.

Getting All the Nutrients You Need—The Plant-Based Way

Below are five ways to assure you are getting all the nutrients you need while working toward a more plant-based diet;

1. Get your protein from foods such as soybeans, tofu, tempeh, lentils, and beans, beans, and more beans. Many of these foods are high in zinc too.
2. Eat foods fortified with vitamins B_{12} and D and calcium. Some examples are soy milk and fortified cereals.
3. Get enough iron in your diet by eating kidney beans, lentils, whole-grain cereals, and leafy green vegetables.
4. To increase iron absorption, eat foods with vitamin C at the same time.
5. Don’t forget that carbohydrates and fats are required in your diet too, especially if you are training. Eat whole-grain breads, cereals, and pastas. For fats, eat an avocado, add some olive oil to a salad or stir-fry, or spread some peanut or cashew butter on a bran muffin.

Key Takeaways

- The RDA set for protein for adults is 0.8 grams per kilogram of body weight and represents the amount of protein in the diet required to balance the protein that is used up by the body and that is excreted.
- The protein foods group consists of foods made from meat, seafood, poultry, eggs, soy, beans, peas, and seeds.
- By determining a food’s amino acid content and the amount of protein that is actually digested and absorbed we can determine that food’s protein quality.
- Most animal-based proteins are complete protein sources and most plant-based proteins are incomplete protein sources. The exceptions are soy, which is a plant-based complete protein source, and gelatin, which is an incomplete animal-based protein source.
- A vegan’s protein needs are slightly higher because of the lower digestibility of plant-based sources. The elderly may require more protein in their diets to prevent significant muscle wasting. There is debate on whether athletes require more proteins in their diet.

- Protein and amino acid supplements do not enhance exercise performance and do not promote a gain in muscle mass anymore so than protein from foods.
- Unless you are an endurance or strength athlete, commercially sold protein bars and shakes are not a good dietary source of protein.

Discussion Starters

1. What is the consensus in your class on how easy it is to follow a more plant-based diet?
2. Even though high-protein diets may not cause significant health problems in healthy people, are they a sustainable option for losing weight? What are the consequences to the environment of consuming more and not less animal-based sources of protein?

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5.E: Proteins (Exercises)

It's Your Turn

1. Calculate your daily protein requirements.
2. List ten of your favorite protein-rich foods and find out the actual protein contents using the USDA National Nutrient Database, http://www.ars.usda.gov/Services/docs.htm?docid=8964. How easy is it for you to get all the protein you need? Are there some protein-rich food choices that you need to replace with a lower saturated fat alternative?
3. Design a more plant-based menu for a day that you are willing to follow. Make sure it is balanced and has variety. Give examples of the micronutrients (other than protein) the foods contain in appreciable amounts.

Apply It

1. In class or at home, use two inexpensive cake mixes. Make one without adding eggs and the other by following the recipe correctly. Bake them and summarize the differences in taste, texture, and structure.
2. Create a recipe for a shake made from your favorite whole foods that has the macronutrients in their recommended ranges. Also list the different micronutrients in your shake. Now that you know the shake is of good nutritional value, conduct a taste test on your friends or family.
3. Read these articles about nutrition in the future http://www.nature.com/nature/journal/v468/n7327_supp/full/468S21a.html and http://www.nature.com/nature/journal/v468/n7327_supp/full/468S10a.html.
4. Summarize three basic points about how tailoring the diet can reduce the risk for chronic disease.

Expand Your Knowledge

1. Take a trip to a nearby ethnic market and either write down the names of certain foods or purchase a few interesting ones. At home, use the USDA National Nutrient Database to find out the protein contents and other nutrients in the new food items. If you cannot find values for these new foods, try these websites: many-calories.com/, http://www.myfitnesspal.com/nutrition-facts-calories/chinese-food and http://caloriecount.about.com/calories-ethnic-foods-ic3500.
2. Plan a menu for one week that is completely plant-based. Look up the whole nutrient package for the items in your menu by visiting the website, http://www.ars.usda.gov/Services/docs.htm?docid=17032. Follow your diet plan. Record some basic health parameters, such as blood pressure and body weight, before and after following your menu plan. Assess how you feel in general after following the diet. Are you less tired or more? Are you irritable or happy? Did you exercise with more intensity or less?
3. Seafood is a good source of high-quality protein. The DGAC has assessed the nutrient adequacy of diets high in seafood. Read the following document and plan a weekly menu where you consume at least 8 ounces of seafood. 1.usa.gov/OXdk2X

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CHAPTER OVERVIEW

6: Energy Metabolism

In this chapter, we take a look at the obesity epidemic and eating disorders—the extremes of energy imbalance—and we look at evidence-based recommendations for maintaining a healthy weight. You will learn how to assess body weight and fatness and learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

6.1: Chapter Introduction
6.2: Metabolism Overview
6.3: Vitamins Important for Metabolism
6.4: Minerals Important for Metabolism and for Blood Function and Renewal
6.5: Balancing Energy Input with Energy Output
6.6: Too Little or Too Much Weight?
6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
6.E: Exercises

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6.1: Chapter Introduction

As you probably already know, the number of people who struggle with being overweight and/or obese is rising rapidly in the United States of America and in many other countries around the world. There is a new term being used to try to understand this rapid rise in obesity. The new term is "obesogenic" environments. The Centers for Disease Control and Prevention (CDC) defines an obesogenic environment as “an environment that **promotes increased food intake of non-healthful foods, and physical inactivity**.” The CDC reports that in 2009 in the United States, 33 percent of adults and 16 percent of children were obese, a doubling and tripling of the numbers since 1980, respectively, while in Canada the obesity rate was 24.1 percent for 2007–2009. The health consequences of too much body fat are numerous, including increased risks for cardiovascular disease, Type 2 diabetes, and some cancers. The medical costs related to obesity are well over one hundred billion dollars and on the individual level, people who are obese spend $1,429 more per year for medical care than people of healthy weight. No one WANTS to become obese, so what are the factors causing rates of obesity to rise so rapidly? What can we do about these factors?



Video Link 6.1.1*: The Obesity Epidemic: This video from the Centers for Disease Control and Prevention provides an overview of the burden of the obesity epidemic in the United States and its contributing causes.. www.cdc.gov/cdctv/ObesityEpidemic/*

Numerous obesogenic agents contribute to the immense public health problem that has become a part of everyday life in American society. Most agree that the **fast food** industry is playing a role. Fast food has been growing for decades and continues to grow, even when the economy struggles. In America today there are over twelve thousand McDonald’s restaurants, while in 1960 there was one. Another factor is that **food portions have been getting bigger** since the 1960s, and in the 1990s North American society experienced the “super-size” marketing boom, which is still very popular. **Another factor is physical inactivity is getting worse**. Between 1960 and 2000 more than 123 million vehicles were added to the American society. Escalators, elevators, and horizontal walkways now dominate shopping malls and office buildings, factory work has become increasingly mechanized and automated, the typical American watches more than four hours of television daily, and in many workplaces the only tools required to conduct work are a chair and a computer. **The list of all the societal obesogenic factors goes on and on**. They are the result of modernization, industrialization, and urbanization continuing on without individuals, public health officials, or government adequately addressing the concurrent rise in overweight and obesity.

With obesity at epidemic proportions in America it is critical we make changes that will help to remedy this growing problem. The good news is we can make a difference! Policies are being implemented and reinforced at all levels of society including education, agriculture, industry, urban planning, healthcare, and government. Reversing and stopping obesity are two different things. The former will require much more societal change and change on the individual level than the latter. The following are some ideas that are being demonstrated to work for constructing an environment in America that promotes health and confronts the obesity epidemic:

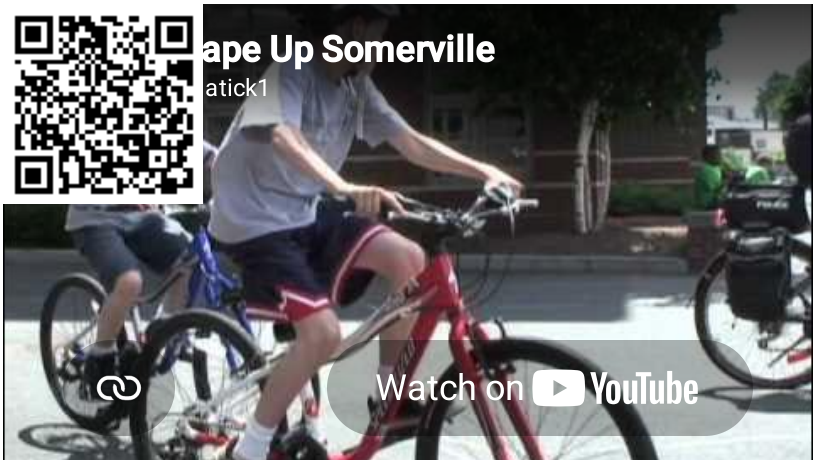
- **Individual Level: What you can do NOW**
  - Purchase less prepared foods and eat more whole foods.
  - Decrease portion sizes when eating or serving food.
  - Eat out less, and when you do eat out choose low-calorie options.
  - Walk or bike to work. If this is not feasible, walk while you are at work.
  - Take the stairs when you come upon them or better yet, seek them out.

- Walk your neighborhood and know your surroundings. This benefits both health and safety.
- Watch less television.

- **Community Level: What you and your friends, family, and co-workers can do together!**
  - Request that your college/workplace provides more access to healthy low-cost foods.
  - Support changes in school lunch programs—this is happening now but needs vocal parents to continue!
  - Participate in cleaning up local green spaces and then enjoy them during your leisure time, get outside!
  - Patronize local farms and fruit-and-vegetable stands.
  - Talk to your grocer and ask for better whole-food choices and seafood at a decent price.
  - Ask your favorite restaurant to serve more nutritious food and to accurately display calories of menu items.
- **National Level: What we can do as a country!**
  - Support policies that increase the walkability of cities.
  - Support national campaigns addressing obesity, such as America on the Move.
  - Support policies that support local farmers and the increased access and affordability of healthy food.

Interactive 6.1.1

Watch this video about "Shape up Sommerville" in which a city in Massachusetts was able to make some amazing changes to the health and wellness of its citizens!



You Decide

How can you assist in the American transition from an obesogenic environment to a healthier environment at the individual, community, and national levels?

In this chapter, you will learn how to assess body weight and fatness. You will also learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

“Thou seest I have more flesh than another man, and therefore more frailty.” -William Shakespeare (1564–1616)

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6.2: Metabolism Overview

Learning Objectives

- Summarize how energy from the energy-yielding nutrients is obtained and used, and how and where it is stored in the body for later use.
- Explain the role of energy in the process of building tissues and organs.

Throughout the various chapters in this text, we have explored the metabolism of carbohydrates, lipids, and proteins. In this next section, we will compile this information for a clear picture of the importance of metabolism in human nutrition.

Metabolism is defined as the sum of all chemical reactions required to support cellular function and hence the life of an organism. Metabolism is either categorized as catabolism, referring to all metabolic processes involved in molecule breakdown, or anabolism, which includes all metabolic processes involved in building bigger molecules. Generally, catabolic processes release energy and anabolic processes consume energy. The overall goals of metabolism are energy transfer and matter transport. Energy is transformed from food macronutrients into cellular energy, which is used to perform cellular work. Metabolism transforms the matter of macronutrients into substances a cell can use to grow and reproduce and also into waste products.

In Chapter 5, you learned that enzymes are proteins and that their job is to catalyze chemical reactions. (Recall that the word catalyzes means to speed up a chemical reaction and reduce the energy required to complete the chemical reaction, without the catalyst being used up in the reaction.) Without enzymes, chemical reactions would not happen at a fast enough rate and would use up too much energy for life to exist. A metabolic pathway is a series of enzymatic reactions that transform the starting material (known as a substrate) into intermediates, which are the substrates for the next enzymatic reactions in the pathway, until, finally, an end product is synthesized by the last enzymatic reaction in the pathway. Some metabolic pathways are complex and involve many enzymatic reactions, and others involve only a few chemical reactions.

To ensure cellular efficiency, the metabolic pathways involved in catabolism and anabolism are regulated in concert by energy status, hormones, and substrate and end-product levels. The concerted regulation of metabolic pathways prevents cells from inefficiently building a molecule when it is already available. Just as it would be inefficient to build a wall at the same time as it is being broken down, it is not metabolically efficient for a cell to synthesize fatty acids and break them down at the same time.

Catabolism of food molecules begins when food enters the mouth, as the enzyme salivary amylase initiates the breakdown of carbohydrates. The entire process of digestion converts the large polymers in food to monomers that can be absorbed. Carbohydrates are broken down to monosaccharides, lipids are broken down into fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with fatty acids and other fat-soluble molecules. Once absorbed, blood transports the nutrients to cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathway. The organ systems of the body require fuel and building blocks to perform the many functions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells.monosaccharides, lipids are broken down into fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with fatty acids and other fat-soluble molecules. Once absorbed, blood transports the nutrients to cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathway. The organ systems of the body require fuel and building blocks to perform the many functions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells.

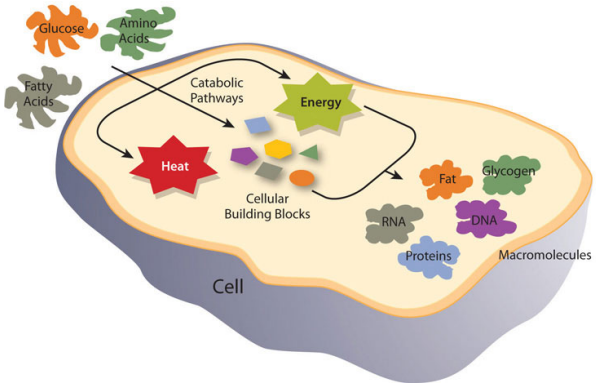


Figure 6.2.1: Metabolism is categorized into metabolic pathways that break down the molecules that release energy (catabolism) and the molecules that consume energy by building bigger molecules (anabolism).

Energy metabolism refers more specifically to the metabolic pathways that release or store energy. Some of these are catabolic pathways, like glycolysis (the splitting of glucose), β-oxidation (fatty-acid breakdown), and amino acid catabolism. Others are anabolic pathways, and include those involved in storing excess energy (such as glycogenisis), and synthesizing triglycerides (lipogenesis). Table 6.2.1 summarizes some of the catabolic and anabolic pathways and their functions in energy metabolism.

Table 6.2.1: Metabolic Pathways

Catabolic Pathways	Function	Anabolic Pathways	Function
Glycolysis	Glucose breakdown	Gluconeogenesis	Synthesize glucose
Glycogenolysis	Glycogen breakdown	Glycogenesis	Synthesize glycogen
β-oxidation	Fatty-acid breakdown	Lipogenesis	Synthesize triglycerides
Proteolysis	Protein breakdown to amino acids	Amino-acid synthesis	Synthesize amino acids

Catabolism: The Breakdown

All cells are in tune to their energy balance. When energy levels are high cells build molecules, and when energy levels are low catabolic pathways are initiated to make energy. Glucose is the preferred energy source by most tissues, but fatty acids and amino acids can also be catabolized to the cellular energy molecule, ATP. The catabolism of nutrients to energy can be separated into three stages, each containing individual metabolic pathways. The three stages of nutrient breakdown allow for cells to reassess their energy requirements, as end products of each pathway can either be further processed to energy or diverted to anabolic pathways. Additionally, intermediates of metabolic pathways can sometimes be diverted to anabolic pathways once cellular energy requirements have been met. The three stages of nutrient breakdown are the following:

- **Stage 1:** Glycolysis for glucose, β-oxidation for fatty acids, or amino acid catabolism
- **Stage 2:** Citric Acid Cycle (or Kreb cycle)
- **Stage 3:** Electron Transport Chain and ATP synthesis

The breakdown of glucose begins with glycolysis, which is a ten-step metabolic pathway yielding two ATP per glucose molecule; glycolysis takes place in the cytosol and does not require oxygen. In addition to ATP, the end products of glycolysis include two three-carbon molecules, called pyruvate. Pyruvate has several metabolic fates. One, if there is insufficient oxygen, it is converted to lactate then shunted to the liver. Two, if there is sufficient oxygen and the cell needs energy, it is shunted to the mitochondria and enters the citric acid cycle (or Cori cycle or Krebs cycle), or three, it may be converted to other molecules (anabolism).

Pyruvate that is transported into the mitochondria gets one of its carbons chopped off, yielding acetyl-CoA. Acetyl-CoA, a two-carbon molecule common to glucose, lipid, and protein metabolism enters the second stage of energy metabolism, the citric acid cycle. This is an irreversible process. The breakdown of fatty acids begins with the catabolic pathway, known as β-oxidation, which takes place in the mitochondria. In this catabolic pathway, four enzymatic steps sequentially remove two-carbon molecules from long chains of fatty acids, yielding acetyl-CoA molecules. In the case of amino acids, once the nitrogen is removed (deamination) from the amino acid the remaining carbon skeleton can be enzymatically converted into acetyl-CoA or some other intermediate of the citric acid cycle.

In the citric acid, cycle acetyl-CoA is joined to a four-carbon molecule. In this multistep pathway, two carbons are lost as two molecules of carbon dioxide are formed. The energy obtained from the breaking of chemical bonds in the citric acid cycle is transformed into two more ATP molecules (or equivalents thereof) and high energy electrons that are carried by the molecules, nicotinamide adenine dinucleotide (NADH) and flavin adenine dinucleotide ($FADH_2$). NADH and $FADH_2$ carry the electrons (hydrogen) to the inner membrane of the mitochondria where the third stage of energy synthesis takes place, in what is called the electron transport chain. In this metabolic pathway, a sequential transfer of electrons between multiple proteins occurs and ATP is synthesized. Water is also formed.

The entire process of nutrient catabolism is chemically similar to burning, as carbon molecules are burnt producing carbon dioxide, water, and heat. However, the many chemical reactions in nutrient catabolism slow the breakdown of carbon molecules so that much of the energy can be captured and not transformed into heat and light. Complete nutrient catabolism is between 30 and 40 percent efficient, and some of the energy is therefore released as heat. Heat is a vital product of nutrient catabolism and is involved in maintaining body temperature. If cells were too efficient at transforming nutrient energy into ATP, humans would not last to the next meal, as they would die of hypothermia.

We measure energy in calories which are the amount of energy released to raise one gram of water one degree Celsius. Food calories are measured in kcal or Calories or 1000 calories. When burned, carbohydrates produce 4 kcal/gm.; protein produce 4 kcal/gm; fat produces 9 kcal/gm; and, alcohol produces 7 kcal/gm.

Some amino acids have the nitrogen removed then enter the citric acid cycle for energy production. The nitrogen is incorporated into urea and then removed in the urine. The carbon skeleton is converted to pyruvate or enters the citric acid cycle directly. These amino acids are called gluconeogenic because they can be used to make glucose. Amino acids that are deaminated and become acetyl-CoA are called ketogenic amino acids and can never become glucose.

Fatty acids can never be made into glucose but are a high source of energy. These are broken down into two carbon units by a process called beta-oxidation enter the citric acid cycle as acetyl-CoA. In the presence of glucose, these two carbon units enter the citric acid cycle and burned to make energy (ATP) and produce the by-product CO_2. If glucose is low, ketones are formed. Ketone bodies can be burned to produce energy. The brain can use ketones.

Anabolism: The Building

The energy released by catabolic pathways powers anabolic pathways in the building of macromolecules such as the proteins RNA and DNA, and even entire new cells and tissues. Anabolic pathways are required to build new tissue, such as muscle, after prolonged exercise or the remodeling of bone tissue, a process involving both catabolic and anabolic pathways. Anabolic pathways also build energy-storage molecules, such as glycogen and triglycerides. Intermediates in the catabolic pathways of energy metabolism are sometimes diverted from ATP production and used as building blocks instead. This happens when a cell is in positive energy balance. For example, the citric-acid-cycle intermediate, α-ketoglutarate can be anabolically processed to the amino acids glutamate or glutamine if they are required. Recall that the human body is capable of synthesizing eleven of the twenty amino acids that make up proteins. The metabolic pathways of amino acid synthesis are all inhibited by the specific amino acid that is the end-product of a given pathway. Thus, if a cell has enough glutamine it turns off its synthesis.

Anabolic pathways are regulated by their end-products, but even more so by the energy state of the cell. When there is ample energy, bigger molecules, such as protein, RNA, and DNA, will be built as needed. Alternatively, when energy is insufficient, proteins and other molecules will be destroyed and catabolized to release energy. A dramatic example of this is seen in children with Marasmus. These children have severely compromised bodily functions, often culminating in death by infection. Children with Marasmus are starving for calories and protein, which are required to make energy and build macromolecules. The negative-energy balance in children who have Marasmus results in the breakdown of muscle tissue and tissues of other organs in the body's attempt to survive. The large decrease in muscle tissue makes children with Marasmus look emaciated or "muscle-wasted."

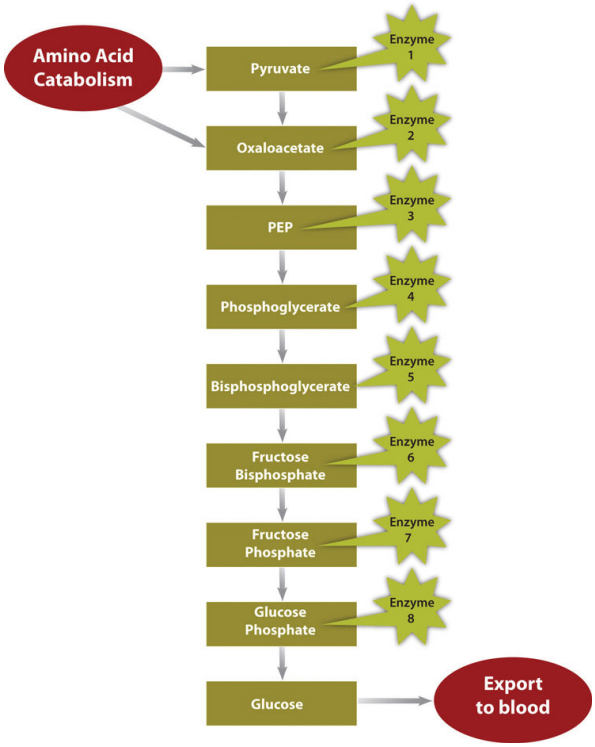


Figure 6.2.2: Metabolic Pathway of Gluconeogenesis

In a much less severe example, a person is also in negative energy balance between meals. During this time, blood glucose levels start to drop. In order to restore blood glucose levels to their normal range, the anabolic pathway, called gluconeogenesis, is stimulated. Gluconeogenesis is the process of building glucose molecules from certain amino acids and it occurs primarily in the liver (Figure 6.2.2). The liver exports the synthesized glucose into the blood for other tissues to use.

Energy Storage

In contrast, in the "fed" state (when energy levels are high), extra energy from nutrients will be stored. Glucose can be stored only in muscle and liver tissues. In these tissues, it is stored as glycogen, a highly branched macromolecule consisting of thousands of glucose monomers held together by chemical bonds. The glucose monomers are joined together by an anabolic pathway called glycogenesis. For each molecule of glucose stored, one molecule of ATP is used. Therefore, it costs energy to store energy. Glycogen levels do not take long to reach their physiological limit and when this happens excess glucose will be converted to fat. A cell in positive energy balance detects a high concentration of ATP as well as acetyl-CoA produced by catabolic pathways. In response, catabolism is shut off and the synthesis of triglycerides, which occurs by an anabolic pathway called lipogenesis, is turned on. The newly made triglycerides are transported to fat-storing cells called adipocytes. Fat is a better alternative to glycogen for energy storage as it is more compact (per unit of energy) and, unlike glycogen, the body does not store water along with fat. Water weighs a significant amount and increased glycogen stores, which are accompanied by water, would dramatically increase body weight. When the body is in positive energy balance, excess carbohydrates, lipids, and protein are all metabolized to fat.

Key Takeaways

- The overall goals of metabolism are energy transfer and matter transport. Metabolism is defined as the sum of all chemical reactions required to support cellular function and is either categorized as catabolism (referring to all metabolic processes involved in molecule breakdown) or anabolism (which includes all metabolic processes involved in building bigger molecules). Generally, catabolic processes release energy and anabolic processes consume energy.
- A metabolic pathway is a series of enzymatic steps that transforms a substrate (the starting material) into intermediates, which are substrates for the proceeding enzymatic reactions until finally an end-product is synthesized by the last enzymatic reaction in the pathway.
- The organ systems of the body require fuel and building blocks to digest, absorb, breathe, pump blood, transport nutrients in and wastes out, maintain body temperature, and make new cells amongst a multitude of other functions.

- When energy levels are high, cells build molecules, and when energy levels are low, catabolic pathways are stimulated to release energy.
- The energy released by catabolic pathways powers anabolic pathways in the building of bigger macromolecules.
- In the “fed” state (when energy levels are high), extra nutrient fuel will be stored as glycogen or triglycerides.

Discussion Starters

1. Discuss the practicality of storing energy in early human civilizations and the consequences of these metabolic processes in today’s world. Refer back to the story of the Pima Indians in Chapter 1 and the concept of the “thrifty gene.”
2. Can an overweight person blame their excess weight on having a slower metabolism?

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6.3: Vitamins Important for Metabolism

Learning Objectives

- Summarize the role of the B vitamins in metabolism.
- Explain how Vitamin K supports a life-saving function of blood.

While the macronutrients (carbohydrates, lipids, and proteins) and alcohol can be catabolized to release energy, vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage. Vitamins and minerals that make up part of enzymes are referred to as coenzymes and cofactors, respectively. Coenzymes and cofactors are required by enzymes to catalyze a specific reaction. They assist in converting a substrate to an end-product (Figure 6.3.1). Coenzymes and cofactors are essential in catabolic pathways and play a role in many anabolic pathways too.

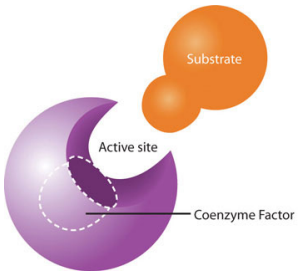


Figure 6.3.1: Coenzymes and cofactors are the particular vitamin or mineral required for enzymes to catalyze a specific reaction.

Vitamins: Functions in Catabolic Pathways and Anabolic Pathways

Thiamine (B_1)

Thiamine, one of the water-soluble vitamins, is especially important in glucose metabolism. It acts as a cofactor for enzymes that break down glucose for energy production (Figure 6.3.1). Additionally, thiamine plays a role in the synthesis of ribose from glucose and is therefore required for RNA, DNA, and ATP synthesis. The brain and heart are most affected by a deficiency in thiamine. Thiamine deficiency, also known as beriberi, can cause symptoms of fatigue, confusion, movement impairment, pain in the lower extremities, swelling, and heart failure. It is prevalent in societies whose main dietary staple is white rice. During the processing of white rice, the bran is removed, along with what were called in the early nineteenth century, “accessory factors,” that are vital for metabolism. Dutch physician Dr. Christiaan Eijkman cured chickens of beriberi by feeding them unpolished rice bran in 1897. By 1912, Sir Frederick Gowland Hopkins determined from his experiments with animals that the “accessory factors,” eventually renamed vitamins, are needed in the diet to support growth, since animals fed a diet of pure carbohydrates, proteins, fats, and minerals failed to grow. Encyclopedia Brittanica Blog. “Frederick Gowland Hopkins and his “Accessory Food Factors.” Accessed October 1, 2011. www.britannica.com/blogs/2011/06/frederick-gowland-hopkins-accessory-food-factors/. Eijkman and Hopkins were awarded the Nobel Prize in Physiology (or Medicine) in 1929 for their discoveries in the emerging science of nutrition. There are two forms of beriberi, wet and dry. Wet beriberi causes edema and heart failure while dry beriberi results in muscle wasting, weakness, and paralysis.

Another deficiency syndrome is the Wernicke-Korsakoff syndrome characterized by disorientation, amnesia, jerky eye movements, and staggering gait. It is the third most common dementia in the US and is due to alcohol excess and glucose excess. Excess alcohol intake increases thiamine excretion in the urine.

Thiamine is a water-soluble vitamin, so it is not stored in the body and excess consumption increases its excretion in the urine. Thiamine need is increased with exercise. Whole grains, enriched flour, green leafy vegetables, legumes, and pork are excellent dietary sources of thiamine but you need to select an appropriate cooking method because prolonged cooking and cooking in water will destroy thiamine. The best way to cook thiamine-containing foods is in the microwave or by steaming.

Riboflavin (B_2)

Riboflavin, also a water-soluble vitamin, is an essential component of flavoproteins, which are coenzymes involved in many metabolic pathways of carbohydrate, lipid, and protein metabolism. Flavoproteins aid in the transfer of electrons in the electron transport chain, thus the production of energy or ATP, and the active form is flavin adenine dinucleotide (FAD) or flavin

mononucleotide (FMN). Furthermore, the functions of other B-vitamin coenzymes, such as vitamin B_6 and folate, are dependent on the actions of flavoproteins. The “flavin” portion of riboflavin gives a bright yellow color to riboflavin, an attribute that help lead to its discovery as a vitamin. Riboflavin deficiency sometimes referred to as ariboflavinosis, is often accompanied by other dietary deficiencies (most notably protein) and can be common in people that suffer from alcoholism. Its signs and symptoms are numerous and can include weakness, dry, scaly skin, mouth inflammation and sores, cracks at the corner of the mouth, painful magenta (purplish-red) tongue, smoothness of the tongue (glossitis), sore throat, itchy eyes, and light sensitivity. Alcoholics, people with liver disease, and diabetics are particularly at risk of developing a riboflavin deficiency.

Whole grains, enriched flour products, milk and green leafy vegetables are good sources of this vitamin. Riboflavin is very sensitive to irradiation and UV light, so this is the reason milk is not sold in clear bottles. Cooking does not destroy riboflavin.

Niacin (B_3)

Niacin is a water-soluble vitamin and is found as nicotinamide (niacinamide) or nicotinic acid. It is a component of the coenzymes nicotinamide adenine dinucleotide (NAD) and its phosphorylated form (NADP), which are involved in the catabolism and/or anabolism of carbohydrates, lipids, and proteins. NADH is the predominant electron carrier and transfers electrons to the electron transport chain to make ATP. NADPH is required for the anabolic pathways of fatty acid and cholesterol synthesis. In contrast to other vitamins, niacin can be synthesized by humans from the amino acid tryptophan in an anabolic process requiring enzymes dependent on riboflavin, vitamin B_6, and iron. Niacin is made from tryptophan only after tryptophan has met all of its other needs in the body. The contribution of tryptophan-derived niacin to niacin needs in the body varies widely and a few scientific studies have demonstrated that diets high in tryptophan have very little effect on niacin deficiency. Niacin deficiency is commonly known as pellagra and is characterized by diarrhea, dermatitis, dementia, and sometimes death (Video 6.3.1). It is still seen in poor urban US, Africa and Asia. People at risk of developing pellagra are alcoholics, people consuming a low protein diet, and people using drugs used to treat tuberculosis and leukemia.

Dietary sources of niacin are whole grains, enriched flour, legumes and protein containing tryptophan such as meat and poultry. Of special note, nicotinic acid in lard amounts is used as a blood cholesterol lowering drug. If the dose is too high (3-4 times the RDA) the following can occur: flushing due to dilation of the capillaries, diarrhea, liver damage, impaired glucose tolerance, nausea and emesis, blurred vision, and/or edema of the eyes.

Pantothenic Acid (B_5)

Pantothenic acid, another water-soluble vitamin, forms coenzyme A, which is the main carrier of carbon molecules in a cell. Acetyl-CoA is the carbon carrier of glucose, fatty acids, and amino acids into the citric acid cycle (Figure 6.3.2). Coenzyme A is also involved in the synthesis of lipids, cholesterol, and acetylcholine (a neurotransmitter). Vitamin B_5 deficiency is exceptionally rare and may be caused by malabsorption. Signs and symptoms include fatigue or weakness, irritability, gastrointestinal distress, numbness, muscle pain, and cramps. You may have seen pantothenic acid on many ingredients lists for skin and hair care products; however, there is no good scientific evidence that pantothenic acid improves human skin or hair.

Pantothenic acid is found in all foods but better sources are whole grains, oats, tomatoes, broccoli, meat especially chicken, milk, and egg yolks. This vitamin is easily destroyed by food processing.

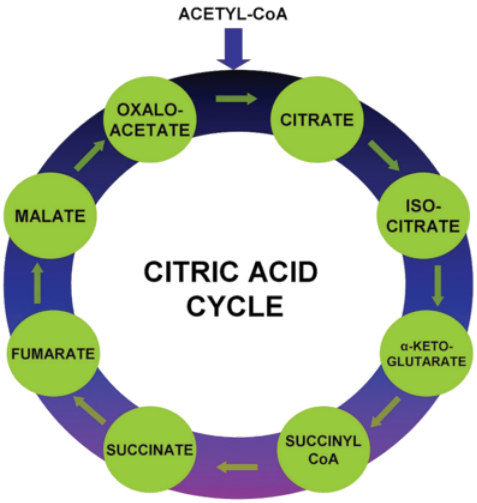


Figure 6.3.2: Vitamin B_5 makes up coenzyme A, which carries the carbons of glucose, fatty acids, and amino acids into the citric acid cycle as Acetyl-CoA.

Pyroxidine (B_6)

Pyroxidine (water-soluble vitamin) is the coenzyme involved in nitrogen transfer between amino acids and therefore plays a role in amino-acid synthesis and catabolism. Also, it functions to release glucose from glycogen in the catabolic pathway of glycogenolysis and is required by enzymes for the synthesis of multiple neurotransmitters and hemoglobin. A deficiency in vitamin B_6 can cause signs and symptoms of muscle weakness, dermatitis, mouth sores, fatigue, and confusion.

Vitamin B_6 is a required coenzyme for the synthesis of hemoglobin. A deficiency in vitamin B_6 can cause anemia, but it is of a different type than that caused by insufficient folate, cobalamin, or iron; although the symptoms are similar. The size of red blood cells is normal or somewhat smaller but the hemoglobin content is lower. This means each red blood cell has less capacity for carrying oxygen, resulting in muscle weakness, fatigue, and shortness of breath.

Biotin (B_7)

Biotin (water-soluble vitamin) is required as a coenzyme in the citric acid cycle and in lipid metabolism. It is also required as an enzyme in the synthesis of glucose, fatty acids, and some nonessential amino acids and carries carbon dioxide (CO_2) away from the citric acid cycle (TCA cycle). A specific enzyme, biotinidase, is required to release biotin from protein so that it can be absorbed in the gut. There is some bacterial synthesis of biotin that occurs in the colon; however, this is not a significant source of biotin. Biotin deficiency is rare but can be caused by eating large amounts of egg whites over an extended period of time. This is because a protein in egg whites tightly binds to biotin making it unavailable for absorption. A rare genetic disease-causing malfunction of the biotinidase enzyme also results in biotin deficiency. Biotin deficiency is very rare and deficiency symptoms are similar to those of other B vitamins such as weakness, but may also include hair loss when severe, a rash around the eyes, nose and mouth, depression, lethargy and hallucinations. People at risk of developing a biotin deficiency include individuals who eat a lot of raw egg whites (the uncooked protein binds biotin making it unavailable for absorption), and patients receiving total parental nutrition.

Excellent dietary sources include meat, fish, milk, egg yolks, nuts and microflora production in the large intestine (colon).

Folate

Folate is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic, also called megaloblastic, anemia. Macrocytic and megaloblastic mean “big cell,” and anemia refers to fewer red blood cells or red blood cells containing less hemoglobin. Macrocytic anemia is characterized by larger and fewer red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size.

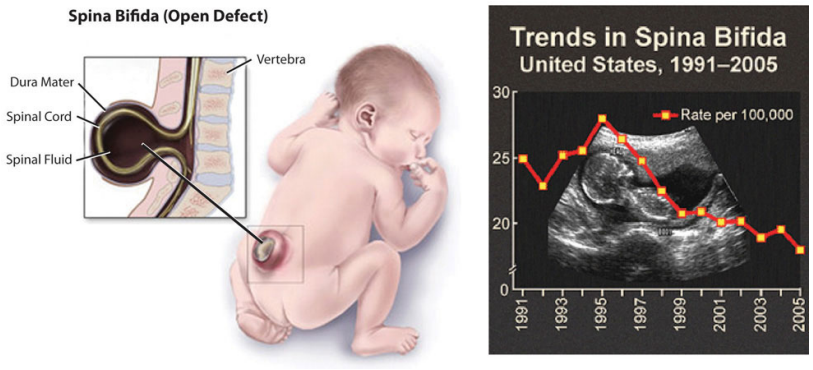


Figure 6.3.3: Spina bifida is a neural-tube defect that can have severe health consequences

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural-tube defect that occurs when the spine does not completely enclose the spinal cord. Spina bifida can lead to many physical and mental disabilities (Figure 6.3.3). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate (Figure 10.4.3). Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer, however scientific studies refute this hypothesis.

Cobalamin (B_{12})

Cobalamin contains cobalt, making it the only vitamin that contains a metal ion. Cobalamin is an essential part of coenzymes. It is necessary for fat and protein catabolism, for folate coenzyme function, and for hemoglobin synthesis. An enzyme requiring cobalamin is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in cobalamin has similar consequences to health as folate deficiency. In children and adults cobalamin deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers, there is an increased risk of neural-tube defects. In order for the human body to absorb cobalamin, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for cobalamin absorption, which occurs in the small intestine. Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Pernicious anemia is treated with large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the blood stream without passing through the intestine. In patients that do not respond to oral or sublingual treatment, vitamin B_{12} is given by injection.

A summary of the prominent functions of the B vitamins in metabolism and their deficiency syndromes is given in Table 6.3.1.

Table 6.3.1: *B-Vitamin Functions in Metabolism*

B Vitamin	Function	Deficiency: Signs and Symptoms
B_1 (thiamine)	Coenzyme: assists in glucose metabolism, RNA, DNA, and ATP synthesis	Beriberi: fatigue, confusion, movement impairment, swelling, heart failure
B_2 (riboflavin)	Coenzyme: assists in glucose, fat and carbohydrate metabolism, electron carrier, other B vitamins are dependent on	Ariboflavinosis: dry scaly skin, mouth inflammation and sores, sore throat, itchy eyes, light sensitivity
B_3 (niacin)	Coenzyme: assists in glucose, fat, and protein metabolism, electron carrier	Pellagra: diarrhea, dermatitis, dementia, death
B_5 (pantothenic acid)	Coenzyme: assists in glucose, fat, and protein metabolism, cholesterol, and neurotransmitter synthesis	Muscle numbness and pain, fatigue, irritability

B Vitamin	Function	Deficiency: Signs and Symptoms
B_6 (pyroxidine)	Coenzyme; assists in amino-acid synthesis, glycogenolysis, neurotransmitter and hemoglobin synthesis	Muscle weakness, dermatitis, mouth sores, fatigue, confusion
Biotin	Coenzyme; assists in glucose, fat, and protein metabolism, amino-acid synthesis	Muscle weakness, dermatitis, fatigue, hair loss
Folate	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural-tube defects
B_{12} (cobalamin)	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural-tube defects

Do B-Vitamin Supplements Provide an Energy Boost?

Although some marketers claim taking a vitamin that contains one-thousand times the daily value of certain B vitamins boosts energy and performance, this is a myth that is not backed by science. The “feeling” of more energy from energy-boosting supplements stems from the high amount of added sugars, caffeine, and other herbal stimulants that accompany the high doses of B vitamins. As discussed, B vitamins are needed to support energy metabolism and growth, but taking in more than required does not supply you with more energy. A great analogy of this phenomenon is the gas in your car. Does it drive faster with a half-tank of gas or a full one? It does not matter; the car drives just as fast as long as it has gas. Similarly, depletion of B vitamins will cause problems in energy metabolism, but having more than is required to run metabolism does not speed it up. Buyers of B-vitamin supplements beware; B vitamins are not stored in the body and all excess will be flushed down the toilet along with the extra money spent.

B vitamins are naturally present in numerous foods, and many other foods are enriched with them. In the United States, B-vitamin deficiencies are rare; however, in the nineteenth century, some vitamin-B deficiencies plagued many people in North America. Niacin deficiency, also known as pellagra, was prominent in poorer Americans whose main dietary staple was refined cornmeal (Video 6.3.1). Its symptoms were severe and included diarrhea, dermatitis, dementia, and even death. Some of the health consequences of pellagra are the result of niacin being in insufficient supply to support the body’s metabolic functions.



Video 6.3.1*: Pellagra Video. Review this video on how Dr. Joseph Goldberger discovered that pellagra was a diet-related illness . (click to see video)*

Dietary Reference Intakes and Sources of B Vitamins

B vitamins are water-soluble and are not stored in significant amounts in the body. Therefore, they must be continuously obtained from the diet. Fortunately, B vitamins are generally well-absorbed in the gut. The Recommended Dietary Allowances (RDA) or Adequate Intakes (AI) set by the IOM, for the B vitamins are listed in Table 6.3.2, which also gives some dietary sources for these micronutrients. It should be noted that B vitamins are lost from foods during storage, processing, and cooking. To maximize B vitamin uptake, fruits and vegetables should not be stored for long periods of time, should be eaten more as whole foods, and

vegetables should be steamed rather than boiled. Also, alcohol disrupts intestinal absorption of B vitamins. The US Department of Agriculture has reports of the nutrient contents in foods, including all B vitamins, available at their website.

Table 6.3.2: Dietary Reference Intakes and Food Sources for B Vitamins

B Vitamin	RDA (mg/day)	Food Sources
B_1 (thiamine)	1.2 (males)	Whole grains, enriched grains, orange juice, milk, peanuts, dried beans and seeds
	1.1 (females)	
B_2 (riboflavin)	1.3 (males)	Milk, yogurt, fortified breakfast cereals, organ meats, mushrooms, eggs, clams, spinach
	1.1 (females)	
B_3 (niacin)	16 (males)	Meat, poultry, fish, whole grains, fortified breakfast cereals, enriched grains, mushrooms, peanuts
	14 (females)	
B_5 (pantothenic acid)	5 (males)	Eggs, sunflower seeds, peanuts, meat, milk, vegetables
	5 (females)*	
B_6 (pyroxidine)	1.3 (males)	Meats, whole grains, potatoes, fortified breakfast cereals, bananas, avocados
	1.3 (females)	
Biotin	0.03 (males)	Egg yolks, peanuts, cheese
	0.03 (females)*	
Folate	0.4 (males)	Green leafy vegetables, legumes, fortified breakfast cereals, orange juice, sunflower seeds, liver
	0.4 (females)	
B_{12} (cobalamin)	0.0024 (males)	Animal derived foods, some soy milks, and fortified breakfast cereals
	0.0024 (females)	

* denotes Adequate Intake

Source: Institute of Medicine. *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline.* June 12, 2000. www.iom.edu/Reports/2000/Dietary-Reference-Intakes-for-Thiamin-Riboflavin-Niacin-Vitamin-B6-Folate-Vitamin-B12-Pantothenic-Acid-Biotin-and-Choline.aspx.

Interactive 6.3.1

The USDA has an interactive database of nutrient contents in food. To view reports of single nutrients simply click on the one you are interested in and view the report. http://www.ars.usda.gov/Services/docs.htm?docid=20958

Dietary Sources Rich in Folate and Vitamin B_{12}

To assist you in getting all the vitamin B_{12} and folate you need to support metabolism and blood cell synthesis look over Table 6.3.3 and 6.6 for good dietary sources of these micronutrients.

Table 6.3.3: *Dietary Sources of Folate*

Food	Micrograms per Serving	Percent Daily Value
Liver	185 (3 oz.)	45
Calf liver	650 (3 oz.)	160
Fortified breakfast cereals	400 (¾ c.)	100
Spinach	100 (½ c., boiled)	25

Food	Micrograms per Serving	Percent Daily Value
Northern beans	100 (½ c., boiled)	25
Asparagus	85 (4 spears, boiled)	20
Vegetarian baked beans	60 (1 c.)	15
Broccoli	45 (2 spears)	10
Avocado	45 (½ c.)	10
Bread (enriched)	25 (1 slice)	6

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Folate." Last reviewed April 15, 2009. http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/.

Table 6.3.4: *Dietary Sources of Vitamins B_{12}*

Food	Micrograms per Serving	Percent Daily Value
Liver	48 (1 slice)	800
Clams	34.2 (3 oz.)	570
Organic calf liver	31 (3 oz.)	520
Fortified breakfast cereals	6.0 (1 serving)	100
Trout (wild)	5.4 (3 oz.)	90
Trout (farmed)	3.5 (3 oz.)	58
Salmon (sockeye)	4.8 (3 oz.)	80
Cheeseburger	2.1	35
Yogurt (plain)	1.4 (1 c.)	23
Beef (top sirloin)	1.4 (3 oz.)	23
Milk	0.9 (1 c.)	15
Egg	0.6 (1 large)	10

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin B_{12}." Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/.

Vitamin K: Functions in Metabolism

There is emerging evidence that vitamin K may play a role in energy metabolism, but currently, the exact functions of vitamin K-dependent enzymes in energy metabolism remain elusive. Vitamin K is required for optimal bone metabolism. Vitamin K is also critical for blood function.

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins as discussed in the previous chapter.

Dietary Reference Intakes and Sources of Vitamin K

The RDA for vitamin K for adult males is 120 mcg/day and for adult females is 90 mcg/day. Vitamin K is present in many foods and most highly concentrated in green leafy vegetables. See Table 10.4.5 for a list of dietary sources of vitamin K.

Table 6.3.5: *Dietary Sources of Vitamin K*

Food	Micrograms per Serving	Percent Daily Value
Broccoli (½ c.)	160.0	133
Asparagus (4 spears)	34.0	28
Cabbage (½ c.)	56.0	47
Spinach (½ c.)	27.0	23
Green peas (½ c.)	16.0	13
Cheese (1 oz.)	10.0	8
Ham (3 oz.)	13.0	11
Ground beef (3 oz.)	6.0	5
Bread	1.1	<1
Orange	1.3	1

Key Takeaways

- Vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage.
- The water-soluble B vitamins are involved as coenzymes in the breakdown of nutrients and in the building of macromolecules, such as protein, RNA, and DNA.
- B-vitamin deficiencies are relatively rare especially in developed countries; although the health consequences can be severe as with folate deficiency during pregnancy and the increased risk of neural-tube defects in offspring.

Discussion Starters

1. Discuss how the actions of B vitamins are interdependent; meaning the level of one affects the function of another.
2. Have a classroom debate on whether it is prudent for the federal government to regulate claims on micronutrient supplements, such as those containing B vitamins.

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6.4: Minerals Important for Metabolism and for Blood Function and Renewal

Learning Objectives

- List the primary function of each of the minerals involved in metabolism.
- Summarize the roles of minerals important in blood function and renewal.

In a well-balanced diet, minerals are plentiful, and herbs are power-packed with minerals. Eat more plants, spice up your food, and drink herbal teas to obtain optimum mineral nutrition.



Figure 6.4.1: Several different minerals. Notice color and texture is different.

Magnesium

Magnesium is the eleventh most abundant element in the human body and is known to participate as a cofactor in hundreds of metabolic reactions. ATP exists as a complex with magnesium and therefore this mineral is involved in all reactions that synthesize or require ATP including carbohydrate, lipid, protein, RNA, and DNA synthesis. Many Americans do not get the recommended intake of magnesium from their diets. Some observational studies suggest mild magnesium deficiency is linked to increased risk for cardiovascular disease. Signs and symptoms of severe magnesium deficiency may include tremor, muscle spasms, loss of appetite, and nausea.

Iron

Red blood cells contain the oxygen carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 6.4.2). Iron is a key component of hundreds of metabolic enzymes. Many of the proteins of the electron transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

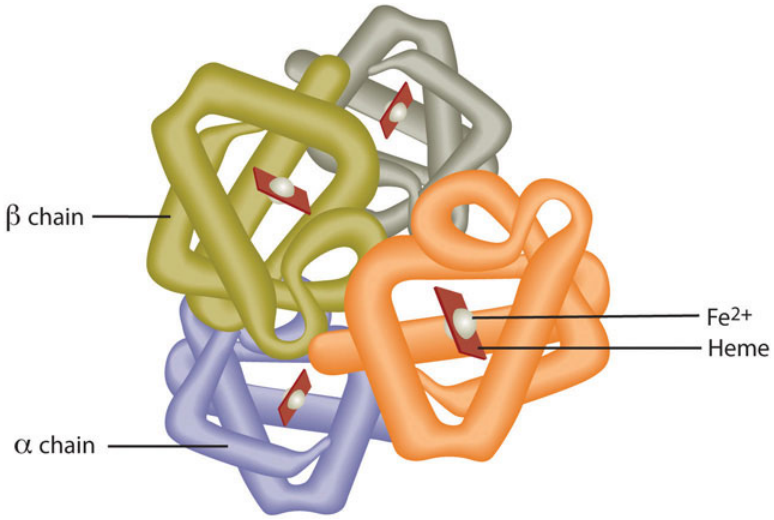


Figure 6.4.2: Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released (video below). If iron level is low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. When blood cells are decommissioned for use, the body recycles the iron back to the bone marrow where red blood cells are made. The body stores some iron in the bone marrow, liver, spleen, and skeletal muscle. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

Video: Oxygen Transport



Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.

The bioavailability of iron is highly dependent on dietary sources. In animal-based foods, about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the *American Journal of Clinical Nutrition* reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent and that from vegetarian diets ranges between 5 and 12 percent.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. Iron deficiency is the most common of all micronutrient deficiencies and will be explored in depth in Section 10.5.

Zinc

Zinc is a cofactor for over two hundred enzymes in the human body and plays a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world’s population has a zinc-deficient diet.Prasad, Ananda. “Zinc deficiency.” BMJ 2003 February 22; 326(7386): 409–410. doi: 10.1136/bmj.326.7386.409. Accessed October 2, 2011. www.ncbi.nlm.nih.gov/pmc/articles/PMC1125304/?tool=pmcentrez. This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, loss of appetite, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia.

Iodine

Iodine is a trace mineral that is an anion and part of thyroid hormone. Recall from Chapter 1 the information about the discovery of iodine and its use as a means of preventing goiter, a gross enlargement of the thyroid gland in the neck. Iodine is essential for the

synthesis of thyroid hormone, which regulates basal metabolism, growth, and development. Low iodine levels and consequently hypothyroidism has many signs and symptoms including fatigue, sensitivity to cold, constipation, weight gain, depression, and dry, itchy skin and paleness. The development of goiter may often be the most visible sign of chronic iodine deficiency, but the consequences of low levels of thyroid hormone can be severe during infancy, childhood, and adolescence as it affects all stages of growth and development. Thyroid hormone plays a major role in brain development and growth and fetuses and infants with severe iodine deficiency develop a condition known as cretinism, in which physical and neurological impairment can be severe. The World Health Organization (WHO) estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.World Health Organization. “Iodine Status Worldwide.” Accessed October 2, 2011. http://whqlibdoc.who.int/publications/2004/9241592001.pdf. People who live in areas with low soil iodine content are at a greater risk of developing an iodine deficiency. In the US, iodine deficiency is uncommon because salt has been iodized. You can also find iodine in seafood and baked goods. The upper limit of iodine intake is 1000 ug/day and this is close to the RDA.

Selenium

Selenium is a cofactor of enzymes that release active thyroid hormone in cells and therefore low levels can cause similar signs and symptoms as iodine deficiency. The other important function of selenium is an antioxidant, which was discussed in detail in Chapter 8.

Copper

Copper, like iron, assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport. The other important function of copper is an antioxidant, which was also discussed in Chapter 8. Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves.

Manganese

Manganese is a trace mineral that is a cofactor for enzymes involved in glucose production (gluconeogenesis), cholesterol synthesis, and formation of urea (amino-acid catabolism in the liver). Manganese deficiency is rare but signs and symptoms include impaired growth and reproduction, reduced bone mineral density, impaired skeletal growth, impaired glucose and lipid metabolism, and skin rash. Toxicity has been reported in individuals who inhale manganeses dust, water with high amounts. Manganese impairers the neuromuscular system causing muscle spasms and tremors. Dietary sources include whole grain foods, pineapples, pine nuts, okra, spinach, and raspberries.

Chromium

Chromium is called a trace mineral because you need very little amounts in your diet. It is a cation that is positively charged in its active form. The functioning of chromium in the body is less understood than that of most other minerals. It enhances the actions of insulin so plays a role in carbohydrate, fat, and protein metabolism. Currently, the results of scientific studies evaluating the usefulness of chromium supplementation in preventing and treating Type 2 diabetes are largely inconclusive. It has also been proposed as a weight loss aid, but there is no scientific evidence for this use. More research is needed to better determine if chromium is helpful in treating certain chronic diseases and, if so, at what doses. Deficiency symptoms may include a diabetes-like condition but this has not been well studied and documented. Groups at risk of developing a chromium deficiency include individuals consuming excess sugar. Studies suggest 90% of the US population is below the recommended minimum intake of chromium.

Dietary sources of chromium include whole grains, liver, seafood, Brewer's yeast, mushrooms, prunes, dark chocolate, nuts, asparagus, red wine, and processed meats.

Summary of Minerals

A summary of the prominent functions of minerals in metabolism and their related deficiency syndromes is given in Table 6.4.1.

Table 6.4.1: Mineral Functions in Metabolism and Blood and Deficiency Syndrome

Mineral	Function	Deficiency: Signs and Symptoms
	Macro	

Mineral	Function	Deficiency: Signs and Symptoms
Magnesium	ATP synthesis and utilization, carbohydrate, lipid, protein, RNA, and DNA synthesis	Tremor, muscle spasms, loss of appetite, nausea
Trace		
Iron	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate
Zinc	Assists in energy production, protein, RNA, and DNA synthesis; required for hemoglobin synthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss
Iodine	Making thyroid hormone, metabolism, growth and development	Goiter, cretinism, other signs, and symptoms include fatigue, depression, weight gain, itchy skin, low heart-rate
Selenium	Essential for thyroid hormone activity	fatigue
Copper	Assists in energy production, iron metabolism	Anemia: fatigue, paleness, faster heart rate
Manganese	Glucose synthesis, amino acid catabolism	Impaired growth, skeletal abnormalities, abnormal glucose metabolism
Chromium	Assists insulin in carbohydrate, lipid and protein metabolism	abnormal glucose metabolism

Dietary Reference Intakes for Minerals and Dietary Sources

The RDA set by the IOM for minerals involved in metabolism are listed for adults in Table 6.4.2. The table also lists dietary sources for these micronutrients. The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 6.4.2: Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism

Mineral	**RDA (mg/day)**	**Food Sources**
Macro		
Magnesium	420.000 (males)	Nuts, vegetables, coffee and tea, cocoa
	320.000 (females)**	
Trace		
Iron	8.000 (males)	Animal products, fortified breakfast cereals, beans, spinach, peas
	18.000 (females)	
Zinc	11.000 (males)	Red meat, poultry, seafood, fortified breakfast cereals, beans, nuts, whole grains
	8.000 (females)	
Iodine	0.150 (males)	Seafood, dairy products
	0.150 (females)	
Selenium	0.055 (males)	Tuna, beef, chicken, nuts, dairy products

* denotes Adequate Intake, **for ages 31–50 only

Mineral	RDA (mg/day)	Food Sources
	0.055 (females)	
Copper	0.900 (males)	Whole grains, liver, legumes, seeds, cocoa
	0.900 (females)	
Manganese	2.300 (males)	Whole grains, brown rice, spinach, nuts, tea
	1.800 (females)*	
Chromium	0.035 (males)	Egg yolks, whole grains, meats, organ meats, mushrooms, nuts, broccoli
	0.025 (females)*	

* denotes Adequate Intake, **for ages 31–50 only

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, such as oxalate and phytate, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

Key Takeaways

- Minerals cannot be broken down to release energy.
- Minerals are cofactors for hundreds of enzymes involved in metabolism.
- Iron especially, but also copper and zinc are critical for blood function and renewal.
- Minerals are not as efficiently absorbed as most vitamins and bioavailability can be very low.

Discussion Starters

1. Discuss why "more is not always better," especially how this saying pertains to micronutrient intake.
2. Look up the chemical structure of phytate and explain how it inhibits the absorption of positively charged minerals.

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6.5: Balancing Energy Input with Energy Output

Learning Objectives

- Estimate your daily energy requirement.
- Define basal metabolism and explain the factors that affect the basal metabolic rate.
- Summarize why the amount of food we eat (appetite) is not completely under our conscious control.

To Maintain Weight, Energy Intake Must Balance Energy Output

Before you begin your journey to learn about energy balance, we need to define a few terms. These are shown in Table 6.5.1.

Table 6.5.1: Terms for understanding energy balance.

Term	Definition
Hunger	physiological drive to eat
Appetite	psychological drive to eat
Satiety	State in which both drives are satisfied and there is no longer a desire to eat. Being satisfied.
Hypothalamus	A group of cells at the base of the brain which participates in many regulatory functions including hunger
Leptin	Hormone produced by body fat that plays a role in regulating food intake and physical activity
Ghrelin	Hormone produced by the stomach that regulates appetite
Peptide YY (PYY)	Protein produced by gastrointestinal tract that regulates appetite and food intake
Calorie or kilocalories	amount of heat energy needed to raise temperature of 1 kg of water 1 C (unit of energy measurement)

Recall that the macronutrients you consume are either converted to energy, stored, or used to synthesize macromolecules. A nutrient's metabolic path is dependent upon energy balance. When you are in a positive energy balance the excess nutrient energy will be stored or used to grow (e.g., during childhood, pregnancy, and wound healing). When you are in negative energy balance you aren't taking in enough energy to meet your needs, so your body will need to use its stores to provide energy. Energy balance is achieved when intake of energy is equal to the energy expended. Weight can be thought of as a whole body estimate of energy balance; body weight is maintained when the body is in energy balance, lost when it is in negative energy balance (intake or input < expenditure or output), and gained when it is in positive energy balance (intake or input > expenditure or output). When your energy intake matches your energy output, you will maintain your weight, whatever that is. People who are overweight or obese can be in energy balance. In other words, their intake matches their energy output but at some point in their life, their energy intake exceeded their energy intake. In general, weight is a good predictor of energy balance, but many other factors play a role in energy intake and energy expenditure. Some of these factors are under your control and others are not. Let us begin with the basics on how to estimate energy intake, energy requirement, and energy output. Then we will consider the other factors that play a role in maintaining energy balance and hence, body weight. In Figure 6.5.1, energy output exceeds energy input, so this person would be losing weight.

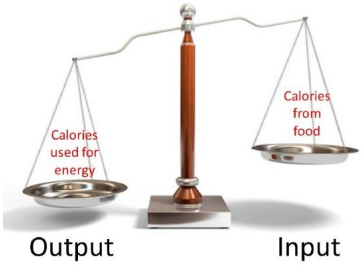


Figure 6.5.1: Energy is a balance between energy input and energy output. When one exceeds the other you will lose or gain weight.

One pound of body fat is approximately 3,500 kcal and 1 kg is 7,700 kcal. If you consume 10 more kcal per day than what you need, you will gain 1 lb per year. If you eat 100 kcal more than you expend per day, that is one slice of white bread, you will gain 10 lbs in a year. Portion sized have increased. In 1950, a burger, fry, and drink were 590 kcal. Today, a quarter-pound burger with cheese, large fries and drink is 1,550 kcal. Wow! What a huge increase in half a century - almost 300%.

Total Energy Expenditure (Output)

The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn while at rest (basal metabolism), the calories you burn when you digest food and heat production (minor). The sum of caloric expenditure is referred to as total energy expenditure (TEE). Basal metabolism refers to those metabolic pathways necessary to support and maintain the body's basic functions (e.g. breathing, heartbeat, liver, and kidney function) while at rest. The basal metabolic rate (BMR) is the amount of energy required by the body to conduct its basic functions over a certain time period. The great majority of energy expended (between 50 and 80 percent) daily is from conducting life's basic processes. Of all the organs, the liver requires the most energy (see Table 6.5.5). Unfortunately, you cannot tell your liver to ramp up its activity level to expend more energy so you can lose weight. BMR is dependent on body size, body composition, sex, age, nutritional status, and genetics. People with a larger frame size have a higher BMR simply because they have more mass. Muscle tissue burns more calories than fat tissue even while at rest and thus the more muscle mass a person has the higher their BMR. Since females typically have less muscle mass and a smaller frame size than men, their BMRs are generally lower than men's. As we get older muscle mass declines and thus so does BMR. Nutritional status also affects basal metabolism. Caloric restriction, as occurs while dieting, for example, causes a decline in BMR. This is because the body attempts to maintain homeostasis and will adapt by slowing down its basic functions to offset the decrease in energy intake. Body temperature, thyroid hormone levels, and pregnancy and lactation are additional determinants of BMR.

Usually, we measure RMR (resting metabolic rate) or REE (resting energy expenditure). Both are measured shortly after awakening in the morning after at least a twelve hour fast. RMR or REE are slightly higher than BMR because the individual may have ambulated, for example, walked to urinated before measuring RMR. BMR is measured with no ambulatory movement.

Table 6.5.2: Energy Breakdown of Organs

Organ	Percent of Energy Expended
Liver	27
Brain	19
Heart	7
Kidneys	10
Skeletal muscle (at rest)	18
Other organs	19

The energy required for all the enzymatic reactions that take place during food digestion and absorption of nutrients is called the "thermic effect of food" and accounts for about 5-10 percent of the total energy expended per day. Fat is metabolized more efficiently than protein or carbohydrate so the TEF for high-fat foods is less. Also, dietary fat is usually stored, not burned, after eaten.

The other energy required during the day is for physical activity. Depending on lifestyle, the energy required for this ranges between 15 and 50 percent of the total energy expended. The percent varies among individuals. The energy cost of physical activity depends on the activity, for example walking vs running, the length the activity is sustained, body weight, and training. The benefits of physical activity continue after the activity has stopped. The main control a person has over TEE is to increase physical activity.

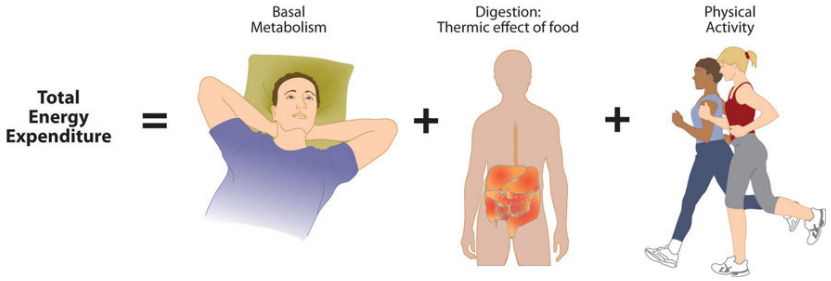


Figure 6.5.2: Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity.

Estimating Energy Requirement

To maintain body weight you have to balance the calories obtained from food and beverages with the calories expended every day. Here, we will discuss how to calculate your energy needs in kilocalories per day so that you can determine whether your caloric intake falls short, meets, or exceeds your energy needs. The Institute of Medicine has devised a formula for calculating your Estimated Energy Requirement (EER). It takes into account your age, sex, weight, height, and physical activity level (PA). The EER is a standardized mathematical prediction of a person's daily energy needs in kilocalories per day required to maintain weight. It is calculated via the following formulas:

- Adult male:

$$EER = 662 - [9.53 \times age(y)] + PA \times [15.91 \times wt(kg) + 5.39.6 \times ht(m)] \quad (6.5.1)$$

- Adult female:

$$EER = 354 - [6.91 \times age(y)] + PA \times [9.36 \times wt(kg) + 726 \times ht(m)] \quad (6.5.2)$$

Note: to convert pounds to kilograms, divide weight in pounds by 2.2. To convert feet to meters, divide height in feet by 3.3.

The **Harris Benedict Equation** is a way to calculate RMR. You must add additional kcal for activity.

- Men: RMR = 66.47 + 13.75(kg) + 5 (cm) - 6.76(age)
- Women: RMR = 6.55.1 + 9.56(kg) + 1.85(cm)-4.68(age)

Examples of physical activity adjustments are as follows. Multiple the RMR by this number you calculate above by this number to get the total energy requirement: males and females bed rest - 1.1-1.3; males and females very sedentary - 1.2-1.4; males and females sedentary/maintenance - 1.3-1.5; males and females light activity - 1.4-1.5.

Estimating Caloric Intake

In Chapter 2, you learned how to calculate the number of calories in food. To determine your caloric intake per day requires that you conduct a dietary assessment and record the number of calories you eat.

Interactive 6.5.1

To begin your dietary assessment, go to MyPlate, which is available on the US Department of Agriculture (USDA) website: http://www.choosemyplate.gov/.

Table 6.5.3: Physical Activity (PA) Categories and Values

Activity Level	Men PA Value	Women PA Value	Description
Sedentary	1.00	1.00	No physical activity beyond that required for independent living
These values only apply to normal-weight adults and not to children or pregnant or lactating women.			

Activity Level	Men PA Value	Women PA Value	Description
Low	1.11	1.12	Equivalent to walking 1.5 to 3 miles per day
Moderate	1.25	1.27	Equivalent to walking 3 to 10 miles per day
High	1.48	1.45	Equivalent to walking 10 or more miles per day
These values only apply to normal-weight adults and not to children or pregnant or lactating women.			

Source: Health Canada. "Dietary Reference Intake Tables." Last modified November 29, 2010. http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/index-eng.php#eeer.

The numbers within the equations for the EER were derived from measurements taken from a group of people of the same sex and age with similar body size and physical activity level. These standardized formulas are then applied to individuals whose measurements have not been taken, but who have similar characteristics in order to estimate their energy requirements. Thus, a person's EER is, as the name suggests, an estimate for an average person of similar characteristics. EER values are different for children, pregnant or lactating women, and for overweight and obese people. Also, remember the EER is calculated based on weight maintenance, not for weight loss or weight gain.

Table 6.5.4: Estimated Daily Calorie Needs

Sex	Age (years)	Sedentary	Moderately Active	Active
Child (female and male)	2–3	1,000–1,200	1,000–1,400	1,000–1,400
Female	4–8	1,200–1,400	1,400–1,600	1,400–1,800
	9–13	1,400–1,600	1,600–2,000	1,800–2,200
	14–18	1,800	2,000	2,400
	19–30	1,800–2,000	2,000–2,200	2,400
	31–50	1,800	2,000	2,200
	51+	1,600	1,800	2,000–2,200
Male	4–8	1,200–1,400	1400–1,600	1,600–2,000
	9–13	1,600–2,000	1,800–2,200	2,000–2,600
	14–18	2,000–2,400	2,400–2,800	2,800–3,200
	19–30	2,400–2,600	2,600–2,800	3,000
	31–50	2,200–2,400	2,400–2,600	2,800–3,000
	51+	2,000–2,200	2,200–2,400	2,400–2,800

Source: US Department of Agriculture. *2010 Dietary Guidelines for Americans.* 2010. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

The *2010 Dietary Guidelines* provides a table (Table 6.5.4) that gives the estimated daily calorie needs for different age groups of males and females with various activity levels. The *2010 Dietary Guidelines* also states that while knowing the number of calories you need each day is useful, it is also pertinent to obtain your calories from nutrient-dense foods and consume the various macronutrients in their Acceptable Macronutrient Distribution Ranges (AMDRs) (Table 6.5.5).

Table 6.5.5: Acceptable Macronutrient Distribution Ranges

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)
Young Children (1–3)	45–65	5–20	30–40
Older children/adolescents (4–18)	45–65	10–30	25–35
Adults (19 and older)	45–65	10–35	20–35

Source: Institute of Medicine. "Dietary Reference Intakes: Macronutrients." *Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* September 5, 2002. www.iom.edu/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI_Macronutrients.pdf

How to Calculate Total Energy Expenditure

Calculating TEE can be tedious but has been made easier as there are now calculators available on the Web. TEE is dependent on age, sex, height, weight, and physical activity level. The equations are based on standardized formulas produced from actual measurements on groups of people with similar characteristics. To get accurate results from web-based TEE calculators, it is necessary to record your daily activities and the time spent performing them. A spreadsheet for doing so is available online at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf.

Interactive 6.5.1: Health-calc.com offers an interactive TEE calculator.

http://www.health-calc.com/diet/energy-expenditure-advanced

Factors Affecting Energy Intake

Physiology

In the last few decades, scientific studies have revealed that how much we eat and what we eat is controlled not only by our own desires but also is regulated physiologically and influenced by genetics. The hypothalamus in the brain is the main control point of appetite. It receives hormonal and neural signals, which determine if you feel hungry or full. Hunger is an unpleasant sensation of feeling empty that is communicated to the brain by both mechanical and chemical signals from the periphery. Conversely, satiety is the sensation of feeling full and it also is determined by mechanical and chemical signals relayed from the periphery. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety (Figure 6.5.2).

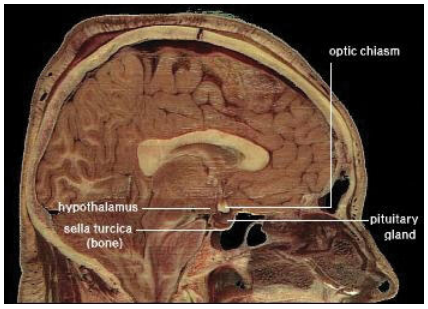


Figure 6.5.3: This is a scan of a brain. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety. Source: Diabesity, Sixth Framework Programme. "Novel Molecular Targets for Obesity and Type 2 Diabetes." 2002-2006. www.diabesity.eu/.honours.htm.

Hunger pangs are real and so is a "growling" stomach. When the stomach is empty it contracts, producing the characteristic pang and "growl." The stomach's mechanical movements relay neural signals to the hypothalamus, which relays other neural signals to parts of the brain. This results in the conscious feeling of the need to eat. Alternatively, after you eat a meal the stomach stretches and sends a neural signal to the brain stimulating the sensation of satiety and relaying the message to stop eating. The stomach also sends out certain hormones when it is full and others when it is empty. These hormones communicate to the hypothalamus and other areas of the brain either to stop eating or to find some food. Thus hunger signals change as we eat.

Fat tissue also plays a role in regulating food intake. Fat tissue produces the hormone leptin, which communicates to the satiety center in the hypothalamus that the body is in positive energy balance. The discovery of leptin's functions sparked a craze in the

research world and in the diet pill industry as it was hypothesized that if you give leptin to a person who is overweight, they will decrease their food intake. Alas, this is not the case. In several clinical trials, it was found that people who are overweight or obese are actually resistant to the hormone, meaning their brain does not respond as well to it.Dardeno, T. A. et al. “Leptin in Human Physiology and Therapeutics.” *Front Neuroendocrinol* 31, no. 3 (2010): 377–93. www.ncbi.nlm.nih.gov/pmc/articles/PMC2916735/?tool=pubmed. Therefore, when you administer leptin to an overweight or obese person there is no sustained effect on food intake.

Nutrients themselves also play a role in influencing food intake. The hypothalamus senses nutrient levels in the blood. When they are low the hunger center is stimulated, and when they are high the satiety center is stimulated. Furthermore, cravings for salty and sweet foods have an underlying physiological basis. Both undernutrition and overnutrition affect hormone levels and the neural circuitry controlling appetite, which makes losing or gaining weight a substantial physiological hurdle.

Genetic Influences

Genetics certainly play a role in body fatness and weight and also affects food intake. Children who have been adopted typically are similar in weight and body fatness to their biological parents. Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins. The scientific search for obesity genes is ongoing and a few have been identified, such as the gene that encodes for leptin. However, overweight and obesity that manifests in millions of people is not likely to be attributed to one or even a few genes but to rather the interactions of hundreds of genes with the environment. In fact, when an individual has a mutated version of the gene coding for leptin, they are obese, but only a few dozen people around the world have been identified as having a completely defective leptin gene.

Psychological/Behavioral Influences

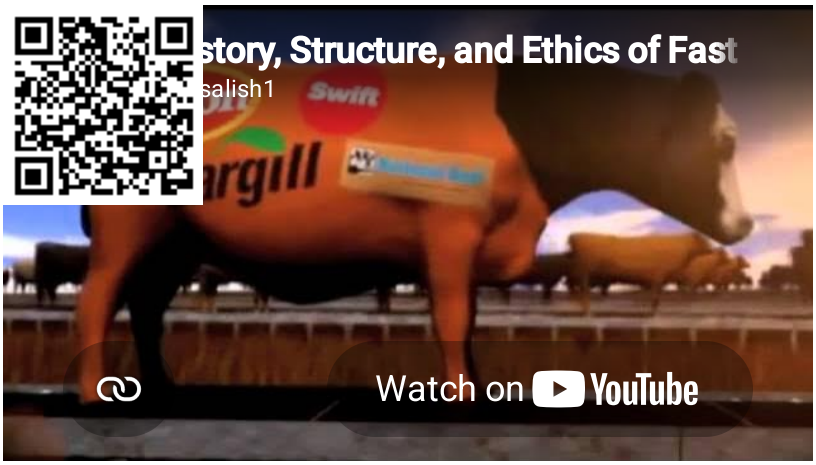
When your mouth waters in response to the smell of a roasting Thanksgiving turkey and steaming hot pies, you are experiencing a psychological influence on food intake. A person’s perception of good-smelling and good-tasting food influences what they eat and how much they eat. Mood and emotions are associated with food intake. Depression, low self-esteem, compulsive disorders, and emotional trauma are sometimes linked with increased food intake and obesity.

Certain behaviors can be predictive of how much a person eats. Some of these are how much food a person heaps onto their plate, how often they snack on calorie-dense, salty foods, how often they watch television or sit at a computer, and how often they eat out. A study published in a 2008 issue of *Obesity* looked at characteristics of Chinese buffet patrons. The study found that those who chose to immediately eat before browsing the buffet, used larger plates, used a fork rather than chopsticks, and chewed less per bite of food, had higher BMIs than patrons who did not exhibit these behaviors.Levin, B. E. “Developmental Gene X Environment Interactions Affecting Systems Regulating Energy Homeostasis and Obesity.” *Front Neuroendocrinol* 3 (2010): 270–83. www.ncbi.nlm.nih.gov/pmc/articles/PMC2903638/?tool=pubmed. Of course, many behaviors are reflective of what we have easy access to—a concept we will discuss next.

Societal Influences

It is without a doubt that the American society affects what and how much we eat. Portion sizes have increased dramatically in the past few decades. For example, a bagel is now more than twice the size it was in the 1960s. Today, American teenagers have access to a massive amount of calorie-dense foods and beverages, which is a large contributor to the recent rapid increase in overweight and obesity in adolescents in this country. Even different cultures within the United States have different eating habits. For instance, southern Americans, in general, consume more foods high in fat, which is a contributing factor to their higher incidences of overweight and obesity than Americans who live in the northern states. (Alaska is an exception because it also has a high incidence of overweight and obesity, which is also partly attributed to diet.)

The fast food industry in America not only supplies Americans with a large proportion of their diet but because of its massive presence in society dominates the workings of the entire food system (Note 9.23 "Video 6.5.1). To generalize, most fast food items have little nutritional merit as they are highly processed and rich in saturated fat, salt, and added sugars. Despite fast foods being a poor source of nourishment, Americans spend over one hundred billion dollars per year on fast food, up from six billion dollars in the early 1970s. The fast food business is likely to continue to grow in North America (and the rest of the world) and greatly affect the diets of whole populations. Because it is unrealistic to say that Americans should abruptly quit eating fast food to save their health (because they will not) society needs to come up with ideas that push nutrient-dense whole foods into the fast food industry. You may have observed that this largely consumer-driven push is having some effect on the foods the fast food industry serves (just watch a recent Subway commercial, or check the options now available in a McDonald’s Happy Meal). Pushing the fast food industry to serve healthier foods is a realistic and positive way to improve the American diet.



Video 6.5.1. *History, Structure, and Ethics of the Fast Food Industry (click to see video) A brief clip about the fast food industry and its effect on the United States.*

Tools for Change

Support the consumer movement of pushing the fast food industry and your favorite local restaurants into serving more nutrient-dense foods. You can begin this task by starting simple, such as requesting extra tomatoes and lettuce on your burger and more nutrient-dense choices in the salad bar. Also, choose their low-calorie menu options and help support the emerging market of healthier choices in the fast food industry. In today's fast-paced society, it is difficult for most people to avoid fast food all the time. When you do need a quick bite on the run, choose the fast food restaurants that serve healthier foods. Also, start asking for caloric contents of foods so that the restaurant becomes more aware that their patrons are being calorie conscious.

Factors Affecting Energy Expenditure

Physiological and Genetic Influences

Why is it so difficult for some people to lose weight and for others to gain weight? One theory is that every person has a "set point" of energy balance. This set point can also be called a fat-stat or lipostat, meaning the brain senses body fatness and triggers changes in energy intake or expenditure to maintain body fatness within a target range. Some believe that this theory provides an explanation as to why after dieting, most people return to their original weight not long after stopping the diet. Another theory is referred to as the "settling" point system, which takes into account (more so than the "set-point" theory) the contribution of the obesogenic environment to weight gain. In this model, the reservoir of body fatness responds to energy intake or energy expenditure, such that if a person is exposed to a greater amount of food, body fatness increases, or if a person watches more television body fatness increases. A major problem with these theories is that they overgeneralize and do not take into account that not all individuals respond in the same way to changes in food intake or energy expenditure. This brings up the importance of the interactions of genes and the environment.

Not all individuals who take a weight-loss drug lose weight and not all people who smoke are thin. An explanation for these discrepancies is that each individual's genes respond differently to a specific environment. Alternatively, environmental factors can influence a person's gene profile, which is exemplified by the effects of the prenatal environment on body weight and fatness and disease incidence later in life. One of the first scientific investigations of prenatal control over energy balance was conducted in Germany. In this observational study, scientists found that offspring born to mothers who experienced famine were more likely to be obese in adulthood than offspring born to mothers who were pregnant just after World War II who lived in the same geographical locations.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Other studies have shown that the offspring of women who were overweight during pregnancy have a greater propensity for being overweight and for developing Type 2 diabetes. Thus, undernutrition and overnutrition during pregnancy influence body weight and disease risk for offspring later in life. They do so by adapting energy metabolism to the early nutrient and hormonal environment in the womb.

Audio Link 6.5.1: Rethinking Thin: The Myths and Realities of Dieting

Listen to this NPR broadcast for scientific information about why it is so difficult for some people to lose weight. Rethinking Thin

Psychological/Behavioral Influence

Sedentary behavior is defined as the participation in the pursuits in which energy expenditure is no more than one-and-one-half times the amount of energy expended while at rest and include sitting, reclining, or lying down while awake. Of course, the sedentary lifestyle of many North Americans contributes to their average energy expenditure in daily life. Simply put, the more you sit, the less energy you expend. A study published in a 2008 issue of the *American Journal of Epidemiology* reports that 55 percent of Americans spend 7.7 hours in sedentary behavior daily.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Fortunately, including only a small amount of low-level physical activity benefits weight control. A study published in the June 2001 issue of the *International Journal of Behavioral Nutrition and Physical Activity* reports that even breaking up sitting time with frequent, but briefly increased energy expenditure activities, such as walking for five minutes every hour, helps maintain weight and even aids in weight loss.Wu, Y. "Overweight and Obesity in China." *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362. Americans partake in an excessive amount of screen time, which is a sedentary behavior that not only reduces energy expenditure but also contributes to weight gain because of the exposure to aggressive advertising campaigns for unhealthy foods.

Societal Influence

In the United States, many societal factors influence the number of calories burned in a day. Escalators, moving walkways, and elevators (not to mention cars!) are common modes of transportation that reduce average daily energy expenditure. Office work, high-stress jobs, and occupations requiring extended working hours are all societal pressures that reduce the time allotted for the exercise of large populations of Americans. Even the remote controls that many have for various electronic devices in their homes contribute to the US society being less active. More "obesogenic" factors were discussed in the opening of this chapter.

Socioeconomic status has been found to be inversely proportional to weight gain. One reason for this relationship is that inhabitants of low-income neighborhoods have reduced access to safe streets and parks for walking. Another is that fitness clubs are expensive and few are found in lower-income neighborhoods. The recent and long-lasting economic crisis in this country is predicted to have profound effects on the average body weight of Americans. The number of homeless in this country is rising with many children and adults living in hotels and cars. As you can imagine neither of these "home spaces" has a kitchen, making it impossible to cook nutritious meals and resulting in increased economically-forced access to cheap, unhealthy foods, such as that at a nearby gas station.

Key Takeaways

Energy balance is achieved when energy intake is equal to the energy expended. Energy balance is essential for maintaining weight. Knowing the number of calories you need each day is a useful reference point, but it is also important to obtain your calories from nutrient-dense foods and consume the macronutrients in their AMDRs. The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn at rest (basal metabolism), and the calories you burn when you digest food. Basal metabolic rate (BMR) is dependent on body size, body composition, sex, age, nutritional status, genetics, body temperature, and thyroid hormone levels. The great majority of energy expended (between 50 and 70 percent) daily comes from conducting life's basic processes. The main control a person has over TEE is to increase physical activity. Energy intake is regulated by complex physiological responses and is influenced by genetics, behavior, and society. Energy expenditure is also regulated by complex physiological responses and is influenced by genetics, behavior, and society.

Discussion Starters

1. Some types of transportation are becoming economically unfeasible for obese people. Discuss whether or not it is acceptable that air carriers can enforce that obese people (or what they politely call "passengers of size" or "passengers requiring extra space") pay more for their seats.
2. Many people have a hard time understanding the difficulties of being too skinny. Discuss with your peers how to empathize with the weight problems of underweight people. Read the article to understand that being skinny does not mean a person necessarily has a lower risk of chronic disease.

   http://www.msnbc.msn.com/id/18594089/ns/health-fitness/t/thin-people-can-be-fat-inside/

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6.6: Too Little or Too Much Weight?

Learning Objectives

- Discern the differences in health risks associated with being underweight and being overweight.

The number of people considered overweight and obese in the world has now surpassed the number that is starving, with some officials estimating that the number of overweight people is nearly double the number of underweight people worldwide. Countries that have more recently modernized, industrialized, and urbanized are experiencing a surge in their overweight and obese populations. China, the most populous country in the world, now has more than 215 million people, approximately one-fifth of their population, that are considered overweight or obese (Wu, Yangfeng. "Overweight and obesity in China." BMJ. 2006 August 19; 333(7564): 362–363. doi: 10.1136/bmj.333.7564.362. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1550451/). The increase in China's waistline is partly attributed to changes in the traditional diet, more sedentary lives, and a massive increase in motor vehicle use. Moreover, China's recent famines in the 1950s, which affected the poor and lower classes to a greater extent than the upper class, has sanctioned lax social attitudes toward body fat and reinspired the age-old Chinese belief that excess body fat represents health and prosperity.

One of the worst statistics regarding overweight and obesity in China is that more than ten million adolescents between ages seventeen and eighteen were overweight in 2000, which is twenty-eight times the number that was overweight in 1985 (Wu, Y. "Overweight and Obesity in China." *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362). The associated diseases of overweight and obesity happen over many years and signs and symptoms commonly take decades to manifest. With China's younger population and other developed countries experiencing a dramatic weight increase, the associated chronic diseases will come about much earlier in life than in previous generations. This will put an even greater burden on society.

Video 6.6.1

Chinese Obesity

(click to see video)

Watch this video on the surge in Chinese obesity and how the country's rapid increase in modernization contributes to its obesity epidemic.

Health Risks of Being Overweight and Being Obese

The health consequences of obesity are great and are responsible for more than one hundred thousand deaths per year in the United States. According to the CDC, in the United States in 2007–2008:

- 34 percent of adults aged twenty years and over are obese
- 34 percent of adults aged twenty years and over are overweight (but not obese)
- 18 percent of adolescents age twelve to nineteen years are obese
- 20 percent of children age six to eleven years are obese
- 10 percent of children age two to five years are obese (The Centers for Disease Control and Prevention. "Obesity and Overweight." Accessed October 8, 2011. http://www.cdc.gov/nchs/fastats/overwt.htm).

The health risks of being overweight include cardiovascular disease, hypertension (>140/90 mmHg), type 2 diabetes mellitus (risk is 3 times higher), metabolic syndrome (glucose intolerance, insulin resistance, hyperinsulinemia, hyperlipidemia, and hypertension), cancer, osteoarthritis (pressure placed on knees is 7x body weight), increased risk if surgery is needed, emotional disturbances and societal problems.

State Map of the Prevalence of Obesity in America

Visit www.cdc.gov/obesity/downloads/obesity_trends_2010.ppt to see the obesity trends from 1985 to 2010. As you will see, the percentages of obese adults are rising.

As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, postmenopausal breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. The WHO reports that overweight and obesity are the fifth leading cause for deaths globally, and estimates that more than 2.8 million adults die annually as a result of being overweight or obese.World Health Organization. "Obesity and Overweight." Accessed October 8,

2011. http://www.who.int/mediacentre/factsheets/fs311/en/. Moreover, overweight and obesity contribute to 44 percent of the Type 2 diabetes burden, 23 percent of the heart disease burden, and between 7 and 41 percent of the burden of certain cancers.World Health Organization. “Obesity and Overweight.” Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

Similar to other public health organizations, the WHO states the main causes of the obesity epidemic worldwide is the increased intake of energy-dense food and decreased level of physical activity that is mainly associated with modernization, industrialization, and urbanization. The environmental changes that contribute to the dietary and physical activity patterns of the world today are associated with the lack of policies that address the obesity epidemic in the health, urban planning, agriculture, food industry, and education sectors.

Health Risks of Being Underweight

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight.Centers for Disease Control and Prevention. “NCHS Health E-Stat. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006.” Accessed October 8, 2011. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm. Being underweight is linked to nutritional deficiencies, especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. The most common underlying cause of underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men) and frequently co-occur with depression, substance abuse or anxiety disorders.

Anorexia Nervosa

Anorexia nervosa, more often referred to as “anorexia,” is a psychiatric illness in which a person obsesses about their weight and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. Anorexia is relatively rare—the National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will have anorexia at some point in their lifetime, The National Institute of Mental Health. “Eating Disorders among Adults: Anorexia Nervosa.” Accessed October 8, 2011. http://mentalhealth.gov/statistics/1EAT_ADULT_ANX.shtml. but it is an extreme example of how an unbalanced diet can affect health. Anorexia frequently manifests during adolescence and it has the highest rate of mortality of all mental illnesses. People with anorexia consume, on average, fewer than 1,000 kilocalories per day (self-induced semi-starvation) and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may participate in binge eating, self-induced vomiting, and purging with laxatives or enemas. The very first time a person starves him- or herself may trigger the onset of anorexia. The exact causes of anorexia are not completely known, but many things contribute to its development including economic status, as it is most prevalent in high-income families. It is a genetic disease and is often passed from one generation to the next. Pregnancy complications and abnormalities in the brain, endocrine system, and immune system may all contribute to the development of this illness.

The primary signs of anorexia are fear of being overweight, extreme dieting, an unusual perception of body image, and depression. The secondary signs and symptoms of anorexia are all related to the caloric and nutrient deficiencies of the unbalanced diet and include excessive weight loss; reduced BMR; a multitude of skin abnormalities like dry, scaly, cold skin with or without languno; diarrhea; cavities and tooth loss; osteoporosis; anemia; and liver, kidney, and heart failure. They may be cold from lack of body fat for insulation. There is no physical test that can be used to diagnose anorexia and distinguish it from other mental illnesses. Therefore a correct diagnosis involves eliminating other mental illnesses, hormonal imbalances, and nervous system abnormalities. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined. Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviors associated with causing the eating disorder. Relapse to an unbalanced diet is high. Many people do recover from anorexia, however, most continue to have a lower-than-normal body weight for the rest of their lives (see Note 11.33 "Video 6.6.2").

Video 6.6.2: What I Gained in Recovery from Anorexia

On a more positive note, watch this personal account of what can be gained from anorexia recovery.(click to see video)

Bulimia

Bulimia, like anorexia, is a psychiatric illness that can have severe health consequences. The NIMH reports that 0.5 percent of females and 0.1 percent of males will have bulimia at some point in their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Bulimia Nervosa.” Accessed October 8, 2011. mentalhealth.gov/statistics/1EAT_ADULT_RBUL.shtml. Bulimia is characterized by episodes of eating large amounts of food followed by purging, which is accomplished by vomiting and with the use of laxatives and diuretics. Unlike people with anorexia, those with bulimia often have a normal weight, making the disorder more difficult to detect and diagnose. The disorder is characterized by signs similar to anorexia such as fear of being overweight, extreme dieting, and bouts of excessive exercise. Secondary signs and symptoms include gastric reflux, severe erosion of tooth enamel, dehydration, electrolyte imbalances, lacerations in the mouth and esophagus from vomiting, and peptic ulcers. Repeated damage to the esophagus puts people with bulimia at an increased risk for esophageal cancer. The disorder is also highly genetic, linked to depression and anxiety disorders, and most commonly occurs in adolescent girls and young women. Treatment often involves antidepressant medications and, like anorexia, has better results when both the family and the individual with the disorder participate in nutritional and psychiatric counseling.

Binge-Eating Disorder

Similar to those who experience anorexia and bulimia, people who have a binge-eating disorder have lost control over their eating. Binge-eating disorder is not currently diagnosed as a distinct psychiatric illness, although there is a proposal from the American Psychiatric Association to categorize it more specifically. People with binge-eating disorder will periodically overeat to the extreme, but their loss of control over eating is not followed by fasting, purging, or compulsive exercise. As a result, people with this disorder are often overweight or obese, and their chronic disease risks are those linked to having an abnormally high body weight such as hypertension, cardiovascular disease, and Type 2 diabetes. Additionally, they often experience guilt, shame, and depression. Binge-eating disorder is commonly associated with depression and anxiety disorders. According to the NIMH, binge-eating disorder is more prevalent than anorexia and bulimia, and affects 3.5 percent of females and 2.0 percent of males at some point during their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Binge Eating Disorder.” Accessed October 8, 2011. www.nimh.nih.gov/statistics/1EAT_ADULT_RB.shtml. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

Key Takeaways

The number of people considered overweight and obese in the world has now surpassed the number that is starving. As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. Being underweight is linked to nutritional deficiencies. These deficiencies cause iron-deficiency anemia and also delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. Eating disorders resulting in being underweight can have severe consequences to health. The eating disorder anorexia nervosa has the highest mortality rate of all mental illnesses. All underweight people do not have anorexia and all overweight people do not have an eating disorder.

Discussion Starters

1. Visit the Food and Agriculture Organization of the United Nations website and discuss the impact of the rise in obesity in developing countries.

   http://www.fao.org/FOCUS/E/obesity/obes1.htm

2. Even as adults in this society we “profile” people with excess body fat as lazy and other disrespectful adjectives. Moreover, society commonly “profiles” people who are too skinny as being compulsive and vain. Propose ideas for improving body image during teenage years.

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6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution

Learning Objectives

- Be able to calculate body mass index (BMI) given a particular weight and height.
- Name the factors that affect body composition and distribution.

What weight should you weigh? This has been a difficult question to answer because humans come in so many different sizes and shapes. We do know that carrying too much fat is not good for one's health. Ideal body weight (IBW) has been used to determine one's desirable weight. Usually, IBW is determined by reference weight-for-height charts and the most commonly used chart is the Metropolitan Life Insurance Tables which include data for men and women by height and frame size. Hamwi is another method which does not require reading a table. Instead, it is a calculation:

- Males: 106 lbs for 5' in height plus 6 lbs for every inch over
- Females: 100 lbs for 5' in height plus 5 lbs for every inch over

If the individual has a large from then the number is increased 10% and if that person's frame is small, then 10% is subtracted from the number. Once you have calculated their suggested weight, the following interpretative guidelines can be applied. If the person's weight is a certain percent over then they would be considered:

- Overweight if greater than 10% over IBW
- Mild obesity if greater than 20% over IBW
- Moderate obesity if greater than 40% over IBW
- Severe obesity if greater than 100% over IBW

There are limitations to both methods. Neither method is based on a representative population or all populations. The Metropolitan Life Insurance tables are based on mortality risk, not just obesity. Finally, there are many examples of people who are defined as overweight but don't have excess fat stores, for example, body builders and weight lifters.

Although the terms "overweight" and "obese" are often used interchangeably and considered as gradations of the same thing, they can denote different things. You weigh what you weigh because of your: water weight, lean muscle weight, bone weight, and weight from body fat (adipose). "Overweight" refers to having more weight than is typical for a particular height. That weight may be the result of water weight, muscle weight, or fat mass. "Obese" refers specifically to having excess body fat. In most cases, people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population.

> *The "ideal" healthy body weight for a particular person is dependent on many things, such as frame size, sex (hormone profile), muscle mass, bone density, age, and height. The perception of the "ideal" body weight can be additionally dependent on cultural factors and the mainstream societal advertisement of beauty.*

In this author's opinion, the concept of "ideal body weight" is concerning. I feel that each of us should be eating healthfully (not just saying it but doing it), exercising healthfully and then allowing our body weight to go where it wants to go. However, medical doctors, public health officials, and others needed to find a simple tool to look at patterns of weight gain in the U.S.A. and elsewhere. The easy tool that was developed is called the Body Mass Index (BMI). BMI is a tool meant to tell an individual if they weigh too much, too little or just right. BMI uses the information that we already have readily available from every doctor's visit: weight and height. The general idea is if you are very tall and have a low weight you are probably underweight. If you are very short and you weigh a lot you are probably overweight. It is a crude tool but one that can quickly, inexpensively give estimates of overweight and/or underweight.

The Body Mass Index (BMI) and Its Limitations

Body mass index (BMI) is calculated using **height** and **weight** measurements and is more predictive of a health risk than using weight alone. BMI measurements are used to indicate whether an individual may be underweight (with a BMI less than 18.5), overweight (with a BMI over 25), or obese (with a BMI over 30). Very high AND very low BMI's appear to increase a person's risk of dying. If you look at a graph of BMI (Figure 6.7.1) as it relates to your risk of dying, it has a "J-shaped Curve" or a "U-shaped

Curve" because being too low and/or too high both raise your risk of mortality. Instead, you'd like to be in the middle range of the BMI which is what they use for "Normal weight". You will notice that, even though you will be categorized as "overweight" at a BMI of 25 and "obese" at a BMI of 30, the risk of dying goes up gradually. Like a teacher assigning a letter grade, the decision of exactly where to draw the lines for underweight, normal weight, overweight and obese are somewhat arbitrary.

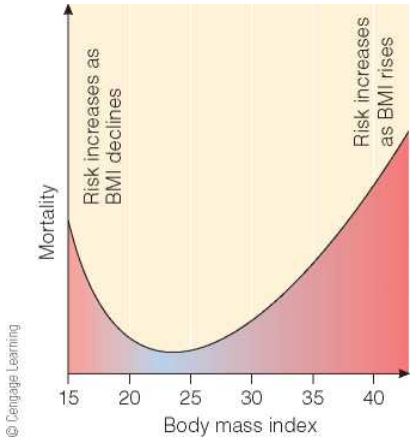


Figure 6.7.1 Relationship between body mass index and mortality.

To calculate your BMI, multiply your weight in pounds by 703 (conversion factor for converting to metric units) and then divide the product by your height in inches, squared.

$$BMI = \frac{weight\ (lb) \times 703}{height\ (in)^2} \tag{11.2.1a}$$

or

$$BMI = \frac{weight\ (kg)}{height\ (m)^2} \tag{11.2.1b}$$

Note

The National Heart, Lung, and Blood Institute and the CDC have automatic BMI calculators on their websites:

- www.nhlbisupport.com/bmi/
- http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

To see how your BMI indicates the weight category you are in, see Table 6.7.1 or use a chart of weight and height to figure out your BMI.

Table 6.7.1: BMI Categories

Categories	BMI
Underweight	< 18.5
Normal weight	18.5–24.9
Overweight	25–29.9
Obese	30.0-34.9
Severe	35-40

Source: National Heart, Lung, and Blood Institute. Accessed November 4, 2012. http://www.nhlbi.nih.gov.

BMI Limitations

A BMI is a fairly simple measurement and does not take into account fat mass or fat distribution in the body, both of which are additional predictors of disease risk. Body fat weighs less than muscle mass. Therefore, BMI can sometimes underestimate the amount of body fat in overweight or obese people and overestimate it in more muscular people. For instance, a muscular athlete

will have more muscle mass (which is heavier than fat mass) than a couch potato of the same height. Based on their BMIs the muscular athlete would be less “ideal” and may be categorized as more overweight or obese than the couch potato; however, this is an infrequent problem with BMI calculation. Additionally, an older person with osteoporosis (decreased bone mass) will have a lower BMI than an older person of the same height without osteoporosis, even though the person with osteoporosis may have more fat mass. A BMI is a useful inexpensive tool to categorize people and is highly correlative with disease risk, but other measurements are needed to diagnose obesity and more accurately assess disease risk.

BMI is not a good measure for children and adolescents because they are growing. A new BMI for these ages was recently introduced in which the weight in kg is divided by the height in meters cubed. Its use is not well-established yet.

BMI does not consider where the fat is located. Individuals with abdominal fat or android shape have a greater risk of obesity associated diseases than individuals who carry their fat in the hips (gynoid or "pear shape"). Men tend to be "apple-shaped" while women tend to be "pear shaped." Gynoid shape tends to be associated with fewer health risks. For this reason, a ratio of body waist circumference to hip circumference may be measured and the ratio calculated. If you are male and your ratio is greater than 0.95, then you have excessive abdominal fat. If you are female and your ratio is greater than 0.86, then you have excessive abdominal fat.

Measuring Body Fat Content

Water, organs, bone tissue, fat, and muscle tissue make up a person’s weight. Having more fat mass may be indicative of disease risk, but fat mass also varies with sex, age, and physical activity level. Females have more fat mass, which is needed for reproduction and, in part, is a consequence of different levels of hormones. The optimal fat content of a female is between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent. Fat mass can be measured in a variety of ways. The simplest and lowest-cost way is the skin-fold test. A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. It is a noninvasive and fairly accurate method of measuring fat mass, but similar to BMI, is compared to standards of mostly young to middle-aged adults. Other methods of measuring fat mass are more expensive and more technically challenging. They include:

- **Underwater Weighing (Hydrostatic).** This technique requires a chamber full of water big enough for the whole body can fit in. First, a person is weighed outside the chamber and then weighed again while immersed in water. Bone and muscle weigh more than water, but fat does not—therefore a person with a higher muscle and bone mass will weigh more when in water than a person with less bone and muscle mass. This method is considered the gold standard but requires special facilities and not many places offer underwater weighing even for highly trained athletes. Also, this method is not easy or useful with children, the elderly or those afraid of water.
- **Bioelectric Impedance Analysis (BIA).** This device is based on the fact that fat slows down the passage of electricity through the body. When a small amount of electricity is passed through the body, the rate at which it travels is used to determine body composition. The percent of body fat is proportional to the body's resistance to the flow of current. A limitation of the method is BIA measures total body water which only estimates muscle and fat. Since water conducts the current, it is imperative that the individual is fully hydrated. These devices are also sold for home use and commonly called body composition scales.
- **Dual-energy x-ray absorptiometry.** This technique can be used to measure bone density. It also can determine fat content via the same method, which directs two low-dose x-ray beams through the body and determines the amount of the energy absorbed from the beams. The amount of energy absorbed is dependent on the body’s content of bone, lean tissue mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated.
- **Skinfold measurements.** This technique picks up the skin and measures the thickness. Calipers are used to measure the thickness of the fold which is bigger if there are abundant fat stores. A number of body sites are measured and the selection of sites depends on gender and which method is going to be used to estimate body fat percent. This method has several limitations and its accuracy is dependent on the training of the person completing the measurements. Several body sites must be measured and there is wide variation in the numbers obtained among different technicians.
- **BOD POD (Air Displacement)**. This machine measures how much air your body displaces within its chamber. Percent body fat is calculated based on the relationship between body weight, density, and volume. This machine requires a special facility and is not easy or useful for children and the elderly.

Measuring Fat Distribution

Total body fat mass is one predictor of health; another is how the fat is distributed in the body. You may have heard that fat on the hips is better than fat in the belly—this is true. Fat can be found in different areas in the body and it does not all act the same,

meaning it differs physiologically based on location. Fat deposited in the abdominal cavity is called visceral fat and it is a better predictor of disease risk than total fat mass. Visceral fat releases hormones and inflammatory factors that contribute to disease risk. The only tool required for measuring visceral fat is a measuring tape. The measurement (of waist circumference) is taken just above the belly button. Men with a waist circumference greater than 40 inches and women with a waist circumference greater than 35 inches are predicted to face greater health risks.

The waist-to-hip ratio is often considered a better measurement than waist circumference alone in predicting disease risk. To calculate your waist-to-hip ratio, use a measuring tape to measure your waist circumference and then measure your hip circumference at its widest part. Next, divide the waist circumference by the hip circumference to arrive at the waist-to-hip ratio. Observational studies have demonstrated that people with "apple-shaped" bodies, (who carry more weight around the waist) have greater risks for chronic disease than those with "pear-shaped" bodies, (who carry more weight around the hips). A study published in the November 2005 issue of *Lancet* with more than twenty-seven thousand participants from fifty-two countries concluded that the waist-to-hip ratio is highly correlated with heart attack risk worldwide and is a better predictor of heart attacks than BMI.Yusuf, S. et al. "Obesity and the Risk of Myocardial Infarction in 27,000 Participants from 52 Countries: A Case-Control Study." *Lancet* 366, no. 9497 (2005): 1640–9. Accessed October 5, 2011. http://www.ncbi.nlm.nih.gov/pubmed/16271645 ?dopt=AbstractPlus. Abdominal obesity is defined by the World Health Organization (WHO) as having a waist-to-hip ratio above 0.95 for males and above 0.85 for females.

Key Takeaways

Most people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population. To standardize the "ideal" body weight and relate it to health, scientists have devised some computational measurements to better define a healthy ideal weight. Body weight in relation to height is called BMI and is correlated with disease risk. Total body fat mass is another predictor of disease risk; another is where the fat is distributed. Fat deposits in different areas in the body and do not all act the same, meaning it differs physiologically based on location. Visceral fat contributes more to disease risk, for example.

Discussion Starters

1. Read the article, "Exercise Keeps Dangerous Visceral Fat Away a Year After Weight Loss, Study Finds," at http://www.sciencedaily.com/releases/2009/10/091029102740.htm. Then discuss the importance of exercise in eradicating excessive fat.
2. Based on what you learned, why would an individual with a high BMI have a decreased risk of osteoporosis?

6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management

Learning Objectives

- Explain the complementary actions of dietary changes and increased physical activity level on health.
- Formulate an exercise plan that fits your lifestyle and that follows the *2008 Physical Activity Guidelines for Americans*.

Theories of Obesity

Scientists have been looking for a cause of obesity for many decades now. Clearly, the evidence shows this a multifaceted disease that is not explained by one cause, for example, one gene. Clearly, it is an energy imbalance - too many calories in for the calories expended. Yet, for some, there are other explanations that help contribute. These include genetic variation, metabolic, and environmental influences and each interacts with the other. For example, since sequencing the human genome was completed, scientists have learned that the environment plays a powerful role in determining which genes are expressed.

Genetic Influences: A number of examples suggest gene can play a role in one's weight. There is an 80% propensity for offspring to gain weight if both parents are overweight, 60^ chance if one parent is obese and a 10% chance if neither parent is obese. Identical twins raised apart have similar weight gain patterns and gain fat in similar sites. Also, body shape is a heritable trait. The ectomorph tends to be lean, the mesomorph muscular and the endomorph large. Finally, rare genetic disorders give us insight into genes that control weight. There are several rare genetic defects that cause excessive weight gain. Examples are Prader-Willi syndrome (absence of chromosome 15) and Laurence-Moon syndrome. Individuals with Prader-Willi have an insatiable appetite.

Metabolic Influences: A number of metabolic theories have been proposed. A few are detailed here:

- Set-point theory: This theory states that a person is programmed to be a certain weight and have a certain body fat content. If a person weighs less than this set point, then their body will make adjustments in food intake or BMR to compensate and get the person back to their set point weight. If a person weighs more, again, their body will compensate to bring them back to the set point. People become obese because they have a high set point.
- Enzyme theory: Lipoprotein lipase (LPL) is an enzyme that breaks down LDL or VLDL at the cell surface to release the particles triglyceride into the cell. The activity of LPL increases when a fat cell is starving or seeking fat. Obese people have more LPL, but they also have more fat cells.
- Fat cell theory: This theory is based on the number of fat cells in your body. Fat cells want to store fat and body fat is related to the number of fat cells you have and the amount of fat they are storing. According to this theory, childhood overeating increases the number of fat cells. Obese children tend to have the same number of adipocytes as lean adults. Obese adults have more fat cells. We do not grow much more fat cells as an adult; these are laid down when we are children. When someone who is obese loses weight, they shrink the fat cells size and do not reduce the number of fat cells. These cells then are very hungry and hoard fat causing the person to gain back the weight they lost.
- Brown fat thermogenesis: Our body has white and brown fat. Brown fat makes heat from fat. It does not store fat like white fat. Newborns and true hibernators, like bears, have a lot of brown fat while adult humans have less. This theory states that obese people have less brown fat.

Environmental Influences: A wide variety of influences in our social and built environment encourage a lifestyle associated with fat accumulations. We call these environmental influences and examples include lack of activity such as walking 10,000 steps a day; lack of aerobic exercise; an excessive amount of time spent sitting at our computers, playing video games and/or watching television; excessive portion sizes; an infrastructure conducive to driving not walking or bike riding; and easy access to food high in calories.

Combating Excessive Fat

Throughout the years, many different weight loss programs have come and gone each promising quick weight loss. All weight loss diets involve reducing one's caloric intake but the most successful programs also 1) meet the dieter's nutrient needs except energy, 2) meet the individual's tastes and habits, 3) favors development and maintenance of changed eating patterns, and 4) is consistent with the improvement of overall health. The programs with the greatest probability of long-term success modify the dieter's eating behavior, encourage moderate portion control, include moderate exercise most days of the week.

Weight loss should be slow to promote loss of fat, not muscle. A loss of two pounds or less a week is recommended. A pound of fat is approximately 3500 kcal so to lose 1 lbs of fat a week one should cut 500 calories from their diet without falling below 1,200 calories per day. This is the minimum amount of calories to assure adequate nutrient intake. At least 100 grams of carbohydrate is recommended per day, and this should be complex and include dietary fiber. Fat should provide between 10 and 30% of the total calories and protein near the RDA, 50 to 60 grams per day. It is essential to eat a variety of different foods to avoid boredom and assure one is getting all their micronutrients. The following are weight loss programs that do not meet some or all of these recommendations: very low energy diets (<1,000 calories per day), carbohydrate restrictive diets like the Atkins diet, diets that rely on special formulas or products, and diets that use appetite suppressant drugs. For some people, bariatric surgery has helped them reduce their body fat. These surgeries bypass part of the digestive tract. Other surgical procedures include stomach stapling or placing a band on the stomach to shrink its size.

Most dieters are not successful at keeping the weight they lost off and most gain the weight back plus more weight than they lost. This syndrome is called the yo-yo syndrome or weight cycling. It is a vicious cycle of weight loss, weight gain, weight loss, weight gain in which the dieter ends up

weighing more and has more body fat. Scientists theorize that the body becomes more efficient at storing calories once the dieter stops their weight loss diet.

We have just considered the gravity of the obesity problem in America and worldwide. How is America combating its weight problem on a national level and have the approaches been successful?

Successful weight loss is defined as individuals intentionally losing at least 10 percent of their body weight and keeping it off for at least one year.Wing, R. R. and J. O. Hill. "Successful Weight Loss Maintenance." *Annu Rev Nutr* 21 (2001): 323–41. Accessed October 8, 2011. http://www.ncbi.nlm.nih.gov/pubmed/11375440?dopt=Abstract. Results from lifestyle intervention studies suggest fewer than 20 percent of participants (3-5 year success is 5%) are successful at weight loss. An evaluation of successful weight loss, involving more than fourteen thousand participants published in the November 2011 issue of the *International Journal of Obesity* estimates that more than one in six Americans who were overweight or obese were successful in achieving long-term weight loss.Kraschnewski, J. L. et al. "Long-Term Weight Loss Maintenance in the United States." *Int J Obes* 34, no. 11 (2010): 1644–54. http://www.ncbi.nlm.nih.gov/pubmed/20479763. However, these numbers are on the high end because many similar studies report fewer than 10 percent of participants as successful in weight loss.

The National Weight Control Registry (NWCR) tracks over ten thousand people who have been successful in losing at least 30 pounds and maintaining this weight loss for at least one year. Their research findings are that 98 percent of participants in the registry modified their food intake and 94 percent increased their physical activity (mainly walking.)The National Weight Control Registry. "Research Findings." Accessed October 8, 2011. http://www.nwcr.ws/Research/default.htm. Although there are a great variety of approaches taken by NWCR members to achieve successful weight loss, most report that their approach involved adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day). Moreover, most members eat breakfast every day, watch fewer than ten hours of television per week, and weigh themselves at least once per week. About half of them lost weight on their own and the other half used some type of weight-loss program. In most scientific studies successful weight loss is accomplished only by changing the diet *and* by increasing physical activity. Doing one without the other limits the amount of weight lost and the length of time that weight loss is sustained. On an individual level, it is quite possible to achieve successful weight loss, as over ten thousand Americans can attest. Moreover, losing as little as 10 percent of your body weight can significantly improve health and reduce disease risk.National Heart, Lung, and Blood Institute. "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report." *Obes Res* 6 supplement (1998): 51S–210S. http://www.ncbi.nlm.nih.gov/books/NBK2003/. You do not have to be overweight or obese to reap benefits from eating a healthier diet and increasing physical activity as both provide numerous benefits beyond weight loss and maintenance.

Evidence-Based Dietary Recommendations

The *2010 Dietary Guidelines for Americans* offers specific, evidence-based recommendations for dietary changes aimed at keeping calorie intake in balance with physical activity, which is key for weight management. These recommendations include: US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

- **Increase intake of whole grains, vegetables, and fruits.** Scientific evidence demonstrates that adults who have a higher intake of whole grains, mainly those high in dietary fiber, have lower body weights compared to adults who eat a smaller amount of whole grains. Moreover, diets incorporating more whole grains reduce chronic disease risk. A higher intake of fruits and vegetables is scientifically shown to protect against weight gain in adults and there is some evidence that this is also true for children and adolescents.
- **Reduce intake of sugar-sweetened beverages.** There is good evidence that reducing consumption of sugar-sweetened beverages, especially in children and adolescents, decreases body weight and reduces chronic disease risk.
- **Monitor intake of 100 percent fruit juice for children and adolescents, especially those who are overweight or obese.** There is some evidence that increased intake of 100 percent juice exacerbates weight problems in children and adolescents who are already overweight or obese.
- **Monitor calorie intake from alcoholic beverages for adults.** Drinking in moderation is not linked to weight gain; however, excessive intake of alcohol over time is associated with weight gain.

Evidence-Based Behavioral Recommendations

In addition to the dietary recommendations, the *2010 Dietary Guidelines for Americans* offers specific evidence-based recommendations that address behavioral changes aimed to keep calorie intake in balance with physical activity. The recommendations include:

- **Focus on the total number of calories consumed.** Reducing calorie intake improves health and aids in weight management.
- **Monitoring food and caloric intake.** Being more aware of the calories in foods and beverages by reading the Nutrition Facts panel is helpful for consumers to monitor intake. Vigilant monitoring of food and caloric intake assists in weight management.
- **When eating out, choose smaller portions or lower-calorie options.** As mentioned in an earlier section of this chapter, eating out more often, especially at fast food restaurants, contributes to weight gain. The *Dietary Guidelines* advise people that when they are eating out to order smaller portions, share meals when possible, or take home part of the meal.
- **Prepare, serve, and consume smaller portions of foods and beverages, especially those high in calories.** Having less on your plate helps you eat less.
- **Eat a nutrient-dense breakfast.** The old adage that "breakfast is the most important meal of the day" holds true when you consider that not eating breakfast is associated with higher body weights, especially among children and adolescents. Moreover, eating a nutrient-dense breakfast has in some scientific studies been shown to stimulate weight loss.

- **Limit screen time.** In children, adolescents, and adults, the sedentary activities of watching television and spending time on the computer are linked to increased overweight and obesity. The *Dietary Guidelines* recommend children and adolescents spend no more than one to two hours daily watching television, playing electronic games, or using the computer (other than for homework).US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

Evidence-Based Physical Activity Recommendations

The other part of the energy balance equation is physical activity. The *2010 Dietary Guidelines* are complemented by the *2008 Physical Activity Guidelines for Americans* issued by the Department of Health and Human Services in an effort to provide evidence-based guidelines for appropriate physical activity levels. The *2008 Physical Activity Guidelines* provide guidance to Americans aged six and older about how to improve health and reduce chronic disease risk through physical activity. Increased physical activity has been found in scientific studies to lower the risk of heart disease, stroke, high blood pressure, Type 2 diabetes, colon, breast, and lung cancer, falls and fractures, depression, and dying early. Increased physical activity not only reduces disease risk, but also improves overall health by increasing cardiovascular and muscular fitness, increasing bone density and strength, improving cognitive function, and assisting in weight loss and weight maintenance. The key guidelines for adults are the following (those for pregnant women, children, and older people will be given elsewhere): US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

- Even small amounts of activity are beneficial to your health.
- More substantial health benefits are obtained by doing at least two hours and thirty minutes per week of moderate-intensity, or one hour and fifteen minutes per week of vigorous-intensity aerobic physical activity, or an equivalent combination thereof. Aerobic activity has better benefits if performed for at least ten minutes at a time, spread throughout the week.
- More extensive health benefits occur when moderate aerobic physical activity is increased to five hours per week of moderate-intensity, or to two hours and thirty minutes of vigorous-intensity aerobic physical activity, or a combination thereof. Additional health benefits are gained by going beyond these recommended amounts of physical activity.
- Muscle-strengthening activities at moderate or high intensity involving all major muscle groups two or more days per week provide additional health benefits to aerobic exercise.

The *2008 Physical Activity Guidelines* broadly classify moderate physical activities as those when “you can talk while you do them, but can’t sing” and vigorous activities as those when “you can only say a few words without stopping to catch your breath.”US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

Table 6.8.1: Moderate and Vigorous Physical Activities

Moderate Activities	Vigorous Activities
Ballroom/line dancing	Aerobic dance
Biking on level ground	Biking (more than 10 miles per hour)
Canoeing	Heavy gardening (digging, hoeing)
Gardening	Hiking uphill
Baseball, softball, volleyball	Fast dancing
Tennis (doubles)	Jumping rope
Walking briskly	Martial arts (karate)
Water aerobics	Race walking
Using hand cyclers	Jogging or running
	Sports with running (basketball, hockey, soccer)
	Swimming laps
	Tennis (singles)
	Ice hockey

Source: US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* 2008. http://www.health.gov/paguidelines/.

Interactive 11.5

To get started on ramping up your physical activity or following a new exercise program use the toolkit, “Be Active Your Way” available from HHS: www.health.gov/paguidelines/adultguide/activeguide.aspx.

Campaigns for a Healthy-Weight America

On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies aimed to meet the challenge of improving the health of all Americans.

In 2010 the national campaign to reduce obesity was reinforced when First Lady Michelle Obama launched the "Let's Move" initiative, which has the goal of "solving the challenge of childhood obesity within a generation so that children born today will reach adulthood at a healthy weight."The White House, Office of the First Lady. "First Lady Michelle Obama Launches Let's Move: America's Move to Raise a Healthier Generation of Kids." February 9, 2010. www.whitehouse.gov/the-press-office/first-lady-michelle-obama-launches -lets-move-americas-move-raise-a-healthier-genera. Another campaign, "Campaign to End Obesity," was recently established to try to enable more Americans to eat healthily and be active by bringing together leaders from academia and industry, as well as public health policy-makers in order to create policies that will reverse the obesity trend and its associated diseases. It remains to be seen whether these new initiatives will finally help improve American health.



Video Link 6.8.1*: View this brief video on the Campaign to End Obesity.*

The "Small-Change" Approach

Currently, most people are not obese in this country. The gradual rise in overweight is happening because, on average, people consume slightly more calories daily than they expend, resulting in a gradual weight gain of one to two pounds a year. In 2003 the idea was first published that promoting small lifestyle changes to reduce weight gain occurring over time in all age groups may better reduce obesity rates in the American population.Hill, J. O. "Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council." *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. Scientific studies have demonstrated that asking people to increase the number of steps they take each day while providing them with pedometers that count the steps they take each day successfully prevented weight gain. A "small-changes" study published in the October 2007 issue of *Pediatrics* evaluated whether families that made two small lifestyle changes, which were to walk an additional two thousand steps per day and to eliminate 100 kilocalories per day from their typical diet by replacing dietary sugar with a noncaloric sweetener, would prevent weight gain in overweight children.Rodearmel, S. J. et al. "Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study." *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. The results of this study were that a higher percentage of children who made the small changes maintained or reduced their BMI in comparison to children of families given a pedometer but not asked to also make physical activity or dietary changes.Rodearmel, S. J. et al. "Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study." *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. Several more studies funded by the National Institutes of Health and USDA are ongoing and are evaluating the effectiveness of the "small-changes" approach in reducing weight gain.

In 2009, a report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council proposed that the "small-changes" approach when supported by the community, industry, and governmental levels will be more effective than current strategies in gradually reducing the obesity rate in America.Hill, J. O. "Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food

Information Council.” *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. The HHS encouraged the approach and launched a “Small Step” website in 2008.

Key Takeaways

- Successful weight loss is defined as when individuals intentionally lose at least 10 percent of their body weight and keep it off for at least one year.
- Although there is a great variety of approaches to achieve successful weight loss most report that it involves adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day).
- The *2015 Dietary Guidelines for Americans* recommendations are based on scientific evidence.
- The other part of the energy balance equation is physical activity. The *2015 Dietary Guidelines* were complemented by the *2008 Physical Activity Guidelines for Americans* issued by the HHS in an effort to provide evidence-based guidelines for appropriate physical activity levels.
- On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies that aim to meet the challenge of improving the health of all Americans.

Discussion Starters

1. Discuss ways to address the childhood obesity problem in your own community.
2. Calculate your EER by using the formula in this chapter and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.

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6.E: Exercises

It's Your Turn

1. Summarize in a paragraph or two why (with respect to reducing future chronic disease burden) it is of utmost importance to combat childhood obesity. Watch this video of First Lady Michelle Obama's unveiling of the initiative to combat childhood obesity to assist you in this assignment.

   US First Lady Michelle Obama Unveils Initiative to Battle Childhood Obesity

   (click to see video)
2. The CDC website provides a list of physical activities and categorizes them as moderate or vigorous (http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf). Use this source to develop an exercise program that fits your lifestyle and follows the recommended amounts of physical activity.

Expand Your Knowledge

1. Make a daily log of your physical activities using the spreadsheet available at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf. Then calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced.
2. Harvard Health Publications has a document that lists the calories burned for various physical activities. It is available at http://www.health.harvard.edu/newsweek/Calories-burned-in-30-minutes-of-leisure-and -routine-activities.htm. Use it to develop a physical activity program that is attractive to you and follows the recommended physical activity guidelines.

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7: Nutrition and Cancer

In Chapter 7, we look at one particular chronic disease, cancer. It is the second leading cause of death after heart disease and your food choice can promote the development of cancer.

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7.1: Chapter Introduction

Incidence

Cancer is the second leading cause of death in the USA behind heart disease but in the world, it is the leading cause of death. In 2016, the National Cancer Institute estimated 1,685,210 new cases of cancer would be diagnosed in the USA (National Cancer Institute) while the World Health Organization estimated 14 million cases in the world in 2012. In the USA in 2016, approximately 595,690 people died from the disease. From 2004 to 2013, the number of people that died from cancer dropped 13%. More people are surviving cancer. Here is a video on cancer survival: https://youtu.be/sQpIFGj6N_w. The most common types of cancer are breast cancer, lung and bronchus cancer, prostate cancer, colon and rectum cancer, bladder cancer, melanoma of the skin, non-Hodgkin lymphoma, thyroid cancer, kidney and renal pelvis cancer, leukemia, endometrial cancer, and pancreatic cancer. Approximately 38.5% of men and women will be diagnosed with cancer sometime in their life. Here is a video to help you understand cancer statistics: https://youtu.be/rF8iEaReujo.

What is Cancer?

What Is Cancer?

In order to understand cancer, you need to know the definition of several cancer terms.

Cell cycle refers to the series of events that occur for the cell to duplicate their DNA and split into two cells. Part of the normal cell cycle is cell death. One way cells die is via apoptosis.

- Necrosis is cell death caused by disease, injury or lack of oxygen or blood.
- Neoplasm - the new growth of tissue which may or may not be cancerous.
- Tumor - abnormal growth of tissue that may be benign or malignant
- Benign - not harmful
- Malignant - threatens life or well-being

The National Cancer Institute has a dictionary of cancer terms: https://www.cancer.gov/publications/dictionaries/cancer-terms?cdrid=390316

The following text is from the National Cancer Institute (National Cancer Institute, *What is cancer?*, 2015, https://www.cancer.gov/about-cancer/...what-is-cancer) and describes cancer.

Figure 7.1.1: A dividing lung cancer cell. Credit: National Institutes of Health

A Collection of Related Diseases

Cancer is the name given to a collection of related diseases. In all types of cancer, some of the body's cells begin to divide without stopping and then may spread into surrounding tissues or travel to distant sites (metastasis).

The human body is made up of trillions of cells and cancer can start almost anywhere. Normally, cells grow and divide to form new cells as the body needs them. When cells grow old or become damaged, they die, and new cells take their place.

Cancer develops when this orderly process breaks down and the molecular changes allow the altered cell to survive. As cells become more and more abnormal, old or damaged cells survive when they should die, and new cells form when they are not needed. These extra cells can divide without stopping and/or evade programmed death and their accumulation forms growths called tumors.

Many cancers form solid tumors, which are masses of tissue. Cancers of the blood, such as leukemias, generally do not form solid tumors.

Cancerous tumors are malignant, which means they can spread into, or invade, nearby tissues. In addition, as these tumors grow, some cancer cells can break off and travel to distant places in the body through the blood or the lymph system and form new tumors far from the original tumor.

Unlike malignant tumors, benign tumors do not spread into, or invade nearby tissues. Benign tumors can sometimes be quite large, however. When removed, they usually don't grow back, whereas malignant tumors sometimes do. Unlike most benign tumors elsewhere in the body, benign brain tumors can be life threatening.

Cancer is a collection of diseases that all share the same characteristics, cells that don't die when planned, begin to divide without stopping and then spread to surrounding tissues. There are many different sites where cancer grows. Can you name a few? What are the most prominent types of cancer? Within a particular tissue, for example breast, the molecular changes defining that cancer are not the same from patient to patient to patient, yet they all have breast cancer. This is what makes cancer a diverse disease, yet a collection of related diseases.

Differences between Cancer Cells and Normal Cells

Cancer cells differ from normal cells in many ways that allow them to grow out of control and become invasive. One important difference is that cancer cells are less specialized than normal cells. That is, whereas normal cells mature into very distinct cell types with specific functions, cancer cells do not. This is one reason that, unlike normal cells, cancer cells continue to divide without stopping.

In addition, cancer cells are able to ignore signals that normally tell cells to stop dividing or that begin a process known as programmed cell death, or apoptosis, which the body uses to get rid of unneeded cells.

Cancer cells may be able to influence the normal cells, molecules, and blood vessels that surround and feed a tumor—an area known as the microenvironment. For instance, cancer cells can induce nearby normal cells to form blood vessels that supply tumors with oxygen and nutrients, which they need to grow. These blood vessels also remove waste products from tumors.

Cancer cells are also often able to evade the immune system, a network of organs, tissues, and specialized cells that protects the body from infections and other conditions. Although the immune system normally removes damaged or abnormal cells from the body, some cancer cells are able to “hide” from the immune system.

Tumors can also use the immune system to stay alive and grow. For example, with the help of certain immune system cells that normally prevent a runaway immune response, cancer cells can actually keep the immune system from killing cancer cells.

How Cancer Arises

Cancer is a genetic disease—that is, it is caused by changes in genes that control the way our cells function, especially how they grow and divide.

Genetic changes that cause cancer can be inherited from our parents. They can also arise during a person’s lifetime as a result of errors that occur as cells divide or because of damage to DNA caused by certain environmental exposures. Cancer-causing environmental exposures include substances, such as the chemicals in tobacco smoke, and radiation, such as ultraviolet rays from the sun. (Our Cancer Causes and Prevention section has more information.)

Each person’s cancer has a unique combination of genetic changes. As the cancer continues to grow, additional changes will occur. Even within the same tumor, different cells may have different genetic changes.

In general, cancer cells have more genetic changes, such as mutations in DNA, than normal cells. Some of these changes may have nothing to do with the cancer; they may be the result of the cancer, rather than its cause.

"Drivers" of Cancer

The genetic changes that contribute to cancer tend to affect three main types of genes—proto-oncogenes, tumor suppressor genes, and DNA repair genes. These changes are sometimes called “drivers” of cancer.

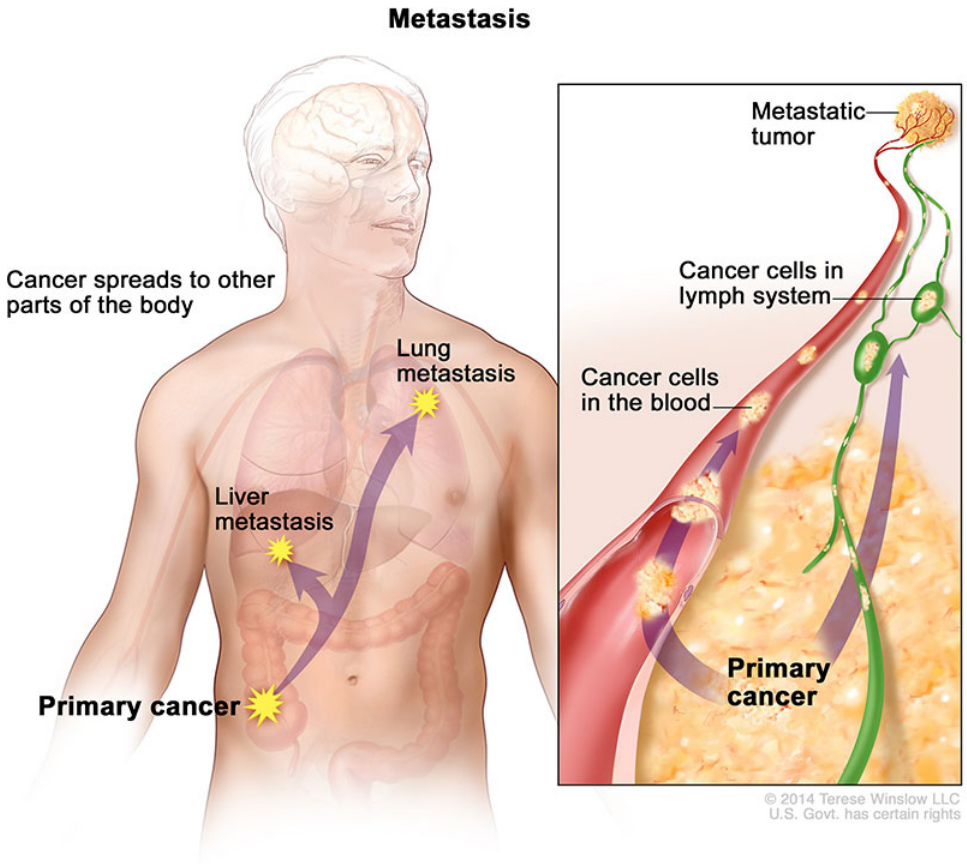
Proto-oncogenes are involved in normal cell growth and division. However, when these genes are altered in certain ways or are more active than normal, they may become cancer-causing genes (or oncogenes), allowing cells to grow and survive when they should not.

Tumor suppressor genes are also involved in controlling cell growth and division. Cells with certain alterations in tumor suppressor genes may divide in an uncontrolled manner.

DNA repair genes are involved in fixing damaged DNA. Cells with mutations in these genes tend to develop additional mutations in other genes. Together, these mutations may cause the cells to become cancerous.

As scientists have learned more about the molecular changes that lead to cancer, they have found that certain mutations commonly occur in many types of cancer. Because of this, cancers are sometimes characterized by the types of genetic alterations that are believed to be driving them, not just by where they develop in the body and how the cancer cells look under the microscope.

When Cancer Spreads



ENLARGE

Figure 7.1.3: In metastasis, cancer cells break away from where they first formed (primary cancer), travel through the blood or lymph system, and form new tumors (metastatic tumors) in other parts of the body. The metastatic tumor is the same type of cancer as the primary tumor.

A cancer that has spread from the place where it first started to another place in the body is called metastatic cancer. The process by which cancer cells spread to other parts of the body is called metastasis.

Metastatic cancer has the same name and the same type of cancer cells as the original, or primary, cancer. For example, breast cancer that spreads to and forms a metastatic tumor in the lung is metastatic breast cancer, not lung cancer.

Under a microscope, metastatic cancer cells generally look the same as cells of the original cancer. Moreover, metastatic cancer cells and cells of the original cancer usually have some molecular features in common, such as the presence of specific chromosome changes.

Treatment may help prolong the lives of some people with metastatic cancer. In general, though, the primary goal of treatments for metastatic cancer is to control the growth of the cancer or to relieve symptoms caused by it. Metastatic tumors can cause severe damage to how the body functions and most people who die of cancer die of metastatic disease.

Tissue Changes that Are Not Cancer

Not every change in the body's tissues is cancer. Some tissue changes may develop into cancer if they are not treated, however. Here are some examples of tissue changes that are not cancer but, in some cases, are monitored:

Hyperplasia occurs when cells within a tissue divide faster than normal and extra cells build up or proliferate. However, the cells and the way the tissue is organized look normal under a microscope. Hyperplasia can be caused by several factors or conditions, including chronic irritation.

Dysplasia is a more serious condition than hyperplasia. In dysplasia, there is also a buildup of extra cells. But the cells look abnormal and there are changes in how the tissue is organized. In general, the more abnormal the cells and tissue look, the greater the chance that cancer will form.

Some types of dysplasia may need to be monitored or treated. An example of dysplasia is an abnormal mole (called a dysplastic nevus) that forms on the skin. A dysplastic nevus can turn into melanoma, although most do not.

An even more serious condition is carcinoma in situ. Although it is sometimes called cancer, carcinoma in situ is not cancer because the abnormal cells do not spread beyond the original tissue. That is, they do not invade nearby tissue the way that cancer cells do. But, because some carcinomas in situ may become cancer, they are usually treated.

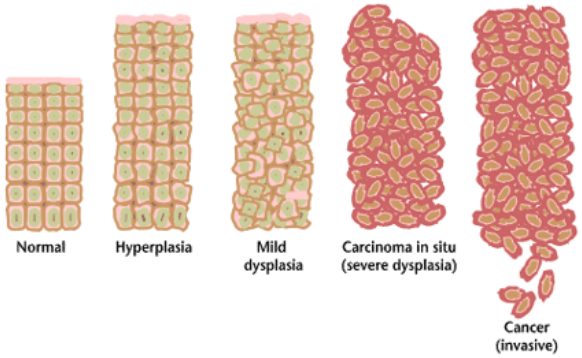


Figure 7.1.4: Normal cells may become cancer cells. Before cancer cells form in tissues of the body, the cells go through abnormal changes called hyperplasia and dysplasia. In hyperplasia, there is an increase in the number of cells in an organ or tissue that appear normal under a microscope. In dysplasia, the cells look abnormal under a microscope but are not cancer. Hyperplasia and dysplasia may or may not become cancer.

Types of Cancer

There are more than 100 types of cancer. Types of cancer are usually named for the organs or tissues where the cancers form. For example, lung cancer starts in cells of the lung, and brain cancer starts in cells of the brain. Cancers also may be described by the type of cell that formed them, such as an epithelial cell or a squamous cell.

You can search NCI's website for information on specific types of cancer-based on the cancer's location in the body or by using our A to Z List of Cancers. We also have collections of information on childhood cancers and cancers in adolescents and young adults.

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7.2: Carcinogenesis

Learning Objectives

- Describe the process by which a normal cell becomes a cancer cell.

The transformation of a normal cell into a cancer cell is a multi-step process that involves initiation, promotion, progression and finally malignancy (see Figure 7.2.1). This process takes years and starts with a single cell in which the right genes are mutated so the cell does not appropriately die and begins to proliferate abnormally. Then, additional mutations occur that select for more rapidly growing cells within this population leading to a tumor with rapid growth and malignancy. By the time the cells are cancerous, proto-oncogenes have been activated and tumor suppressor genes inactivated. Even within the same tumor type, like colon cancer, the specific genes mutated can vary from person to person making cancer a unique disease for each individual. Using measures of age-dependent cancer incidence, scientists have been able to determine at least four to six independent steps are needed. What drives initiation and progression?

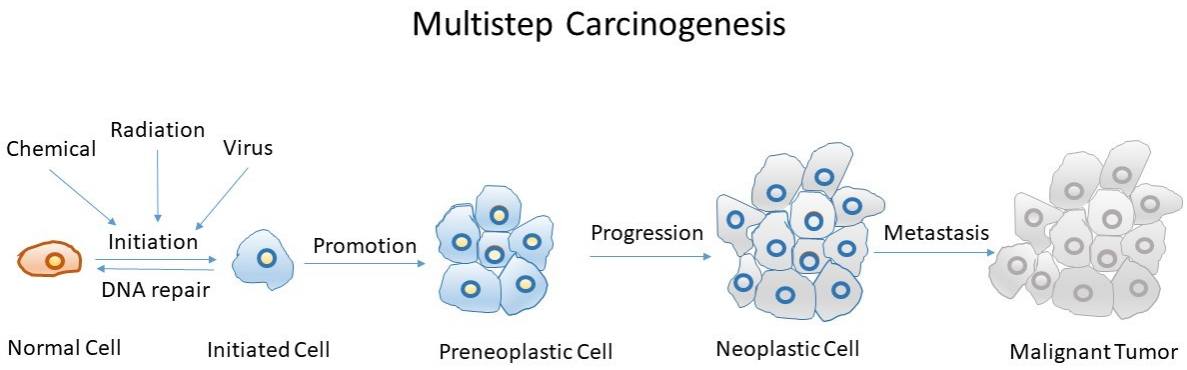


Figure 7.2.1: Multistep process involved in carcinogenesis that transforms a normal cell into a malignant tumor.

Initiation

As you can see in the figure, both endogenous and exogenous substances can initiate DNA damage. Endogenous agents are substances that are in our body that can cause DNA damage directly or indirectly, for example, bile acids or reactive oxygen species. Exogenous agents are agents that are in our environment like cigarette smoke, radiation, or smog. Diet is an exogenous agent and consumption of certain foods, like processed meats, have been linked to a higher incidence of cancer while consumption of other foods, like fruits and vegetables, have been linked to a lower risk of developing a tumor. Doll and Peto estimated 35% of cancers could be contributed to diet alone with a range from 10 to 70% (Doll R, Peto R. The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. J Natl Cancer Inst. 1981;66(6):1191– 1308). They made their landmark observations thirty-five years ago and it has remained generally true since then.

Carcinogens are substances or exposures that can cause cancer in a living tissue. Not all carcinogens affect DNA directly. For example, they may cause cells to divide faster which increases the risk for DNA damage. Also, not all carcinogens cause cancer upon exposure because most have different levels of cancer-causing potential and the length of exposure is also critical. So, the risk of developing cancer depends on many factors including how you are exposed, how long you are exposed, and your genetic makeup.

Lab studies are used to determine if a substance is a carcinogen. Most studies expose lab animals to the potential carcinogen at much higher levels than common to human exposures. Then, scientists observe if the animal grows a tumor.

A carcinogen can modify the molecular structure of DNA in a variety of different ways, indirectly or directly. One common way is to form a new compound (adduct) between the chemical carcinogen, or one of its functional groups, and DNA. Usually, this adduct is recognized and broken down my our cells; but if it escapes detection or degradation, then it can go on and multiply.

Promotion

The next step in the multistep carcinogenesis model is the clonal expansion of the initiated cells. Promoters help speed this process but are not generally mutagenic so they do not initiate tumorigenesis but speed up the process. Also, promoters do not need metabolic activation; instead, they work by reducing the latency period for tumor formation after exposure of a tissue to a tumor initiator or they increase the number of tumors formed in that tissue. Examples of tumor promoters are alcohol, high estrogen, dietary fat, chronic irritation, ultraviolet light, and chemicals like dioxin, saccharin, tryptophan, polychlorinated biphenyl (PCBs) to name a few. Specific types of dietary fat have been linked to colon, breast and prostate cancer, and may promote tumor formation by causing the body to secrete more hormones favorable to cancer growth (ex. estrogen), promote the secretion of bile acid in the intestine which microorganisms convert to carcinogens, or are incorporated into cell membranes increasing the cells' susceptibility to carcinogens.

Dietary fiber and calorie restriction are two anti-carcinogen or anti-promoters that decrease the risk of tumor formation. Dietary fiber is both and is inversely associated with cancer, particularly colon cancer. So the more fiber you eat, the less risk you have of developing colon cancer. One mechanism by which fiber acts is hastening bile acid excretion. Fiber also increases the rate of passage of materials through the colon resulting in decreased production and exposure of the colon to cancer-causing agents, ie dilutes the concentration of carcinogens.

Animal studies have shown that restricting caloric intake by 30% reduces tumor growth and increases life span. The mechanism is not known but may be due to less oxidation thus damage to DNA.

Antioxidants can help block the action of initiators or promoters if their mode of action is to damage DNA by oxidation. Vitamin A, C, E, beta-carotene, and selenium are antioxidant nutrients. Some work locally, like vitamin E in the colon, while other work more globally like selenium and vitamin C. Vitamin A appears to work by keeping cells differentiated which slows the growth rate.

Other compounds in food, particularly fruits and vegetables, have been shown to slow tumor formation. Cruciferous vegetables (eg broccoli, cauliflower, cabbage, and Brussel sprouts to name a few) are rich in nutrients, fiber, glucosinolates which are sulfur-containing chemicals, indoles, and isothiocyanates. Animal studies have found these substances inhibit the development of cancer in several organs in rats and mice (Hecht SS. Inhibition of carcinogenesis by isothiocyanates. *Drug Metabolism Reviews* 2000;32(3-4):395-411; Murillo G, Mehta RG. Cruciferous vegetables and cancer prevention. *Nutrition and Cancer* 2001;41(1-2):17-28). Indoles and isothiocyanates help protect cells from DNA damage; help inactivate carcinogens; have antiviral and antibacterial effects; have anti-inflammatory effects; induce cell death (apoptosis); and inhibit tumor blood vessel formation (angiogenesis) and tumor cell migration (needed for metastasis) (National Cancer Insitute, Cruciferous Vegetables and Cancer Prevention, 2012, https://www.cancer.gov/about-cancer/...les-fact-sheet). Studies in humans, however, have shown mixed results.

Progression and Malignancy

Conversion of a preneoplastic cell into one that expresses the malignant phenotype is malignant conversion and requires more genetic changes. The rate of conversion can be increased by repeated exposure of preneoplastic cells to DNA-damaging agents which results in activation of proto-oncogenes and inactivation of tumor suppressor genes. Tumor progression is the expression of this malignant phenotype and the tendency for these cells to become more aggressive over time. A common characteristic of malignant cells is genomic instability and uncontrolled growth. It is the accumulation of genetic mutations and not the order or stage in which they occur that is important for tumor formation.

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7.3: Diet and Cancer

Learning Objectives

- Identify food substances known to cause cancer.
- Identify an anti-cancer diet.

Food Substances That May Promote Cancer

Several foods increase the risk of cancer. Alcohol is one example and increases the risk of mouth cancer, pharynx (throat), larynx (voice box), esophagus, liver, breast, colon, and rectum. People who drink should limit their alcohol intake to no more than 2 drinks per day for men and one drink per day for women. A drink is defined as 12 ounces of beer, 5 ounces of wine, or 1 1/2 ounces of 80-proof distilled spirits (hard liquor). Recent studies suggest there is no safe level of alcohol intake for women who are at high risk of developing breast cancer.

Scientific studies have shown that people who eat more fruit and vegetable have a lower risk of developing cancer certain cancers. Those individuals that eat less fruit and vegetables may increase their risk of developing cancer. Fruit and vegetables are rich in antioxidants but several studies of antioxidant supplements have not found a lower cancer risk, so the other compounds in fruits and vegetables may confer this protective effect.

Epidemiological studies have linked a high fat intake with higher rates of breast, prostate, colon, and other cancers. Randomized studies have not found that fat intake increases tumor development or lowers cancer risk either. So, at this time, the evidence is unclear and total amount of fat consumed does not appear to be linked to cancer risk.

Consumption of large amounts of processed meats has been associated with an increased risk of colorectal and stomach cancer. The exact mechanism is not known but nitrites, used to maintain color and bacterial growth in lunch meats, hams, and hot dogs, may play a role.

Frying, broiling, or grilling meats, cooking processes that use high heat, form chemicals that may increase cancer risk. These chemicals are polycyclic aromatic hydrocarbons or heterocyclic aromatic amines.

Eating a lot of foods preserved by salting and/or pickling increase one's risk of stomach, nasopharyngeal, and throat cancer. There is very little evidence that the level of salt used in cooking or flavoring foods or added during processing affect cancer risk.

Food As an Anti-Carcinogens

Dietary fiber and calorie restriction are two anti-carcinogen or anti-promoters that decrease the risk of tumor formation. Dietary fiber is both and is inversely associated with cancer, particularly colon cancer. So the more fiber you eat, the less risk you have of developing colon cancer. One mechanism by which fiber acts is hastening bile acid excretion. Fiber also increases the rate of passage of materials through the colon resulting in decreased production and exposure of the colon to cancer-causing agents, ie dilutes the concentration of carcinogens.

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Dietary Recommendation for Decreasing Cancer Risk

The American Institute for Cancer Research, American Cancer Society, and National Cancer Institute provide dietary recommendations to reduce cancer risk. These guidelines are remarkably similar and focus on eating more fruits and vegetables, whole grains, and legumes; reducing processed meat and red meat intake; and limit your intake of alcohol. Fruits, vegetables, and whole grains are rich in fiber. Refined grains, such as white rice, are low or devoid of fiber. All types of fibers should be emphasized. Fruits and vegetables contain antioxidants, phytochemicals, and fiber.

American Institute for Cancer Research recommendations (http://www.aicr.org/reduce-your-canc...ww.google.com/)

These ten recommendations for cancer prevention are drawn from the WCRF/AICR Second Expert Report. Each recommendation links to more details.

1. Be as lean as possible without becoming underweight.
2. Be physically active for at least 30 minutes every day. Limit sedentary habits.
3. Avoid sugary drinks. Limit consumption of energy-dense foods.
4. Eat more of a variety of vegetables, fruits, whole grains and legumes such as beans.
5. Limit consumption of red meats (such as beef, pork, and lamb) and avoid processed meats.
6. If consumed at all, limit alcoholic drinks to 2 for men and 1 for women a day.
7. Limit consumption of salty foods and foods processed with salt (sodium).
8. Don't use supplements to protect against cancer.
9. * It is best for mothers to breastfeed exclusively for up to 6 months and then add other liquids and foods.
10. * After treatment, cancer survivors should follow the recommendations for cancer prevention.

American Cancer Society recommendations are:

Eat a healthy diet, with an emphasis on plant foods.
• Choose foods and drinks in amounts that help you get to and maintain a healthy weight.

- Limit how much processed meat and red meat you eat.
- Eat at least 2½ cups of vegetables and fruits each day.
- Choose whole grains instead of refined grain products.

If you drink alcohol, limit your intake.

- Drink no more than 1 drink per day for women or 2 per day for men.

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8: Antioxidant Nutrients

In Chapter 8, nutrients important as antioxidants are explored, starting with an explanation of what oxidation and antioxidants are, then looking at vitamins E, C, and A, selenium, and phytochemicals.

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8.1: Chapter Introduction

Big Idea

Eating foods such as fruits, vegetables, herbs, and spices that are high in antioxidants can help prevent cell damage and promote health.



Figure 8.1.1 Nutmeg, which is obtained from the seed of the evergreen tree, *Myristica fragrans*, was once a highly coveted spice. IMage used with permission (public domain).

Government trickery and greed are a big part of the history of the woody, bittersweet nutmeg people sprinkle in their eggnog and add to their pumpkin pie. Arabs originally controlled the lucrative nutmeg trade. Run Island, part of the Banda archipelago in the Maluku province of Indonesia, and (for a while) the sole source of nutmeg, remained a well-kept secret under their control. Then, in 1521, the Portuguese conquered the southern region of Malay in Indonesia and discovered the island.

Control of this nutmeg source switched hands rapidly from this point on. Although the Portuguese claimed ownership for a moment, the Spaniards were quick to take over. In the seventeenth century, the Dutch East India Company invaded the Band Islands. They then ran plantation estates on Run Island and actively patrolled the sea in war vessels to discourage the stealing of seeds from *Myristica fragrans*. They went so far as to track the movement of pigeons and other animals that might unwittingly transport the seeds elsewhere, and they burned any trees found off of Run Island.

The battles over Run Island had one important motivation: money. Trade was lucrative in the seventeenth century because nutmeg was valued as a curative for stomach ailments, as an aphrodisiac, and as a healer of the liver. The spice even had a reputation for curing the plague, which might have worked—wearing a clove of it around the neck may have deterred fleas and other disease carriers. Buyers were also well aware of nutmeg's hallucinogenic properties and used it in high doses as a psychoactive drug. Its price was astronomically high and kept so by the Dutch, who burned their own nutmeg warehouses down to assure the laws of supply and demand did not lower the spice's value.

During the Napoleonic wars, while the Dutch were battling the French, the British slipped onto Run Island, stole *Myristica fragras* seeds, and successfully grew the tree on plantations on the island of Grenada. Today, Grenada, also known as the "Isle of Spice," produces about one-third of the world's supply, which is why its flag boasts a clove of nutmeg.

Our ancestors were probably right to value nutmeg for its curative properties. While it does not actually cure disease outright, nutmeg contains a variety of antioxidants, including phenolic compounds, lignans, and eugenol. Foods rich in antioxidants have been touted as preventative and curative, and some believe they delay certain aspects of the aging process. While we are no longer fighting over nutmeg's production and sale, we are waging a fierce debate about the lack of scientific proof of these believed benefits.

The "antioxidant hypothesis"—the educated guess that antioxidant chemicals protect against chronic disease—has existed for decades. Despite thousands of studies conducted on the health benefits of particular antioxidants, there is little evidence supporting the idea that they singularly prevent disease, reduce the effects of aging, or promote health. It is the *combination* of antioxidants, phytochemicals, and nutrient-rich foods that achieve these end goals.

Nutmeg has been shown in animal and laboratory studies to act as an antimicrobial, antifungal, and anti-inflammatory agent. It has protected against liver damage and stimulated male sexual activity in rats. However, none of these effects have been scientifically shown to occur in humans. On the other hand, nutmeg has proven effective as a psychoactive drug when taken in high doses.

In this chapter, you will learn there is no miracle food or supplement. The debate over the nutmeg's effectiveness as an antioxidant —and over the effects of antioxidants in general—is proof of this. You will also learn that plant chemicals can affect the body in

many different ways, depending on the type of chemical and the dosage. Different antioxidants are believed to have different functions, and those functions are sometimes interdependent or dependent on the amount of nutrient-rich foods you eat.

You Decide

Will you increase your intake of antioxidant- and nutrient-rich foods to improve health and reduce the risk of chronic disease? Why and how?

“Shall I not have intelligence with the earth? Am I not partly leaves and vegetable mold myself?” - Henry David Thoreau (July 12, 1817–May 6, 1862)

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8.2: Generation of Free Radicals in the Body

Learning Objectives

- Describe how free radicals are generated in the body.
- Explain oxidative stress and what diseases it is associated with.

In mainstream advertising, you may have heard that antioxidants can extend your life by preventing disease and slowing the aging process. But what are antioxidants? And how do they work in the body? Is there any truth to the marketers' claims? Are there better sources than supplements for antioxidants? After reading this chapter you will be able to answer these questions, and your new knowledge will assist you in making dietary decisions to optimize your health.

Keep in mind as you read there is no scientific evidence that antioxidants *singularly* provide bodily benefits, but there is evidence that certain benefits are achieved by ingesting antioxidants as part of a balanced, healthy, nutrient-rich diet. This is to say antioxidants may go a long way toward preventing damage, but other nutrients are necessary to repair damage and sustain health. No one chemical acts alone!

The Atom

Before we can talk about the nutritional value of antioxidants we must review a few chemistry basics, starting with the atom. Cells are the basic building blocks of life, but atoms are the basic building blocks of all matter, living and non-living.

The structural elements of an atom are protons (positively charged), neutrons (no charge), and electrons (negatively charged). Protons and neutrons are contained in the dense nucleus of the atom; the nucleus thus has a positive charge. Because opposites attract, electrons are attracted to this nucleus and move around it in the electron cloud.

Electrons contain energy, and this energy is stored within the charge and movement of electrons and the bonds atoms make with one another. However, this energy is not always stable, depending on the number of electrons within an atom.

Atoms are more stable when their electrons orbit in pairs. An atom with an odd number of electrons must have an unpaired electron. In most cases, these unpaired electrons are used to create chemical bonds. A chemical bond is an attractive force between atoms and contains potential energy. By bonding, electrons find pairs and chemicals become part of a molecule.

Bond formation and bond breaking are chemical reactions that involve the movement of electrons between atoms. These chemical reactions occur continuously in the body and many of them will be discussed in more detail later.

Previous, we reviewed how glucose breaks down into water and carbon dioxide as part of cellular respiration. The energy released by breaking those bonds is used to form molecules of adenosine triphosphate (ATP). Recall how during this process electrons are extracted from glucose in a stepwise manner and transferred to other molecules. Occasionally electrons "escape" and, instead of completing the cellular respiration cycle, are transferred to an oxygen molecule. Oxygen (a molecule with two atoms) with one unpaired electron is known as superoxide (Figure 8.1).

Atoms and molecules such as superoxide that have unpaired electrons are called free radicals; those containing oxygen are more specifically referred to as reactive oxygen species. The unpaired electron in free radicals destabilizes them, making them highly reactive. Other reactive oxygen species include hydrogen peroxide and the hydroxyl radical.



Figure 8.2.1: Superoxide: A molecule with one unpaired electron, which makes it a free radical. Source: Wikipedia. "Superoxide." Last modified November 2, 2012. (CC-BY-SA 3.0; DoSiDo).

The reactivity of free radicals is what poses a threat to macromolecules such as DNA, RNA, proteins, and fatty acids. Free radicals can cause chain reactions that ultimately damage cells. For example, a superoxide molecule may react with a fatty acid and steal one of its electrons. The fatty acid then becomes a free radical that can react with another fatty acid nearby. As this chain reaction continues, the permeability and fluidity of cell membranes changes, proteins in cell membranes experience decreased activity, and receptor proteins undergo changes in structure that either alter or stop their function. If receptor proteins designed to react to insulin levels undergo a structural change it can negatively affect glucose uptake.

Our bodies required oxygen to survive and oxidation is the process by which oxygen takes electrons from a material. This process can be beneficial, such as in making energy, or harmful, for example, free radicals that change the structure of a molecule. Free radicals are highly reactive molecules that can react with other molecules and cause damage; rusting is an example.

Free radicals occur naturally in our body (endogenous) during many different metabolic processes. Here are several examples. Aerobic metabolism, discussed in the chapter on energy metabolism, uses oxygen to burn substrate (glucose, fatty acids, and amino acids). The process of detoxifying drugs can generate free radicals. Finally, one way our immune system fights invaders is to produce free radicals.

Our environment also exposes us to free radicals. Examples of exogenous sources are cigarette smoke, air pollution, alcohol and polyunsaturated fatty acids.

Free radical reactions can continue unchecked unless stopped by a defense mechanism.

The Body's Defense

Free radical development is unavoidable, but human bodies have adapted by setting up and maintaining defense mechanisms that reduce their impact. The body's two major defense systems are free radical detoxifying enzymes and antioxidant chemicals. Free radical detoxifying enzyme systems are responsible for protecting the insides of cells from free radical damage. An antioxidant is any molecule that can block free radicals from stealing electrons; antioxidants act both inside and outside of cells.

Antioxidants sequester free radicals to make them less damaging and fruits, vegetables, herbs, and spices are high in antioxidants and thus help prevent cell damage and promote health. Vitamin C, vitamin E, and carotenoids are natural antioxidants present in fruits and vegetables. Also, there are several enzymes involved in detoxifying that require the essential minerals selenium, copper, and zinc.

Free Radical Detoxifying Enzymes

The three major enzyme systems and the chemical reactions they catalyze are:

1. **Superoxide Dismutases (SOD).** These enzymes have either a manganese, copper, or zinc cofactor, which is essential for their free radical detoxifying activity. During SOD-mediated enzymatic catalysis, two superoxides are converted into hydrogen peroxide and oxygen. Hydrogen peroxide (H_2O_2) is still considered a reactive oxygen species, but it is markedly less reactive than a superoxide. SOD enzymes are one of the fastest enzymes known, and they are also inducible, meaning that the higher their exposure to superoxides the greater their number and detoxifying activity.
2. **Catalase.** This enzyme contains iron as a cofactor and converts hydrogen peroxide to water and oxygen, thereby finishing the detoxification reaction started by SOD. In cells, catalase enzymes are found in high numbers and continuously patrol for hydrogen peroxide molecules. Catalase is highly efficient and is capable of destroying millions of hydrogen peroxide molecules per second.
3. **Glutathione Peroxidases.** The majority of enzymes within this family are dependent on the micronutrient selenium. Similar to catalase, these enzymes convert hydrogen peroxide to water and oxygen.

Antioxidant Chemicals

Antioxidants are broadly classified as either hydrophilic (water soluble) or hydrophobic (lipid soluble) chemicals, and this classification determines where they act in the body. Hydrophilic antioxidants act in the cytosol of cells or in extracellular fluids such as blood; hydrophobic antioxidants are largely responsible for protecting cell membranes from free radical damage.

The body can synthesize some antioxidants, but others must be obtained from the diet.

Antioxidant Chemicals the Body Synthesizes

There are two antioxidant chemicals that the body synthesizes. They are:

1. **Glutathione.** This molecule is composed of three amino acids and is found in high concentrations in cells. The cysteine amino acid of glutathione contains a sulfur group that can donate an electron to a free radical, thereby stabilizing it. After glutathione has lost its electron, it is regenerated enzymatically so that it can perform its antioxidant function once again.
2. **Uric Acid.** This molecule is a metabolic intermediate in the breakdown of nucleotides such as adenine, which is found in DNA and RNA, among other macromolecules. It circulates at high concentrations in the blood and disables circulating free radicals. However, uric acid is a good example of the adage “it’s the dose that makes the poison” because high concentrations in the blood can cause gout, a painful joint disorder.

Antioxidant Chemicals Obtained from the Diet

There are many different antioxidants in food, including selenium, which is one of the major antioxidants. However, the antioxidants you may be the most familiar with are vitamins. The “big three” vitamin antioxidants are vitamins E, A, and C, although it may be that they are called the “big three” only because they are the most studied.

Table 8.2.1: Some Antioxidants Obtained from Diet and Their Related Functions

Antioxidant	Functions Attributed to Antioxidant Capacity
Vitamin A	Protects cellular membranes, prevents glutathione depletion, maintains free radical detoxifying enzyme systems, reduces inflammation
Vitamin E	Protects cellular membranes, prevents glutathione depletion
Vitamin C	Protects DNA, RNA, proteins, and lipids, aids in regenerating vitamin E
Carotenoids	Free radical scavengers
Lipoic acid	Free radical scavenger, aids in regeneration of vitamins C and E
Phenolic acids	Free radical scavengers, protect cellular membranes
Selenium	Cofactor of free radical detoxifying enzymes, maintains glutathione levels, aids in regeneration of vitamins C and E

The Body’s Offense

While our bodies have acquired multiple defenses against free radicals, we also use free radicals to support its functions. For example, the immune system uses the cell-damaging properties of free radicals to kill pathogens. First, immune cells engulf an invader (such as a bacterium), then they expose it to free radicals such as hydrogen peroxide, which destroys its membrane. The invader is thus neutralized.

Scientific studies also suggest hydrogen peroxide acts as a signaling molecule that calls immune cells to injury sites, meaning free radicals may aid with tissue repair when you get cut.

Free radicals are necessary for many other bodily functions as well. The thyroid gland synthesizes its own hydrogen peroxide, which is required for the production of thyroid hormone. Reactive oxygen species and reactive nitrogen species, which are free radicals containing nitrogen, have been found to interact with proteins in cells to produce signaling molecules. The free radical nitric oxide has been found to help dilate blood vessels and act as a chemical messenger in the brain.

By acting as signaling molecules, free radicals are involved in the control of their own synthesis, stress responses, regulation of cell growth and death, and metabolism.

Sources of Free Radicals in the Environment

The body creates free radicals through the normal processes of metabolism. When the amount of free radicals exceeds the body’s ability to eliminate or neutralize them, an oxidative imbalance occurs.

Substances and energy sources from the environment can add to or accelerate the production of free radicals within the body. Exposure to excessive sunlight, ozone, smoke, heavy metals, ionizing radiation, asbestos, and other toxic chemicals increase the number of free radicals in the body. They do so by being free radicals themselves or by adding energy that provokes electrons to move between atoms. Excessive exposure to environmental sources of free radicals can contribute to disease by overwhelming the free radical detoxifying systems and those processes involved in repairing oxidative damage.

Video 8.2.1

Free Radical Formation (click to see video)

Oxidative Stress

Oxidative stress refers to an imbalance in any cell, tissue, or organ between a number of free radicals and the capabilities of the detoxifying and repair systems. Sustained oxidative damage results only under conditions of oxidative stress—when the detoxifying and repair systems are insufficient. Free radical-induced damage, when left unrepaired, destroys lipids, proteins, RNA, and DNA, and can contribute to disease. Oxidative stress has been implicated as a contributing factor to cancer, atherosclerosis (hardening of arteries), arthritis, diabetes, kidney disease, Alzheimer’s disease, Parkinson’s disease, schizophrenia, bipolar disorder, emphysema, and cataracts.

Aging is a process that is genetically determined but modulated by factors in the environment. In the process of aging, tissue function declines. The idea that oxidative stress is the primary contributor to age-related tissue decline has been around for decades, and it is true that tissues accumulate free radical-induced damage as we age. Recent scientific evidence slightly modifies this theory by suggesting oxidative stress is not the initial trigger for the age-related decline of tissues; it is suggested that the true culprit is progressive dysfunction of metabolic processes, which leads to increases in free radical production, thus influencing the stress response of tissues as they age.

Video 8.2.2

Free Radicals or Oxidative Stress Will Age Our Bodies' Cells (click to see video)

Oxidative stress occurs when there is an imbalance between free radical production and their detoxification. Sustained oxidative tissue damage that can contribute to disease occurs only when free radical detoxification systems and repair systems are overwhelmed.

Key Takeaways

- Free radicals, unstable molecules with unpaired electrons, are an unavoidable byproduct of cellular metabolism.
- Free radicals can steal electrons from lipids, proteins, RNA, and DNA, causing them damage.
- The body has defenses against free radicals—free radical detoxifying enzymes and antioxidant chemicals.

- The body can synthesize some antioxidant molecules, but many are obtained from the diet.
- The body sometimes uses free radicals for beneficial functions such as killing pathogens and regulating cell growth and death.
- Oxidative stress is an imbalance between free radical production and detoxification and repair systems. It also plays an integral role in the development of many chronic diseases and in age-related decline of tissues.
- Excessive sunlight, ozone, smoke, heavy metals, radiation, asbestos, and other toxic chemicals increase the amount of free radicals in the body and can accelerate the progression of diseases in which oxidative stress is a contributing cause.

Discussion Starter

1. What are some ways you can prevent exposure to environmental factors that increase free radical production in your body?

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8.3: Antioxidant Micronutrients

Learning Objectives

1. List the antioxidant nutrients.
2. Give examples of the best food sources of antioxidant nutrients.
3. Name some phytochemicals and their health benefits as backed by scientific evidence.

The market is flooded with advertisements for "super antioxidant" supplements teeming with molecules that block free radical production, stimulate the immune system, prevent cancer, and reduce the signs of aging. Based on the antioxidant-supplement industry's success, the general public appears to believe these health claims. However, these claims are not backed by scientific evidence; rather, there is some evidence suggesting supplements can actually cause harm.

While scientists have found evidence supporting the consumption of antioxidant-rich foods as a method of reducing the risk of chronic disease, there is no "miracle cure;" no pill or supplement alone can provide the same benefits as a healthy diet. Remember, it is the combination of antioxidants and other nutrients in healthy foods that is beneficial.

In this section, we will review how particular antioxidants function in the body, learn how they work together to protect the body against free radicals, and explore the best nutrient-rich dietary sources of antioxidants.

Antioxidant Vitamins

One dietary source of antioxidants is vitamins. In our discussion of antioxidant vitamins, we will focus on vitamins C, E, and A.

Vitamin C Functions and Health Benefits

Vitamin C, also commonly called ascorbic acid, is a water-soluble micronutrient essential in the diet for humans, although most other mammals can readily synthesize it. Vitamin C's ability to easily donate electrons makes it a highly effective antioxidant. It is effective in scavenging reactive oxygen species, reactive nitrogen species, and many other free radicals. It protects lipids both by disabling free radicals and by aiding in the regeneration of vitamin E.

In addition to its role as an antioxidant, vitamin C is a required part of several enzymes involved in the synthesis of collagen, signaling molecules in the brain, some hormones, and amino acids. Vitamin C levels in the body are affected by the amount in the diet, which influences how much is absorbed and how much the kidney allows to be excreted, such that the higher the intake, the more vitamin C is excreted. Vitamin C is not stored in any significant amount in the body, but once it has reduced a free radical, it is very effectively regenerated and therefore it can exist in the body as a functioning antioxidant for many weeks.

Other Functions

Vitamin C has several other important functions. It is a co-factor in the formation of collagen. Collagen is a fibrous structural protein found in skin, scars, blood vessels, tendons, ligaments, bone, and teeth. Another function, vitamin C assists in the absorption of iron.

Deficiency signs and symptoms

The classic condition associated with vitamin C deficiency is scurvy. You only need about 10 mg/day of ascorbic acid to prevent scurvy and it takes about one month to appear. The signs and symptoms of scurvy include skin disorders such as rough, dry, scaly skin, bleeding gums, degeneration of muscles, painful joints, weakness, depression, and increased susceptibility to infections. These are associated with the physiological changes in collagen. In children, growth is impeded. People who smoke, experience physical stress and are alcoholics at a greater risk of developing a vitamin C deficiency and may need extra vitamin C. Scurvy is prevented by having an adequate Intake of fruits and vegetables rich in vitamin C.

Cardiovascular Disease

Vitamin C's ability to prevent disease has been debated for many years. Overall, higher dietary intakes of vitamin C (via food intake, not supplements), are linked to decreased disease risk. A review of multiple studies published in the April 2009 issue of the *Archives of Internal Medicine* concludes there is moderate scientific evidence supporting the idea that higher dietary vitamin C intakes are correlated with reduced cardiovascular disease risk, but there is insufficient evidence to conclude that taking vitamin C supplements influences cardiovascular disease risk.Mente, A., et al. "A Systematic Review of the Evidence Supporting a Causal Link between Dietary Factors and Coronary Heart Disease." *Arch Intern Med* 169, no.7 (2009): 659–69. http://archinte.ama-assn.org/cgi/content/full/169/7/659.

Vitamin C levels in the body have been shown to correlate well with fruit and vegetable intake, and higher plasma vitamin C levels are linked to reduced risk of some chronic diseases. In a study involving over twenty thousand participants, people with the highest levels of circulating vitamin C had a 42 percent decreased risk for having a stroke.Myint, P.K. et al. "Plasma Vitamin C Concentrations Predict Risk of Incident Stroke Over 10 Y[ears] in 20,649 Participants of the European Prospective Investigation into Cancer, Norfolk Prospective Population Study." *Am J Clin Nutr* 87, no.1 (2008): 64–69. http://www.ajcn.org/content/87/1/64.long.

Cancer

There is some evidence that a higher vitamin C intake is linked to a reduced risk of cancers of the mouth, throat, esophagus, stomach, colon, and lung, but not all studies confirm this is true. As with the studies on cardiovascular disease, the reduced risk of cancer is the result of eating foods rich in vitamin C, such as fruits and vegetables, not from taking vitamin C supplements. In these studies, the specific protective effects of vitamin C cannot be separated from the many other beneficial chemicals in fruits and vegetables.

Immunity

Vitamin C does have several roles in the immune system, and many people increase vitamin C intake either from diet or supplements when they have a cold. Many others take vitamin C supplements routinely to prevent colds. Contrary to this popular practice, however, there is no good scientific evidence that vitamin C prevents a cold. A review of more than fifty years of studies published in 2004 in the *Cochrane Database of Systematic Reviews* concludes that taking vitamin C routinely does not prevent colds in most people, but it does slightly reduce cold severity and duration. Moreover, taking megadoses (up to 4 grams per day) at the onset of a cold provides no benefits.Douglas, R.M. et al. "Vitamin C for Preventing and Treating the Common Cold." *Cochrane Database of Systematic Reviews* 4 (2004): CD000980. http://www.ncbi.nlm.nih.gov/pubmed/15495002?dopt=Abstract.

Gout is a disease caused by elevated circulating levels of uric acid and is characterized by recurrent attacks of tender, hot, and painful joints. There is some evidence that a higher intake of vitamin C reduces the risk of gout.

Dietary Reference Intakes for Vitamin C

The RDAs and ULs for different age groups for vitamin C are listed in Table 8.3.1. They are considered adequate to prevent scurvy. Vitamin C's effectiveness as a free radical scavenger motivated the Institute of Medicine (IOM) to increase the RDA for smokers by 35 milligrams, as tobacco smoke is an environmental and behavioral contributor to free radicals in the body.

Table 8.3.1: Dietary Reference Intakes for Vitamin C

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	40*	–
Infants (7–12 months)	50*	–
Children (1–3 years)	15	400

*denotes Adequate Intake

Age Group	RDA Males and Females mg/day	UL
Children (4–8 years)	25	650
Children (9–13 years)	45	1200
Adolescents (14–18 years)	75 (males), 65 (females)	1800
Adults (> 19 years)	90 (males), 75 (females)	2000
*denotes Adequate Intake		

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin C.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminC-QuickFacts/.

Heat, iron, copper, and oxygen can destroy vitamin C in foods.

High doses of vitamin C have been reported to cause numerous problems, but the only consistently shown side effects are gastrointestinal upset and diarrhea. To prevent these discomforts the IOM has set a UL for adults at 2,000 milligrams per day (greater than twenty times the RDA). Greater than 4000 grams per day may cause health problems including nausea, abdominal cramps, diarrhea, interference with medications like anti-clotting drugs, act as a pro-oxidant, and give a false positive/negative urine analysis for diabetes detection.

At very high doses in combination with iron, vitamin C has sometimes been found to increase oxidative stress, reaffirming that getting your antioxidants from foods is better than getting them from supplements, as that helps regulate your intake levels. There is some evidence that taking vitamin C supplements at high doses increases the likelihood of developing kidney stones, however, this effect is most often observed in people that already have multiple risk factors for kidney stones.

Discontinuing your intake of high doses of vitamin C can cause rebound scurvy because enzyme levels for vitamin C are elevated. It is best to taper down a high dose instead of stopping immediately.

Dietary Sources of Vitamin C

Citrus fruits are great sources of vitamin C and so are many vegetables. In fact, British sailors in the past were often referred to as “limeys” as they carried sacks of limes onto ships to prevent scurvy. Vitamin C is not found in significant amounts in animal-based foods like meat and dairy, and grains and legumes.

Because vitamin C is water-soluble, it leeches away from foods considerably during cooking, freezing, thawing, and canning. Up to 50 percent of vitamin C can be boiled away. Therefore, to maximize vitamin C intake from foods, you should eat fruits and vegetables raw or lightly steamed. For the vitamin C content of various foods, see Table 8.3.2.

Table 8.3.2: Vitamin C Content of Various Foods

Food	Serving	Vitamin C (mg)
Orange juice	6 oz.	62–93
Grapefruit juice	6 oz.	62–70
Orange	1 medium	70
Grapefruit	½ medium	38
Strawberries	1 c.	85
Tomato	1 medium	16
Sweet red pepper	½ c. raw	95
Broccoli	½ c. cooked	51
Asparagus	1 c. cooked	20
Romaine lettuce	2 c.	27
Kale	1 c. boiled	53
Cauliflower	1 c. boiled	55
Potato	1 medium, baked	17

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin C.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminC-HealthProfessional/.

Vitamin E Functions and Health Benefits

Vitamin E is actually eight chemically similar substances, of which alpha-tocopherol appears to be the most potent antioxidant. Alpha-tocopherol and vitamin E’s other constituents (tocotrienols) are fat-soluble and primarily responsible for protecting cell membranes against lipid destruction caused by free radicals.

After alpha-tocopherol interacts with a free radical it is no longer capable of acting as an antioxidant unless it is enzymatically regenerated. Vitamin C helps to regenerate some of the alpha-tocopherol, but the remainder is eliminated from the body. Therefore, to maintain vitamin E levels, you ingest it as part of your diet.

In addition to its antioxidant functions, vitamin E, mainly as alpha-tocopherol, can change the functions of proteins in cells, plays a role in the operations of the immune system, enhances the dilation of blood vessels, and inhibits blood clot formation. Despite vitamin E’s numerous beneficial functions when taken in recommended amounts, large studies do not support the idea that taking higher doses of this vitamin will increase its power to prevent or reduce disease risk.Goodman, M., Bostlick RM, Kucuk O, Jones DP. 2011. Clinical trials of antioxidants as cancer prevention agents: past, present, and future. Free Radic Biol Med. 51(5): 1068–84.' McGinley C, Shafat A. Donnelly AE. 2009. Does antioxidant vitamin supplementation protect against muscle damage? Sports Med. 39(12): 1011–32.

Deficiency signs and symptoms

Inadequate intake of vitamin E can cause erythrocyte hemolysis or fragile red blood cells, hemolytic anemia, and/or neuromuscular dysfunction involving the spinal cord and retina. Groups at risk of developing a deficiency are premature infants because they lack fat stores, people eating very little food, individuals with fat malabsorption (e.g. cystic fibrosis), people who consume large amounts of polyunsaturated fatty acids, and people who smoke or live in a smoggy area.

Cardiovascular Disease

Recall from Chapter 4 that low-density lipoproteins (LDLs) transport cholesterol and other lipids from the liver to the rest of the body. LDLs are often referred to as “bad cholesterol,” as an elevation in their levels in the blood is a risk factor for cardiovascular disease. Oxidation of the lipids and proteins in LDLs causes them to stick to the walls of arteries and this contributes to the development of fatty streaks and, eventually, plaque, which hardens the arteries. Hardening of the arteries, called atherosclerosis can lead to a heart attack.

Vitamin E reduces the oxidation of LDLs, and it was therefore hypothesized that vitamin E supplements would protect against atherosclerosis. However, large clinical trials have not consistently found evidence to support this hypothesis. In fact, in the “Women’s Angiographic Vitamin and Estrogen Study,” postmenopausal women who took 400 international units (264 milligrams) of

vitamin E and 500 milligrams of vitamin C twice per day had higher death rates from all causes.Waters, D.D. et al. “Effects of Hormone Replacement Therapy and Antioxidant Vitamin Supplements on Coronary Atherosclerosis in Postmenopausal Women: A Randomized Controlled Trial.” *JAMA* 288, no. 19 (2002): 2432–40. doi: 10.1001/jama.288.19.2432

Other studies have not confirmed the association between increased vitamin E intake from supplements and increased mortality. There is more consistent evidence from observational studies that a higher intake of vitamin E from foods is linked to a decreased risk of dying from a heart attack.

Cancer

The large clinical trials that evaluated whether there was a link between vitamin E and cardiovascular disease risk also looked at cancer risk. These trials, called the HOPE-TOO Trial and Women’s Health Study, did not find that vitamin E at doses of 400 international units (264 milligrams) per day or 600 international units (396 milligrams) every other day reduced the risk of developing any form of cancer.HOPE and HOPE-TOO Trial Investigators. “Effects of Long-Term Vitamin E Supplementation on Cardiovascular Events and Cancer.” *JAMA* 293 (2005):1338–47. http://jama.ama-assn.org/content/293/11/1338.long.· Lee, I-M., et al. “Vitamin E in the Primary Prevention of Cardiovascular Disease and Cancer: The Women’s Health Study.” *JAMA* 294 (2005): 56–65. http://jama.ama-assn.org/content/294/1/56.long.

Eye Conditions

Oxidative stress plays a role in the age-related loss of vision, called macular degeneration. Age-related macular degeneration (AMD) primarily occurs in people over age fifty and is the progressive loss of central vision resulting from damage to the center of the retina, referred to as the macula. There are two forms of AMD, dry and wet, with wet being the more severe form.

In the dry form, deposits form in the macula; the deposits may or may not directly impair vision, at least in the early stages of the disease. In the wet form, abnormal blood vessel growth in the macula causes vision loss. Clinical trials evaluating the effects of vitamin E supplements on AMD and cataracts (clouding of the lens of an eye) did not consistently observe a decreased risk for either. However, scientists do believe vitamin E in combination with other antioxidants such as zinc and copper may slow the progression of macular degeneration in people with early-stage disease.

Dementia

The brain’s high glucose consumption makes it more vulnerable than other organs to oxidative stress. Oxidative stress has been implicated as a major contributing factor to dementia and Alzheimer’s disease. Some studies suggest vitamin E supplements delay the progression of Alzheimer’s disease and cognitive decline, but again, not all of the studies confirm the relationship. A recent study with over five thousand participants published in the July 2010 issue of the *Archives of Neurology* demonstrated that people with the highest intakes of dietary vitamin E were 25 percent less likely to develop dementia than those with the lowest intakes of vitamin E.Devore, E. E. et al. “Dietary Antioxidants and Long-Term Risk of Dementia.” *Arch Neurol* 67, no.7 (2010): 819–25. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923546/?tool=pubmed. More studies are needed to better assess the dose and dietary requirements of vitamin E and, for that matter, whether other antioxidants lower the risk of dementia, a disease that not only devastates the mind, but also puts a substantial burden on loved ones, caretakers, and society in general.

Dietary Reference Intakes for Vitamin E

The Recommended Dietary Allowances (RDAs) and Tolerable Upper Intake Levels (ULs) for different age groups for vitamin E are given in Table 8.3.3 "Dietary Reference Intakes for Vitamin E". The RDAs are based on scientific evidence that these levels of vitamin E in the diet prevent conditions associated with vitamin E deficiency, which is rare (signs and symptoms of such conditions are not always evident) but is primarily the result of nerve degeneration. People with malabsorption disorders, such as Crohn’s disease or cystic fibrosis, and babies born prematurely, are at higher risk for vitamin E deficiency. High doses interfere with vitamin K and enhance anti-blood clotting medications.

Fat in the diet is required for vitamin E absorption as it is packaged into lipid-rich chylomicrons in intestinal cells and transported to the liver. The liver stores some of the vitamin E or packages it into lipoproteins, which deliver it to cells.

Table 8.3.3: Dietary Reference Intakes for Vitamin E

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	4*	–
Infants (7–12 months)	5*	–
Children (1–3 years)	6	200
Children (4–8 years)	7	300
Children (9–13 years)	11	600
Adolescents (14–18 years)	15	800
Adults (> 19 years)	15	1,000
*denotes Adequate Intake		

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin E.” Last modified October 11, 2011. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/.

Vitamin E supplements often contain more than 400 international units, which is almost twenty times the RDA. The UL for vitamin E is set at 1,500 international units for adults. There is some evidence that taking vitamin E supplements at high doses has negative effects on health. As mentioned, vitamin E inhibits blood clotting and a few clinical trials have found that people taking vitamin E supplements have an increased risk of stroke. In contrast to vitamin E from supplements, there is no evidence that consuming foods containing vitamin E compromises health.

Dietary Sources of Vitamin E

Vitamin E is found in many foods, especially those higher in fat, such as nuts and oils. Some spices, such as paprika and red chili pepper, and herbs, such as oregano, basil, cumin, and thyme, also contain vitamin E. (Keep in mind spices and herbs are commonly used in small amounts in cooking and therefore are a lesser source of dietary vitamin E.) See Table 8.3 for a list of foods and their vitamin E contents.

> *To increase your dietary intake of vitamin E from plant-based foods try a spinach salad with tomatoes and sunflower seeds, and add a dressing made with sunflower oil, oregano, and basil.*

Table 8.3.4: Vitamin E Content of Various Foods

Food	Vitamin E (mg)	Percent Daily Value
Wheat-germ oil (1 Tbsp.)	20.3	100
Sunflower seeds (1 oz.)	7.4	37
Almonds (1 oz.)	6.8	34
Sunflower oil (1 Tbsp.)	5.6	28
Safflower oil (1 Tbsp.)	4.6	23
Hazelnuts (1 oz.)	4.3	22
Peanut butter (2 Tbsp.)	2.9	15

Food	Vitamin E (mg)	Percent Daily Value
Peanuts (1 oz.)	2.2	11
Corn oil (1 Tbsp.)	1.9	10
Kiwi (1 medium)	1.1	6
Tomato (1 medium)	0.7	4
Spinach (1 c. raw)	0.6	3

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin E." Last reviewed October 11, 2011. http://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/.

Vitamin A Functions and Health Benefits

Vitamin A is a generic term for a group of similar compounds called retinoids. Retinol is the form of vitamin A found in animal-derived foods, and it is converted in the body to the biologically active forms of vitamin A: retinal and retinoic acid (thus retinol is sometimes referred to as "preformed vitamin A"). About 10 percent of plant-derived carotenoids, including beta-carotene, can be converted in the body to retinoids and are another source of functional vitamin A. The retinoids are aptly named as their most notable function is in the retina of the eye where they aid in vision, particularly in seeing under low-light conditions. This is why night blindness is the most definitive sign of vitamin A deficiency.

Like vitamin E, vitamin A is fat-soluble and is packaged into chylomicrons in small intestine mucosal cells, and then transported to the liver. The liver stores and exports vitamin A as needed; it is released into the blood bound to a retinol-binding protein, which transports it to cells.

Beta-carotene is not considered a vitamin but is split by an intestinal enzyme to form retinol. It is brightly colored green, yellow, orange and/or red. It acts as an antioxidant.

Vitamin A has several important functions in the body, including maintaining vision and a healthy immune system. Many of vitamin A's functions in the body are similar to the functions of hormones (for example, vitamin A can interact with DNA, causing a change in protein function). Vitamin A assists in maintaining healthy skin and the linings and coverings of tissues; it also regulates growth and development. As an antioxidant, vitamin A protects cellular membranes, helps in maintaining glutathione levels, and influences the amount and activity of enzymes that detoxify free radicals.

Deficiency signs and symptoms

A deficiency of vitamin A can 1-2 years to manifest since it fat soluble and stored in the body. Signs and symptoms include night blindness, xerophthalmia which can progress to total blindness, an irreversible condition, keratinization, and exacerbate infectious diseases. Keratin is a protein that is secreted from epithelial cells. Without adequate intake of vitamin, A keratin accumulates in lumps in hair follicles and skin becomes dry, scaly and rough. In the gastrointestinal tract, the cells do not form properly and malabsorption of nutrients can occur. A lack of vitamin A is correlated with the severity of measles. Groups at risk of developing a vitamin A deficiency include infants and children in developing countries, people who eat very little fat and individuals with fat malabsorption as seen with Cystic fibrosis and AIDS.

Vision

Retinol that is circulating in the blood is taken up by cells in the retina, where it is converted to retinal and is used as part of the pigment rhodopsin, which is involved in the eye's ability to see under low light conditions. A deficiency in vitamin A thus results in less rhodopsin and a decrease in the detection of low-level light, a condition referred to as night blindness.

Insufficient intake of dietary vitamin A over time can also cause complete vision loss. In fact, vitamin A deficiency is the number one cause of preventable blindness worldwide. Vitamin A not only supports the vision function of eyes but also maintains the coverings and linings of the eyes. Vitamin A deficiency can lead to the dysfunction of the linings and coverings of the eye, causing dryness of the eyes, a condition called xerophthalmia. This condition can progress, causing ulceration of the cornea and eventually blindness.

Immunity

The common occurrence of advanced xerophthalmia in children who died from infectious diseases led scientists to hypothesize that supplementing vitamin A in the diet for children with xerophthalmia might reduce disease-related mortality. In Asia in the late 1980s, targeted populations of children were administered vitamin A supplements, and the death rates from measles and diarrhea declined by up to 50 percent. Vitamin A supplementation in these deficient populations did not reduce the number of children who contracted these diseases, but it did decrease the severity of the diseases so that they were no longer fatal. Soon after the results of these studies were communicated to the rest of the world, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) commenced worldwide campaigns against vitamin A deficiency. UNICEF estimates that the distribution of over half a billion vitamin A capsules prevents 350,000 childhood deaths annually.Sommer, A. "Vitamin A Deficiency and Clinical Disease: A Historical Overview." *J Nutr* 138 (2008):1835–39. http://jn.nutrition.org/content/138/10/1835.long.

In the twenty-first century, science has demonstrated that vitamin A greatly affects the immune system. What we are still lacking are clinical trials investigating the proper doses of vitamin A required to help ward off infectious disease and how large of an effect vitamin A supplementation has on populations that are not deficient in this vitamin. This brings up one of our common themes in this text—micronutrient deficiencies may contribute to the development, progression, and severity of a disease, but this does not mean that an increased intake of these micronutrients will solely prevent or cure disease. The effect, as usual, is cumulative and depends on the diet as a whole, among other things.

Growth and Development

Vitamin A acts similarly to some hormones in that it is able to change the amount of proteins in cells by interacting with DNA. This is the primary way that vitamin A affects growth and development. Vitamin A deficiency in children is linked to growth retardation; however, vitamin A deficiency is often accompanied by protein malnutrition and iron deficiency, thereby confounding the investigation of vitamin A's specific effects on growth and development.

In the fetal stages of life, vitamin A is important for limb, heart, eye, and ear development and in both deficiency and excess, vitamin A causes birth defects. Furthermore, both males and females require vitamin A in the diet to effectively reproduce.

Cancer

Vitamin A's role in regulating cell growth and death, especially in tissues that line and cover organs, suggests it may be effective in treating certain cancers of the lung, neck, and liver. It has been shown in some observational studies that vitamin A-deficient populations have a higher risk for some cancers. However, vitamin A supplements have actually been found to increase the risk of lung cancer in people who are at high risk for the disease (i.e., smokers, ex-smokers, workers exposed to asbestos). The Beta-Carotene and Retinol Efficacy Trial (CARET) involving over eighteen thousand participants who were at high risk for lung cancer found that people who took supplements containing very high doses of vitamin A (25,000 international units) and beta-carotene had a 28 percent higher incidence of lung cancer midway through the study, which was consequently stopped.Goodman, G.E. et al. "The Beta-Carotene and Retinol Efficacy Trial: Incidence of Lung Cancer and Cardiovascular Disease Mortality During 6-year Follow-up after Stopping Beta-Carotene and Retinol Supplements." *J Natl Cancer Inst* 96, no. 23 (2004): 1743–50. http://jnci.oxfordjournals.org/content/96/23/1743.long.

Vitamin A supplementation is a relatively common practice in treating some types of cancer patients and is thought to improve the effectiveness of some anti-cancer drugs, but many oncologists (physicians who treat cancer patients) do not recommend this practice as vitamin A may actually inhibit the actions of some anticancer drugs.

Vitamin A Toxicity

Vitamin A toxicity, or hypervitaminosis A, is rare. Typically it requires you to ingest ten times the RDA of preformed vitamin A in the form of supplements (it would be hard to consume such high levels from a regular diet) for a substantial amount of time, although some people may be more susceptible to vitamin A toxicity at lower doses. The signs and symptoms of vitamin A toxicity include dry, itchy skin, loss of appetite, swelling of the brain, joint pain and birth defects. In severe cases, vitamin A toxicity may cause permanent liver damage, coma, and death.

Some acne medications, like Accutane, are a derivative of vitamin A; in other words, they are made from vitamin A but are chemically different. Physicians prescribing these drugs will monitor vitamin A levels closely to avoid toxicity. Eating dietary vitamin A is not beneficial for acne.

Vitamin A is essential during pregnancy, but doses above 3,000 micrograms per day (10,000 international units) have been linked to an increased incidence of birth defects. Pregnant women should check the amount of vitamin A contained in any prenatal or pregnancy multivitamin she is taking to assure the amount is below the UL.

Dietary Reference Intakes for Vitamin A

There is more than one source of vitamin A in the diet. There is preformed vitamin A, which is abundant in many animal-derived foods, and there are carotenoids, which are found in high concentrations in vibrantly colored fruits and vegetables and some oils.

Some carotenoids are converted to retinol in the body by intestinal cells and liver cells. However, only minuscule amounts of certain carotenoids are converted to retinol, meaning fruits and vegetables are not necessarily good sources of vitamin A. Beta-carotene dissolved in oil is more readily converted to retinol; one-half of a microgram of beta-carotene is converted to retinol. Overall, the carotenoids do not have the same biological potency of preformed vitamin A, but as you will soon find out, they have other attributes that influence health, most notably their antioxidant activity.

The RDA for vitamin A includes all sources of vitamin A. The amount of vitamin A obtained from carotenoids—the retinol activity equivalent (RAE)—can be calculated. For example, 12 micrograms of fruit- or vegetable-based beta-carotene will yield 1 microgram of retinol, as mentioned.

The RDA for vitamin A is considered sufficient to support growth and development, reproduction, vision, and immune system function while maintaining adequate stores (good for four months) in the liver.

Table 8.3.5: Dietary Reference Intakes for Vitamin A

Age Group	RDA Males and Females mcg/day	UL
Infants (0–6 months)	400*	600
Infants (7–12 months)	500*	600
Children (1–3 years)	300	600
Children (4–8 years)	400	900
Children (9–13 years)	600	1,700
Adolescents (14–18 years)	Males: 900	2,800
	Females: 700	
Adults (> 19 years)	Males: 900	3,000
	Females: 700	
*denotes Adequate Intake		

Source: Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin A.” Last reviewed September 5, 2012. http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/.

Dietary Sources of Vitamin A

Preformed vitamin A is found only in foods from animals, with the liver being the richest source because that’s where vitamin A is stored (see Table 8.3.6). Fortified milk and milk products, eggs, butter and fish liver oils are also good sources of vitamin A. The dietary sources of carotenoids will be given in the following text.

Table 8.3.6: Vitamin A Content of Various Foods

Food	Serving	Vitamin A (IU)	Percent Daily Value
Beef liver	3 oz.	27,185	545
Chicken liver	3 oz.	12,325	245
Milk, skim	1 c.	500	10
Milk, whole	1 c.	249	5
Cheddar cheese	1 oz.	284	6

Source: Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin A.” Last reviewed July 25, 2012. http://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/.

Phytochemicals

Phytochemicals are chemicals in plants that may provide some health benefit; they are not nutrients. Carotenoids are one type of phytochemical. Phytochemicals also include indoles, lignans, phytoestrogens, stanols, saponins, terpenes, flavonoids, carotenoids, anthocyanidins, phenolic acids, and much more. They are found not only in fruits and vegetables, but also in grains, seeds, nuts, and legumes. They are present to give the plant color, flavor, odor, and protection.

Many phytochemicals act as antioxidants, but they have several other functions, such as mimicking hormones, altering the absorption of cholesterol, inhibiting inflammatory responses, and blocking the actions of certain enzymes.

Phytochemicals are present in small amounts in the food supply, and although thousands have been and are currently being scientifically studied, their health benefits remain largely unknown. It is not known if they are essential; no deficiency syndromes have been found. Also, largely unknown is their potential for toxicity, which could be substantial if taken in large amounts in the form of supplements. Moreover, phytochemicals often act in conjunction with each other and with micronutrients. Thus, supplementing with only a few may impair the functions of other phytochemicals or micronutrients. As with the antioxidant vitamins, it is the mixture and variety of phytochemicals in foods that are linked to health benefits.

Carotenoids Function and Health Benefits

Carotenoids are pigments synthesized by plants that give them their yellow, orange, and red color. Over six hundred carotenoids have been identified and, with just a few exceptions, all are found in the plant kingdom. There are two classes of carotenoids—the xanthophylls, which contain oxygen, and the carotenes, which do not.

In plants, carotenoids absorb light for use in photosynthesis and act as antioxidants. Beta-carotene, alpha-carotene, gamma-carotene, and beta-cryptoxanthin are converted to some extent to retinol in the body. The other carotenoids, such as lycopene, are not. Many biological actions of carotenoids are attributed to their antioxidant activity, but they likely act by other mechanisms, too.

Beta-carotene from foods is not toxic but may turn skin yellow or orange.

Eye Conditions

Lutein, found in green leafy vegetables, and zeaxanthin, found in peppers, corn, and saffron, act as antioxidants in the retina of the eye and protect it from ultraviolet light damage. Diets high in these carotenoids are associated with a decreased risk of AMD, and there is good evidence that supplements containing these carotenoids also provide vision benefits. A review published in the August

2010 issue of *Current Medical Research and Opinion* concludes that supplementation with lutein and zeaxanthin reduces the incidence of AMD and cataracts.Barker II, F. M. "Dietary Supplementation: Effects on Visual Performance and Occurrence of AMD and Cataracts." *Curr Med Res Opin* 26, no. 8 (2010): 2011–23. http://informahealthcare.com/doi/abs/10.1185/03007995.2010.494549.

The data that supports that beta-carotene supplementation may delay the progression of AMD is more convincing when beta-carotene is taken in combination with other micronutrients. The Age-Related Eye Disease Study found that a supplement containing 500 milligrams of vitamin C, 400 international units of vitamin E, 15 milligrams of beta-carotene, 80 milligrams of zinc oxide, and 2 milligrams of copper as cupric oxide reduced the risk of progressing to advanced stages of AMD by 25 percent.Age-Related Eye Disease Study Research Group. "A Randomized, Placebo-Controlled, Clinical Trial of High-Dose Supplementation with Vitamins C and E, Beta-Carotene, and Zinc for Age-Related Macular Degeneration and Vision Loss." *Arch Ophthalmol* 119, no. 10 (2001): 1417–36. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1462955/. This study did not find that the formulated supplement significantly prevented the onset of disease, only that it delayed its progression specifically in people with intermediate or advanced stage AMD. Studies are ongoing to determine if other antioxidant combinations actually protect against developing AMD at all.

Cardiovascular Disease

While some studies do associate a decreased risk for atherosclerosis with higher dietary intake of carotenoids, others do not. There is a large number of studies that show total carotenoid intake is associated with improvement in blood vessel function. A smaller number of studies show that intake of specific carotenoids, such as lycopene and alpha-carotene, are also associated with improved blood vessel function. The main problems associated with linking carotenoids to a decrease in cardiovascular disease risk, or any other disease for that matter, are that they are present in foods containing many other beneficial plant chemicals, and trials evaluating the effects of specific carotenoids in the form of supplements provide inconsistent and sometimes contradictory results.

Cancer

A higher intake of some carotenoids, but not others, is linked to decreased risks for some cancers. A review of two large studies (> 120,000 men and women) published in the October 2000 issue of *The American Journal of Clinical Nutrition* reports that there is no significant association between beta-carotene intake and lung cancer risk, but men and women with the highest intakes of total carotenoids had a more than 30 percent risk reduction for developing lung cancer.Michaud, D.S. et al. "Intake of Specific Carotenoids and Risk of Lung Cancer in 2 Prospective US Cohorts." *Am J Clin Nutr* 72, no. 4 (2000): 990–97. http://www.ajcn.org/content/72/4/990.long. Other large studies conducted in Europe have confirmed the inverse relationship of total dietary carotenoid intake with lung cancer risk. There is some evidence that diets rich in lycopene, which is present in high concentrations in tomatoes, is linked to decreased prostate cancer risk, but it is not known if it is lycopene specifically or some other component in tomatoes that protects against prostate cancer.

Carotenoid Bioavailability and Dietary Sources

Carotenoids are not absorbed as well as vitamin A, but similar to vitamin A, they do require fat in the meal for absorption. In intestinal cells, carotenoids are packaged into the lipid-containing chylomicrons inside small intestine mucosal cells and then transported to the liver. In the liver, carotenoids are repackaged into lipoproteins, which transport them to cells.

In contrast to most micronutrients, carotenoid availability is actually increased by the cooking process because cooking, along with chopping and homogenizing, releases carotenoids from the plant matrix. Thus, eating a can of tomatoes provides more lycopene than eating a raw tomato. However, overcooking transforms some of the carotenoids into inactive products, and in general, it is best to chop and lightly steam vegetables containing carotenoids to maximize their availability from foods. Cooking carotenoid-containing foods in oil also enhance the bioavailability of carotenoids. In the United States, the most consumed carotenoids are alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin. See Table 8.3.7 and Note 8.18 for the carotenoid content of various foods.

Table 8.3.7: Alpha- and Beta-Carotene Content of Various Foods

Food	Serving	Beta-carotene (mg)	Alpha-carotene (mg)
Pumpkin, canned	1c.	17.00	11.70
Carrot juice	1c.	22.00	10.20
Carrots, cooked	1c.	13.00	5.90
Carrots, raw	1 medium	5.10	2.10
Winter squash, baked	1c.	5.70	1.40
Collards, cooked	1c.	11.60	0.20
Tomato	1 medium	0.55	0.10
Tangerine	1 medium	0.13	0.09
Peas, cooked	1c.	1.20	0.09

Source: US Department of Agriculture, Agricultural Research Service. 2010. *USDA National Nutrient Database for Standard Reference*, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl.

Interactive 8.3.1

Visit the USDA website and find out more about the carotenoid content of various foods.

http://www.ars.usda.gov/Services/docs.htm?docid=20958

Three Other Phytochemicals and Their Potential Health Benefits

Three classes of phytochemicals (other than carotenoids) are flavonoids, organosulfur compounds, and lignans. Their potential health benefits are discussed below.

Flavonoids

Flavonoids are a large class of chemicals including anthocyanidins (found in red, blue, and purple berries), flavanols (found in teas, chocolate, berries, apples, yellow onions, kale, and broccoli), and isoflavones (found in soy products). Flavonoids are very effective free radical scavengers, and there is some evidence that higher intakes of flavonoid-rich foods and/or beverages reduce the risk of cardiovascular disease, but this has not been consistently observed. Although flavonoids have been shown to reduce the incidence of some tumors in animals, similar studies in humans have been inconclusive.

Organosulfur Compounds

These compounds are predominantly found in garlic, but can also be found in onions and leeks. It's suspected that the higher intake of garlic is the aspect of the Mediterranean diet that contributes to a decreased risk of cardiovascular disease. Animal and laboratory studies suggest the organosulfur compounds in garlic reduce cholesterol, are anti-inflammatory, stimulate the synthesis of glutathione, and cause the death of cancer cells. There is some evidence in humans that garlic reduces cholesterol, but more recent studies did not confirm that the effect was significant or sustained. A higher intake of garlic likely inhibits blood clot formation in humans.

Observational studies suggest diets high in organosulfur compounds decrease the risk of gastric and colorectal cancer. For other cancers, the data is less consistent.

Lignans

Lignans are a group of chemical compounds obtained from many food sources, including grains, nuts, seeds, fruits, and vegetables, and especially flax seed. Some lignans are also called phytoestrogens as they can mimic or inhibit some of the actions of the hormone estrogen in the body.

The antiestrogenic effect of some lignans suggests they may be helpful in treating hormone-dependent cancers, such as breast and ovarian cancers. However, studies are few and conflicting on whether eating foods high in lignans reduces breast or ovarian cancer.

In regard to cardiovascular disease risk, diets rich in whole grains are protective, but it remains unclear whether it is the lignans in whole grains that are responsible for the reduced risk. Whole grains contain many other beneficial phytochemicals, micronutrients, and fiber.

Interactive 8.3.2

To discover more about phytochemicals, visit the website for the Micronutrient Information Center of the Linus Pauling Institute at Oregon State University.

http://lpi.oregonstate.edu/infocenter/phytochemicals.html

Other Dietary Sources of Beneficial Phytochemicals

Herbs and Spices

These are the aromatic parts of plants, such as the leaves, seeds, pods, and berries. They are an additional dietary source of phytochemicals, and many have exceptional antioxidant capacity.

Throughout the ages, people have used spices and herbs not only for adding flavor to foods but also as medicines. Curcumin, the principal component of turmeric, has been used for over two thousand years in India to treat a variety of ailments. As of 2011, over seventy clinical trials are investigating the health benefits of curcumin, which may include reducing cancer risk and delaying the progression of Alzheimer's disease.

You learned in the beginning of this chapter that nutmeg comes from the dried seed kernel of *Myristica fragrans* and has been used as an antimicrobial, antifungal, and anti-inflammatory agent, and as a pain reliever. In high doses, nutmeg acts similar to a psychoactive drug in that it causes euphoria, delusions, and hallucinations. According to a study conducted on over 3,100 foods, beverages, spices, herbs, and supplements, the spices and herbs were the dietary sources most rich in antioxidants (see Note 8.20 "Interactive 8.3").

Interactive 8.3.3

Read the article, "The Total Antioxidant Content of More than 3,100 Foods, Beverages, Spices, Herbs, and Supplements Used Worldwide," published in the January 2010 issue of the *Nutrition Journal*. It is a useful source to find dietary sources of antioxidants.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2841576/?tool=pubmed

Tools for Change

Add some spice, flavor, and decoration to your food along with beneficial antioxidants and phytochemicals. Embracing cuisine rich in spices and herbs further enhances the health benefits of eating a diet rich in fruit and vegetables. Think spices are too hot for your palate? As little as half a teaspoon of cinnamon has been shown in scientific studies to provide health benefits, such as improving glucose homeostasis in people with Type 2 diabetes. Over fifteen clinical trials are now evaluating the effectiveness of cinnamon as an adjunct treatment for Type 2 diabetes and/or cardiovascular disease.

Tea

Tea is an aromatic beverage made from the dried parts of plants steeped in hot water. Its health benefits have been known for years, and as with coffee, the benefits are not just physiological, but also mental and social. In folklore, teas are considered curatives of stomachache, diarrhea, and even the plague. In *The Book of Tea*, Okakura Kakuzo asserts that consuming a cup of tea provides "the adoration of the beautiful among the sordid facts of everyday existence."Okakura Kakuzo. *The Book of Tea*. (Berlin, Germany: Dover Publications, 1964).

Teas can contain more than seven hundred different phytochemicals. Some of them may be beneficial and others may not be, as some reduce the dietary absorption of some micronutrients. The health claims of drinking tea—black, green, or red—number at least in the hundreds but remain mostly scientifically unsupported. There are a great number of studies showing that drinking tea is at least linked to a decreased risk of heart disease, cancer, and diabetes, but the exact phyotchemicals eliciting these health benefits are under intense scrutiny. Moreover, people who consume more tea are likely to drink fewer soft drinks and therefore, based on a "replacement theory," have a reduced likelihood of having a chronic disease.

Antioxidant Minerals

In addition to the antioxidant vitamins and phytochemicals, several minerals have antioxidant function, including selenium, manganese, iron, copper, and zinc.

Selenium Functions and Health Benefits

Selenium is a trace mineral because we need it in ultra small amounts, but it packs a powerful punch. Around twenty-five, known proteins require selenium to function. Some are enzymes involved in detoxifying free radicals and include glutathione peroxidases and thioredoxin reductase. As an integral functioning part of these enzymes, selenium aids in the regeneration of glutathione and oxidized vitamin C. Selenium as part of glutathione peroxidase also protects lipids from free radicals, and, in doing so, spares vitamin E. This is just one example of how antioxidants work together to protect the body against free radical-induced damage.

Other functions of selenium-containing proteins include protecting endothelial cells that line tissues, converting the inactive thyroid hormone to the active form in cells, and mediating inflammatory and immune system responses.

Observational studies have demonstrated that selenium deficiency is linked to an increased risk of cancer. A review of forty-nine observational studies published in the May 2011 issue of the *Cochrane Database of Systematic Reviews* concludes that higher selenium exposure reduces overall cancer incidence by about 34 percent in men and 10 percent in women, but notes these studies had several limitations, including data quality, bias, and large differences among different studies.Dennert, G. et al. "Selenium for Preventing Cancer." *Cochrane Database of Systematic Reviews* 5 (2011): CD005195. http://www.ncbi.nlm.nih.gov/pubmed/21563143. Additionally, this review states that there is no convincing evidence from six clinical trials that selenium supplements reduce cancer risk.

Because of its role as a lipid protector, selenium has been suspected to prevent cardiovascular disease. In some observational studies, low levels of selenium are associated with a decreased risk of cardiovascular disease. However, other studies have not always confirmed this association and clinical trials are lacking.

Deficiency signs and symptoms

A deficiency of selenium predisposes an individual to the virus that causes Keshan's disease, a degenerative heart disease. As well, inadequate selenium intake can cause Kashin-Beck disease, a form of arthritis. People at risk of developing these deficiencies are ones who eat food grown in areas where the soil levels of selenium are low, for example, Keshan, China.

Dietary Reference Intakes for Selenium

The IOM has set the RDAs for selenium based on the amount required to maximize the activity of glutathione peroxidases found in blood plasma. The RDAs for different age groups are listed in Table 8.9.

Table 8.3.8: Dietary Reference Intakes for Selenium

Age Group	RDA Males and Females mcg/day	UL
Infants (0–6 months)	15*	45
Infants (7–12 months)	20*	65
Children (1–3 years)	20	90

*denotes Adequate Intake

Age Group	RDA Males and Females mcg/day	UL
Children (4–8 years)	30	150
Children (9–13 years)	40	280
Adolescents (14–18 years)	55	400
Adults (> 19 years)	55	400
*denotes Adequate Intake		

Selenium at doses several thousand times the RDA can cause acute toxicity, and when ingested in gram quantities can be fatal. Chronic exposure to foods grown in soils containing high levels of selenium (significantly above the UL) can cause brittle hair and nails, gastrointestinal discomfort, skin rashes, halitosis (garlic breath), fatigue, and irritability. The IOM has set the UL for selenium for adults at 400 micrograms per day.

Dietary Sources of Selenium

Organ meats, muscle meats, and seafood have the highest selenium content. Plants do not require selenium, so the selenium content in fruits and vegetables is usually low. Animals fed grains from selenium-rich soils do contain some selenium. Grains and some nuts contain selenium when grown in selenium-containing soils. See Table 8.3.9 for the selenium content of various foods.

Table 8.3.9: *Selenium Contents of Various Foods*

Food	Serving	mcg
Brazil nuts	1 oz.	544.0
Shrimp	3 oz.	34.0
Crab meat	3 oz.	41.0
Ricotta cheese	1 c.	41.0
Salmon	3 oz.	40.0
Pork	3 oz.	35.0
Ground beef	3 oz.	18.0
Round steak	3 oz.	28.5
Beef liver	3 oz.	28.0
Chicken	3 oz.	13.0
Whole-wheat bread	2 slices	23.0
Couscous	1 c.	43.0
Barley, cooked	1 c.	13.5
Milk, low-fat	1 c.	8.0
Walnuts, black	1 oz.	5.0

Source: US Department of Agriculture, Agricultural Research Service. 2010. *USDA National Nutrient Database for Standard Reference*, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl.

Manganese, Iron, Copper, and Zinc: Functions and Health Benefits

As with selenium, manganese, iron, copper, and zinc are essential cofactors for enzymes involved in detoxifying free radicals. In the proper doses, they allow for optimal detoxification of free radicals. In excess and when not bound to proteins, manganese, iron, and copper actually accelerate the production of free radicals. This is an attribute of all antioxidants in general, although the effect is greater for certain antioxidants.

Antioxidants can become pro-oxidants when the conditions are altered. Recall from Section 8.2 of this chapter that oxidative stress results from an imbalance in free radicals with their detoxifying and repair systems. Another factor that can cause oxidative stress is a high level of antioxidants, as some will revert to acting as pro-oxidants.

Key Takeaways

- Health claims of antioxidant supplements are not backed by scientific evidence and there is some evidence suggesting they cause harm.
- Consuming antioxidant-rich foods is scientifically supported to reduce the risk of chronic diseases.
- Antioxidants have specific functions, and they can act in concert with each other to protect against free radicals.
- Some antioxidants are involved in the regeneration of other antioxidants.
- Many phytochemicals act as antioxidants, but they perform several other functions as well.
- Dietary antioxidants and phytochemicals in the proper doses are beneficial to health but can cause harm in excess.

Discussion Starters

1. In regard to doses, discuss why it is better to obtain antioxidants from the diet and not from supplements. When might supplements be advantageous?
2. With more scientific evidence in hand, debate whether or not the supplement industry requires more regulation.

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8.4: The Whole Nutrient Package versus Disease

Learning Objectives

- List some of the health-related conditions that might be mitigated by eating antioxidant- and phytochemical-rich foods regularly.
- Explain the importance of eating a variety of fruits, vegetables, nuts, legumes, teas, and grains to obtain antioxidants and phytochemicals.



Figure 8.4.1: Forget the antioxidant-pill hype and get all of the health benefits of antioxidants and phytochemicals by eating a variety of fruits and vegetables. © Thinkstock

A healthy diet incorporating seven or more servings of fruits and vegetables has been shown in many scientific studies to reduce cardiovascular disease and overall deaths attributable to cancer. The WHO states that insufficient fruit and vegetable intake is linked to approximately 14 percent of gastrointestinal cancer deaths, about 11 percent of heart attack deaths, and 9 percent of stroke deaths globally.World Health Organization. “Global Strategies on Diet, Physical Activity, and Health.” Accessed September 30, 2011. http://www.who.int/dietphysicalactivity/fruit/en/index.html. The WHO estimates that, overall, 2.7 million deaths could be avoided annually by increasing fruit and vegetable intake. These preventable deaths place an economic, social, and mental burden on society. This is why, in 2003, the WHO and the Food and Agricultural Organization of the United Nations launched a campaign to promote fruit and vegetable intake worldwide.

In the last section, we reviewed the health benefits of particular antioxidants and phytochemicals obtained from fruits and vegetables and discovered that naturally incorporating them into the diet rather than taking supplements is best. Here we will consider the scientific evidence that diets rich in antioxidants actually lower chronic disease risk.

Antioxidant Variety in Food Provides Health Benefits

Not only has the several-billion-dollar supplement industry inundated us with FDA-unapproved health claims, but science is continuously advancing and providing us with a multitude of promising health benefits from particular fruits, vegetables, teas, herbs, and spices. For instance, blueberries protect against cardiovascular disease, an apple or pear a day reduces stroke risk by over 52 percent, eating more carrots significantly reduces the risk of bladder cancer, drinking tea reduces cholesterol and helps glucose homeostasis, and cinnamon blocks infection and reduces the risk of some cancers. However, recall that science also tells us that no one nutrient alone is shown to provide these effects.

What micronutrient and phytochemical sources are best at protecting against chronic disease? All of them, together. Just as there is no wonder supplement or drug, there is no superior fruit, vegetable, spice, herb, or tea that protects against all diseases. A review in the July–August 2010 issue of *Oxidative Medicine and Cellular Longevity* concludes that the plant-food benefits to health are attributed to two main factors—that nutrients and phytochemicals are present at low concentrations in general, and that the complex mixtures of nutrients and phytochemicals provide additive and synergistic effects.Bouayed, J. and T. Bohn. “Exogenous Antioxidants—Double-Edged Swords in Cellular Redox State: Health Beneficial Effects at Physiologic Doses versus Deleterious Effects at High Doses.” *Oxidative Medicine and Cellular Longevity* 3, no. 4 (2010): 228–37. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2952083/?tool=pubmed. In short, don’t overdo it with supplements and make sure you incorporate a wide variety of nutrients in your diet.

Eating a variety of fruits and vegetables rich in antioxidants and phytochemicals promotes health. Consider these diets:

- **Mediterranean diet.** Fresh fruit and vegetables are abundant in this diet, and the cultural identity of the diet involves multiple herbs and spices. Moreover, olive oil is the main source of fat. Fish and poultry are consumed in low amounts and red meat is consumed in very low amounts. An analysis of twelve studies involving over one million subjects published in the September 2008 issue of the *British Medical Journal* reports that people who followed the Mediterranean diet had a 9 percent decrease in overall deaths, a 9 percent decrease in cardiovascular death, a 6 percent decrease in cancer deaths, and a 13 percent reduced incidence of Parkinson's disease and Alzheimer's disease.Sofi, F. et al. "Adherence to Mediterranean Diet and Health Status: Meta-Analysis." *Br Med J* 337 (2008): a1344. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2533524/. The authors of this study concluded that the Mediterranean diet is useful as a primary prevention against some major chronic diseases.
- **Dietary Approaches to Stop Hypertension (DASH diet).** Recall from Chapter 11 that the DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. Results from a follow-up study published in the December 2009 issue of the *Journal of Human Hypertension* suggest the low-sodium DASH diet reduces oxidative stress, which may have contributed to the improved blood vessel function observed in salt-sensitive people (between 10 to 20 percent of the population).Al-Solaiman, Y. et al. "Low-Sodium DASH Reduces Oxidative Stress and Improves Vascular Function in Salt-Sensitive Humans." *J Hum Hypertens* 12 (2009): 826–35. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2783838/?tool=pubmed.
- **Diets high in fruits and vegetables.** An analysis of The Nurses' Health Study and the Health Professionals' Follow-up Study reported that for every increased serving of fruits or vegetables per day, especially green leafy vegetables and vitamin C-rich fruits, there was a 4 percent lower risk for heart disease.Joshipura, K.J. et al. "The Effect of Fruit and Vegetable Intake on Risk for Coronary Heart Disease." *Ann Intern Med* 134, no. 12 (2001): 1106–14. http://www.ncbi.nlm.nih.gov/pubmed/11412050.

Americans Typically Eat Fewer than the Recommended Servings of Fruits and Vegetables

An article in the January 2009 issue of the *Medscape Journal of Medicine* reports that fewer than one in ten Americans consumes the recommended amount of fruits and vegetables, which is between five and thirteen servings per day.Kimmons, J. et al. "Fruit and Vegetable Intake among Adolescents and Adults in the United States: Percentage Meeting Individualized Recommendations." *Medscape Journal of Medicine* 11, no. 1 (2009): 26. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2654704/?tool=pubmed. According to this study, the largest single contributor to fruit intake was orange juice, and potatoes were the dominant vegetable.

The USDA recommends that you fill half your plate with fruits and vegetables. The number of servings of fruits and vegetables that a person should consume every day is dependent on age, sex, and level of physical activity. For example, a forty-year-old male who exercises for sixty minutes per day should consume 2 cups of fruit and 3½ cups of vegetables, while a fifteen-year-old female who exercises for thirty minutes per day should consume 1½ cups of fruit and 2½ cups of vegetables. (One cup of a fruit or vegetable is equal to one banana, one small apple, twelve baby carrots, one orange, or one large sweet potato.) To find out the amount of fruits and vegetables the Centers for Disease Control and Prevention (CDC) recommends, see the Interactive 8.4.1.

Interactive 8.4.1

The CDC provides a fruit- and vegetable-intake calculator.

www.fruitsandveggiesmatter.gov/form.html

Improving Fruit and Vegetable Intake at Home and in Your Community

Eating more fruits and vegetables can make you think better, too. According to a study published in 2009 in the *Journal of Alzheimer's Disease*, no matter your age, eating more fruits and vegetables improves your brain function.Polidori, M.C. et al. "High Fruit and Vegetable Intake Is Positively Correlated with Antioxidant Status and Cognitive Performance in Healthy Subjects." *Journal of Alzheimer's Disease* 17, no. 4 (2009): 921–7. http://www.ncbi.nlm.nih.gov/pubmed/19542607. Check out "Interactive 8.4.2" for thirteen fun ways to increase your fruit and vegetable intake.

Interactive 8.4.2

Visit the University of Nebraska-Lincoln's website to discover thirteen fun ways to increase your fruit and vegetable intake. http://food.unl.edu/web/fnh/freezer-bags

For individually based strategies on how to stretch your fruit and vegetable budget see "Interactive 8.4.3".

Interactive 8.4.3

The Department of Health and Human Services provides “30 Ways in 30 Days to Stretch Your Fruit and Vegetable Budget.” www.fruitsandveggiesmatter.gov/downloads/Stretch_FV_Budget.pdf

Tools for Change

Accept the challenge of optimizing your fruit and vegetable intake. Make it easier on your wallet by choosing five of the thirty ways ("Interactive 8.4.2) to stretch your fruit and vegetable budget, and implement them in the next seven days.

The CDC has developed seven strategies to increase American’s intake of fruits and vegetables.Centers for Disease Control and Prevention. “The CDC Guide to Fruit and Vegetable Strategies to Increase Access, Availability, and Consumption.” March 2010. www.cdph.ca.gov/SiteCollectionDocuments/StratstoIncreaseFruitVegConsumption.pdf.

1. Support local and state governments in the implementation of a Food Policy Council, which develops policies and programs that increase the availability of affordable fruits and vegetables.
2. In the food system, increase the availability and affordability of high-quality fruits and vegetables in underserved populations.
3. Promote farm-to-where-you-are programs, which is the delivery of regionally grown farm produce to community institutions, farmers markets, and individuals.
4. Encourage worksites, medical centers, universities, and other community and business establishments to serve more fruits and vegetables in cafeterias and onsite eateries.
5. Support schools in developing healthy food messages to students by incorporating activities such as gardening into curricula.
6. Encourage the development and support of community and home gardens.
7. Have emergency food programs, including food banks and food rescue programs, increase their supply of fruits and vegetables.

The seven strategies developed by the CDC are based on the idea that improving access to and availability of fruits and vegetables will lead to an increase in their consumption.

Key Takeaways

- Antioxidants and phytochemicals from fruits and vegetables are thought to reduce disease risk.
- Antioxidants and phytochemicals may be beneficial in low doses but not in high doses.
- Eat a variety of foods rich in micronutrient antioxidants and phytochemicals to promote health.
- Fewer than one in ten Americans consume the recommended amount of fruits and vegetables, which is between five and thirteen servings per day.
- National and international campaigns aim to increase the intake of fruits and vegetables worldwide.

Discussion Starters

1. Discuss the various strategies you use, or plan to use, to increase the quantity of fruits and vegetables in your diet. Learn other interesting and fun ways to do so from your peers.
2. Share with your classmates your favorite spices, how you use them, and where you buy them.

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8.E: Exercises

It's Your Turn

1. Use the fruit- and vegetable-intake calculator provided by the CDC to determine the amount of fruit and vegetables recommended for your diet, and then plan a menu for a day that incorporates the recommended amount of fruits and vegetables. www.fruitsandveggiesmatter.gov/form.html
2. The next time you're at the grocery store, record the number, color, and names of the fruits and vegetables available. Draw a table of them, sorted by color. Write a brief statement on whether you have access to an affordable variety of fruits and vegetables.
3. Visit the website "Nutrition-and-You" and choose three herbs and/or spices to write a brief summary on, including the plant they come from, their potential health benefits, and how they are used in foods. http://www.nutrition-and-you.com/healthy_spices.html

Apply It

1. Visit the Oldways website at http://www.oldwayspt.org/mediterranean-diet-pyramid and construct a pyramid of the Mediterranean diet.

Expand Your Knowledge

1. Read the article, "Antioxidant Content of Whole-Grain Breakfast Cereals, Fruits, and Vegetables" in the *Journal of the American College of Nutrition* (http://www.jacn.org/content/19/suppl_3/312S.long) and summarize in a paragraph the unique phytochemical profile and antioxidant capacity of whole grains.
2. Find out how much fruit and vegetables cost by reviewing this document published by the USDA (www.ers.usda.gov/Publications/EIB71/EIB71.pdf), and make a chart of the costs of your favorite fruits and vegetables.

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9: Nutrients and Bone Metabolism

In this chapter, we delve into nutrients important for bone health. First, we explore the structure and function of bones, and then calcium, vitamin D, phosphorus, magnesium, fluoride, and vitamin K. A look at osteoporosis and at supplements rounds out this chapter.

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9.1: Chapter Introduction

Note: Big Idea

Build peak bone mass during youth to preserve bone mass during aging.

Milk has been and will continue to be a key component in the diets of millions of people. During the agrarian age, people drank milk from the animals they raised. At the dawn of the twentieth century, nutritional science appeared on the scene and quickly acknowledged milk's importance as a part of a balanced diet. For over one hundred years, several US government nutrition programs have highlighted milk's value. How does milk get from a cow to your doorstep?

In the early nineteenth century, raw milk was distributed in carelessly washed metal pails and was, at times, still warm from the cow when it reached its destination. If you got up too late to fetch your milk you received little of the coagulated cream on top. This distribution method did not suffice for the widespread delivery of fresh milk to the masses living in cities, thus milk and its preparation methods had to be changed in several ways. Consuming raw milk can be a potential health hazard as harmful bacteria such as Salmonella, E. coli, and Listeria may be present, all of which are known as culprits for many foodborne illnesses. Pasteurization, homogenization, fortification, and eventually packaging in plastic containers were developed to address distribution and food-safety issues.

In 1863, Louis Pasteur invented pasteurization. Pasteurization involves heating the milk to a high temperature (greater than 161 degrees Fahrenheit) for a short time (less than 20 seconds) and is an effective method of killing 99.999 percent of bacteria, molds, and yeast. Pasteurization was a welcome technology as it extended the shelf life of milk by about two to three weeks and destroyed infectious bacteria, such as those that caused diphtheria, typhoid fever, tuberculosis, and scarlet fever, thereby making milk safe to drink. Unfortunately, pasteurization also destroys vitamins, enzymes, and some beneficial bacteria. Milk may also be microfiltered, a process that pushes milk forcefully through ceramic filters that remove bacteria. Milk is homogenized so that it does not separate into butterfat globules and milk fluid. During homogenization, milk is emulsified under intense pressure as it is pumped through narrow tubes. Fat globules are broken into smaller ones and they do not recoagulate. The homogenization process, however, does not have a negative effect on the milk's nutritional value or effectiveness.



Figure 9.1.1: Milk: An ever-changing product of the dairy industry. © Shutterstock

The dairy industry has gone through many changes to increase milk production, quality, and distribution. As a result of pasteurization and to meet the health needs of the American population, a public-policy decision was made in 1933 to fortify milk with vitamin D to prevent childhood bone disease. More recently, changes include expanding the number of cows per herd, increasing milk production per cow by over six-fold, improving dairy cow nutrition and herd management practices, and advancing technologies that increase storage time and decrease bacterial contamination. How did milk production increase six-fold per cow? Most cows are Holsteins, bred with optimum genetics for producing milk. They are provided with the best nutrition, a dietary pattern taken from many scientific studies that provides optimal nutrients specifically for cows to make milk. Some people are concerned about the changes that were brought about by controversial methods, such as injecting dairy cows with bovine growth hormone. This increases milk production by about 15 percent but also increases the risk of udder infection in the cows. As a result, antibiotics are widely used in the dairy industry. There is evidence linking widespread antibiotic use with the increase in the resistance of bacteria. This practice also decreases the effectiveness of antibiotics in humans.

Note: You Decide

How will you ensure that you are building strong bones and will be able to avoid detrimental bone loss in old age?

It is estimated that every three seconds around the globe, an osteoporotic fracture occurs. Over two hundred million women worldwide suffer from this disease.Kanis, J. A. *WHO Technical Report*, (University of Sheffield, United Kingdom, 2007): 66. Statistics also show that one in three women and one in five men over sixty will experience an osteoporotic fracture.European Foundation for Osteoporosis and National Osteoporosis Foundation. “Who Are Candidates for Prevention and Treatment for Osteoporosis?” *Osteoporos Int* 7, no. 1 (1997):Melton 3rd, L. J. et al. “Perspective. How Many Women Have Osteoporosis?” *J Bone Miner Res* 7 (1992): 1005.Kanis, J. A. et al. “Long-Term Risk of Osteoporotic Fracture.” *Malmo Osteoporos Int* 11 (2000): 669. How can you prepare yourself and fortify your bones against this disease? Milk is a ready and convenient source of calcium and vitamin D, but one glass of milk per day is not sufficient to provide adequate intake of these nutrients and many people have an allergy or intolerance to dairy products. Other good sources of calcium and vitamin D are soybeans, parsley, kale, salmon, broccoli, eggs, tuna, beans, and fortified products such as soymilk, rice milk, and almond milk. As you read this chapter you will learn the importance of building and preserving healthy bones through proper diet and exercise. Whatever you decide, know that your bone health will be affected by your dietary and lifestyle choices for years to come.

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9.2: Bone Structure and Function

Learning Objectives

- Explain the process of bone remodeling and explain why bones are living tissues.

Your bones are stronger than reinforced concrete. Bone tissue is a composite of fibrous collagen strands that resemble the steel rebar in concrete and a hardened mineralized matrix that contains large amounts of calcium, just like concrete. But this is where the similarities end. Bone outperforms reinforced concrete by several orders of magnitude in compression and tension strength tests. Why? The microarchitecture of bone is complex and built to withstand extreme forces. Moreover, bone is a living tissue that is continuously breaking down and forming new bone to adapt to mechanical stresses.



Video Link 9.2.1*: The Human Body: Bone Strength. This video is a dramatic demonstration of bone strength. (https://www.youtube.com/watch?v=FlATeMqTH2g).*

Why Is the Skeletal System Important?

The human skeleton consists of 206 bones and other connective tissues called ligaments, tendons, and cartilage. Ligaments connect bones to other bones, tendons connect bones to muscles, and cartilage provides bones with more flexibility and acts as a cushion in the joints between bones. The skeleton's many bones and connective tissues allow for multiple types of **movement** such as typing and running. The skeleton provides **structural support** and **protection** for all the other organ systems in the body. The skull, or cranium, is like a helmet and protects the eyes, ears, and brain. The ribs form a cage that surrounds and protects the lungs and heart. In addition to aiding in movement, protecting organs, and providing structural support, **red** and **white blood cells** and **platelets** are synthesized in bone marrow. Another vital function of bones is that they act as a **storage depot** for minerals such as calcium, phosphorous, and magnesium. Although bone tissue may look inactive at first glance, at the microscopic level you will find that bones are continuously breaking down and reforming. Bones also contain a complex network of canals, blood vessels, and nerves that allow for nutrient transport and communication with other organ systems.

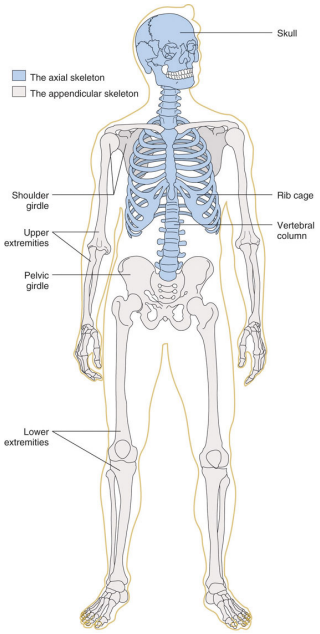


Figure 9.2.1: The human skeleton contains 206 bones. It is divided into two main parts, the axial and appendicular. © Networkgraphics

Bone Anatomy and Structure

To optimize bone health through nutrition, it is important to understand bone anatomy. The skeleton is composed of two main parts, the axial and the appendicular parts. The axial skeleton consists of the skull, vertebral column, and rib cage, and is composed of eighty bones. The appendicular skeleton consists of the shoulder girdle, pelvic girdle, and upper and lower extremities and is composed of 126 bones. Bones are also categorized by size and shape. There are four types of bone: long bones, short bones, flat bones, and irregular bones. The longest bone in your body is the femur (or "thigh" bone), which extends from your hip to your knee. It is a long bone and functions to support your weight as you stand, walk, or run. Your wrist is composed of eight irregular-shaped bones, which allows for the intricate movements of your hands. Your twelve ribs on each side of your body are curved flat bones that protect your heart and lungs. Thus, the bones' different sizes and shapes allow for their different functions.

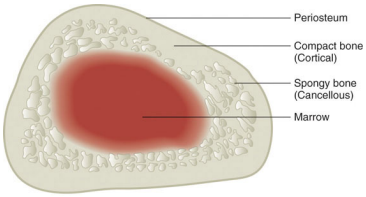


Figure 9.2.2: The Arrangement of Bone Tissues. Bone is composed of organized living tissues. © Networkgraphics

Bones are composed of approximately 65 percent inorganic material known as mineralized matrix. This mineralized matrix consists of mostly crystallized hydroxyapatite. The bone's hard crystal matrix of bone tissue gives it its rigid structure. Ninety-nine percent of all calcium in the body in bone and teeth. The other 35 percent of bone is organic material, most of which is the fibrous protein, collagen. The collagen fibers are networked throughout bone tissue and provide it with flexibility and strength. The bones' inorganic and organic materials are structured into two different tissue types. There is spongy bone, also called trabecular or cancellous bone, and compact bone also called cortical bone (Figure 9.2.1). The two tissue types differ in their microarchitecture and porosity. Trabecular bone is 50 to 90 percent porous and appears as a lattice-like structure under the microscope. It is found at the ends of long bones, in the cores of vertebrae, and in the pelvis. Trabecular bone tissue makes up about 20 percent of the adult skeleton. The denser cortical bone is about 10 percent porous and it looks like many concentric circles, similar to the rings in a tree trunk, sandwiched together (Figure 9.2.2). Cortical bone tissue makes up approximately 80 percent of the adult skeleton. It surrounds all trabecular tissue and is the only bone tissue in the shafts of long bones.

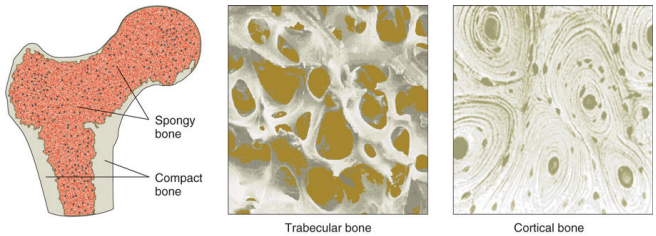


Figure 9.2.3: The two basic tissue types of bones are trabecular and cortical. Trabecular (spongy) and cortical (compact) bone tissues differ in their microarchitecture and porosity. © Networkgraphics

Bone tissue is arranged in an organized manner. A thin membrane, called the periosteum, surrounds the bone. It contains connective tissue with many blood vessels and nerves. Lying below the periosteum is the cortical bone. In some bones, the cortical bone surrounds the less-dense trabecular bone and the bone marrow lies within the trabecular bone, but not all bones contain trabecular tissue or marrow.

Bone Tissues and Cells, Modeling and Remodeling

Bone tissue contains many different cell types that constantly resize and reshape bones throughout growth and adulthood. Bone tissue cells include osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. The osteoprogenitor cells are cells that have not matured yet. Once they are stimulated, some will become osteoblasts, the bone builders, and others will become osteoclasts, the cells that break bone down. Osteocytes are the most abundant cells in bone tissue. Osteocytes are star-shaped cells that are networked throughout the bone via their long cytoplasmic arms that allow for the exchange of nutrients and other factors from bones to the blood and lymph.

Bone Modeling and Remodeling

During infancy, childhood, and adolescence, bones are continuously growing and changing shape through two processes called growth (or ossification) and modeling. In fact, in the first year of life, almost 100 percent of the bone tissue in the skeleton is replaced. In the process of modeling, bone tissue is dismantled at one site and built up at a different site. Between 35 and 45 years of life, bone formation equals bone breakdown; the mineral density of the bones is greatest in our late twenties. After 45 years, our bones stop growing and modeling but continue to go through a process of bone remodeling. In the process of remodeling, bone tissue is degraded and built up at the same location. About 10 percent of bone tissue is remodeled each year in adults. As observed in Video 9.2.1, bones adapt their structure to the forces acting upon them, even in adulthood. This phenomenon is called **Wolff's law**, which states that bones will develop a structure that is best able to resist the forces acting upon them. This is why exercising, especially when it involves weight-bearing activities, increases bone strength.



***Video 9.2.1**: Bone Modification. This video on bone remodeling demonstrates a bone's adaptability to mechanical stresses (click to see video).*

The first step in bone remodeling is osteocyte activation (see Figure 9.2.3). Osteocytes detect changes in mechanical forces, calcium homeostasis, or hormone levels. In the second step, osteoclasts are recruited to the site of the degradation. Osteoclasts are large cells with a highly irregular ruffled membrane. These cells fuse tightly to the bone and secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone tissue matrix. This process is called bone resorption and resembles pit excavation. Our bodies excavate pits in our bone tissue because bones act as storehouses for calcium and other minerals. Bones supply these minerals to other body tissues as the demand arises. Bone tissue also remodels when it breaks so that it can repair itself. Moreover, if you decide to train to run a marathon your bones will restructure themselves by remodeling to better able sustain the forces of their new function.

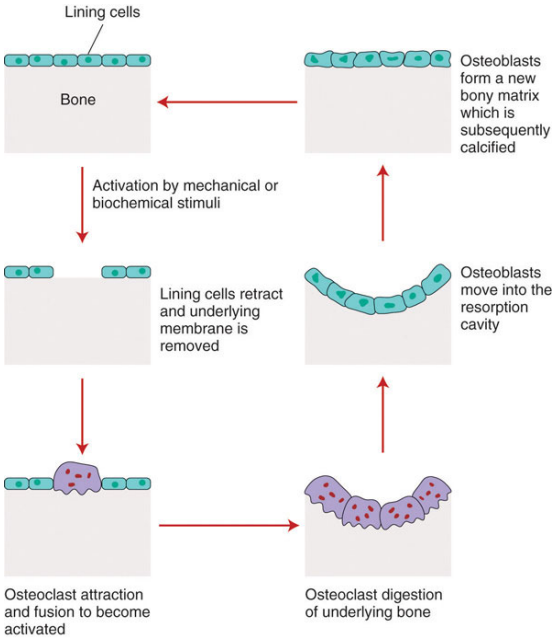


Figure 9.2.4*: Bone remodeling occurs in four steps: activation, osteoclast resorption, surface preparation, and building new bone tissue. © Networkgraphics*

After a certain amount of bone is excavated, the osteoclasts begin to die and bone resorption stops. In the third step of bone remodeling, the site is prepared for building. In this stage, sugars and proteins accumulate along the bone's surface, forming a cement line which acts to form a strong bond between the old bone and the new bone that will be made. These first three steps take approximately two to three weeks to complete. In the last step of bone remodeling, osteoblasts lay down new osteoid tissue that fills up the cavities that were excavated during the resorption process. Osteoid is bone matrix tissue that is composed of proteins such as collagen and is not mineralized yet. To make collagen, vitamin C is required. A symptom of vitamin C deficiency (known as scurvy) is bone pain, which is caused by diminished bone remodeling. After the osteoid tissue is built up, the bone tissue begins to mineralize. The last step of bone remodeling continues for months, and for a much longer time afterward the mineralized bone is continuously packed in a more dense fashion.

After menopause, breakdown is much greater than formation. This process can be slowed with the use of hormone replacement therapy.

Thus, we can say that bone is a living tissue that continually adapts itself to mechanical stress through the process of remodeling. For bone tissue to remodel certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K are required.

Key Takeaways

The skeletal system aids in movement, provides support for and protects organs, synthesizes platelets and red and white blood cells, and serves as a storage depot for minerals, such as calcium. The skeleton is composed of connective tissues including bones, cartilage, tendons, and ligaments.Bones are made up of a periosteum that surrounds compact bone, which in turn surrounds trabecular bone. Bone marrow resides within the trabecular bone. Bone tissue cells are osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. Bone is a living tissue that adapts to mechanical stress via the remodeling process. Bone remodeling is a multifaceted process involving four steps: osteocyte activation, osteoclast-mediated bone resorption, surface preparation, and osteoblast-mediated bone building. The bone remodeling process requires certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K.

Discussion Starters

1. Analyze the shape of some of your bones. Recognize the varying structure of different bones that allows for the performance of multiple functions. With a classmate, compare the shape of hand bones (that allow for fine articulated movements) to the shape of foot bones and toe bones (that allow more awkward movement). If you designed a bone system to grasp a doorknob or hang upside down, what would it look like? For inspiration, go to the web and look at bat bones, monkey bones, and human bones.
2. Why do you think it hurts when you hit your funny bone? Why are there no bones to protect the nerves?

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9.3: Bone Mineral Density is an Indicator of Bone Health

Learning Objectives

- Identify the tests used to measure bone mass.

Bone mineral density (BMD) is a measurement of the amount of calcified tissue in grams per centimeter squared of bone tissue. BMD can be thought of as the total amount of bone mass in a defined area. When BMD is high, bone strength will be great. Similar to measuring blood pressure to predict the risk of stroke, a BMD measurement can help predict the risk of bone fracture. The most common tool used to measure BMD is called dual energy X-ray absorptiometry (DEXA). During this procedure, a person lies on their back and a DEXA scanner passes two X-ray beams through their body (Figure 9.3.1). The amount of X-ray energy that passes through the bone is measured for both beams. The total amount of the X-ray energy that passes through a person varies depending on their bone thickness. Using this information and a defined area of bone, the amount of calcified tissue in grams per unit area (cm^2) is calculated.

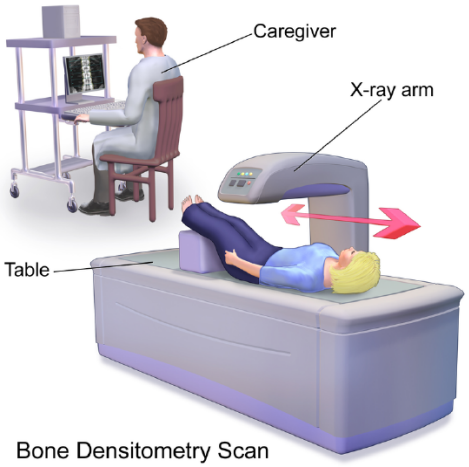
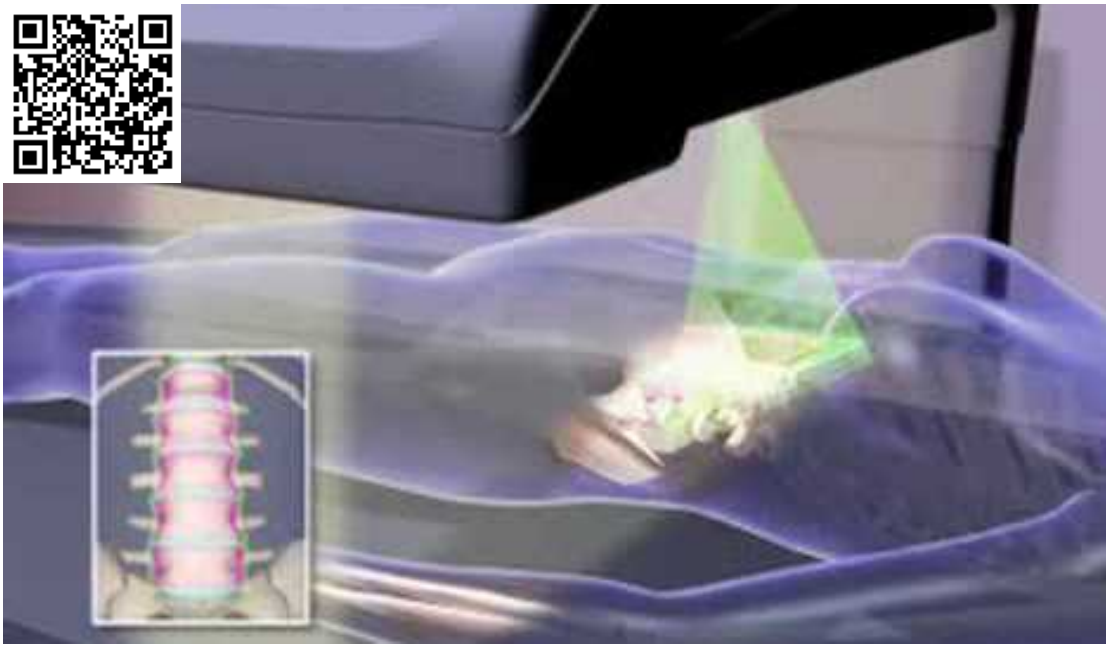


Figure 9.3.1: Bone Densitometry Scan. This image was donated by Blausen Medical. "Blausen gallery 2014". Wikiversity Journal of Medicine. DOI:10.15347/wjm/2014.010. ISSN 20018762.

Most often the DEXA scan focuses on measuring BMD in the hip and the spine. These measurements are then used as indicators of overall bone strength and health. DEXA is the cheapest and most accurate way to measure BMD. It also uses the lowest dose of radiation. Other methods of measuring BMD include quantitative computed tomography (QCT) and radiographic absorptiometry. People at risk for developing bone disease are advised to have a DEXA scan. We will discuss the many risk factors linked to an increased incidence of osteoporosis and the steps a person can take to prevent the disease from developing.



Video9.3.1: *DEXA—Dual Energy X-Ray Absorptiometry (click to see video).*

Key Takeaways

Bone-mineral density is a measurement of calcified bone tissue and positively correlates with overall bone health. DEXA is a clinical tool used to assess BMD.

Discussion Starter

1. Evaluate the animation below that discusses the technology of the DEXA procedure. Form a hypothesis on why doctors recommend this procedure for women over age fifty. Discuss your findings.

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9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D

Learning Objectives

- List the four primary functions of calcium in the human body.
- Identify the Dietary Reference Intake for calcium.

Calcium

Calcium is a major mineral nutrient that is a cation with two positive charges. When bound to anionic compounds like carbonate, it is water soluble. The most abundant mineral in the body is calcium, and greater than 99 percent of it is stored in bone tissue. Although only 1 percent of the calcium in the human body is found in the blood and soft tissues, it is here that it performs the most critical functions. Blood calcium levels are rigorously controlled so that if blood levels drop the body will rapidly respond by stimulating bone resorption, thereby releasing stored calcium into the blood. (This is discussed in further detail shortly.) Thus, bone tissue sacrifices its stored calcium to maintain blood calcium levels. This is why bone health is dependent on the intake of dietary calcium and also why blood levels of calcium do not always correspond to dietary intake. A fall in blood calcium is not due to diet but abnormal regulatory control of blood levels.

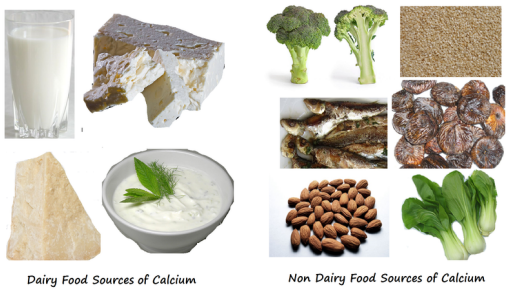


Figure 9.4.1: Calcium is an important mineral for multiple body functions. It is important to consume calcium-rich foods to sustain proper dietary intake of calcium. (CC BY-SA 4.0;'Brookepinsent)

Calcium's Functional Roles

Calcium plays a role in a number of different functions in the body:

- **Bone and tooth formation.** The most well-known calcium function is to build and strengthen bones and teeth. Recall that when bone tissue first forms during the modeling or remodeling process, it is unhardened, protein-rich osteoid tissue. In the osteoblast-directed process of bone mineralization, calcium phosphates (salts) are deposited on the protein matrix. The calcium salts gradually crystallize into hydroxyapatite, which typically makes up about 65 percent of bone tissue. When your diet is calcium deficient, the mineral content of bone decreases (becomes less dense) causing it to become brittle and weak. Thus, increased calcium intake helps to increase the mineralized content of bone tissue. Greater mineralized bone tissue corresponds to a greater BMD, and to greater bone strength. The varying arrangements of the calcium-rich hydroxyapatite crystals on bone tissue's protein matrix contribute to bone's differing mechanical properties. In tooth enamel, hydroxyapatite crystals are densely packed, making it the most mineralized tissue (more than 95 percent) in the human body. Tooth enamel's densely packed crystal architecture provides it with its incredible strength and durability. The mineralized bone tissue in human teeth is so incredibly strong that back molars can withstand bite forces exceeding four hundred pounds of pressure.
- **Nerve impulse transmission.** Calcium facilitates electrical impulse transmission from one nerve cell to another. Calcium binds to vesicles that contain neurotransmitters, causing a release into the neural synapses (junction between nerve cells). This allows the flow of ions in and out of nerve cells. If calcium is lacking, nerve-cell function will fail (see Note 9.30 "Interactive 9.1").
- **Muscle contraction.** The flow of calcium ions along the muscle cell's surface and the influx of calcium into the muscle cell are critical for muscle contraction. If calcium levels fall below a crucial range, the muscles can't relax after contracting. The muscles become stiff, and involuntary twitching may ensue in a condition known as tetany.
- **Clotting factors.** When a blood vessel is injured and bleeding starts, it must be stopped or death may result. Clotting factors and platelets are continuously circulating in the blood in case of such an emergency. When an injury occurs, the damaged tissue releases specific factors that activate the circulating clotting factors and platelets. Some of the clotting factors require calcium for activation. If clotting factors weren't activated blood clots would not form.

In addition to calcium's four primary functions calcium has several other minor functions that are also critical for maintaining normal physiology. For example, without calcium, the hormone insulin could not be released from cells in the pancreas and glycogen could not be broken down in muscle cells and used to provide energy for muscle contraction. Calcium is also important for vascular control and blood pressure.

Maintaining Calcium Levels

Because calcium performs such vital functions in the body, blood calcium level is closely regulated by the hormones parathyroid hormone (PTH), calcitriol, and calcitonin. Calcitriol is the active hormone produced from vitamin D. Parathyroid hormone and calcitriol act in a concert to increase calcium levels in the blood, while calcitonin does the opposite and decreases blood calcium levels. These hormones maintain calcium levels in the blood in a range between 9 and 11 milligrams per deciliter.

Parathyroid Hormone

Four parathyroid glands, each the size of a grain of rice, can be found in the neck on the sides of the thyroid gland. PTH increases blood calcium levels via three different mechanisms (Figure 9.4). First, PTH stimulates the release of calcium stored in the bone. Second, PTH acts on kidney cells to increase calcium reabsorption and decrease its excretion in the urine. Third, PTH stimulates enzymes in the kidney that activate vitamin D to calcitriol. Calcitriol acts on intestinal cells and increases dietary calcium absorption. Thus, stored calcium is released, more calcium is absorbed from the diet, and less calcium is excreted, all of which increase calcium levels in the blood.

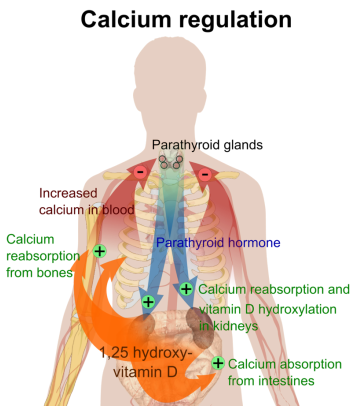


Figure 9.4.2: This is a typical negative feedback loop in which low calcium levels in the blood stimulate PTH release. PTH increases the movement of calcium from the bones, kidneys, and intestine to the blood with the help of activated vitamin D. The now higher calcium levels in the blood shut off further PTH release. (CC-BY-SA 3.0; Mikael Häggström).

Calcitriol (1,25 Hydroxy-Vitamin D)

Calcitriol functions as a second hand to PTH. It not only increases calcium release from bone tissue but also it increases the absorption of calcium in the small intestine and increases calcium reabsorption by the kidneys. Neither hormone will work unless accompanied by the other. Vitamin D regulates PTH secretion and PTH regulates vitamin D activation to calcitriol. Adequate levels of vitamin D allow for a balance of the calcium between what is released by bone tissue and what is incorporated into bone tissue so that bone health is not compromised. Calcitriol and PTH function together to maintain calcium homeostasis.

Calcitonin

Calcitonin is a hormone secreted by certain cells in the thyroid gland in response to high calcium levels in the blood. In comparison to PTH and calcitriol, calcitonin plays a small role in regulating calcium levels on a day-to-day basis. This is because as calcium levels rise in the blood, calcium feedback inhibits PTH release and effectively shuts off the actions of PTH and calcitriol. This route of feedback inhibition helps prevent calcium's further accumulation in the blood. At higher nonphysiological concentrations, calcitonin lowers blood calcium levels by increasing calcium excretion in the urine, preventing further absorption of calcium in the gut and by directly inhibiting bone resorption.

Other Health Benefits of Calcium in the Body

Besides forming and maintaining strong bones and teeth, calcium has been shown to have other health benefits for the body, including:

- **Cancer.** The National Cancer Institute reports that there is enough scientific evidence to conclude that higher intakes of calcium decrease colon cancer risk and may suppress the growth of polyps that often precipitate cancer. Although higher calcium consumption protects against colon cancer, some studies have looked at the relationship between calcium and prostate cancer and found higher intakes may increase the risk for prostate cancer; however, the data is inconsistent and more studies are needed to confirm any negative association.
- **Blood pressure.** Multiple studies provide clear evidence that higher calcium consumption reduces blood pressure. A review of twenty-three observational studies concluded that for every 100 milligrams of calcium consumed daily, systolic blood pressure is reduced 0.34 millimeters of mercury (mmHg) and diastolic blood pressure is decreased by 0.15 mmHg.Birkett, N. J. "Comments on a Meta-Analysis of the Relation between Dietary Calcium Intake and Blood Pressure." *Am J Epidemiol* 148, no. 3 (1998): 223–28. http://aje.oxfordjournals.org/content/148/3/223.long. There is emerging evidence that higher calcium intakes prevent against other risk factors for cardiovascular disease, such as high cholesterol and obesity, but the scientific evidence is weak or inconclusive.
- **Kidney stones.** Another health benefit of a high-calcium diet is that it blocks kidney stone formation. Calcium inhibits the absorption of oxalate, a chemical in plants such as parsley and spinach, which is associated with an increased risk of developing kidney stones. Calcium's protective effects on kidney stone formation occur only when you obtain calcium from dietary sources. Calcium supplements may actually increase the risk for kidney stones in susceptible people.

Deficiency Signs and Symptoms

Children who do not eat enough calcium and vitamin D may experience rickets. In adults, osteomalacia, osteopenia, and osteoporosis are progressed when calcium intakes are inadequate. People at risk of developing these diseases include individuals who lack enough money to eat the right foods, children, pregnant women, elderly, people with a low milk intake and post menopausal women.

Calcium Needs, Sources, and Bioavailability

Dietary Reference Intake for Calcium

The recommended dietary allowances (RDA) for calcium are listed in Table 9.4.1. The RDA is elevated to 1,300 milligrams per day during adolescence because this is the life stage of accelerated bone growth. Studies have shown that a higher intake of calcium during puberty increases the total amount of bone tissue that accumulates in a person. For women above age fifty and men older than seventy-one, the RDAs are also a bit higher for several reasons including that as we age, calcium absorption in the gut decreases, vitamin D_3 activation is reduced, and maintaining adequate blood levels of calcium is important to prevent an acceleration of bone tissue loss (especially during menopause). Currently, the dietary intake of calcium for females above age nine is, on average, below the RDA for calcium. The Institute of Medicine (IOM) recommends that people do not consume over 2,500 milligrams per day of calcium as it may cause adverse effects in some people.

Calcium needs are also increased during lactation, kidney or liver failure, aging, and a diet high in phosphate. Consuming too much calcium has been associated with constipation, urinary stone formation, kidney dysfunction, and/or interference of other mineral absorption such as non-heme iron.

Table 9.4.1: Dietary Reference Intakes for Calcium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	200*	–
Infants (6–12 months)	260*	–
Children (1–3 years)	700	2,500
Children (4–8 years)	1,000	2,500
Children (9–13 years)	1,300	2,500
Adolescents (14–18 years)	1,300	2,500
Adults (19–50 years)	1,000	2,500

* denotes Adequate Intake

Age Group	RDA (mg/day)	UL (mg/day)
Adult females (50–71 years)	1,200	2,500
Adults, male & female (> 71 years)	1,200	2,500
* denotes Adequate Intake		

Source: Ross, A. C. et al. “The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know.” J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. US National Library of Medicine. http://www.ncbi.nlm.nih.gov/pubmed/21118827.



Figure 9.4.3: Incorporate tofu, an excellent source of calcium, into your diet. Tofu kabobs make a delicious meal. © Shutterstock

In the typical American diet, calcium is obtained mostly from dairy products, primarily cheese. A slice of cheddar or Swiss cheese contains just over 200 milligrams of calcium. One cup of nonfat milk contains approximately 300 milligrams of calcium, which is about a third of the RDA for calcium for most adults. Foods fortified with calcium such as cereals, soy milk, and orange juice also provide one-third or greater of the calcium RDA. Although the typical American diet relies mostly on dairy products for obtaining calcium, there are many other good nondairy sources of calcium (see Section 9.4 and Table 9.4.2). A food’s calcium content can be calculated from the percent daily value (percent DV) displayed on the Nutrition Facts panel (Figure 9.4.4). Since the RDA for calcium used to calculate the daily value (DV) is 1,000 milligrams, you multiply the percent DV by ten to arrive at the calcium content in milligrams for a serving of a particular food. It is important to note that most processed foods offer a poor source for this vital mineral as the refinement process strips away the nutrients in the food.

Tools for Change

If you need to increase calcium intake, are a vegan, or have a food allergy to dairy products, it is helpful to know that there are several plant-based foods that are high in calcium. Broccoli, kale, mustard greens, and Brussel sprouts are excellent sources. One cup of these cooked vegetables provides between 100 and 180 milligrams of calcium. To increase the calcium content in your lunch and add some texture to your food, chop up some kale and put it on your sandwich or in your soup. For a list of nondairy sources that are high in calcium, see Table 9.4.2 "Nondairy Dietary Sources of Calcium". Additionally, you can find the calcium content for thousands of foods by visiting the USDA National Nutrient Database (www.nal.usda.gov/fnic/foodcomp/search/). When obtaining your calcium from a vegan diet, it is important to know that some plant-based foods significantly impair the absorption of calcium. These include spinach, Swiss chard, rhubarb, beets, cashews, and peanuts. With careful planning and good selections, you can ensure that you are getting enough calcium in your diet even if you do not drink milk or consume other dairy products.

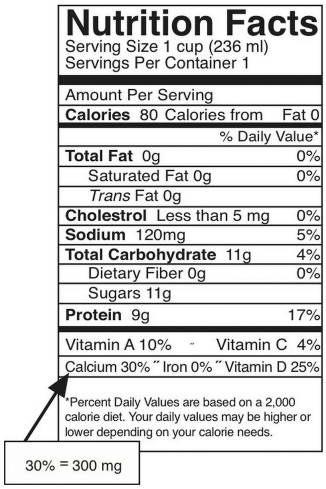


Figure 9.4.4: How to Calculate Calcium in Milligrams from the Nutrition Facts Panel

The percent DV of calcium is given on the Nutrition Facts panel. To convert this to milligrams (mg), multiply this number by ten. This is the amount of calcium in milligrams in one serving. This can be done this easily ONLY for calcium and not for other nutrients because the DV for calcium, based on the RDA for adults between the ages of nineteen and fifty, is equal to 1,000 milligrams.

Table 9.4.2: Nondairy Dietary Sources of Calcium

Food, Standard Amount	Calcium (mg)	Calories
Fortified ready-to-eat cereals (various), 1 oz.	236–1043	88–106
Soy beverage, calcium fortified, 1 c.	368	98
Sardines, Atlantic, in oil, drained, 3 oz.	325	177
Tofu, firm, prepared with nigarib, ½ c.	253	88

Food, Standard Amount	Calcium (mg)	Calories
Pink salmon, canned, with bone, 3 oz.	181	118
Collards, cooked from frozen, ½ c.	178	31
Molasses, blackstrap, 1 Tbsp.	172	47
Soybeans, green, cooked, ½ c.	130	127
Turnip greens, cooked from frozen, ½ c.	124	24
Ocean perch, Atlantic, cooked, 3 oz.	116	103
Oatmeal, plain and flavored, instant, fortified, 1 packet prepared	99–110	97–157
Cowpeas, cooked, ½ c.	106	80
White beans, canned, ½ c.	96	153
Kale, cooked from frozen, ½ c.	90	20
Okra, cooked from frozen, ½ c.	88	26
Soybeans, mature, cooked, ½ c.	88	149
Blue crab, canned, 3 oz.	86	84
Beet greens, cooked from fresh, ½ c.	82	19
Pak-choi, Chinese cabbage, cooked from fresh, ½ c.	79	10
Clams, canned, 3 oz.	78	126
Dandelion greens, cooked from fresh, ½ c.	74	17
Rainbow trout, farmed, cooked, 3 oz.	73	144

Source: US Department of Agriculture. Appendix B-4, "Nondairy Food Sources of Calcium." *2005 Dietary Guidelines for Americans*. Updated July 9, 2008. www.health.gov/dietaryguidelines/dga2005/document/html/appendixb.htm.

Calcium Bioavailability

Bioavailability refers to the amount of a particular nutrient in foods that is actually absorbed in the intestine and not eliminated in the urine or feces. Simply put, the bioavailability of calcium is the amount that is on hand to perform its biological functions. In the small intestine, calcium absorption primarily takes place in the duodenum (first section of the small intestine) when intakes are low, but calcium is also absorbed passively in the jejunum and ileum (second and third sections of the small intestine), especially when intakes are higher. The body doesn't completely absorb all the calcium in food. About 30 percent of calcium is absorbed from milk and other dairy products. Interestingly, the calcium in some vegetables such as kale, Brussel sprouts, and bok choy, is better absorbed by the body than are dairy products. The body absorbs approximately 50 percent of calcium from these plant-based sources.

Factors that Increase Calcium Bioavailability

Stomach acid releases calcium from foods and ionizes it to Ca^{++}. Calcium must be in its ionized form to be absorbed in the small intestine. The greatest positive influence on calcium absorption comes from having an adequate intake of vitamin D. People deficient in vitamin D absorb less than 15 percent of calcium from the foods they eat. The hormone estrogen is another factor that enhances calcium bioavailability. Thus, as a woman ages and goes through menopause, during which estrogen levels fall, the amount of calcium absorbed decreases and the risk for bone disease increases. Some fibers, such as inulin, found in jicama, onions, and garlic, also promote calcium intestinal uptake.

Factors that Decrease Calcium Bioavailability

Chemicals that bind to calcium decrease its bioavailability. These negative effectors of calcium absorption include the oxalates in certain plants, the tannins in tea, phytates in nuts, seeds, and grains, and some fibers. Oxalates are found in high concentrations in spinach, parsley, cocoa, and beets. In general, the calcium bioavailability is inversely correlated to the oxalate content in foods. High-fiber, low-fat diets also decrease the amount of calcium absorbed, an effect likely related to how fiber and fat influence the amount of time food stays in the gut. Anything that causes diarrhea, including sicknesses, medications, and certain symptoms related to old age, decreases the transit time of calcium in the gut and therefore decreases calcium absorption. As we get older, stomach acidity sometimes decreases, diarrhea occurs more often, kidney function is impaired, and vitamin D absorption and activation is compromised, all of which contribute to a decrease in calcium bioavailability.

Vitamin D

Vitamin D refers to a group of fat-soluble vitamins derived from cholesterol. Vitamins D_2 and D_3 are the only ones known to have biological actions in the human body. Although vitamin D_3 is called a vitamin, the body can actually synthesize vitamin D_3. When exposed to sunlight, a cholesterol precursor in the skin is transformed into vitamin D_3. However, this is not the bioactive form of vitamin D. It first must be acted upon by enzymes in the liver and then transported to the kidney where vitamin D_3 is finally transformed into the active hormone, calcitriol (1,25-dihydroxy vitamin D_3) (Figure 9.7).

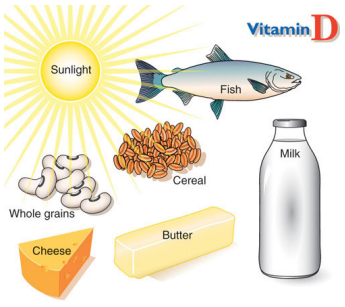


Figure 9.4.5: *Vitamin D Food Sources. © Networkgraphics*

The skin synthesizes vitamin D when exposed to sunlight. In fact, for most people, more than 90 percent of their vitamin D_3 comes from the casual exposure to the UVB rays in sunlight. For example, healthy light skinned individuals can make sufficient vitamin D to meet the body's need with about 15 minutes of sun exposure on their face, arms and hands two to three times per week. Anything that reduces your exposure to the sun's UVB rays decreases the amount of vitamin D_3 your skin synthesizes. That would include long winters, your home's altitude, whether

you are wearing sunscreen, and the color of your skin (including tanned skin). Do you ever wonder about an increased risk for skin cancer by spending too much time in the sun? Do not fret. Less than thirty minutes of sun exposure to the arms and legs will increase blood levels of vitamin D_3 more than orally taking 10,000 IU (250 micrograms) of vitamin D_3. However, it important to remember that the skin production of vitamin D_3 is a regulated process, so too much sun does cause vitamin D toxicity.

Interactive 9.4.1 Vitamin D Production in the Body

Visit the University of North Carolina Gillings School of Global Public Health website to review the activation of vitamin D to calcitriol. www.unc.edu/tlim/nutr240/?6

A person's vitamin D status is determined by measuring 25-hydroxy vitamin D_3 levels in the blood serum because it reflects both the vitamin D obtained from production in the skin and that from dietary sources. Measuring the active hormone, calcitriol, does not accurately reflect one's vitamin D status because of its short half-life (six to twelve hours). The vast majority of nutrition experts consider a concentration of 25-hydroxy vitamin D_3 in the blood serum less than 20 nanograms per milliliter as an indicator of vitamin D deficiency. The IOM states that serum levels above 20 nanograms per milliliter are sufficient to maintain bone health in healthy individuals. Both nutrition experts and health advocates currently are debating what the optimal levels of vitamin D_3 should be to take full advantage of all of its health benefits. Some advocates propose that serum levels of vitamin D_3 above 40 nonograms per milliliter are optimal. To determine whether higher levels of vitamin D_3 provide advantages in fighting diseases such as cancer, a large clinical trial called VITAL (Vitamin D and Omega-3 Trial) has been initiated at Brigham and Women's Hospital and Harvard Medical School in Boston, Massachusetts. To remain updated on this trial, visit their website at http://www.vitalstudy.org/index.html.

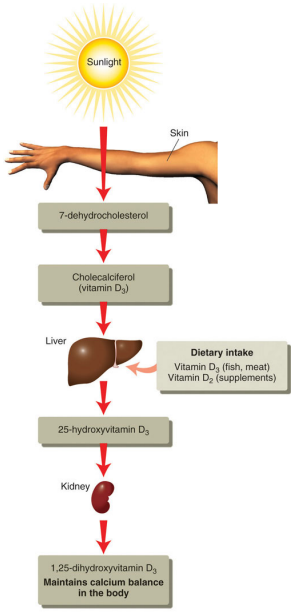


Figure 9.4.6: The Activation of Vitamin D to Calcitriol. © Networkgraphics

Vitamin D's Functional Role

As previously discussed, activated vitamin D_3 (calcitriol) regulates blood calcium levels in concert with parathyroid hormone. In the absence of an adequate intake of vitamin D, less than 15 percent of calcium is absorbed from foods or supplements. The effects of calcitriol on calcium homeostasis are critical for bone health. Vitamin D is important for bone metabolism, enhancing calcium absorption from the intestinal tract and reabsorption of calcium in the kidney.

A deficiency of vitamin D in children causes the bone disease nutritional rickets. Rickets is very common among children in developing countries and is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture. In adults, vitamin D deficiency causes a similar disease called osteomalacia, which is characterized by low BMD. Osteomalacia has the same symptoms and consequences as osteoporosis and often coexists with osteoporosis. Vitamin D deficiency is common, especially in the elderly population, dark-skinned populations, and in the many people who live in the northern latitudes where sunlight exposure is much decreased during the long winter season. Other groups at risk are people with fat malabsorption, people with kidney or liver failure, and people with low milk consumption or non-fortified milk consumption.malabsorption, people with kidney or liver failure, and people with low milk consumption or non-fortified milk consumption.

Observational studies have shown that people with low levels of vitamin D in their blood have lower BMD and an increased incidence of osteoporosis. In contrast, diets with high intakes of salmon, which contains a large amount of vitamin D, are linked with better bone health. A review of twelve clinical trials, published in the May 2005 issue of the *Journal of the American Medical Association*, concluded that oral vitamin D supplements at doses of 700–800 international units per day, with or without coadministration of calcium supplements, reduced the incidence of hip fracture by 26 percent and other nonvertebral fractures by 23 percent."Fracture Prevention with Vitamin D Supplementation: A Meta-Analysis of Randomized Controlled Trials." *JAMA* 293, no. 18 (2005): 2257–64. http://jama.ama-assn.org/content/293/18/2257.long. A reduction in fracture risk was not observed when people took vitamin D supplements at doses of 400 international units.

Vitamin D Needs and Sources

Dietary Reference Intake for Vitamin D

The Institute of Medicine RDAs for vitamin D for different age groups is listed in Table 9.4.3 "Dietary Reference Intakes for Vitamin D". For adults, the RDA is 600 international units, which is equivalent to 15 micrograms of vitamin D. The National Osteoporosis Foundation recommends slightly higher levels and that adults under age fifty get between 400 and 800 international units of vitamin D every day, and adults fifty and older get between 800 and 1,000 international units of vitamin D every day. According to the IOM, the tolerable upper intake level (UL) for vitamin D is 4,000 international units per day. Toxicity from excess vitamin D is rare, but certain diseases such as hyperparathyroidism, lymphoma, and tuberculosis make people more sensitive to the increases in calcium caused by high intakes of vitamin D.

Table 9.4.3: Dietary Reference Intakes for Vitamin D

Age Group	RDA (mcg/day)	UL (mcg/day)
Infant (0–6 months)	10*	25

* denotes Adequate Intake

Age Group	RDA (mcg/day)	UL (mcg/day)
Infants (6–12 months)	10*	25
Children (1–3 years)	15	50
Children (4–8 years)	15	50
Children (9–13 years)	15	50
Adolescents (14–18 years)	15	50
Adults (19–71 years)	15	50
Adults (> 71 years)	20	50
* denotes Adequate Intake		

Source: Ross, A. C. et al. “The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know.” J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. http://www.ncbi.nlm.nih.gov/pubmed/21118827.

Vitamin D Bioavailability

There are few food sources of vitamin D. Oily fish, such as salmon, is one of the best. The amount of vitamin D obtained from one 3-ounce piece of salmon is greater than the recommended intake for one day. Many foods, including dairy products (milk, margarine, butter), orange juice, and cereals are now fortified with vitamin D. Most vitamin-D-fortified foods contain about 25 percent of the RDA for vitamin D per serving, but check the label. Many people are deficient in vitamin D as a result of the few dietary sources for this vitamin. Other less abundant vitamin D containing foods are egg yolk, veal, and beef.

Other Health Benefits of Vitamin D in the Body

Many other health benefits have been linked to higher intakes of vitamin D, from decreased cardiovascular disease to the prevention of infection. Furthermore, evidence from laboratory studies conducted in cells, tissues, and animals suggest vitamin D prevents the growth of certain cancers, blocks inflammatory pathways, reverses atherosclerosis, increases insulin secretion, and blocks viral and bacterial infection and many other things. Vitamin D deficiency has been linked to an increased risk for autoimmune diseases. (Autoimmune diseases are those that result from an abnormal immune response targeted against the body’s own tissues.) An increased prevalence of the autoimmune diseases, rheumatoid arthritis, multiple sclerosis, and Type 1 diabetes has been observed in populations with inadequate vitamin D levels. Additionally, vitamin D deficiency is linked to an increased incidence of hypertension. Until the results come out from the VITAL study, the bulk of scientific evidence touting other health benefits of vitamin D is from laboratory and observational studies and requires confirmation in clinical intervention studies.

Key Takeaways

Calcium is the most abundant mineral in the body and has four primary functions: making bones strong and healthy, facilitating nerve-to-nerve communication, stimulating muscle contraction, and activating blood-clotting factors. Other benefits of calcium in the body include decreasing blood pressure and preventing colon cancer. Calcium blood-levels are rigorously controlled by three hormones: PTH, calcitriol, and calcitonin. The DRI for calcium intake for adults averages from 1,000–1,200 milligrams per day. Only some of the calcium in food is absorbed by the body. Vitamin D and estrogen enhance the bioavailability of calcium in the body. Alternately, diets high in oxalates, some types of fiber, and diets low in fat decrease the bioavailability of calcium in the body. Vitamin D is essential for maintaining calcium levels in the body. Once activated to calcitriol, it acts in concert with PTH to keep blood levels of calcium constant, especially by enhancing its intestinal absorption. High levels of vitamin D in the blood promote bone health.

Discussion Starters

1. Talk about some of the vital functions of calcium and vitamin D in the body. Why are these nutrients so important to health? What can you do to increase these vitamins in your diet?
2. Watch the video below. List the pros and cons of consuming both raw and pasteurized milk. Develop an informed opinion based upon the history of milk and the scientific evidence about both types of milk consumption.

   Raw Milk

   (click to see video)

9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

9.5: Other Essential Micronutrients for Bone Health

Learning Objectives

- Identify additional nutrients that are vital in maintaining bone health and state their primary role.
- Identify food sources for each nutrient.

Bone tissue is greater than 70 percent inorganic material and as such, minerals are important for maintaining skeletal health. In addition to calcium, other minerals critical for bone health are phosphorus, magnesium, and fluoride. Vitamin K is also important to bone health. But that is not all—iron, copper, zinc, and vitamin C are also essential for the synthesis of collagen. Consuming too much or too little vitamin A affects bone health too, as it plays a role in osteoclast and osteoblast activities. The fact that there are many bone-friendly nutrients provides us with one more reason why it is better to eat a diet rich in many nutrients than taking one particular supplement. In Table 9.5.1, notice the important nutrients for bone health and good food sources for each.

Table 9.5.1: Micronutrients and Bone Health

Micronutrient	Functional Role in Bone Health	Food Sources
Calcium	• Component of mineralized bone • Provides structure and microarchitecture	collards, mustard greens, kale, turnips, broccoli, beans, black molasses, and fortified juices, cereals, and milk.
Phosphorus	• Component of mineralized bone • Provides structure and microarchitecture	non-genetically-modified soy, legumes, whole grains, dairy, nuts, and seeds
Magnesium	• Component of mineralized bone • Provides structure and microarchitecture	whole grains and legumes, almonds, cashews, hazelnuts, beets, collards, and kelp
Fluoride	• Component of mineralized bone • Provides structure and microarchitecture • Stimulates new bone growth	fluoridated water, foods prepared in fluoridated water, seafood (because the ocean contains natural sodium flouride)
Vitamin D	• Critical for maintaining calcium levels • Aids the absorption of calcium, promotes bone health	salmon, mackerel, tuna, sardines, mushrooms, cod liver oil, egg yolks, and fortified milk, yogurt, and cheese
Vitamin K	• Stimulates bone remodeling	kale, spinach, turnip, and other dark leafy vegetables
Boron	• May enhance calcium absorption and estrogen metabolism	avocado, nuts, peanut butter, green and orange vegetables, grapes, and raisins
Iron	• Helps enzymes and regulators function properly so the body can form optimal bone structure for bone strength	red meat, egg yolks, dark leafy vegetables, dried fruit, iron-fortified foods, beans, lentils, chick peas, liver, and artichoke
Vitamin C	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	citrus fruits, tomatoes and tomato juice, potatoes, Brussel sprouts, cauliflower, broccoli, strawberries, cabbage, and spinach
Zinc	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	oysters, wheat germ, pumpkin seeds, squash, watermelon seeds, beans, sesame seeds, tahini, beef, lamb

Phosphorus's Functional Role

Phosphorus is the second most abundant mineral in the human body. Eighty-five percent of it is housed in the skeleton. In addition to serving as a primary mineral in the skeleton, phosphorus in the form of phosphate is a component of the backbones of RNA and DNA, the cellular energy storing molecule, adenosine triphosphate (ATP), and phospholipids. Because phosphorus is present with calcium in mineralized bone, it is somewhat regulated in parallel with calcium. PTH and calcitriol stimulate bone resorption, increasing not only blood levels of calcium but also blood phosphate levels. However, in contrast to the effect of PTH on calcium reabsorption by the kidney, PTH stimulates the renal excretion of phosphate so that it does not accumulate to toxic levels. It is usually found as phosphate or phosphorous salt.

Deficiency signs and symptoms include muscle weakness, loss of appetite (anorexia) and bone pain. A deficiency is rare but more apt to be found in preterm infants, elderly individuals, excess alcohol intake and postmenopausal women.

Dietary Reference Intake and Food Sources for Phosphorus

In comparison to calcium, most Americans are not at risk for having a phosphate deficiency. Phosphate is present in many foods popular in the American diet including meat, fish, dairy products, processed foods, and beverages. Phosphate is added to many foods because it acts as an emulsifying agent, prevents clumping, improves texture and taste, and extends shelf-life. The average intake of phosphorus in US adults ranges between 1,000 and 1,500 milligrams per day, well above the RDA of 700 milligrams per day. The UL set for phosphorous is 4,000 milligrams per day for adults and 3,000 milligrams per day for people over age seventy.

Table 9.5.2: Dietary Reference Intakes for Phosphorus

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	100*	–
Infants (6–12 months)	275*	–
Children (1–3 years)	460	3,000
Children (4–8 years)	500	3,000
Children (9–13 years)	1,250	4,000
Adolescents (14–18 years)	1,250	4,000
Adults (19–70 years)	700	4,000
Adults (> 70 years)	700	3,000
* denotes Adequate Intake		

Table 9.5.3: Calcium and Phosphorus Contents in 100 Grams of Certain Foods

Foods	Calcium (mg)	Phosphorus (mg)
Dairy Products		
Buttermilk	116	89
Milk, nonfat	123	101

Foods	Calcium (mg)	Phosphorus (mg)
Milk, whole	207	158
Yogurt, low-fat	199	157
Yogurt, whole milk	121	95
Cottage cheese, low-fat	69	151
Swiss cheese	791	567
Meats		
Beef, round steak	7	199
Chicken	15	216
Crab	59	175
Oysters	62	159
Legumes/Nuts		
Macadamia nuts	85	188
Soybeans	145	158
Lentils	19	180
Lima beans	21	74
Vegetables		
Broccoli	47	66
Carrots	27	44
Lettuce, iceberg	19	20
Parsley	140	60
Cereals/Grains		
Barley	32	309
Wheat flour, white	15	108
Oat bran	10	119
Rice, brown	10	77
Rice, white	19	55
Processed Foods		
American cheese	712	923
Au gratin potatoes	83	95
Fish sticks	26	182
Fast food hamburger	46	97
Chocolate cake mix	150	270
Chocolate wafer cookies	31	32
Granola bar	105	230
Carbonated Beverages		
Cola	2	11
Clear soda	2	0

Source: Adapted from US Department of Agriculture National Nutrient Database. Last modified November 1, 2012. www.nal.usda.gov/fnic/foodcomp/search/.

Magnesium's Functional Role

Magnesium is another major mineral and our bodies contain approximately 25 grams. Approximately 60 percent of magnesium in the human body is stored in the skeleton, making up about 1 percent of mineralized bone tissue. Magnesium is not an integral part of the hydroxyapatite crystal, but it does reside on the surface of the crystal and helps crystal formation to maximize bone structure. Observational studies link magnesium deficiency with an increased risk for osteoporosis. A magnesium-deficient diet is associated with decreased levels of parathyroid hormone and the activation of vitamin D, which may lead to an impairment of bone remodeling. A study in nine hundred elderly women and men did show that higher dietary intakes of magnesium correlated to an increased BMD in the hip.Tucker, K. L. et al. "Potassium, Magnesium, and Fruit and Vegetable Intakes Are Associated with Greater Bone Mineral Density in Elderly Men and Women." *Am J Clin Nutr* 69, no. 4 (1999): 727–36. Only a few clinical trials have evaluated the effects of magnesium supplements on bone health and their results suggest some modest benefits on BMD.

In addition to participating in bone maintenance, magnesium has several other functions in the body. In every reaction involving the cellular energy molecule, ATP, magnesium is a required cofactor. More than three hundred enzymatic reactions require magnesium. Magnesium plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids, and is essential for nerve conduction, muscle contraction, and blood clotting. Another health benefit of magnesium is that it may decrease blood pressure.

Dietary Reference Intake and Food Sources for Magnesium

The RDAs for magnesium for adults between ages nineteen and thirty are 400 milligrams per day for males and 310 milligrams per day for females. For adults above age thirty, the RDA increases slightly to 420 milligrams per day for males and 320 milligrams for females.



Figure 9.5.1: For optimal magnesium intake, try consuming whole-grain breads and cereals. (Public domain; Peggy Greb, USDA ARS)

Table 9.5.4: Dietary Reference Intakes for Magnesium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	30*	–
Infants (6–12 months)	75*	–
Children (1–3 years)	80	65
Children (4–8 years)	130	110
Children (9–13 years)	240	350
Adolescents (14–18 years)	410	350
Adults (19–30 years)	400	350
Adults (> 30 years)	420	350

* denotes Adequate Intake Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Magnesium.” Last reviewed July 13, 2009. http://ods.od.nih.gov/factsheets/Magnesium-HealthProfessional/.

Magnesium is part of the green pigment, chlorophyll, which is vital for photosynthesis in plants; therefore green leafy vegetables are a good dietary source of magnesium. Magnesium is also found in high concentrations in fish, dairy products, meats, whole grains, and nuts. Additionally chocolate, coffee, and hard water contain a good amount of magnesium. Most people in America do not fulfill the RDA for magnesium in their diets. Typically, Western diets lean toward a low fish intake and the unbalanced consumption of refined grains versus whole grains.

A deficiency in magnesium causes hypomagnesemia or low levels of magnesium in the blood which is often accompanied by a low blood calcium and potassium levels. Hypomagnesium is associated with long-term use of protein inhibitor drugs commonly used to treat GERD. Muscle cramps, spasms, nausea, weakness, irritability, and confusion are also symptoms of a magnesium deficiency. Groups at risk for developing a magnesium deficiency are individuals with renal disease, chronic diarrhea, chronic alcohol abuse and elderly people.

A high intake of magnesium is not toxic but pharmacological doses beyond the upper limit can cause diarrhea, nausea, abdominal cramps, pH imbalances, massive dehydration, cardiac arrest, and death. The excessive use of antacids can cause hypermagnesemia that affects kidney functions and impairs nerve, muscle and heart function.

Fluoride’s Functional Role

Fluoride is a water soluble anion. It is known mostly as the mineral that combats tooth decay and is bound to fluoro-hydroxyapatite. It assists in tooth and bone development and maintenance. Fluoride combats tooth decay via three mechanisms:

1. Blocking acid formation by bacteria
2. Preventing demineralization of teeth
3. Enhancing remineralization of destroyed enamel

Fluoride was first added to drinking water in 1945 in Grand Rapids, Michigan; now over 60 percent of the US population consumes fluoridated drinking water. The Centers for Disease Control and Prevention (CDC) has reported that fluoridation of water prevents, on average, 27 percent of cavities in children and between 20 and 40 percent of cavities in adults. The CDC considers water fluoridation one of the ten great public health achievements of the twentieth century.Centers for Disease Control. “10 Great Public Health Achievements in the 20th Century.” *Morbidity and Mortality Weekly Report* 48, no. 12 (April 2, 1999): 241–43. www.cdc.gov/about/history/tengpha.htm. The optimal fluoride concentration in water to prevent tooth decay ranges between 0.7–1.2 milligrams per liter. Exposure to fluoride at three to five times this concentration before the growth of permanent teeth can cause fluorosis, which is the mottling and discoloring of the teeth. Inadequate intake of fluoride has been linked to dental caries with poor mouth hygiene. People who drink water that is not fluoridated or use toothpaste with no fluoridation, are at a greater risk of developing the signs of a fluoride deficiency. Excess amounts of fluoride are toxic and cause fluorosis.

Fluoride’s benefits to mineralized tissues of the teeth are well substantiated, but the effects of fluoride on bone are not as well known. Fluoride is currently being researched as a potential treatment for osteoporosis. The data are inconsistent on whether consuming fluoridated water reduces the incidence of osteoporosis and fracture risk. Fluoride does stimulate osteoblast bone building activity, and fluoride therapy in patients with osteoporosis has been shown to increase BMD. In general, it appears that at low doses, fluoride treatment increases BMD in people with osteoporosis and is more effective in increasing bone quality when the intakes of calcium and vitamin D are adequate. The Food and Drug Administration has not approved fluoride for the treatment of osteoporosis mainly because its benefits are not sufficiently known and it has several side effects including frequent stomach upset and joint pain. The doses of fluoride used to treat osteoporosis are much greater than that in fluoridated water.

Dietary Reference Intake and Food Sources for Fluoride

The IOM has given Adequate Intakes (AI) for fluoride but has not yet developed RDAs. The AIs are based on the doses of fluoride shown to reduce the incidence of cavities, but not cause dental fluorosis. From infancy to adolescence, the AIs for fluoride increase from 0.01 milligrams per day for ages less than six months to 2 milligrams per day for those between the ages of fourteen and eighteen. In adulthood, the AI for males is 4 milligrams per day and for females is 3 milligrams per day. The UL for young children is set at 1.3 and 2.2 milligrams per day for girls and boys, respectively. For adults, the UL is set at 10 milligrams per day. Greater than 70 percent of a person’s fluoride comes from drinking fluoridated water when they live in a community that fluoridates the drinking water. Other beverages with a high amount of fluoride include teas and grape juice. Solid foods do not contain a large amount of fluoride. Fluoride content in foods depends on whether it was grown in soils and water that contained fluoride or cooked with fluoridated water. Canned meats and fish that contain bones do contain some fluoride.

Table 9.5.5: Dietary Reference Intakes for Fluoride

Age Group	AI (mg/day)	UL (mg/day)
Infants (0–6 months)	0.01	0.7
Infants (6–12 months)	0.50	0.9
Children (1–3 years)	0.70	1.3

Age Group	AI (mg/day)	UL (mg/day)
Children (4–8 years)	1.00	2.2
Children (9–13 years)	2.00	10.0
Adolescents (14–18 years)	3.00	10.0
Adult Males (> 19 years)	4.00	10.0
Adult Females (> 19 years)	3.00	10.0

Source: Institute of Medicine. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride.* January 1, 1997. www.iom.edu/Reports/1997/Dietary-Reference-Intakes-for-Calcium-Phosphorus-Magnesium-Vitamin-D-and-Fluoride.aspx.

Vitamin K's Functional Role

Vitamin K refers to a group of fat-soluble vitamins that are similar in chemical structure. They act as coenzymes and have long been known to play an essential role in blood coagulation. Without vitamin K, blood would not clot. Vitamin K is also required for maintaining bone health. It modifies the protein osteocalcin, which is involved in the bone remodeling process. All the functions of osteocalcin and the other vitamin K-dependent proteins in bone tissue are not well understood and are under intense study. Some studies do show that people who have diets low in vitamin K also have an increased risk of bone fractures.

Dietary Reference Intake and Food Sources for Vitamin K

The AI of vitamin K for adult females is 75 micrograms per day, and for males, it is 120 micrograms per day. A UL for vitamin K has not been set. Vitamin K is present in many foods. It is found in highest concentrations in green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce. Additionally, vitamin K can be synthesized via bacteria in the large intestine. The exact amount of vitamin K synthesized by bacteria that is actually absorbed in the lower intestine is not known, but likely contributes less than 10 percent of the recommended intake. Newborns have low vitamin K stores and it takes time for the sterile newborn gut to acquire the good bacteria it needs to produce vitamin K. So, it has become a routine practice to inject newborns with a single intramuscular dose of vitamin K. This practice has basically eliminated vitamin K-dependent bleeding disorders in babies.

Table 9.5.6: Dietary Reference Intakes for Vitamin K

Age Group	RDA (mcg/day)
Infants (0–6 months)	2.0*
Infants (6–12 months)	2.5*
Children (1–3 years)	30
Children (4–8 years)	55
Children (9–13 years)	60
Adolescents (14–18 years)	75
Adult Males (> 19 years)	120
Adult Females (> 19 years)	90

* denotes Adequate Intake. Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Summary

Phosphorous is a primary mineral component of bone, is regulated in parallel with calcium, and in high amounts is detrimental to bone health. Magnesium helps keep bones strong. A deficiency in magnesium can compromise bone health. Fluoride combats tooth decay and benefits teeth and bones when present in the diet at the recommended intake. Vitamin K is a coenzyme that participates in the modification of proteins that act in bone tissues and promotes normal blood clotting.

Discussion Starters

1. Discuss and plan a dinner menu that specifically contains bone-friendly foods. What are you going to serve? Be sure to include enough bone-friendly foods for the different types of vegetarians.
2. Discuss some of the functional roles that magnesium, phosphorous, fluoride, and vitamin K serve in the body. In the midst of a busy schedule, how can you ensure you are eating the right amount of foods to provide an adequate supply of these nutrients?

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9.6: Osteoporosis

Learning Objectives

- Describe osteoporosis, including its notable characteristics

There are several factors that lead to loss of bone quality during aging, including a reduction in hormone levels, decreased calcium absorption, and increased muscle deterioration. It is comparable to being charged with the task of maintaining and repairing the structure of your home without having all of the necessary materials to do so. However, you will learn that there are many ways to maximize your bone health at any age.

Osteoporosis is the excessive loss of bone over time. It leads to decreased bone strength and an increased susceptibility to bone fracture. The Office of the Surgeon General (OSG) reports that approximately ten million Americans over age fifty are living with osteoporosis, and an additional thirty-four million have osteopenia, which is lower-than-normal bone mineral density.Office of the Surgeon General. “Bone Health and Osteoporosis: A Report of the Surgeon General.” October 2004. www.surgeongeneral.gov/library/bonehealth/chapter_1.html. Osteoporosis is a debilitating disease that markedly increases the risks of suffering from bone fractures. A fracture in the hip causes the most serious consequences—and approximately 20 percent of senior citizens who have one will die in the year after the injury. Osteoporosis affects more women than men, but men are also at risk for developing osteoporosis, especially after the age of seventy. These statistics may appear grim, but many organizations—including the National Osteoporosis Foundation and the OSG—are disseminating information to the public and to healthcare professionals on ways to prevent the disease, while at the same time, science is advancing in the prevention and treatment of this disease.International Osteoporosis Foundation. “Facts and Statistics about Osteoporosis and Its Impact.” © 2012 International Osteoporosis Foundation. Accessed http://www.iofbonehealth.org/facts-and-statistics.html.

As previously discussed, bones grow and mineralize predominately during infancy, childhood, and puberty. During this time, bone growth exceeds bone loss. By age twenty, bone growth is fairly complete and only a small amount (about 10 percent) of bone mass accumulates in the third decade of life. By age thirty, bone mass is at its greatest in both men and women and then gradually declines after age forty. Bone mass refers to the total weight of bone tissue in the human body. The greatest quantity of bone tissue a person develops during his or her lifetime is called peak bone mass. The decline in bone mass after age forty occurs because bone loss is greater than bone growth. On a cellular level, this means that the osteoclast-mediated bone degradation exceeds that of the bone building activity of osteoblasts. The increased bone degradation decreases the mineral content of bone tissue leading to a decrease in bone strength and increased fracture risk.

Osteoporosis is referred to as a silent disease, much like high blood pressure, because symptoms are rarely exhibited. A person with osteoporosis may not know he has the disease until he experiences a bone break or fracture. Detection and treatment of osteoporosis, before the occurrence of a fracture, can significantly improve the quality of life. To detect osteopenia or osteoporosis, BMD must be measured by the DEXA procedure. The results of a BMD scan are most often reported as T-scores. A T-score compares a person’s BMD to an averaged BMD of a healthy thirty-year-old population of the same sex. According to the World Health Organization, a T-score of −1.0 or above indicates normal BMD. A person with a T-score between −1.0 and −2.5 has a low BMD, which is a condition referred to as osteopenia. A person with a T-score of −2.5 or below is diagnosed with osteoporosis. National Osteoporosis Foundation. “Having A Bone Density Test.” © 2011. www.nof.org/node/42 This classification of T-scores is based on studies of white postmenopausal women and does not apply to premenopausal women, nonwhite postmenopausal women, or men.

Osteoporosis is categorized into two types that differ by the age of onset and what type of bone tissue is most severely deteriorated. Type 1 osteoporosis, also called postmenopausal osteoporosis, most often develops in women between the ages of fifty and seventy. Between the ages of forty-five and fifty, women go through menopause and their ovaries stop producing estrogen. Because estrogen plays a role in maintaining bone mass, its rapid decline during menopause accelerates bone loss. This occurs mainly as a result of increased osteoclast activity. The trabecular tissue is more severely affected because it contains more osteoclasts cells than cortical tissue. Type 1 osteoporosis is commonly characterized by wrist and spine fractures. Type 2 osteoporosis is also called senile osteoporosis and typically occurs after the age of seventy. It affects women twice as much as men and is most often associated with hip and spine fractures. In Type 2 osteoporosis, both the trabecular and cortical bone tissues are significantly affected. Not everybody develops osteoporosis as they age. Other factors, which will be discussed in Section 9.6 of this chapter, also contribute to the risk or likelihood of developing the disease.

During the course of both types of osteoporosis, BMD decreases and the bone tissue microarchitecture is compromised. Excessive bone resorption in the trabecular tissue increases the size of the holes in the lattice-like structure making it more porous and weaker. A disproportionate amount of resorption of the strong cortical bone causes it to become thinner. The deterioration of one or both types of bone tissue causes bones to weaken and, consequently, become more susceptible to fractures. The American Academy of Orthopaedic Surgeons reports that one in two women and one in five men older than sixty-five will experience a bone fracture caused by osteoporosis.American Academy of Orthopaedic Surgeons. “Osteoporosis.” © 1995–2012. Last reviewed August 2009. orthoinfo.aaos.org/topic.cfm?topic=a00232.

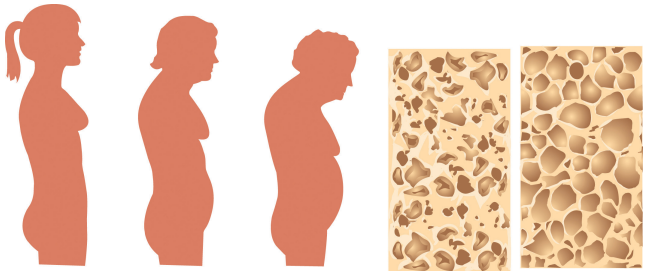


Figure 9.6.1: Osteoporosis in vertebrae. Osteoporosis is characterized by a gradual weakening of the bones, which leads to poor skeletal formation.
© Shutterstock

When the vertebral bone tissue is weakened, it can cause the spine to curve (Figure 9.6.1). The increase in spine curvature not only causes pain but also decreases a person's height. Curvature of the upper spine produces what is called Dowager's hump, also known as kyphosis. Severe upper-spine deformity can compress the chest cavity and cause difficulty breathing. It may also cause abdominal pain and loss of appetite because of the increased pressure on the abdomen.



Video 9.6.1: *Osteoporosis Defined. See this 3D medical animation about osteoporosis (click to see video).*

Key Takeaways

Bone mineral density (BMD) is an indicator of bone quality and correlates with bone strength. Excessive bone loss can lead to the development of osteopenia and eventually osteoporosis. Osteoporosis affects women more than men but is a debilitating disease for either sex. Osteoporosis is often a silent disease that doesn't manifest itself until a fracture is sustained.

Discussion Starters

1. Discuss how bone microarchitecture is changed in people with osteoporosis. How do these structural changes increase the risk of having a bone fracture?
2. Go back to Section 9.2 and review that bone is a living tissue that adapts to changes in mechanical forces. How might weight training help prevent a fracture in someone with osteoporosis?

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9.7: Risk Factors for Osteoporosis

Learning Objectives

- Discuss risk factors for osteoporosis.



Figure 9.7.1: *Certain risk factors for developing osteoporosis are biological, such as being Caucasian or Asian and being over age forty. Other factors are related to lifestyle choices such as smoking. © Shutterstock*

A risk factor is defined as a variable that is linked to an increased probability of developing a disease or adverse outcome. Recall that advanced age and being female increase the likelihood of developing osteoporosis. These factors present risks that should signal doctors and individuals to focus more attention on bone health, especially when the risk factors exist in combination. This is because not all risk factors for osteoporosis are out of your control. Risk factors such as age, gender, and race are biological risk factors and are based on genetics that cannot be changed. By contrast, there are other risk factors that can be modified, such as physical activity, alcohol intake, and diet. The changeable risk factors for osteoporosis provide a mechanism to improve bone health even though some people may be genetically predisposed to the disease.

Non-modifiable Risk Factors

Age, Sex, Body Type, and Heredity

As noted previously, after age forty, bone mass declines due to bone breakdown exceeding bone building (osteoblasts decrease). Therefore, any person over the age of forty has an increased probability of developing osteoporosis in comparison to a younger person. As noted, starting out with more bone (a high peak bone mass) enables you to lose more bone during the aging process and not develop osteoporosis. Females, on average, have a lower peak bone mass in comparison to males and therefore can sustain less bone tissue loss than males before developing a low BMD. Similarly, people with small frames are also at higher risk for osteoporosis. Being of advanced age, being a woman, and having a small frame are all biological risk factors for osteoporosis. Other biological risk factors that are linked to an increased likelihood of developing osteoporosis are having low estrogen levels, or another endocrine disorder such as hyperthyroidism, having a family member with osteoporosis, and being Caucasian or Asian. Caucasians have the highest risk of fractures while Asians have an intermediate risk and African Americans the lowest risk. Risk is correlated with bone density with Caucasians having the lowest bone mineral density and African Americans the highest.

Estrogen Level

Estrogen is the primary female reproductive hormone and it stimulates osteoblast-mediated bone building and reduces osteoclast activity. Any condition in which estrogen levels are reduced throughout a woman's life decreases BMD and increases the risk for osteoporosis. By far the most profound effect on estrogen occurs during female menopause. Around the age of forty-five or fifty,

women stop producing estrogen. The rapid decline in estrogen levels that occurs during menopause speeds up the bone resorptive process, and as a result, the loss of bone tissue in menopausal women lasts for a period of five to ten years. Up to 3 percent of bone tissue is lost annually during menopause and therefore potentially 30 percent of peak bone mass can vanish during this time, leading to a substantial increase in the risk of developing osteoporosis in postmenopausal women.

Medications

Some medications, most notably glucocorticoids (used to treat inflammatory disorders such as rheumatoid arthritis and asthma), are associated with an increased risk for osteoporosis. A side effect of glucocorticoids is that they stimulate bone resorption and decrease bone building. Other medications linked to an increased risk for osteoporosis are certain anticancer drugs, some antidiabetic drugs, and blood thinners.

Other Diseases

Diseases that predispose people to osteoporosis include those that disrupt nutrient absorption and retention, such as anorexia nervosa, chronic kidney disease, and Crohn's disease; diseases that influence bone remodeling such as hyperthyroidism and diabetes; and diseases that are characterized by chronic inflammatory responses such as cancer, chronic obstructive pulmonary disease, and rheumatoid arthritis.

Modifiable Risk Factors

Physical Inactivity

Bone is a living tissue, like muscle, that reacts to exercise by gaining strength. Physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly. Recall that mechanical stress increases bone remodeling and leads to increased bone strength and quality. Weight-bearing exercise puts mechanical stress on bones and therefore increases bone quality. The stimulation of new bone growth occurs when a person participates in weight-bearing or resistance activities that force the body to work against gravity. Research has shown that this is an excellent way to activate osteoblasts to build more new bone. Conversely, physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly. Even in the elderly, weight bearing exercise can increase bone mass.



Figure 9.7.2: Dancing is a form of weight-bearing activity that forces the body to move against gravity and therefore stimulates new bone growth. San Francisco Sunday Streets: Valencia. (CC-BY-2.0; David McSpadden)

Being Underweight

Being underweight significantly increases the risk for developing osteoporosis. This is because people who are underweight often also have a smaller frame size and therefore have a lower peak bone mass. Maintaining a normal, healthy weight is important and acts as a form of weight-bearing exercise for the skeletal system as a person moves about. Additionally, inadequate nutrition negatively impacts peak bone mass and BMD. The most striking relationship between being underweight and bone health is seen in people with the psychiatric illness anorexia nervosa. Anorexia nervosa is strongly correlated with low peak bone mass and a low BMD. In fact, more than 50 percent of men and women who have this illness develop osteoporosis and sometimes it occurs very early in life.Mehler, P. S. and K. Weiner. "The Risk of Osteoporosis in Anorexia Nervosa." Reprinted from *Eating Disorders Recovery Today* 1, no. 5 (Summer 2003). © 2003 Gurze Books. www.eatingdisordersreview.com/nl/nl_edt_1_5_2.html Women with anorexia nervosa are especially at risk because they not only have inadequate nutrition and low body weight, but also the illness is also associated with estrogen deficiency.

Smoking, Alcohol, and Caffeine

Cigarette smoking has long been connected to a decrease in BMD and an increased risk of osteoporosis and fractures. However, because people who smoke are more likely to be physically inactive and have poor diets, it is difficult to determine whether smoking itself causes osteoporosis. What is more, smoking is linked to earlier menopause and therefore the increased risk for developing osteoporosis among female smokers may also be attributed, at least in part, to having stopped estrogen production at an earlier age. A review of several studies, published in the *British Medical Journal* in 1997, reports that in postmenopausal women who smoked, BMD was decreased an additional 2 percent for every ten-year increase in age and that these women had a substantial increase in the incidence of hip fractures.Law, M. R., and A.K. Hackshaw. "A Meta-Analysis of Cigarette Smoking, Bone Mineral Density and Risk of Hip Fracture: Recognition of a Major Effect." *Br Med J* 315, no. 7112 (October 4, 1997): 841–6. http://www.ncbi.nlm.nih.gov/pubmed/9353503.

Alcohol intake's effect on bone health is less clear. In some studies, excessive alcohol consumption was found to be a risk factor for developing osteoporosis, but the results of other studies suggest consuming two drinks per day is actually associated with an increase in BMD and a decreased risk for developing osteoporosis. The International Osteoporosis Foundation states that consuming more than two alcoholic drinks per day is a risk factor for developing osteoporosis and sustaining a hip fracture in both men and women.International Osteoporosis Foundation. "New IOF Report Shows Smoking, Alcohol, Being Underweight, and Poor Nutrition Harm our Bones." Accessed October 2011. http://www.iofbonehealth.org/news/news-detail.html?newsID=193. Moreover, excessive alcohol intake during adolescence and young adulthood have a more profound effect on BMD and osteoporosis risk than drinking too much alcohol later in life.

Some studies have found that similar to alcohol intake, excessive caffeine consumption has been correlated to decreased BMD, but in other studies, moderate caffeine consumption actually improves BMD. Overall, the evidence that caffeine consumption poses a risk for developing osteoporosis is scant, especially when calcium intake is sufficient. Some evidence suggests that carbonated soft drinks negatively affect BMD and increase fracture risk. Their effects, if any, on bone health are not attributed to caffeine content or carbonation. It is probable that any effects of the excessive consumption of soft drinks, caffeinated or not, on bone health can be attributed to the displacement of milk as a dietary source of calcium.

Nutrition

Ensuring adequate nutrition is a key component in maintaining bone health. Having low dietary intakes of calcium and vitamin D are strong risk factors for developing osteoporosis. Another key nutrient for bone health is protein. Remember that the protein collagen comprises almost one-third of bone tissue. A diet inadequate in protein is a risk factor for osteoporosis. Multiple large observational studies have shown that diets high in protein increase BMD and reduce fracture risk and that diets low in protein correlate to decreased BMD and increased fracture risk. There has been some debate over whether diets super high in animal protein decrease bone quality by stimulating bone resorption and increasing calcium excretion in the urine. A review in the May 2008 issue of the *American Journal of Clinical Nutrition* concludes that there is more evidence that diets adequate in protein play a role in maximizing bone health and there is little consistent evidence that suggests high protein diets negatively affect bone health when calcium intake is adequate.Heaney, R. P. and D.K. Layman. "Amount and Type of Protein Influences Bone Health." *Am J Clin Nutr* 87, no. 5 (2008): 1567S–70S. http://www.ajcn.org/content/87/5/1567S.long

Key Takeaways

Non-modifiable risk factors for osteoporosis include: being female, being over age fifty, having a small frame, having an endocrine disorder, having a family member with the disease, and being Caucasian or Asian. The risk factors for osteoporosis that can be changed are smoking, alcohol intake, physical inactivity, and poor nutrition. Dietary inadequacy, certain medications, and diseases increase the risk for developing osteoporosis.

Discussion Starter

1. Discuss why it is important for a person with more than one biological risk factor for osteoporosis to begin to manage their lifestyle early on to prevent the development of the disease.

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9.8: Osteoporosis Prevention and Treatment

Learning Objectives

- Explain why it is important to build peak bone mass when you are young.
- Identify the tests used to measure bone mass.

Although the symptoms of osteoporosis do not occur until old age, osteoporosis is referred to as a childhood disease with old-age consequences. Thus, preventing osteoporosis in old age begins with building strong bones when you are growing. Remember, the more bone mass a person has to start with, the greater the loss a person can withstand without developing osteopenia or osteoporosis. Growing and maintaining healthy bones requires good nutrition, adequate intake of minerals and vitamins that are involved in maintaining bone health, and weight-bearing exercise.



Figure 9.8.1: An exercise group engages in a weight-bearing activity, which is a primary way to prevent osteoporosis. © Shutterstock

Primary Prevention

Actions taken to avoid developing a disease before it starts are considered primary prevention. Primary prevention of osteoporosis begins early on in life. About one-half of mineralized bone is built during puberty and the requirements for calcium intake are higher at this time than at other times in life. Unfortunately, calcium intake in boys and girls during adolescence is usually below the recommended intake of 1,300 milligrams per day. To combat inadequate nutrition and physical inactivity in adolescents, the US Department of Health and Human Services launched the Best Bones Forever!™ campaign in 2009.US Department of Health and Human Services. *Best Bones Forever!* Last updated September 2009. www.bestbonesforever.gov/index.cfm This campaign is focused on promoting bone health, especially in girls, and reducing the incidence of osteoporosis in women.

Interactive 9.8.1 Visit the Best Bones Forever!™ website.

www.bestbonesforever.gov/index.cfm

An article in the October 2008 issue of *Food and Nutrition Research* concluded that there is extensive evidence that when girls and boys exercise they increase their peak bone mass and build a stronger skeleton. The greatest benefits to bone health were observed when exercise was combined with good nutrition.Karlsson, M. K., A. Nordqvist, and C. Karlsson. “Physical Activity Increases Bone Mass during Growth.” *Food and Nutrition Research* 52 (Published online October 1, 2008). doi: 10.3402/fnr.v52i0.1871 Because there is such a strong correlation between peak bone mass and a decreased risk of developing osteoporosis, the main thrust of organizations that promote bone health, such as the National Osteoporosis Foundation, is to provide information on how to increase skeletal health early on in life, particularly during the time period of peak bone growth, which is puberty.

Primary prevention extends throughout life, and people with one or more risk factors for osteoporosis should have their BMD measured. The National Osteoporosis Foundation recommends the following groups of people get BMD screening:

- Women who are sixty-five or older
- Men who are seventy or older
- Women and men who break a bone after age fifty
- Women going through menopause with other risk factors

- Men fifty to sixty-nine years of age with risk factors National Osteoporosis Foundation. “National Osteoporosis Foundation on Bone Mineral Density Testing.” www.nof.org/node/501

Primary Prevention Tactics

Nutrition: Eat Right for Your Bones

Eating a balanced diet throughout life is helpful in preventing the onset of osteoporosis and deleterious fractures in old age. There is ample scientific evidence to suggest that low intakes of calcium and vitamin D in adulthood are linked to an increased risk for developing osteoporosis. Therefore, it is essential to make sure your diet contains adequate levels of these nutrients. The roles of calcium and vitamin D in maintaining bone health are discussed in detail elsewhere in this chapter (Chapter 9.4). A high phosphorus intake coupled with a low calcium intake may contribute bone loss. It is better if your diet contains the appropriate amount of calcium, phosphorus, and protein.

Physical Activity: Use It or Lose It

Mechanical stress is one of the activation signals for bone remodeling and can increase bone strength. Exercises that apply forces to the bone increase BMD. The most helpful are weight-bearing exercises such as strength training with weights, and aerobic weight-bearing activities, such as walking, running, and stair climbing. Certain aerobic exercises such as biking and swimming do not build bones, although they are very good for cardiovascular fitness. The importance of weight-bearing exercise to bone health is seen most clearly in astronauts. Investigators who analyzed the BMD of astronauts found that typically it decreases by 1.8 percent every month in space. That means during a six-month stay at a space station an astronaut may lose greater than 10 percent of their bone mass. The lack of gravity, which tugs on the bones of people on Earth every day, is what causes bone mass loss in astronauts. NASA imposes a rigorous workout to prevent and to restore the loss of bone mass in astronauts. While in space, astronauts exercise two-and-a-half hours each day on a treadmill and use a resistance-exercise device where they pull rubber band-like cords attached to pulleys. Then, when they return to Earth astronauts undergo weeks of rehabilitation to rebuild both bone and muscle tissue.

Video 9.8.1: Exercise Helps Keep Astronauts Healthy in Space

This video from NASA explains the importance of exercise in maintaining the health of astronauts in space. (click to see video)

Fall Prevention

Reducing the number of falls a person has decreases the likelihood of sustaining a fracture. Fairly simple modifications to a person’s environment, such as installing nightlights, railings on stairs, bars to hold onto in showers, and removing cords and throw rugs in walking paths can significantly reduce the likelihood of falling. Importantly, people at risk should have their vision and balance checked frequently.

Secondary Prevention

A person who has undergone a DEXA scan and been diagnosed with osteopenia or osteoporosis has multiple strategies available to reduce the chances of breaking a bone. These types of treatment strategies are referred to as secondary prevention. The OSG reports that the primary goals in the prevention and treatment of osteoporosis are to maintain bone health by preventing its loss and by actually building new bone.Office of the Surgeon General. “Bone Health and Osteoporosis: A Report of the Surgeon General.” October 2004 www.surgeongeneral.gov/library/bonehealth/chapter_9.html To accomplish these goals, the OSG recommends a pyramid approach. The base of the pyramid focuses on balancing nutrition, increasing physical activity, and preventing falls (primary prevention tactics). The second step in the pyramid is to determine if any underlying disorders or diseases are causing osteoporosis and to treat them. The third step is pharmacotherapy and involves administering medications. The second and third steps in the pyramid are secondary prevention tactics.

Secondary Prevention Tactics

We have noted that certain medications and diseases either cause or aggravate osteoporosis. Treating diseases such as hyperparathyroidism or discontinuing the use of or lowering the dose of medications such as prednisone, substantially reduces the risk of further deterioration of bone tissue and fracture. (In Section 9.3 of this chapter, you learned the mechanics of how the parathyroid hormone regulates calcium homeostasis.) When parathyroid hormone is present at continuously high levels in the blood, it causes a marked elevation in calcium levels. It raises blood calcium levels by increasing osteoclast activity, thereby increasing bone breakdown and bone loss. Hyperparathyroidism is treated by the surgical removal of the parathyroid gland tumor.

Chronic kidney disease and vitamin D deficiency can also cause an increase in parathyroid hormone levels. When the increase in parathyroid hormone is the result of disorders in other organs, the condition is referred to as secondary hyperparathyroidism.

Treating diseases such as chronic kidney disease and Crohn's disease, which are associated with decreased activation of vitamin D, increased calcium excretion, or malabsorption, is important in people who have not developed osteoporosis yet in order to arrest further losses in BMD. If these types of conditions exist simultaneously with osteoporosis, it is recommended that both disorders be treated to prevent further bone deterioration.

Key Takeaways

Osteoporosis is a childhood disease with old age consequences. Primary prevention of osteoporosis begins early in life with proper diet and exercise. The strategies of secondary prevention that focus on treating osteoporosis aim to arrest further bone loss and reduce fracture risk. Osteoporosis prevention and treatment involves a three-tiered approach that incorporates lifestyle modifications, the assessment, and treatment of underlying causes of the disease, and pharmacotherapy.

Discussion Starters

1. Do you or any of your classmates have children? What could a parent of a teenager do to help their child achieve a high peak bone mass?
2. Discuss the tactics you might employ at your age to maximize your bone health and minimize your risk for developing osteoporosis.

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9.9: Deficiency, Supplementation, and Choices

Learning Objectives

- List the groups most at risk for calcium inadequacy and explain why they are at risk.
- Understand the benefits and risks of calcium supplementation.



Figure 9.9.1: Calcium inadequacy is most prevalent in adolescent girls and the elderly. Proper dietary intake of calcium is critical for proper bone health. © Shutterstock

Despite the wealth of evidence supporting the many health benefits of calcium (particularly bone health), the average American diet falls short of achieving the recommended dietary intakes of calcium. In fact, in females older than nine years of age, the average daily intake of calcium is only about 70 percent of the recommended intake. Here we will take a closer look at particular groups of people who may require extra calcium intake.

- **Adolescent teens.** A calcium-deficient diet is common in teenage girls as their dairy consumption often considerably drops during adolescence.
- **Amenorrheic women and the "female athlete triad."** Amenorrhea refers to the absence of a menstrual cycle. Women who fail to menstruate suffer from reduced estrogen levels, which can disrupt and have a negative impact on the calcium balance in their bodies. The "female athlete triad" is a combination of three conditions characterized by amenorrhea, disrupted eating patterns, and osteoporosis. Exercise-induced amenorrhea and anorexia nervosa-related amenorrhea can decrease bone mass.Drinkwater, B., B. Bruemner, and C. Chesnut. "Menstrual History As a Determinant of Current Bone Density in Young Athletes." *JAMA* 263, no. 4 (1990): 545–8. http://www.ncbi.nlm.nih.gov/pubmed/2294327?dopt=Abstract;Marcus, R. et al. "Menstrual Function and Bone Mass in Elite Women Distance Runners: Endocrine and Metabolic Features." *Ann Intern Med* 102, no. 2 (1985):158–63. http://www.ncbi.nlm.nih.gov/pubmed/3966752?dopt=Abstract In female athletes, as well as active women in the military, low BMD, menstrual irregularities, and individual dietary habits together with a history of previous stress issues, are related to an increased susceptibility to future stress fractures.Nattiv, A. "Stress Fractures and Bone Health in Track and Field Athletes." *J Sci Med Sport* 3, no. 3 (2000): 268–79. http://www.ncbi.nlm.nih.gov/pubmed/11101266?dopt=Abstract.;Johnson, A.O., et al. "Correlation of Lactose Maldigestion, Lactose Intolerance, and Milk Intolerance." *Am J Clin Nutr* 57, no. 3 (1993): 399–401. http://www.ncbi.nlm.nih.gov/pubmed/8438774?dopt=Abstract.
- **The elderly.** As people age, calcium bioavailability is reduced, the kidneys lose their capacity to convert vitamin D to its most active form, the kidneys are no longer efficient in retaining calcium, the skin is less effective at synthesizing vitamin D, there are changes in overall dietary patterns, and older people tend to get less exposure to sunlight. Thus the risk for calcium inadequacy is great.International Osteoporosis Foundation. "Calcium and Vitamin D in the Elderly." © 2012. http://www.iofbonehealth.org/patients-public/about-osteoporosis/prevention /nutrition/calcium-and-vitamin-d-in-the-elderly.html.
- **Postmenopausal women.** Estrogen enhances calcium absorption. The decline in this hormone during and after menopause puts postmenopausal women especially at risk for calcium deficiency. Decreases in estrogen production are responsible for an increase in bone resorption and a decrease in calcium absorption. During the first years of menopause, annual decreases in bone mass range from 3–5 percent. After age sixty-five, decreases are typically less than 1 percent.Daniels, C. E. "Estrogen Therapy for Osteoporosis Prevention in Postmenopausal Women." *National Institute of Health: Pharmacy Update* (March/April 2001).

- **Lactose-intolerant people.** Groups of people, such as those who are lactose intolerant, or who adhere to diets that avoid dairy products, may not have an adequate calcium intake.
- **Vegans.** Vegans typically absorb reduced amounts of calcium because their diets favor plant-based foods that contain oxalates and phytates.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Calcium and Vitamin D.* (Washington, DC: National Academy Press, 2010). In addition, because vegans avoid dairy products, their overall consumption of calcium-rich foods may be less.

If you are lactose intolerant, have a milk allergy, are a vegan, or you simply do not like dairy products, remember that there are many plant-based foods that have a good amount of calcium (see "Tools for Change" in Section 9.4 and Table 9.4.2 "Nondairy Dietary Sources of Calcium") and there are also some low-lactose and lactose-free dairy products on the market.

Calcium Supplements: Which One to Buy?

As discussed earlier, most people need 1,200 to 1,300 mg of calcium per day and should keep the amount under 2.5 grams per day to avoid kidney stones and an iron deficiency. Many people choose to fulfill their daily calcium requirements by taking calcium supplements. Synthetic calcium supplements are sold primarily as calcium carbonate, calcium chloride, calcium gluconate, calcium citrate, calcium lactate, and calcium phosphate, with elemental calcium contents of about 200 milligrams per pill. It is important to look for the amount of calcium, not the total weight because some calcium supplements contain chelators. There is no relationship between the cost of the supplement and the quality and availability of the calcium. Natural sources of calcium are oyster shells, dolomite (limestone) and bone meal.

Calcium carbonate requires an acidic environment in the stomach to be used effectively. Although this is not a problem for most people, it may be for those on medication to reduce stomach acid production or for the elderly who may have a reduced ability to secrete acid in the stomach. For these people, calcium citrate may be a better choice. Otherwise, calcium carbonate is the cheapest. The body is capable of absorbing approximately 30 percent of the calcium from these forms.



Figure 9.9.2: Getting informed about the risks and benefits of calcium supplementation is important. (Public domain; This image was released by the National Cancer Institute, an agency part of the National Institutes of Health, with the ID 7512)

Beware of Lead

There is public health concern about the lead content of some brands of calcium supplements, as supplements derived from natural sources such as oyster shell, bone meal, and dolomite (a type of rock containing calcium magnesium carbonate) are known to contain high amounts of lead. In one study conducted on twenty-two brands of calcium supplements, it was proven that eight of the brands exceeded the acceptable limit for lead content. This was found to be the case in supplements derived from oyster shell and refined calcium carbonate. The same study also found that brands claiming to be lead-free did, in fact, show very low lead levels. Because lead levels in supplements are not disclosed on labels, it is important to know that products not derived from oyster shell or other natural substances are generally low in lead content (oyster shells, dolomite and bone meal may be high in heavy metals). In addition, it was also found that one brand did not disintegrate as is necessary for absorption, and one brand contained only 77 percent of the stated calcium content.Ross, E. A., N. J. Szabo, and I. R. Tebbett. “Lead Content of Calcium Supplements.” *JAMA* 2000 Sep 20; 284 (2000): 1425–33.

Diet, Supplements, and Chelated Supplements

In general, calcium supplements perform to a lesser degree than dietary sources of calcium in providing many of the health benefits linked to higher calcium intake. This is partly attributed to the fact that dietary sources of calcium supply additional nutrients with

health-promoting activities. It is reported that chelated forms of calcium supplements are easier to absorb as the chelation process protects the calcium from oxalates and phytates that may bind with the calcium in the intestines. However, these are more expensive supplements and only increase calcium absorption up to 10 percent. In people with low dietary intakes of calcium, calcium supplements have a negligible benefit on bone health in the absence of a vitamin D supplement. However, when calcium supplements are taken along with vitamin D, there are many benefits to bone health: peak bone mass is increased in early adulthood, BMD is maintained throughout adulthood, the risk of developing osteoporosis is reduced, and the incidence of fractures is decreased in those who already had osteoporosis. Calcium and vitamin D pills do not have to be taken at the same time for effectiveness. But remember that vitamin D has to be activated and in the bloodstream to promote calcium absorption. Thus, it is important to maintain an adequate intake of vitamin D.

The Calcium Debate

A recent study published in the *British Medical Journal* reported that people who take calcium supplements at doses equal to or greater than 500 milligrams per day in the absence of a vitamin D supplement had a 30 percent greater risk for having a heart attack.Bolland, M. J. et al. “Effect of Calcium Supplements on Risk of Myocardial Infarction and Cardiovascular Events: Meta-Analysis.” *Br Med J* 341, no. c3691 (July 29, 2010). Does this mean that calcium supplements are bad for you? If you look more closely at the study, you will find that 5.8 percent of people (143 people) who took calcium supplements had a heart attack, but so did 5.5 percent of the people (111) people who took the placebo. While this is one study, several other large studies have not shown that calcium supplementation increases the risk for cardiovascular disease. While the debate over this continues in the realm of science, we should focus on the things we do know:

1. There is overwhelming evidence that diets sufficient in calcium prevent osteoporosis and cardiovascular disease.
2. People with risk factors for osteoporosis are advised to take calcium supplements if they are unable to get enough calcium in their diet. The National Osteoporosis Foundation advises that adults age fifty and above consume 1,200 milligrams of calcium per day. This includes calcium both from dietary sources and supplements.
3. Consuming more calcium than is recommended is not better for your health and can prove to be detrimental. Consuming too much calcium at any one time, be it from diet or supplements, impairs not only the absorption of calcium itself but also the absorption of other essential minerals, such as iron and zinc. Since the GI tract can only handle about 500 milligrams of calcium at one time, it is recommended to have split doses of calcium supplements rather than taking a few all at once to get the RDA of calcium.

Other Choices that Affect Bone Health

Too Much Soda

There are many proponents of low-phosphate diets for bone health. Scientific studies do provide evidence that diets consisting of a high intake of processed foods and cola beverages compromise bone health as well as increase the prevalence of obesity. Overall, however, the data is inconsistent to show whether it is the phosphate content that is the culprit. The mechanism by which diets high in phosphate could cause a decrease in bone health is the following: a high dietary intake of phosphate leads to an increase in blood phosphate levels. High levels of phosphate in the blood stimulate the release of parathyroid hormone (PTH), which in turn stimulates bone resorption and calcium is lost from the bone. When calcium intake is adequate, it shuts off PTH release, but when calcium intake is inadequate and phosphate intake is high, bone health suffers. How much it suffers is under a considerable amount of debate in the scientific literature. It is a good idea to eat foods that are good sources of both calcium and phosphorus. Table 9.5.3 "Calcium and Phosphorus Contents in 100 Grams of Certain Foods" shows the calcium and phosphorus contents in certain foods.

Tools for Change

While the scientific community debates the effects of phosphate, we do know that carbonated cola beverages have negative effects on bone health. A study published in the *Archives of Pediatrics and Adolescent Medicine* reports that teenage girls who were physically active and drank carbonated cola beverages were five times more likely to break a bone than physically active girls who did not drink carbonated beverages.Wyshak, G. “Teenaged Girls, Carbonated Beverage Consumption, and Bone Fractures.” *Arch Pediatr Adolesc Med* 154 (2000): 610–13. http://archpedi.ama-assn.org/cgi/content/full/154/6/610?ijkey=d457e7f399850f63fdb8ee9ff3c3a61afcf3e352 The Beverage Guidance Panel, headed by Dr. Barry Popkin from the University of North Carolina, Chapel Hill, recommends drinking not more than one 8-ounce carbonated soft drink per day. A bone-healthy diet is one that does not replace milk and high calcium snacks with carbonated soft drinks and processed foods.



Figure 9.9.3: To decrease cola consumption try replacing sugary processed cola drinks with a nice cold glass of your favorite herbal tea. (CC-BY-SA 3.0l; 663highland).

A Lactose-Free Diet

Evidence has been uncovered recently indicating that lactose-free diets result in decreased calcium absorption because dietary lactose has been shown to actually enhance calcium absorption. Thus, lactose intolerance (and lactose-free diets) may predispose one to inadequate bone mineralization, an issue now correlated to many other disorders involving pediatric patients. Researchers are still working to clarify the effects of lactose-free diets in youth on long-term bone mineral content and the risks of osteoporosis and bone fractures with aging. Calcium homeostasis is also affected by protein intake, vitamin D status (Holick, MF. Ann Epidemiol. 2009 Feb;19(2):73–8. Epub 2008 Mar 10.NIH Public Access: "Vitamin D Status: Measurements, Interpretations, and Clinical Application." http://www.ncbi.nlm.nih.gov/pubmed/18329892), salt intake, and genetic and other factors, making long-term studies critical in determining the risks of each or all of these to bone health. Recent studies also indicate that in the future, genetic testing may be appropriate for spotting people who may be at a higher risk of lactase deficiency and subsequent decreased BMD. This may enable early intervention through dietary modification or supplementation.Heyman, M. B., MD, MPH. "Lactose Intolerance in Infants, Children, and Adolescents." *Pediatrics* 118, no. 3 (September 1, 2006): 1279–86. doi: 10.1542/peds.2006-1721.

Bone Health: A Firm Foundation

In your effort to maintain proper bone health, and prevent and treat osteoporosis, you will need to eat a balanced diet of foods that contain not only calcium and vitamin D, but also the other important bone-building nutrients. You will also need to employ physical exercise habits to encourage bone activity, such as remodeling. By consuming foods rich in bone-building materials on a daily basis, you can reduce your need for supplementation. However, if you cannot get the required amounts of calcium you need through diet alone, there are inexpensive, safe, and effective calcium supplements to choose from. As with anything you choose to consume or with any activity that you choose to undertake, supplementation, diet, and exercise should be uniquely tailored to your circumstances.

Key Takeaways

The groups of people who are most at risk for calcium inadequacy are adolescent teens, amenorrheic women, the female triad athlete, the elderly, lactose-intolerant people, those with milk allergies, and vegans. When taking calcium supplements, be sure to monitor vitamin D intake to ensure that the proper benefits are achieved. Split doses are more effective since the gastrointestinal tract can only absorb up to 500 milligrams at one time. There is need for caution when choosing different brands of calcium supplements. Oyster shell and other naturally derived brands tend to contain unusually high concentrations of lead. Other brands do not contain the stated amount of calcium as advertised. The best sources of calcium come from the diet. If you are considered at risk for inadequate calcium intake, then proper supplementation along with a good diet can produce positive results on bone health.

Discussion Starters

1. Discuss the argument for and against calcium supplementation. Defend your personal view with scientific facts.
2. Visit the websites below and come up with your own opinion on whether carbonated cola beverages increase the risk of developing osteoporosis. Discuss with your classmates what evidence is lacking. What do you and your classmates think about the position of The Coca-Cola Company Beverage Institute? Do they make a good argument? Can you counter it with better scientific evidence?

   http://www.medpagetoday.com/Endocrinology/Osteoporosis/4247

   http://www.jacn.org/content/20/4/271.full

   http://www.beverageinstitute.org/en_US/pages/expert-beverages-and-bone-health-harmful-helpful-or-no-effect.html

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9.E: Nutrients Important for Bone Health (Exercises)

It's Your Turn

1. Watch the following video on the DEXA technology. Then compose a hypothetical list of osteoporosis risk factors for a woman over the age of fifty and provide a recommendation on when she should start having her BMD monitored.

   DEXA—Dual Energy X-Ray Absorptiometry

   (click to see video)
2. Summarize in a written discussion why it is critical to achieve a high peak bone mass early in young adulthood to reduce the risk of developing osteoporosis later in life. Provide a graph of the bone-life cycle in men and women.

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CHAPTER OVERVIEW

10: Water, Electrolytes, Acid-Base Balance

In this Chapter, we look at the nutrients important to fluid and electrolyte balance, including water, sodium, chloride, and potassium. We also look at sports drinks, caffeinated beverages, and alcohol.

10.1: Chapter Introduction
10.2: Overview of Fluid and Electrolyte Balance
10.3: Water's Importance to Vitality
10.4: Regulation of Water Balance
10.5: Electrolytes Important for Fluid Balance
10.6: Consequences of Deficiency or Excess
10.7: Water Concerns
10.E: Water, Electrolytes, Acid-Base Balance (Exercises)

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10.1: Chapter Introduction

Video 11.1.1: Sport Safety: Dehydration

Dr. Casa, researcher and professor at the University of Connecticut, explains the importance of keeping hydrated during sports. (click to see video)

Maintaining the right level of water in your body is crucial to survival, as either too little or too much water in your body will result in less-than-optimal functioning. One mechanism to help ensure the body maintains water balance is thirst. Thirst is the result of your body's physiology telling your brain to initiate the thought to take a drink. Sensory proteins detect when your mouth is dry, your blood volume too low, or blood electrolyte concentrations too high and send signals to the brain stimulating the conscious feeling to drink.



Figure 11.1.1: John O'Brien The US Men's National team practices at SAS Soccer Park in Cary, NC on April 9, 2006 ahead of their international friendly against Jamaica. (CC-SA-BY 3.0; Jarrett Campbell)

In the summer of 1965, the assistant football coach of the University of Florida Gators requested scientists affiliated with the University study why the withering heat of Florida caused so many heat-related illnesses in football players and provide a solution to increase athletic performance and recovery post-training or game. The discovery was that inadequate replenishment of fluids, carbohydrates, and electrolytes were the reason for the "wilting" of their football players. Based on their research, the scientists concocted a drink for the football players containing water, carbohydrates, and electrolytes and called it "Gatorade." In the next football season, the Gators were nine and two and won the Orange Bowl. The Gators' success launched the sports-drink industry, which is now a multibillion-dollar industry that is still dominated by Gatorade.

The latest National Health and Nutrition Examination Survey, covering the period from 2005 to 2008, reports that about 50 percent of Americans consume sugary drinks daily.Ogden, C. et al. "Consumption of Sugar Drinks in the United States, 2005–2008." Centers for Disease Control and Prevention. *NCHS Data Brief*, no. 71 (August 2011). http://www.cdc.gov/nchs/data/databriefs/db71.htm. Excess consumption of sugary soft drinks has been scientifically proven to increase the risk for dental caries, obesity, Type 2 diabetes, and cardiovascular disease. In addition to sugary soft drinks, beverages containing added sugars include fruit drinks, sports drinks, energy drinks and sweetened bottled waters. Previously, we considered in detail the effects of sugary soft drinks on health. In this chapter, we will consider sports drinks. Sports drinks are designed to rehydrate the body after excessive fluid depletion. Electrolytes, in particular, promote normal rehydration to prevent fatigue during physical exertion. Are they a good choice for achieving the recommended fluid intake? Are they performance and endurance enhancers like they claim? Who should drink them?

Typically, eight ounces of a sports drink provides between fifty and eighty calories and 14 to 17 grams of carbohydrate, mostly in the form of simple sugars. Sodium and potassium are the most commonly included electrolytes in sports drinks, with the levels of these in sports drinks being highly variable. The American College of Sports Medicine says a sports drink should contain 125 milligrams of sodium per 8 ounces as it is helpful in replenishing some of the sodium lost in sweat and promotes fluid uptake in the small intestine, improving hydration.

In this chapter, we will consider the importance of maintaining fluid and electrolyte balance in the human body, the functions of water and electrolytes in the body, the consequences of getting too much or too little of water and electrolytes, the best dietary

sources of these nutrients, and healthier beverage choices. After reading this chapter you will know what to look for in sports drinks and will be able to select the best products to keep hydrated.

Video 11.1.1: Effects of Dehydration on Athletes

This video portrays the effects of hard-core training on the ability of an athlete's body to adapt to extremes. "We endorse thirst as the best scientifically supported method for you to use." Association of International Marathons and Distance Races. (click to see video)

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10.2: Overview of Fluid and Electrolyte Balance

Learning Objectives

- Define osmosis.

A human body is made up of mostly water. An adult consists of about 37 to 42 liters of water or about eighty pounds. Fortunately, humans have compartmentalized tissues; otherwise, we might just look like a water balloon! Newborns are approximately 70 percent water. Adult males typically are composed of about 60 percent water and females are about 55 percent water. (This gender difference reflects the differences in body-fat content since body fat is practically water-free. This also means that if a person gains weight in the form of fat the percentage of total body water content declines.) As we age total body water content also diminishes so that by the time we are in our eighties the percent of water in our bodies has decreased to around 45 percent. Does the loss in body water play a role in the aging process? Alas, no one knows. But, we do know that dehydration accelerates the aging process whereas keeping hydrated decreases headaches, muscle aches, and kidney stones. Additionally, a study conducted at the Fred Hutchinson Cancer Research Center in Seattle found that women who drank more than five glasses of water each day had a significantly decreased risk of developing colon cancer.Shannon J. E. et al. “Relationship of Food Groups and Water Intake to Colon Cancer Risk.” *Cancer Epidemiol Biomarkers Prev* 5, no. 7 (1996): 495–502. http://cebp.aacrjournals.org/content/5/7/495.long.

Fluid and Electrolyte Balance

Although water makes up the largest percentage of body volume, it is not actually pure water but rather a mixture of cells, proteins, glucose, lipoproteins, electrolytes, and other substances. **Electrolytes** are substances that, when dissolved in water, disassociate into charged ions. Positively charged electrolytes are called **cations** and negatively charged electrolytes are called **anions**. For example, in water sodium chloride (the chemical name for table salt) disassociates into sodium cations (Na^+) and chloride anions (Cl^-). **Solutes** refer to all dissolved substances in a fluid, which may be charged, such as sodium (Na^+), or uncharged, such as glucose. In the human body, water and solutes are distributed into two compartments: inside cells, called **intracellular**, and outside cells, called **extracellular** (about 40% of total body water). The extracellular water compartment is subdivided into the spaces between cells (interstitial) and intravascular or blood plasma and other bodily fluids (such as cerebrospinal fluid which surrounds and protects the brain and spinal cord). The composition of solutes differs between the fluid compartments. For instance, more protein is inside cells than outside and more chloride anions exist outside of cells than inside.

Osmoregulation

One of the essential homeostatic functions of the body is to maintain fluid balance and the differences in solute composition between cells and their surrounding environment. Osmoregulation is the control of fluid balance and composition in the body. The processes involved keep fluids from becoming too dilute or too concentrated. Fluid compartments are separated by selectively permeable membranes, which allow some things, such as water, to move through while other substances require special transport proteins, channels, and often energy. The movement of water between fluid compartments happens by osmosis, which is simply the movement of water through a selectively permeable membrane from an area where it is highly concentrated in an area where it is not so concentrated. Water is never transported actively; that is, it never takes energy for water to move between compartments. Although cells do not directly control water movement, they do control movement of electrolytes and other solutes and thus indirectly regulate water movement by controlling where there will be regions of high and low concentrations.

Video 11.2.1: Osmosis

This is a short animation of osmosis.(click to see video)

Cells maintain their water volume at a constant level, but the composition of solutes in a cell is in a continuous state of flux. This is because cells are bringing nutrients in, metabolizing them, and disposing of waste products. To maintain water balance a cell controls the movement of electrolytes to keep the total number of dissolved particles, called osmolality the same inside and outside (Figure 7.1). The total number of dissolved substances is the same inside and outside a cell, but the composition of the fluids differs between compartments. For example, sodium exists in extracellular fluid at fourteen times the concentration as compared to that inside a cell.

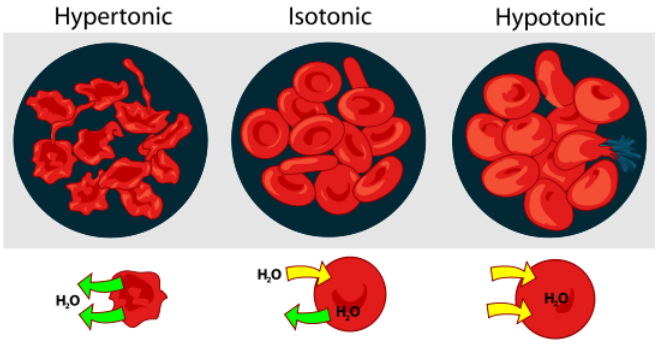


Figure 11.2.1: Cells maintain water volume by actively controlling electrolyte concentrations. Imaged used with permission (Public Domain; LadyofHats)

If a cell is placed in a solution that contains fewer dissolved particles (known as a hypotonic solution) than the cell itself, water moves into the more concentrated cell, causing it to swell (Figure 11.2.1). Alternatively, if a cell is placed in a solution that is more concentrated (known as a hypertonic solution) water moves from inside the cell to the outside, causing it to shrink. Cells keep their water volume constant by pumping electrolytes in and out in an effort to balance the concentrations of dissolved particles on either side of their membranes. When a solution contains an equal concentration of dissolved particles on either side of the membrane, it is known as an isotonic solution.

Key Takeaways

- A human body is mostly water.
- Movement of water is regulated by controlling the movement of electrolytes between fluid compartments.
- While water makes up the largest percentage of body volume it is not pure water but a mixture of water, cells, proteins, glucose, lipoproteins, electrolytes and other substances.
- In the human body water and solutes are distributed into two compartments; inside cells, called intracellular, and outside cells, called extracellular.
- One of the essential homeostatic functions, called osmoregulation of the body is to maintain fluid balance and the differences in composition between fluid compartments.
- The movement of water between fluid compartments happens by the process of osmosis.
- Water is never transported actively; that is, it never takes special proteins and energy for water to move between compartments, it simply flows from an area of high concentration to an area where its concentration is lower.
- Under normal circumstances, a cell maintains its water volume at a constant level, but the composition of solutes in a cell is in a continuous state of flux.
- To maintain water balance a cell controls the movement of electrolytes to keep the total number of dissolved particles the same inside and outside.

Discussion Starters

1. If the membrane surrounding a cell was permeable to sodium what would happen to the concentration of sodium inside and outside a cell?
2. Discuss why maintaining fluid homeostasis is a dynamic process.

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10.3: Water's Importance to Vitality

Learning Objectives

- Describe the four major functions of water in the human body

You get up in the morning, flush wastes down the toilet, take a shower, brush your teeth, drink, eat, drive, wash the grime from your windshield, get to work, and drink coffee. Next, to a fountain, you eat lunch and down it with a glass of water, you use the toilet, again and again, drive home, prepare dinner, etc. Add all the ways you use water every day and you still will not come close to the countless uses water has in the human body. Of all the nutrients, water is the most critical as its absence proves lethal within a few days. Organisms have adapted numerous mechanisms for water conservation. Water uses in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.



Figure 11.3.1: Water is the foundation of all life—the surface of the earth is 70 percent water; the volume of water in humans is about 60 percent. "The Blue Marble" is a famous photograph of the Earth taken on December 7, 1972, by the crew of the Apollo 17 spacecraft en route to the Moon at a distance of about 29,000 kilometers (18,000 statute miles). It shows Africa, Antarctica, and the Arabian Peninsula. (Public Domain; NASA)

Water As a Transportation Vehicle

Water is called the "universal solvent" because more substances dissolve in it than any other fluid. Molecules dissolve in water because of the hydrogen and oxygen molecules ability to loosely bond with other molecules. Molecules of water (H_2O) surround substances, suspending them in a sea of water molecules. The solvent action of water allows for substances to be more readily transported. A pile of undissolved salt would be difficult to move throughout tissues, as would a bubble of gas or a glob of fat. Water moves nutrients and transports waste for excretion in the urine, feces or breath. Blood, the primary transport fluid in the body is about 78 percent water. Dissolved substances in blood include proteins, lipoproteins, glucose, electrolytes, and metabolic waste products, such as carbon dioxide and urea, all of which are either dissolved in the watery surrounding of blood to be transported to cells to support basic functions or are removed from cells to prevent waste build-up and toxicity. Blood is not just the primary vehicle of transport in the body, but also as a fluid tissue blood structurally supports blood vessels that would collapse in its absence. Similarly, the brain is 75 percent water, with the water in the brain providing structure.

Water As a Medium for Chemical Reactions

Water is required for even the most basic chemical reactions. Previously, you learned that enzymes are proteins and proteins fold into their functional shape based on how their amino-acid sequences react with water. Once formed, enzymes must conduct their specific chemical reactions in a medium, which in all organisms is water. Water is an ideal medium for chemical reactions as it can store a large amount of heat, is electrically neutral, and has a pH of 7.0, meaning it is not acidic or basic. Additionally, water is involved in many enzymatic reactions as an agent to break bonds or, by its removal from a molecule, to form bonds.

Water As a Lubricant/Shock Absorber

Many may view the slimy products of a sneeze as gross, but sneezing is essential for removing irritants and could not take place without water. Mucus, which is not only essential to discharge nasal irritants, but also required for breathing, transportation of nutrients along the gastrointestinal tract, and elimination of waste materials through the rectum is composed of more than 90 percent water. Mucus is a frontline defense against injury and foreign invaders. It protects tissues from irritants, entraps pathogens, and contains immune-system cells that destroy pathogens. Water is the main component of the lubricating fluid between joints and eases the movement of articulated bones.

The aqueous and vitreous humors, which are fluids that fill the extra space in the eyes and the cerebrospinal fluid surrounding the brain and spinal cord, are primarily water and buffer these organs against sudden changes in the environment. Watery fluids surrounding organs provide both chemical and mechanical protection. Just two weeks after fertilization water fills the amniotic sac in a pregnant woman providing a cushion of protection for the developing embryo.

Water As a Temperature Regulator

Another homeostatic function of the body, termed **thermoregulation,** is to balance heat gain with heat loss and body water plays an important role in accomplishing this. Human life is supported within a narrow range of temperature, with the temperature set point of the body being 98.6°F (37°C). Too low or too high of a temperature causes enzymes to stop functioning and metabolism is halted. At 82.4°F (28°C) muscle failure occurs and hypothermia sets in. At the opposite extreme of 111.2°F (44°C) the central nervous system fails and death results. Water is good at storing heat, an attribute referred to as **heat capacity** and thus helps maintain the temperature set point of the body despite changes in the surrounding environment. There are several mechanisms in place that move body water from place to place as a method to distribute heat in the body and equalize body temperature (Figure 7.2). The hypothalamus in the brain is the thermoregulatory center. The hypothalamus contains special protein sensors that detect blood temperature. The skin also contains temperature sensors that respond quickly to changes in immediate surroundings. In response to cold sensors in the skin, a neural signal is sent to the hypothalamus, which then sends a signal to smooth muscle tissue surrounding blood vessels causing them to constrict and reduce blood flow. This reduces heat loss to the environment. The hypothalamus also sends signals to muscles to erect hairs and shiver and to endocrine glands like the thyroid to secrete hormones capable of ramping up metabolism. These actions increase heat conservation and stimulate its production in the body in response to cooling temperatures.

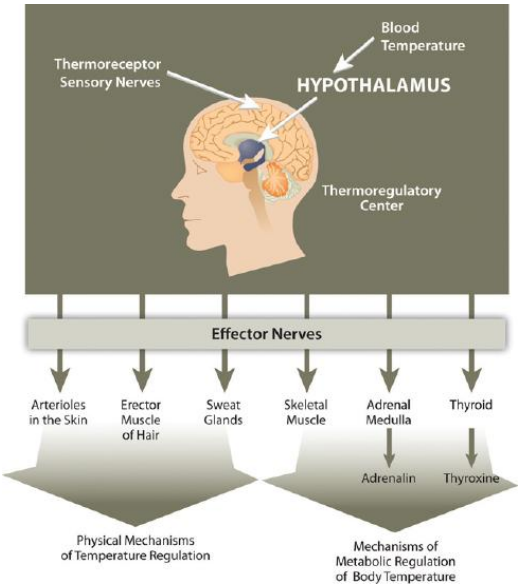


Figure 11.3.2: *Thermoregulation is the ability of an organism to maintain body temperature despite changing environmental temperatures.*

When body temperature rises, as what occurs during exercise, the hypothalamus detects an increase in blood temperature. In response, the hypothalamus sends a signal to the smooth muscle of blood vessels causing them to dilate so that more blood flows to the body's periphery. Once on the skin, extra heat exits the body via perspiration (sweat), which is 98 to 99 percent water. Water on the skin's surface evaporates, a process that takes energy and results in the loss of heat, thereby cooling the body. Perspiration is a

process that intertwines temperature homeostasis with fluid and electrolyte homeostasis. Water and electrolytes lost in sweat need to be replenished in order to maintain fluid and electrolyte balance.

Key Takeaways

- Uses of water in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.
- Water has been termed the “universal solvent” because more substances dissolve in it than any other fluid. Water is essential to form enzymes and serves as a medium for chemical reactions. Water as a component of body fluids acts as a lubricant and shock absorber.
- Water is good at storing heat and buffers the body against extreme variations in temperature.
- There are several mechanisms that move body water from place to place as a method of heat distribution and temperature equalization.

Discussion Starters

1. Refer back to the discussion of lipids and discuss why lipids are coated with proteins, forming chylomicrons, prior to absorption.
2. Why do your fingers turn white in the cold?

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10.4: Regulation of Water Balance

Learning Objectives

- Discuss the physiological events that trigger the thirst mechanism.
- Describe two mechanisms by which the body controls urine output.

As you eat a bite of food, the salivary glands secrete saliva. As the food enters your stomach, gastric juice is secreted. As it enters the small intestine, pancreatic juice is secreted. Each of these fluids contains a great deal of water. How is that water replaced in these organs? What happens to the water now in the intestines? In a day there is an exchange of about 10 liters of water among the body's organs. The osmoregulation of this exchange involves complex communication between the brain, kidneys, and endocrine system. A homeostatic goal for a cell, a tissue, an organ, and an entire organism is to balance water output with water input.

Osmosis is the passage of solutions across a semi-permeable membrane. Water follows the ions in an attempt to equalize the ionic concentration in the compartments on both sides of the membrane. Osmotic pressure is the pressure excreted by particles in a solution to draw water across a membrane.

Regulation of Daily Water Input

Total water output per day averages 2.5 liters. This must be balanced with water input. Our tissues produce around 300 milliliters of water per day through metabolic processes. The remainder of water output must be balanced by drinking fluids and eating solid foods. The average fluid consumption per day is 1.5 liters, and water gained from solid foods approximates 700 milliliters.

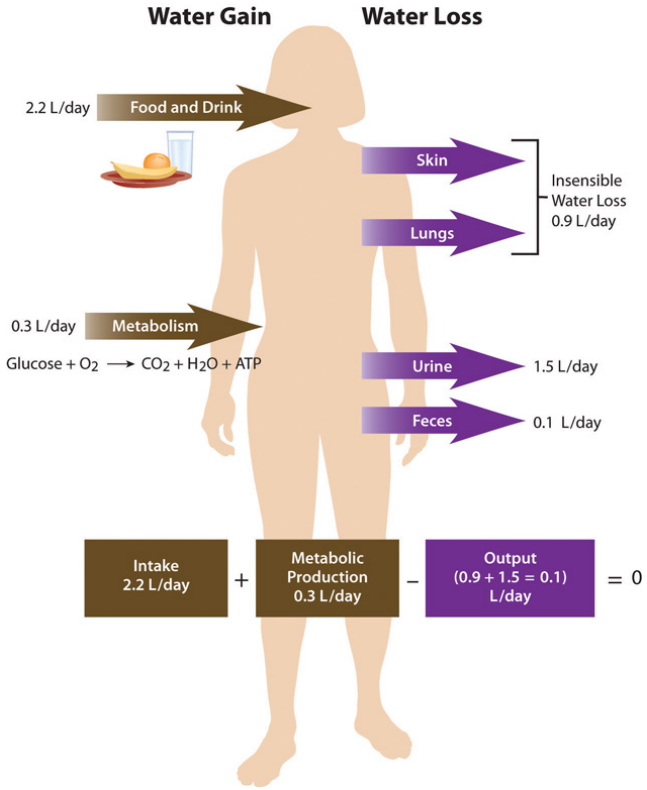


Figure 11.4.1: Daily Fluid Loss and Gain

Dietary Gain of Water

The Food and Nutrition Board of the Institute of Medicine (IOM) has set the Adequate Intake (AI) for water for adult males at 3.7 liters (15.6 cups) and at 2.7 liters (11 cups) for adult females.Institute of Medicine Panel on Dietary Reference Intakes for Electrolytes and Water. *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate*. (Washington, D.C.: National Academies Press, 2005). http://www.nap.edu/openbook.php?record_id=10925&page=73. These intakes are higher than the average intake of 2.2 liters. It is important to note that the AI for water includes water from *all dietary sources*; that is, water

coming from food as well as beverages. People are not expected to consume 15.6 or 11 cups of pure water per day. In America, approximately 20 percent of dietary water comes from solid foods. See Table 11.4.1 for the range of water contents for selected food items. Beverages include water, tea, coffee, sodas, and juices.

Table 11.4.1: Water Content in Foods

Percentage	Food Item
90–99	Nonfat milk, cantaloupe, strawberries, watermelon, lettuce, cabbage, celery, spinach, squash
80–89	Fruit juice, yogurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple
70–79	Bananas, avocados, cottage cheese, ricotta cheese, baked potato, shrimp
60–69	Pasta, legumes, salmon, chicken breast
50–59	Ground beef, hot dogs, steak, feta cheese
40–49	Pizza
30–39	Cheddar cheese, bagels, bread
20–29	Pepperoni, cake, biscuits
10–19	Butter, margarine, raisins
1–9	Walnuts, dry-roasted peanuts, crackers, cereals, pretzels, peanut butter
0	Oils, sugars

Source: US Department of Agriculture, Agricultural Research Service. 2010. *National Nutrient Database for Standard Reference*, Release 23. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl.

There is some debate over the amount of water required to maintain health because there is no consistent scientific evidence proving that drinking a particular amount of water improves health or reduces the risk of disease. In fact, kidney stone prevention seems to be the only premise for water consumption recommendations. You may be surprised to find out that the commonly held belief that people need to drink eight 8-ounce glasses of water per day isn't an official recommendation and isn't based on any scientific evidence! The amount of water/fluids a person should consume every day is actually variable and should be based on the climate a person lives in, as well as their age, physical activity level, and kidney function. No maximum for water intake has been set.

Thirst Mechanism: Why Do We Drink?

Thirst is an osmoregulatory mechanism to increase water input. The thirst mechanism is activated in response to changes in water volume in the blood but is even more sensitive to changes in blood osmolality. Blood osmolality is primarily driven by the concentration of sodium cations. The urge to drink results from a complex interplay of hormones and neuronal responses that coordinate to increase water input and contribute toward fluid balance and composition in the body. The "thirst center" is contained within the hypothalamus, a portion of the brain that lies just above the brain stem. In older people, the thirst mechanism is not as responsive and as we age there is a higher risk for dehydration. Thirst happens in the following sequence of physiological events:

1. Receptor proteins in the kidney, heart, and hypothalamus detect decreased fluid volume or increased sodium concentration in the blood.
2. Hormonal and neural messages are relayed to the brain's thirst center in the hypothalamus.
3. The hypothalamus sends neural signals to higher sensory areas in the cortex of the brain, stimulating the conscious thought to drink.
4. Fluids are consumed.
5. Receptors in the mouth and stomach detect mechanical movements involved with fluid ingestion.
6. Neural signals are sent to the brain and the thirst mechanism is shut off.

The physiological control of thirst is the backup mechanism to increase water input. Fluid intake is controlled primarily by conscious eating and drinking habits dependent on social and cultural influences. For example, you might have a habit of drinking a glass of orange juice and eating a bowl of cereal every morning before school or work. Most American adolescents have a daily habit of soft-drink consumption. Soft-drink consumption is influenced by demographics, access to soft drinks, social impacts, and personal behavior.

Regulation of Daily Water Output

As stated, daily water output averages 2.5 liters. There are two types of outputs. The first type is **insensible water loss**, meaning we are unaware of it. The body loses about 400 milliliters of its daily water output through exhalation. Another 500 milliliters is lost through our skin. The second type of output is **sensible water loss**, meaning we are aware of it. Urine accounts for about 1,500 milliliters of water output, and feces account for roughly 100 milliliters of water output. Regulating urine output is a primary function of the kidneys, and involves communication with the brain and endocrine system.

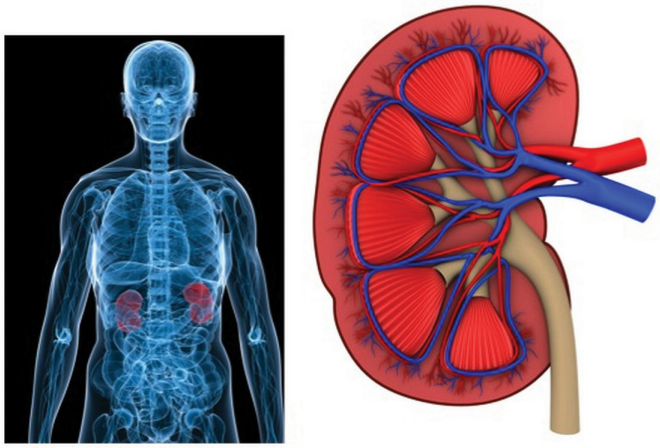


Figure 11.4.2: Kidneys. A primary function of the kidneys is to filter blood and remove wastes. They play a major role in fluid and electrolyte balance.© Thinkstock

The Kidneys Detect Blood Volume

The kidneys are two bean-shaped organs, each about the size of a fist and located on either side of the spine just below the rib cage (Figure 7.4). The kidneys filter about 190 liters of blood and produce (on average) 1.5 liters of urine per day. Urine is mostly water, but it also contains electrolytes and waste products, such as urea. The amount of water filtered from the blood and excreted as urine is dependent on the amount of water in, and the electrolyte composition of, blood.

Kidneys have protein sensors that detect blood volume from the pressure, or stretch, in the blood vessels of the kidneys. When blood volume is low, kidney cells detect decreased pressure and secrete the enzyme, renin. Renin travels in the blood and cleaves another protein into the active hormone, **angiotensin**. Angiotensin targets three different organs (the adrenal glands, the hypothalamus, and the muscle tissue surrounding the arteries) to rapidly restore blood volume and, consequently, pressure.

- First, angiotensin travels to the outer perimeter of the adrenal glands and stimulates the release of the hormone aldosterone. Aldosterone travels back to the kidneys and stimulates the sodium-potassium pump. As a result of the pump's work, the blood reabsorbs the sodium from the liquid that has already been filtered by the kidneys. Water follows sodium into the blood by osmosis, resulting in less water in the urine and restored fluid balance and composition of blood.
- Next, angiotensin travels to the hypothalamus where it stimulates the thirst mechanism and the release of antidiuretic hormone. Antidiuretic hormone travels back to the kidneys where it increases sodium and water reabsorption.
- Lastly, angiotensin targets smooth muscle tissue surrounding arteries, causing them to contract (narrow) the blood vessels, which assists in elevating blood pressure.

The Hypothalamus Detects Blood Osmolality

Osmoreceptors (specialized protein receptors) in the hypothalamus detect sodium concentration in the blood. In response to a high sodium level, the hypothalamus activates the thirst mechanism and concurrently stimulates the release of antidiuretic hormone. Thus, it is not only kidneys that stimulate antidiuretic- hormone release, but also the hypothalamus. This dual control of antidiuretic hormone release allows for the body to respond to both decreased blood volume and increased blood osmolality.

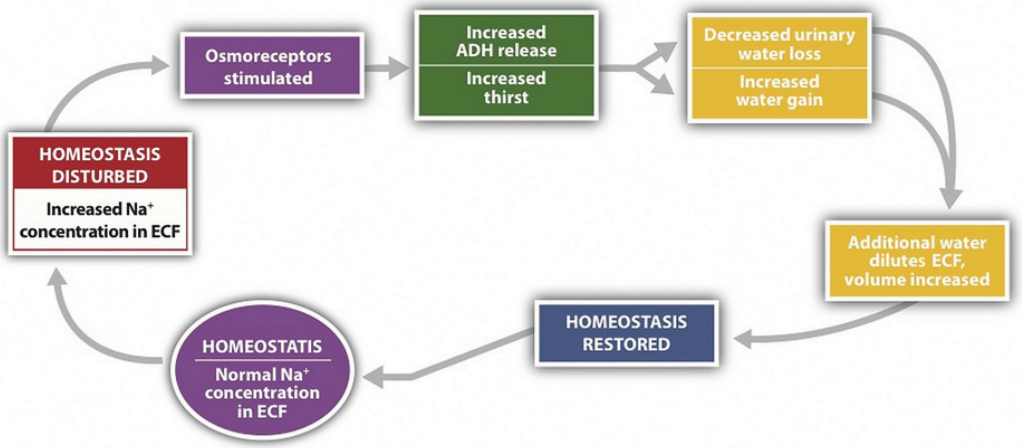


Figure 11.4.3: Sodium and fluid balance are intertwined.

The Adrenal Glands Detect Blood Osmolality

Cells in the adrenal glands sense when sodium levels are low, and when potassium levels are high, in the blood. In response to either stimulus, they release aldosterone. Therefore, aldosterone is released in response to angiotensin stimulation and is also controlled by blood electrolyte concentrations. In either case, aldosterone communicates the same message, which is to increase sodium reabsorption and consequently water reabsorption. In exchange, potassium is excreted.

The mechanisms involved in regulating water input and output are intertwined with those controlling electrolyte balance. In a healthy individual, this multilevel coordinated control of fluid and electrolyte levels in the body ensures homeostasis. However, in a person with heart failure, the crosstalk between organs can have dire consequences. Heart failure results in a decrease in blood output from the heart, which lowers blood pressure. In response to the lower blood pressure, the kidneys release renin leading to the release of antidiuretic hormone. Antidiuretic hormone acts on the kidneys and increases water reabsorption, thereby increasing blood volume and pressure. This makes the heart work harder and exacerbates the heart condition. To block this response, people with heart failure are treated with drugs that block the kidneys' compensatory response. Diuretics are drugs that act either by inhibiting the actions of antidiuretic hormone or by promoting sodium excretion in the urine. This increases water output and blood pressure is reduced. Diuretics, along with other drugs, are useful in treating heart failure and in decreasing blood pressure in people with hypertension.

Key Takeaways

- A homeostatic goal for a cell, tissue, organ, and entire organism is to balance water output with water input. The amount of water a person should consume every day is variable and should be based on the climate a person lives in, as well as their age, physical activity level, and kidney function.
- Thirst results from a complex interaction of hormones and neuronal responses that coordinate to achieve fluid balance and composition in the body. Thirst is triggered by either a decrease in blood volume or an increase in blood osmolality.
- Other mechanisms by which body water balance is maintained are aimed at controlling the water volume of urine. The amount of water filtered from the blood and excreted as urine is dependent upon the amount of water in blood and the electrolyte composition of blood.
- The regulation of water output involves complex communication between the kidneys, hypothalamus, and endocrine glands.

Discussion Starters

1. Why do people urinate more often when it is cold outside?
2. Discuss the signs you first detect when you are thirsty.

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10.5: Electrolytes Important for Fluid Balance

Learning Objectives

- Explain the role of the electrolytes sodium, potassium, and chloride in fluid balance.

Cells are about 75 percent water and blood plasma is about 95 percent water. Why then, does the water not flow from blood plasma to cells? The maintenance of the unequal volumes of water between fluid compartments is achieved by balancing the force of water (hydrostatic pressure) against the force of all dissolved substances. Concentration means the amount of particles in a set volume of water. (Recall that individual solutes can differ in concentration between the intracellular and extracellular fluids, but the total concentration of all dissolved substances is equal.)

The force driving the water movement through the selectively permeable membrane is the higher solute concentration on the one side. Solutes at different concentrations on either side of a selectively permeable membrane exert a force, called osmotic pressure. The higher concentration of solutes on one side compared to the other of the U-tube exerts osmotic pressure, pulling the water to a higher volume on the side of the U-tube containing more dissolved particles. When the osmotic pressure is equal to the pressure of the water on the selectively permeable membrane, net water movement stops (though it still diffuses back and forth at an equal rate).

One equation exemplifying equal concentrations but different volumes is the following

5 grams of glucose in 1 liter = 10 grams of glucose in 2 liters (5g/L = 5g/L)

The differences in concentrations of particular substances provide concentration gradients that cells can use to perform work. A concentration gradient is a form of potential energy, like water above a dam. When water falls through a dam the potential energy is changed to moving energy (kinetic), that in turn is captured by turbines. Similarly, when an electrolyte at a higher concentration in the extracellular fluid is transported into a cell with lower concentration, the potential energy is harnessed and used to perform work.

Cells are constantly transporting nutrients in and waste out. How is the concentration of solutes maintained if they are in a state of flux? This is where electrolytes come into play. The cell (or more specifically the numerous sodium-potassium pumps in its membrane) continuously pumps sodium ions out to establish a chemical gradient. The transport protein, called the sodium-glucose symporter, uses the sodium gradient to power glucose movement into the cell. Sodium and glucose both move into the cell. Water passively follows the sodium. To restore balance, the sodium-potassium pump transfers sodium back to the extracellular fluid and water follows. Every cycle of the sodium-potassium pump involves the movement of three sodium ions out of a cell, in exchange for two potassium ions into a cell. To maintain charge neutrality on the outside of cells every sodium cation is followed by a chloride anion. Every cycle of the pump costs one molecule of ATP (adenosine triphosphate). The constant work of the sodium-potassium pump maintains the solute equilibrium and consequently, water distribution between intracellular and extracellular fluids.

The unequal movement of the positively charged sodium and potassium ions makes intracellular fluid more negatively charged than the extracellular fluid. This charge gradient is another source of energy that a cell uses to perform work. You will soon learn that this charge gradient and the sodium-potassium pump are also essential for nerve conduction and muscle contraction. The many functions of the sodium-potassium pump in the body account for approximately a quarter of total resting energy expenditure.

Interactive

View this animation of the sodium-potassium pump maintaining fluid balance in cells.

http://nutrition.jbpub.com/resources/animations.cfm?id=27&debug=0

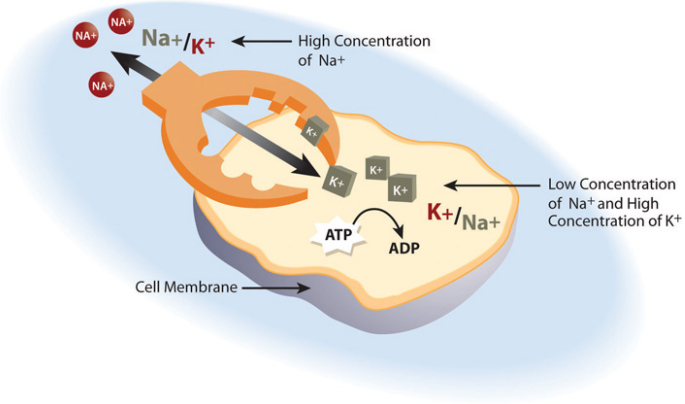


Figure 11.5.1: The sodium-potassium pump is the primary mechanism for cells to maintain water balance between themselves and their surrounding environment.

Sodium

Sodium is a major extracellular cation that is water soluble and vital not only for maintaining fluid balance but also for many other essential functions. In contrast to many minerals, sodium absorption in the small intestine is extremely efficient and in a healthy individual, 90-95% is excreted by the kidneys, the remainder in the feces and sweat. Very little sodium is required in the diet (about 200 milligrams) because the kidneys actively reabsorb sodium. Kidney reabsorption of sodium is hormonally controlled, allowing for a relatively constant sodium concentration in the blood.

Other Functions of Sodium in the Body

The second notable function of sodium is in nerve impulse transmission. Nerve impulse transmission results from the transport of sodium cations into a nerve cell, which creates a charge difference (or voltage) between the nerve cell and its extracellular environment. Similar to how a current moves along a wire, a sodium current moves along a nerve cell. Stimulating a muscle contraction also involves the movement of sodium ions as well as other ion movements. For a muscle to contract, a nerve impulse travels to a muscle. The movement of the sodium current in the nerve communicates to the muscle by releasing the neurotransmitter, acetylcholine. Acetylcholine signals sodium channels in the muscle to open and sodium rushes in, creating another current that travels along the muscle eventually culminating in contraction. In both the nerve cell and the muscle cell, the sodium that went in during a stimulus now has to be moved out by the sodium-potassium pump.

Sodium is essential for nutrient absorption in the small intestine and also for nutrient reabsorption in the kidney. Amino acids, glucose, and water must make their way from the small intestine to the blood. To do so they pass through intestinal cells on their way to the blood. The transport of nutrients through intestinal cells is facilitated by the sodium-potassium pump, which by moving sodium out of the cell, creates a higher sodium concentration outside of the cell (requiring ATP).

Sodium Imbalances

Sweating is a homeostatic mechanism for maintaining body temperature, which influences fluid and electrolyte balance. Sweat is mostly water but also contains some electrolytes, mostly sodium and chloride. Under normal environmental conditions (i.e., not hot, humid days) water and sodium loss through sweat are negligible but is highly variable among individuals. It is estimated that sixty minutes of high-intensity physical activity, like playing a game of tennis, can produce approximately one liter of sweat; however, the amount of sweat produced is highly dependent on environmental conditions. A liter of sweat typically contains between 1 and 2 grams of sodium and therefore exercising for multiple hours can result in a high amount of sodium loss in some people. Additionally, hard labor can produce substantial sodium loss through sweat. In either case, the lost sodium is easily replaced in the next snack or meal.

In athletes, **hyponatremia**, or a low blood-sodium level, is not so much the result of excessive sodium loss in sweat, but rather drinking too much water. The excess water dilutes the sodium concentration in blood. Illnesses causing vomiting, sweating, and diarrhea may also cause hyponatremia. The symptoms of hyponatremia, also called water intoxication since it is often the root cause, include nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death. The physiological events that occur in water intoxication are the following:

1. Excessive sodium loss and/or water intake.
2. Sodium levels fall in blood and in the fluid between cells.

3. Water moves to where solutes are more concentrated (i.e. into cells).
4. Cells swell.
5. Symptoms, including nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death result.



Figure 11.5.2: Pictured is Serena Williams, one of the greatest female tennis players of all time. Only in the extreme does a person lose too much sodium through sweat. © Shutterstock

Hyponatremia in endurance athletes (such as marathon runners) can be avoided by drinking the correct amount of water, which is about 1 cup every twenty minutes during the event. Sports drinks are better at restoring fluid and blood-glucose levels than replacing electrolytes. During an endurance event, you would be better off drinking water and eating an energy bar that contains sugars, proteins, and electrolytes. The American College of Sports Medicine suggests if you are exercising for longer than one hour you eat one high carbohydrate (25–40 grams) per hour of exercise along with ample water.Convertino, V. A. et al. “American College of Sports Medicine Position Stand. Exercise and Fluid Replacement.” US National Library of Medicine, National Institutes of Health. *Medicine and Science in Sports and Exercise* 28, no. 1 (January 1996): i–vii. http://www.ncbi.nlm.nih.gov/pubmed/9303999. Watch out for the fat content, as sometimes energy bars contain a hefty dose. If you’re not exercising over an hour at high intensity, you can skip the sports drinks, but not the water. For those who do not exercise or do so at low to moderate intensity, sports drinks are another source of extra calories, sugar, and salt.

Other people at risk of hyponatremia are people on a very low sodium diet due to special diets. These types of diets are used to treat kidney disease, hypertension, and heart disease. Excessive vomiting, for example, bulimia nervosa, or excessive diarrhea can also cause a loss of sodium resulting in hyponatremia.

Needs and Dietary Sources of Sodium

The IOM has set an AI level for sodium for healthy adults between the ages of nineteen and fifty at 1.5 grams (1,500 milligrams). (See Table 11.5.1 "Dietary Reference Intakes for Sodium".) Table salt is approximately 40 percent sodium and 60 percent chloride. One teaspoon of salt contains approximately 2300 mg sodium. As a reference point, only ⅔ teaspoon of salt is needed in the diet to meet the AI for sodium. The AI takes into account the amount of sodium lost in sweat during recommended physical activity levels and additionally provides for the sufficient intake of other nutrients, such as chloride, meaning that to get all the other nutrients in our diet, we have to allow for a higher intake of sodium. The Tolerable Upper Intake Level (UL) for sodium is 2.3 grams per day for adults. (Just over 1 teaspoon of salt contains the 2.3 grams of sodium recommended). The UL is considered appropriate for healthy individuals but not those with hypertension (high blood pressure). The IOM estimates that greater than 95 percent of men and 75 percent of women in America consume salt in excess of the UL. Many scientific studies demonstrate that reducing salt intake prevents hypertension, is helpful in reducing blood pressure after hypertension is diagnosed, and reduces the risk for cardiovascular disease. The IOM recommends that people over fifty, African Americans, diabetics, and those with chronic kidney disease should consume no more than 1.5 grams of sodium per day. The American Heart Association (AHA) states that all Americans, not just those listed, should consume less than 1.5 grams of sodium per day to prevent cardiovascular disease. The AHA recommends this because millions of people have risk factors for hypertension and there is scientific evidence supporting that lower-sodium diets are preventive against hypertension.

Table 11.5.1: Dietary Reference Intakes for Sodium

Age Group	Adequate Intake (mg/day)	Tolerable Upper Intake Level (mg/day)
Infants (0–6 months)	120	ND
Infants (6–12 months)	370	ND
Children (1–3 years)	1,000	1,500
Children (4–8 years)	1,200	1,900
Children (9–13 years)	1,500	2,200
Adolescents (14–18 years)	1,500	2,300
Adults (19–50 years)	1,500	2,300
Adults (50–70 years)	1,300	2,300
Adults (> 70 years)	1,200	2,300
ND = not determined		

Source: Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Food Sources for Sodium

Most sodium in the typical American diet comes from processed and prepared foods. Manufacturers add salt to foods to improve texture and flavor, and also as a preservative. The amount of salt in similar food products varies widely. Some foods, such as meat, poultry, and dairy foods, contain naturally-occurring sodium. For example, one cup of low-fat milk contains 107 milligrams of sodium. Naturally-occurring sodium accounts for less than 12 percent of dietary intake in a typical diet. Soft water replaced the calcium with sodium which contributes to the sodium content of one's diet. Soy sauce and monosodium glutamate are also sources of sodium. For the sodium contents of various foods see Table 11.5.2.

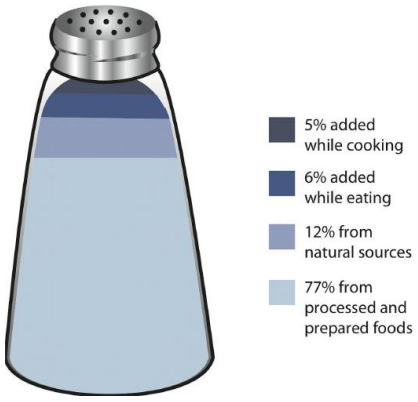


Figure 11.5.3: Dietary Sources of Sodium

Table 11.5.2: Sodium Contents of Selected Foods

Food Group	Serving Size	Sodium (mg)
Breads, all types	1 oz.	95–210
Rice Chex cereal	1 ¼ c.	292
Raisin Bran cereal	1 c.	362
Granola bar	1 bar	83
Frozen pizza, plain, cheese	4 oz.	450–1200
Frozen vegetables, all types	½ c.	2–160

Food Group	Serving Size	Sodium (mg)
Salad dressing, regular fat, all types	2 Tbsp.	110–505
Salsa	2 Tbsp.	150–240
Soup (tomato), reconstituted	8 oz.	700–1260
Tomato juice	8 oz. (~1 c.)	340–1040
Potato chips	1 oz. (28.4 g)	120–180
Tortilla chips	1 oz. (28.4 g)	105–160
Pretzels	1 oz. (28.4 g)	290–560
Potato	1 medium	1–5
Pork	3 oz.	59
Chicken	(½ breast)	69
Chicken fast food dinner		2243
Chicken noodle soup	1 c.	1107
Ham	3 oz.	1114
Dill pickle	1	928
Sweet pickle	1	128
Soy sauce	1 Tbsp.	1029
Corn on cob	1 ear	1
Canned corn	1 c.	384
Baked beans, canned	1 c.	856
Hot dog	1	639
Burger, fast-food	1	990
Catsup	1 Tbsp.	156
Steak	3 oz.	55
Canned tuna	3 oz.	384
Fresh tuna	3 oz.	50
Dry-roasted peanuts	1 c.	986
Cheddar cheese	1 oz.	176
American cheese	1 oz.	406
Tap water	8 oz.	12

Interactive

To find out the sodium content of other foods visit the USDA National Nutrient Database for Standard Reference, Release 17. www.nal.usda.gov/fnic/foodcomp/Data/SR17/wtrank/sr17a307.pdf.

Sodium on the Nutrition Facts Panel

The Nutrition Facts panel displays the amount of sodium (in milligrams) per serving of the food in question (Figure 11.5.4). Food additives are often high in sodium, for example, monosodium glutamate (MSG) contains 12 percent sodium. Additionally, baking soda, baking powder, disodium phosphate, sodium alginate, and sodium nitrate or nitrite contain a significant proportion of sodium.



Nutrition Facts

Serving Size ½ cup (114g)
Servings Per Container 4

Amount Per Serving

Calories 90 Calories from Fat 130

	% Daily Value*
Total Fat 3g	5%
Saturated Fat 0g	0%
Cholestrol 0 mg	0%
Sodium 300mg	13%
Total Carbohydrate 13g	4%
Dietary Fiber 3g	12%
Sugars 3g	
Protein 3g	

Vitamin A 80% • Vitamin C 60%
Calcium 4% • Iron 4%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholestrol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts

8 servings per container
Serving size **2/3 cup (55g)**

Amount per serving
Calories **230**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Figure 11.5.4: Sodium levels in milligrams is a required listing on a nutrition facts panel. The old nutrition facts panel is shown on the left and the new nutrition facts panel is shown on the right. Notice, both still require sodium.

When you see a food's Nutrition Facts label, you can check the ingredients list to identify the source of the added sodium. Various claims about the sodium content in foods must be in accordance with Food and Drug Administration (FDA) regulations (Table 11.5.3).

Table 11.5.3: Food Packaging Claims Regarding Sodium

Claim	Meaning

Claim	Meaning
“Light in Sodium” or “Low in Sodium”	Sodium is reduced by at least 50 percent
“No Salt Added” or “Unsalted”	No salt added during preparation and processing*
“Lightly Salted”	50 percent less sodium than that added to similar food
“Sodium Free” or “Salt Free”	Contains less than 5 mg sodium per serving
“Very Low Salt”	Contains less than 35 mg sodium per serving
“Low Salt”	Contains less than 140 mg sodium per serving

*Must also declare on package “This is not a sodium-free food” if food is not sodium-free. Source: US Food and Drug Administration. “Food Labeling Guide.” Revised October 2009. Accessed October 2, 2011. www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

Tools for Change

To decrease your sodium intake, become a salt-savvy shopper by reading the labels and ingredients lists of processed foods and choosing those lower in salt. Even better, stay away from processed foods and control the seasoning of your foods. Eating a diet with less salty foods diminishes salt cravings so you may need to try a lower sodium diet for a week or two before you will be satisfied with the less salty food.



Figure 11.5.5: Take control of your salt intake and prepare your own foods. Not enough time? A packaged dinner from your grocer’s freezer rarely supplies you with leftovers, a time saver for the next meal, but does supply a large amount of salt. © Shutterstock

Salt Substitutes

For those with hypertension or those looking for a way to decrease salt use, using a salt substitute for food preparation is one option. However, many salt substitutes still contain sodium, just in lesser amounts than table salt. Also, remember that most salt in the diet is not from table-salt use, but from processed foods. Salt substitutes often replace the sodium with potassium. People with kidney disorders often have problems getting rid of excess potassium in the diet and are advised to avoid salt substitutes containing potassium. People with liver disorders should also avoid salt substitutes containing potassium because their treatment is often accompanied by potassium dysregulation. Table 11.5.4 displays the sodium and potassium amounts in some salt substitutes.

Table 11.5.4: Salt Substitutes

Product	Serving Size	Sodium (mg)	Potassium (mg)
Salt	1 tsp.	2,300	0
Mrs. Dash	1 tsp.	0	40
Spike (Salt-Free)	1 tsp.	0	96
Veg-It	1 tsp.	<65	<65

Product	Serving Size	Sodium (mg)	Potassium (mg)
Adolph's Sodium-Free Tenderizer	¼ tsp.	0	420
Accent Low-Sodium Seasoning	1 tsp.	600	0
Salt Sense	1 tsp.	1,560	0
Pleasoning Mini-Mini Salt	1 tsp.	440	0
Morton Lite Salt	1 tsp.	1,100	1,500
Estee Salt-It	1 tsp.	0	3,520
Morton Nature's Seasons	1 tsp.	1,300	2,800
Morton Salt Substitute	1 tsp.	0	2,730
No Salt	1 tsp.	5	2,500
Nu-Salt	1 tsp.	0	529

Source: University of Wisconsin Hospitals and Clinics Authority. "Health Facts for You: Guidelines for a Low Sodium Diet." March 2011. www.uhs.wisc.edu/health-topics/nutrition-fitness-and-heart-health/documents/Sodium.pdf.

Alternative Seasonings

Table salt may seem an essential ingredient of good food, but there are others that provide alternative taste and zest to your foods. See Table 11.5.5 for an AHA list of alternative food seasonings.

Table 11.5.5: Salt Alternatives

Seasoning	Foods
Allspice	Lean ground meats, stews, tomatoes, peaches, applesauce, cranberry sauce, gravies, lean meat
Almond extract	Puddings, fruits
Caraway seeds	Lean meats, stews, soups, salads, breads, cabbage, asparagus, noodles
Chives	Salads, sauces, soups, lean-meat dishes, vegetables
Cider vinegar	Salads, vegetables, sauces
Cinnamon	Fruits, breads, pie crusts
Curry powder	Lean meats (especially lamb), veal, chicken, fish, tomatoes, tomato soup, mayonnaise,
Dill	fish sauces, soups, tomatoes, cabbages, carrots, cauliflower, green beans, cucumbers, potatoes, salads, macaroni, lamb
Garlic (not garlic salt)	Lean meats, fish, soups, salads, vegetables, tomatoes, potatoes
Ginger	Chicken, fruits
Lemon juice	Lean meats, fish, poultry, salads, vegetables
Mace	Hot breads, apples, fruit salads, carrots, cauliflower, squash, potatoes, veal, lamb
Mustard (dry)	lean ground meats, lean meats, chicken, fish, salads, asparagus, broccoli, Brussels sprouts, cabbage, mayonnaise, sauces

Seasoning	Foods
Nutmeg	Fruits, pie crust, lemonade, potatoes, chicken, fish, lean meatloaf, toast, veal, pudding
Onion powder	Lean meats, stews, vegetables, salads, soups
Paprika	Lean meats, fish, soups, salads, sauces, vegetables
Parsley	Lean meats, fish, soups, salads, sauces, vegetables
Peppermint extract	Puddings, fruits
Pimiento	Salads, vegetables, casserole dishes
Rosemary	Chicken, veal, lean meatloaf, lean beef, lean pork, sauces, stuffings, potatoes, peas, lima beans
Sage	Lean meats, stews, biscuits, tomatoes, green beans, fish, lima beans, onions, lean pork
Savory	Salads, lean pork, lean ground meats, soups, green beans, squash, tomatoes, lima beans, peas
Thyme	Lean meats (especially veal and lean pork), sauces, soups, onions, peas, tomatoes, salads
Turmeric	Lean meats, fish, sauces, rice

Source: American Heart Association. "Shaking the Salt Habit." Updated June 6, 2012. http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Shaking-the-Salt-Habit_UCM_303241_Article.jsp.

Tools for Change

Do you think many alternative spices are too expensive? Spices are much cheaper in bulk, and many grocery stores and ethnic markets carry them in this way. For example, when purchased in bulk, cumin is, on average, only one dollar per ounce, a quantity that takes many meals to exhaust.

Chloride

Chloride is the primary anion in extracellular fluid. Chloride moves easily across membranes following the sodium and potassium gradients. In addition to passively following sodium and potassium, chloride has its own protein channels that reside in cell membranes. These protein channels are especially abundant in the gastrointestinal tract, pancreas, and lungs. Chloride is the major anion in sweat and vomit. It is the anion of stomach acid, HCl.

Chloride's Role in Fluid Balance

Chloride aids in fluid balance mainly because it follows sodium in order to maintain charge neutrality. Chloride channels also play a role in regulating fluid secretion, such as pancreatic juice into the small intestine and the flow of water into mucus. Fluid secretion and mucus are important for many of life's processes. Their importance is exemplified in the signs and symptoms of the genetic disease, cystic fibrosis.

Cystic Fibrosis

Cystic fibrosis, or CF, is one of the most prevalent inherited diseases in people of European descent. It is caused by a mutation in a protein that transports chloride ions out of the cell. CF's signs and symptoms include salty skin, poor digestion and absorption (leading to poor growth), sticky mucus accumulation in the lungs (causing increased susceptibility to respiratory infections), liver damage, and infertility.

When chloride channels do not transport chloride out of cells, the following signs and symptoms of CF become apparent:

1. **Salty skin.** Defective chloride channels in the sweat glands cause excess release of chloride, which sodium then follows into the sweat.

2. **Poor digestion and growth.** Defective chloride channels in the pancreas cause pancreatic juices to thicken. As a result of the thickening, the release of pancreatic juices is slowed and nutrient digestion is compromised.
3. **Respiratory infection.** Defective chloride channels in the lungs cause thickened mucus. The mucus then traps bacteria.
4. **Liver damage.** Defective chloride channels in the gall bladder cause thickened gallbladder secretions. The gallbladder ducts then become blocked, leading to liver damage.
5. **Infertility.** Defective chloride channels in male and female reproductive organs can result in impaired sperm transport and viscous mucus in the cervix, respectively.

Other Functions of Chloride

Chloride has several other functions in the body, most importantly in acid-base balance. Blood pH is maintained in a narrow range and the number of positively charged substances is equal to the number of negatively charged substances. Proteins, such as albumin, as well as bicarbonate ions and chloride ions, are negatively charged and aid in maintaining blood pH. Hydrochloric acid (a gastric acid composed of chlorine and hydrogen) aids in digestion and also prevents the growth of unwanted microbes in the stomach. Immune-system cells require chloride, and red blood cells use chloride anions to remove carbon dioxide from the body.

Chloride Imbalances

Low dietary intake of chloride and more often diarrhea can cause low blood levels of chloride. Symptoms typically are similar to those of hyponatremia and include weakness, nausea, and headache. Excess chloride in the blood is rare with no characteristic signs or symptoms.

Needs and Dietary Sources of Chloride

Most chloride in the diet comes from salt. (Salt is 60 percent chloride.) A teaspoon of salt equals 5.6 grams, with each teaspoon of salt containing 3.4 grams of chloride and 2.2 grams of sodium. The chloride AI for adults, set by the IOM, is 2.3 grams. Therefore just ⅔ teaspoon of table salt per day is sufficient for chloride as well as sodium. The AIs for other age groups are listed in Table 11.5.5.

Table 11.5.5: Adequate Intakes for Chloride

Age Group	g/day
Infants (0–6 months)	0.18
Infants (6–12 months)	0.57
Children (1–3 years)	1.50
Children (4–8 years)	1.90
Children (9–13 years)	2.30
Adolescents (14–18 years)	2.30
Adults (19–50 years)	2.30
Adults (51–70 years)	2.00
Adults (> 70 years)	1.80

Source: Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Other Dietary Sources of Chloride

Chloride has dietary sources other than table salt, namely as another form of salt—potassium chloride. Dietary sources of chloride are all foods containing sodium chloride, as well as tomatoes, lettuce, olives, celery, rye, whole-grain foods, and seafood. Although many salt substitutes are sodium-free, they may still contain chloride.

Bioavailability

In the small intestine, the elements of sodium chloride split into sodium cations and chloride anions. Chloride follows the sodium ion into intestinal cells passively, making chloride absorption quite efficient. When chloride exists as a potassium salt, it is also

well absorbed. Other mineral salts, such as magnesium chloride, are not absorbed as well, but bioavailability still remains high.

Potassium

Potassium is a major water-soluble cation that is the most abundant positively charged ion inside of cells (intracellular). Most potassium is lost in the urine (80-90%) and the remainder is via the feces. Ninety percent of potassium exists in intracellular fluid, with about 10 percent in extracellular fluid, and only 1 percent in blood plasma. As with sodium, potassium levels in the blood are strictly regulated. The hormone aldosterone is what primarily controls potassium levels, but other hormones (such as insulin) also play a role. When potassium levels in the blood increase, the adrenal glands release aldosterone. The aldosterone acts on the collecting ducts of kidneys, where it stimulates an increase in the number of sodium-potassium pumps. Sodium is then reabsorbed and more potassium is excreted. Because potassium is required for maintaining sodium levels, and hence fluid balance, about 200 milligrams of potassium are lost from the body every day. So, potassium one of potassium's important functions is fluid and electrolyte balance.

Other Functions of Potassium in the Body

Nerve impulse involves not only sodium but also potassium. A nerve impulse moves along a nerve via the movement of sodium ions into the cell. To end the impulse, potassium ions rush out of the nerve cell, thereby decreasing the positive charge inside the nerve cell. This diminishes the stimulus. To restore the original concentrations of ions between the intracellular and extracellular fluid, the sodium-potassium pump transfers sodium ions out in exchange for potassium ions in. On completion of the restored ion concentrations, a nerve cell is now ready to receive the next impulse. Similarly, in muscle cells, potassium is involved in restoring the normal membrane potential and ending the muscle contraction. Potassium also is involved in protein synthesis, energy metabolism, and platelet function, and acts as a buffer in blood, playing a role in acid-base balance.

Imbalances of Potassium

Insufficient potassium levels in the body (**hypokalemia**) can be caused by a low dietary intake of potassium or by high sodium intakes, but more commonly it results from medications that increase water excretion, mainly diuretics. The signs and symptoms of hypokalemia are related to the functions of potassium in nerve cells and consequently skeletal and smooth muscle contraction. The signs and symptoms include muscle weakness and cramps, respiratory distress, and constipation. Severe potassium depletion can cause the heart to have abnormal contractions and can even be fatal. High levels of potassium in the blood, or **hyperkalemia**, is toxic and also affects the heart. It is a silent condition as it often displays no signs or symptoms. Extremely high levels of potassium in the blood disrupt the electrical impulses that stimulate the heart and can cause the heart to stop. Hyperkalemia is usually the result of kidney dysfunction.

Groups at risk of developing hypokalemia are individuals with renal and large intestine issues such as urine and diarrhea losses; people with uncontrolled diabetes which causes diabetic acidosis and urine losses; dehydration; prolonged diarrhea or emesis; and, certain drugs like diuretics, steroids or laxatives. These deficiencies are due to excessive loss and not a dietary deficiency.

Needs and Dietary Sources of Potassium

The IOM based their AIs for potassium on the levels associated with a decrease in blood pressure, a reduction in salt sensitivity, and a minimal risk of kidney stones. For adult male and females above the age of nineteen, the adequate intake for potassium is 4.7 grams per day. The AIs for other age groups are listed in Table 11.5.6.

Table 11.5.6: Adequate Intakes for Potassium

Age Group	g/day
Infants (0–6 months)	0.4
Infants (6–12 months)	0.7
Children (1–3 years)	3.0
Children (4–8 years)	3.8
Children (9–13 years)	4.5
Adolescents (14–18 years)	4.7
Adults (> 19 years)	4.7

Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Food Sources for Potassium

Fruits and vegetables that contain high amounts of potassium are spinach, lettuce, broccoli, peas, tomatoes, potatoes, bananas, apples, and apricots. Whole grains and seeds, certain fish (such as salmon, cod, and flounder), and meats are also high in potassium. The Dietary Approaches to Stop Hypertension (DASH diet) emphasizes potassium-rich foods and will be discussed in greater detail in the next section.

Video 11.5.4: High Potassium Foods

This slideshow pictures foods high in potassium, with its percentage of the Recommended Daily Allowance.(click to see video)

Bioavailability

Greater than 90 percent of dietary potassium is absorbed in the small intestine. Although highly bioavailable, potassium is a very soluble mineral and easily lost during cooking and processing of foods. Fresh and frozen foods are better sources of potassium than canned.

Key Takeaways

- The maintenance of water volume between fluid compartments is achieved by keeping the concentration of all dissolved substances between the compartments the same.
- Individual solutes are at different concentrations between fluid compartments, providing a mechanism by which to control water movement.
- Sodium is the primary regulator of water balance and plays important roles in nerve transmission, muscle contraction, and nutrient absorption and reabsorption.
- Most sodium in the typical American diet comes from processed and prepared foods.
- Chloride aids in fluid balance by helping to maintain charge neutrality. Chloride channels also play a role in regulating fluid secretion, such as the flow of pancreatic juice into the small intestine and the flow of water into mucus.
- Potassium is the most abundant positively charged ion inside of cells, and similar to sodium, potassium levels in the blood are under strict regulatory control. Potassium is the exchanged cation for sodium and helps maintain fluid balance.

Discussion Starters

1. Why might high sodium intake cause depletion of potassium in the body?
2. Read the following article from *ScienceDaily* and discuss why salt is so prevalent in the diet.

   http://www.sciencedaily.com/releases/2009/03/090310152329.htm

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10.6: Consequences of Deficiency or Excess

Learning Objectives

- Summarize the following fluid and electrolyte imbalance disorders: dehydration, water intoxication, heat stroke, and hypertension.
- Describe the DASH diet and state its benefits.

As with all nutrients, having too much or too little water has health consequences. Excessive water intake can dilute the levels of critical electrolytes in the blood. Water intoxication is rare, however, when it does happen, it can be deadly. On the other hand, having too little water in the body is common. In fact, diarrhea-induced dehydration is the number-one cause of early-childhood death worldwide. In this section, we will discuss subtle changes in electrolytes that compromise health on a chronic basis.

High-Hydration Status: Water Intoxication/Hyponatremia

Water intoxication mainly affects athletes who over hydrate. Water intoxication is extremely rare, primarily because healthy kidneys are capable of excreting up to one liter of excess water per hour. Over hydration was unfortunately demonstrated in 2007 by Jennifer Strange, who drank six liters of water in three hours while competing in a “Hold Your Wee for a Wii” radio contest. Afterward, she complained of a headache, vomited, and died.

Low-Hydration Status: Dehydration

Dehydration refers to water loss from the body without adequate replacement. It can result from either water loss or electrolyte imbalance, or, most commonly, both. Dehydration can be caused by prolonged physical activity without adequate water intake, heat exposure, excessive weight loss, vomiting, diarrhea, blood loss, infectious diseases, malnutrition, electrolyte imbalances, and very high glucose levels. Physiologically, dehydration decreases blood volume. The water in cells moves into the blood to compensate for the low blood volume, and cells shrink. Signs and symptoms of dehydration include thirst, dizziness, fainting, headaches, lack of concentration, low blood pressure, fatigue, low (dark color urine) to no urine output, inability to regulate body temperature, weakness and lethargy, and, in extreme cases, loss of consciousness and death. Signs and symptoms are usually noticeable after about 2 percent of total body water is lost.

Caffeine and alcohol consumption can increase urinary output. If the output is not matched by input, then the person can become dehydrated.

Chronic dehydration is linked to higher incidences of some diseases. There is strong evidence that low-hydration status increases the risk for kidney stones and exercise-induced asthma. There is also some scientific evidence that chronic dehydration increases the risk for kidney disease, heart disease, and the development of hyperglycemia in people with diabetes. Older people often suffer from chronic dehydration as their thirst mechanism is no longer as sensitive as it used to be.



Figure 11.6.1: Older people need to guard against dehydration by taking steps to drink more, especially when exercising. © Shutterstock

Heat Stroke

Heat stroke is a life-threatening condition that occurs when the body temperature is greater than 105.1°F (40.6°C). It is the result of the body being unable to sufficiently cool itself by thermoregulatory mechanisms. Dehydration is a primary cause of heat stroke as there are not enough fluids in the body to maintain adequate sweat production, and cooling of the body is impaired. Signs and symptoms are dry skin (absence of sweating), dizziness, trouble breathing, rapid pulse, confusion, agitation, seizures, coma, and possibly death. Dehydration may be preceded by heat exhaustion, which is characterized by heavy sweating, rapid breathing, and fast pulse. The elderly, infants, and athletes are the most at risk for heat stroke.

Hypertension

Blood pressure is the force of moving blood against arterial walls. It is reported as the systolic pressure over the diastolic pressure, which is the greatest and least pressure on an artery that occurs with each heartbeat. The force of blood against an artery is measured with a device called a sphygmomanometer. The results are recorded in millimeters of mercury, or mmHg. A desirable blood pressure ranges between 90/60 and 120/80 mmHg. Hypertension is the scientific term for high blood pressure and defined as a sustained blood pressure of 140/90 mmHg or greater. Hypertension is a risk factor for cardiovascular disease, and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke. The Centers for Disease Control and Prevention (CDC) reported that in 2007–2008 approximately 33 percent of Americans were hypertensive.Centers for Disease Control and Prevention. “FastStats—Hypertension.” Accessed October 2, 2011. http://www.cdc.gov/nchs/fastats/hyprtens.htm. The percentage of people with hypertension increases to over 60 percent in people over the age of sixty.

Risk factors for hypertension include obesity, cardiovascular disease, age, heredity or genetics, race, BMI over 30, type 2 diabetes, and salt sensitivity. About 30-50% of people with hypertension are sensitive to salt.



Figure 11.6.2: *Blood pressure is measured with a cuff, also known as a sphygmomanometer, that measures blood pressure in millimeters of mercury, or mmHg. © Shutterstock*

There has been much debate about the role sodium plays in hypertension. In the latter 1980s and early 1990s the largest epidemiological study evaluating the relationship of dietary sodium intake with blood pressure, called INTERSALT, was completed and then went through further analyses.Intersalt Cooperative Research Group. “Intersalt: An International Study of Electrolyte Excretion and Blood Pressure. Results for 24 Hour Urinary Sodium and Potassium Excretion.” *BMJ* 297, no. 6644 (1988): 319–28. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1834069/.' Elliott, P. et al. “Intersalt Revisited: Further Analyses of 24 Hour Sodium Excretion and Blood Pressure within and across Populations.” *BMJ* 312, no. 7041 (1996): 1249–53. http://www.ncbi.nlm.nih.gov/pubmed/8634612. More than ten thousand men and women from thirty-two countries participated in the study. The study concluded that a higher sodium intake is linked to an increase in blood pressure. A more recent study, involving over twelve thousand US citizens, concluded that a higher sodium-to-potassium intake is linked to higher cardiovascular mortality and all-causes mortality.Yang Q. et al. “Sodium and Potassium Intake and Mortality among US Adults: Prospective Data from the Third National Health and Nutrition Examination Survey.” *Arch Intern Med* 171, no. 13 (2011): 1183–91. doi:

10.1001/archinternmed.2011.257. The DASH-Sodium trial was a clinical trial which evaluated the effects of a specified eating plan with or without reduced sodium intake. The DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. (To find out more about the DASH eating plan see "Interactive 11.6.1. In this study, people on the low-sodium (1500 milligrams per day) DASH diet had mean systolic blood pressures that were 7.1 mmHg lower than people without hypertension not on the DASH diet. The effect on blood pressure was greatest in participants with hypertension at the beginning of the study who followed the DASH diet. Their systolic blood pressures were, on average, 11.5 mmHg lower than participants with hypertension on the control diet.Sacks, F. M. et al. “Effects on Blood Pressure of Reduced Dietary Sodium and the Dietary Approaches to Stop Hypertension (DASH) Diet.” *N Engl J Med* 344, no. 1 (2001): 3–10. http://www.ncbi.nlm.nih.gov/pubmed/11136953. Following the DASH diet not only reduces sodium intake, but also increases potassium, calcium, and magnesium intake. All of these electrolytes have a positive effect on blood pressure, although the mechanisms by which they reduce blood pressure are largely unknown.

While some other large studies have demonstrated little or no significant relationship between sodium intake and blood pressure, the weight of scientific evidence demonstrating low-sodium diets as effective preventative and treatment measures against hypertension led the US government to pass a focus on salt within the Consolidated Appropriations Act of 2008. A part of this act tasked the CDC, under guidance from the IOM, to make recommendations for Americans to reduce dietary sodium intake. This task is ongoing and involves “studying government approaches (regulatory and legislative actions), food supply approaches (new product development, food reformulation), and information/education strategies for the public and professionals.”Jane E. Henney, Christine L. Taylor, and Caitlin S. Boon, eds., *Strategies to Reduce Sodium Intake in the United States*, by Committee on Strategies to Reduce Sodium Intake, Institute of Medicine (Washington, D.C.: National Academies Press, 2010): 19. http://www.nap.edu/openbook.php?record_id=12818&page= 19#p2001bcf59960019001.

Dietary recommendations to lower blood pressure are as follows. The DASH diet and MyPlate are two diets that meet these recommendations.

- decrease sodium intake
- exercise and lose weight if overweight
- limit consumption of alcohol (one to two drinks per day)
- increase your intake of calcium, potassium, magnesium and vitamin C

Interactive

The National Heart, Lung, and Blood Institute has prepared an informative fact sheet on the DASH diet.

http://www.nhlbi.nih.gov/health/public/heart/hbp/dash/new_dash.pdf.

Use the food group charts to help design a daily menu that follows the DASH eating plan.

Salt Sensitivity

High dietary intake of sodium is one risk factor for hypertension and contributes to high blood pressure in many people. However, studies have shown that not everyone’s blood pressure is affected by lowering sodium intake. About 10 to 20 percent of the population is considered to be salt-sensitive, meaning their blood pressure is affected by salt intake. Genetics, race, gender, weight, and physical activity level are determinants of salt sensitivity. African Americans, women, and overweight individuals are more salt-sensitive than others. Also, if hypertension runs in a person’s family, that person is more likely to be salt-sensitive. Because reducing dietary salt intake will not work for everyone with hypertension or a risk for developing the condition, there are many opponents of reducing dietary salt intake at the national level. Among such opponents is the Salt Institute, a nonprofit trade organization that states, “No evidence demonstrates that current salt intake levels lead to worse health outcomes such as more heart attacks or higher cardiovascular mortality.”The Salt Institute. “Salt and Health.” © 2011 Salt Institute. Accessed October 2, 2011. www.saltinstitute.org/Issues-in-focus/Food-salt-health.

Key Takeaways

- Dehydration decreases blood volume. Dehydration is a primary cause of heat stroke.
- Chronic dehydration is linked to higher incidences of some diseases.
- Hypertension is a risk factor for cardiovascular disease and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke. Many large studies suggest that high sodium intake is linked to an increase in blood

pressure.

- The Dietary Approaches to Stop Hypertension (DASH)-Sodium trial concluded that sodium intake is effective in decreasing blood pressure.
- About 10 to 20 percent of the population is considered to be salt-sensitive. Genetics, race, gender, body weight and physical activity level are determinants of salt sensitivity.

Discussion Starter

1. Does salt restriction need to be a public policy? Compare it to having a public policy on water intake to prevent dehydration in children during school-sponsored sports events.

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10.7: Water Concerns

Learning Objectives

- List sources of fluid intake.
- Learn to examine beverage labels carefully and determine nutritional adequacy.
- Describe the major shifts in beverage consumption in the United States and identify the potentially related health problems.

At this point, you have learned how critical water is to support human life, how it is distributed and moved in the body, how fluid balance and composition is maintained, and the recommended amount of fluids a person should consume daily. In America, you have a choice of thousands of different beverages. Which should you choose to receive the most health benefit and achieve your recommended fluid intake?



Figure 11.7.1: Out of the thousands of beverage choices, which ones are the best dietary choice?

Reading the Label

Most beverages marketed in the United States have a Nutrition Facts panel and ingredients list, but some, such as coffee (for home consumption), beer, and wine, do not. As with foods, beverages that are nutrient-dense are the better choices, with the exception of plain water, which contains few to no other nutrients. Beverages do not make you full; they satiate your thirst. Therefore, the fewer calories in a beverage the better it is for avoiding weight gain. For an estimate of kilocalories in various beverages (Table 11.7.1).

Table 11.7.1 : Calories in Various Beverages

Beverage	*Serving Size (oz)*	*Kilocalories*
Soda	12.0	124–189
Diet soda	12.0	0–7
Bottled sweet tea	12.0	129–143
Brewed tea (unsweetened)	12.0	4
Orange juice (unsweetened)	12.0	157–168
Apple juice (unsweetened)	12.0	169–175
Tomato/vegetable juice	12.0	80
Cranberry juice cocktail	12.0	205
Whole milk	12.0	220
Nonfat milk	12.0	125
Soy milk	12.0	147–191
Coffee, black	12.0	0–4
Coffee, with cream	12.0	39–43

Beverage	*Serving Size (oz)*	*Kilocalories*
Caffe latte, whole milk	12.0	200
Caffe latte, nonfat milk	12.0	120
Sports drink	12.0	94
Energy drink	12.0	160
Beer	12.0	153
Red wine	5.0	125
White wine	5.0	122
Hard liquor (80 proof)	1.5	96

Source: WebMD.com. “Calories in Drinks and Popular Beverages.” Healthy Weight Neighborhood. © 2012 WebMD, LLC. All rights reserved. http://www.webmd.com/community/healthy-weight-8/calorie-chart.

Beverage Consumption in the United States

According to the Beverage Marketing Corporation, in the United States in 2010 Americans consumed 29,325 millions of gallons of refreshment beverages including soft drinks, coffee, tea, sports drinks, energy drinks, fruit drinks, and bottled water.Beverage Marketing Corporation. “US Liquid Refreshment Beverage Market Increased by 1.2% in 2010, Beverage Marketing Corporation Reports.” Accessed March 17, 2011. http://www.beveragemarketing.com/?section=pressreleases. As in the past, carbonated soft drinks remained the largest category of consumed beverages. In recent decades total caloric consumption has increased in the United States and is largely attributed to increased consumption of snacks and caloric beverages. People between the ages of nineteen and thirty-nine obtain 10 percent of their total energy intake from soft drinks.The Beverage Panel, University of North Carolina, Chapel Hill. “Beverage Intake in the United States.” Accessed October 2, 2011. http://www.cpc.unc.edu/projects/beverage. (Figure 11.7.2). In all age groups, the consumption of total beverages provides, on average, 21 percent of daily caloric intake. This is 7 percent higher than the IOM acceptable caloric intake from beverages. Moreover, the high intakes of soft drinks and sugary beverages displace the intake of more nutrient-dense beverages, such as low-fat milk.

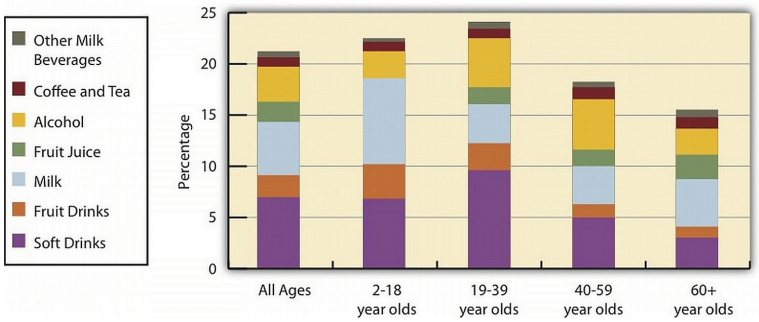


Figure 11.7.2: Percentage of Daily Caloric Intake from Beverage Groups. Source: University of North Carolina, Chapel Hill. US Beverage Guidance Council. “You Are What You Drink, and We Are Drinking Far Too Many Calories from Beverages!” Accessed November 6, 2012. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel/.

Scientific studies have demonstrated that while all beverages are capable of satisfying thirst they do not make you feel full, or satiated. This means that drinking a calorie-containing beverage with a meal only provides more calories, as it won’t be offset by eating less food. The Beverage Panel of the University of North Carolina, Chapel Hill has taken on the challenge of scientifically evaluating the health benefits and risks of beverage groups and providing recommendations for beverage groups (Table 7.7.2). In regards to soft drinks and fruit drinks, The Beverage Panel states that they increase energy intake, are not satiating, and that there is little if any reduction in other foods to compensate for the excess calories. All of these factors contribute to increased energy intake and obesity.Beverage Marketing Corporation. “US Liquid Refreshment Beverage Market Increased by 1.2% in 2010, Beverage Marketing Corporation Reports.” Accessed March 17, 2011. http://www.beveragemarketing.com/?section=pressreleases. The Beverage Panel recommends an even lower intake of calories from beverages than IOM—10 percent or less of total caloric intake.

Table 11.07.2: Recommendations of the Beverage Panel

Beverage	Servings per day*
Water	≥ 4 (women), ≥ 6 (men)
Unsweetened coffee and tea	≤ 8 for tea, ≤ 4 for coffee
Nonfat and low-fat milk; fortified soy drinks	≤ 2
Diet beverages with sugar substitutes	≤ 4
100 percent fruit juices, whole milk, sports drinks	≤ 1
Calorie-rich beverages without nutrients	≤ 1, less if trying to lose weight
*One serving is eight ounces.	

Source: University of North Carolina, Chapel Hill. US Beverage Guidance Council. “Beverage Panel Recommendations and Analysis.” Accessed November 6, 2012. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel.

Sources of Drinking Water

The Beverage Panel recommends that women drink at least 32 ounces and men drink at least 48 ounces of water daily. In 1974, the US federal government enacted The Safe Drinking Water Act with the intention of providing the American public with safe drinking water. This act requires the Environmental Protection Agency (EPA) to set water-quality standards and assure that the 150,000-plus public water systems in the country adhere to the standards. About 15 percent of Americans obtain drinking water from private wells, which are not subject to EPA standards.

Interactive

For more information on the health risks of and the maintenance of private wells visit the EPA website.

http://water.epa.gov/drink/info/well/index.cfm

Producing water safe for drinking involves some or all of the following processes: screening out large objects, removing excess calcium carbonate from hard water sources, flocculation, which adds a precipitating agent to remove solid particles, clarification, sedimentation, filtration, and disinfection These processes aim to remove unhealthy substances and produce high-quality, colorless, odorless, good-tasting water (watch video 11.7.1).



***Video 11.7.1**: The Water Treatment Process. Here is a brief video on how drinking water is treated (click to see video).*

Most drinking water is disinfected by the process of chlorination, which involves adding chlorine compounds to the water. Chlorination is cheap and effective at killing bacteria. However, it is less effective at removing protozoa, such as *Giardia lamblia*. Chlorine-resistant protozoa and viruses are instead removed by extensive filtration methods. In the decades immediately following the implementation of water chlorination and disinfection methods in this country, water-borne illnesses, such as cholera and

typhoid fever, essentially disappeared in the United States (Figure 7.7.2). In fact, the treatment of drinking water is touted as one of the top public-health achievements of the last century.

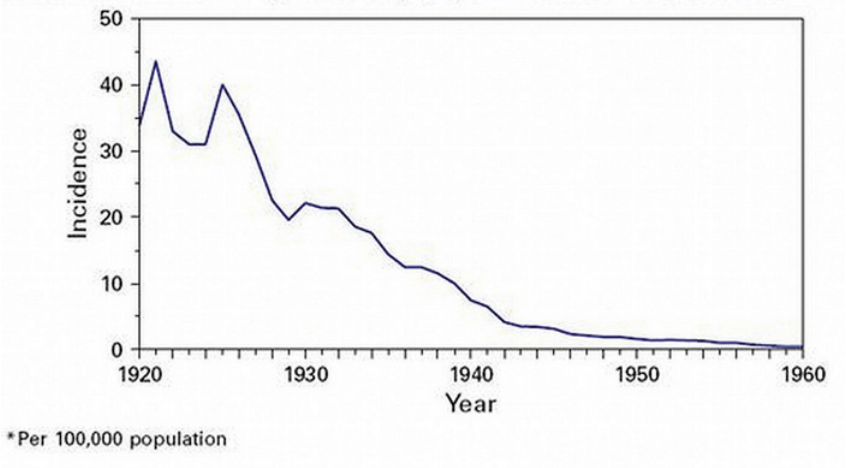


Figure 11.7.3: *Deadly water-borne illnesses decreased to almost nonexistent levels in the United States after the implementation of water disinfection methods. Source: Image credit Robert Tauxe. Centers for Disease Control and Prevention. "Drinking Water Week." Reviewed May 17, 2012. http://www.cdc.gov/features/drinkingwater/graph.html.*

Chlorine reaction with inadequately filtered water can result in the formation of potentially harmful substances. Some of these chlorinated compounds, when present at extremely high levels, have been shown to cause cancer in studies conducted in rodents. In addition to many other contaminants, the EPA has set maximum contaminant levels (legal threshold limits) for these chlorinated compounds in water, in order to guard against disease risk. The oversight of public water systems in this country is not perfect and water-borne illnesses are significantly underreported; however, there are far fewer cases of water-borne illnesses than those attributed to foodborne illnesses that have occurred in the recent past.

Interactive

For a full list of contaminants regulated by the EPA view the tables on the EPA website.

http://water.epa.gov/drink/contaminants/index.cfm

Hard versus Soft Water

The characteristics of hard water are attributed to higher concentration of calcium and magnesium salts. Hard water is prevalent in the mountain and central time zones and in the Midwestern United States. Hard water is characterized by a calcium carbonate concentration of at least 60 milligrams per liter. Higher concentrations of cations in hard water make it difficult to get soap to lather and clean effectively. Also, the cations precipitate as salts in pipes, dishes, and industrial equipment and can reduce the palatability of drinking water. The average dietary contribution of calcium and magnesium from water ranges between 5 and 20 percent.World Health Organization. "Hardness in Drinking Water." © 2011. http://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf The World Health Organization states that there is no convincing evidence that consumption of hard water adversely affects human health.World Health Organization. "Hardness in Drinking Water." © 2011. http://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf On the contrary, there is some evidence from observational studies that consuming hard water is inversely associated with the incidence of some chronic diseases, including cardiovascular disease and some cancers, although the studies have not been consistent and often have multiple confounding variables.

Soft water is produced primarily by running water through a resin system which exchanges sodium cations for calcium and magnesium ions. Treating exceptionally hard waters can significantly increase the sodium concentration in drinking water. The practical benefits of soft water are that soap scum no longer makes dishes and bathrooms dingy, clothes are softer, and there is less of a toll on household and industrial equipment. On the other hand, the increased sodium in soft water can make it taste worse and potentially exacerbate health problems such as hypertension, especially in salt-sensitive populations. Soft water can be treated by a

process called “reverse osmosis,” which removes the sodium ions. These filtration systems can be purchased for home use, although their cost is a bit high.

Is Bottled Water a Better than Tap Water?

Bottled water is not regulated by the EPA but by FDA. For bottled water, the FDA adheres to the same quality standards as those set by the EPA for tap water. Therefore, the contaminant levels set by the EPA for tap water are not different for bottled water; although there is much less testing, monitoring, and oversight of bottled water in comparison to tap water. Similar to tap water the source and treatment of bottled water determines its taste and quality. Depending on where you live, tap water can be a dietary source of minerals (such as calcium and magnesium), but remember that food rather than water serves as a more prominent dietary source of these minerals.

Distilled and purified bottled waters have had all minerals removed during processing, but not all bottled waters have had minerals removed. Mineral waters, sparkling waters, and Artesian waters are examples of bottled waters that contain some minerals, but they are more expensive. Tap water in the United States costs, on average, much less than one cent per gallon, while bottled water is upwards of three dollars per gallon. Moreover, bottled water uses more resources and produces more waste in comparison to tap water. Iowa State University reports that in the United States alone, the making of plastic bottles for bottled water consumption uses more than 1.5 million barrels of oil every year, which is more than the fuel required for one hundred thousand cars.Iowa State University. “Bottled Water, Know the Facts.” Accessed October 2, 2011. http://www.extension.iastate.edu/publications/pm1813.pdf.



Figure 11.7.4: The consumption of bottled water in the United States creates a mound of plastic waste. © Shutterstock

See Table 11.07.3 for a list of the definitions of different types of marketed bottled waters. Soda, seltzer, and tonic waters are not considered bottled waters and are classified as soft drinks by the FDA. Recently, flavored and nutrient-added water beverages have arrived on the market and are regulated by the FDA in accordance with the regulation of bottled waters.

Table 11.07.3: Bottled Water Labels and Corresponding Meanings

Label	Meaning
Artesian	Water from a confined aquifer
Mineral	Water containing > 250 ppm total dissolved solids; from protected underground water source (no minerals are added)
Purified	Water treated by distillation, deionization, reverse osmosis or other processes*
Sterile	Meets the definition of purified water*
Spring	Water derived from an underground formation from which water flows naturally to the surface of the earth
*Meets the definition of “purified water” in the United States. Pharmacopeia, 23d Revision, Jan. 1, 1995. It may also be called “demineralized water” or “deionized water.”	
ppm = parts per million	

Label	Meaning
Well	Water from a hole-bored, drilled, or otherwise constructed in the ground which taps the water of an aquifer
Sparkling	Water that replaces (by treatment) natural (contained within source) carbon dioxide levels
*Meets the definition of “purified water” in the United States. Pharmacopeia, 23d Revision, Jan. 1, 1995. It may also be called “demineralized water” or “deionized water.”	
ppm = parts per million	

Source: US Food and Drug Administration. “Bottled Water Regulation and the FDA.” Ask the Regulators. February/March 2002. www.fda.gov/Food/FoodSafety/Product-SpecificInformation/BottledWaterCarbonatedSoftDrinks/ucm077079.htm.

What Is Bisphenol A and Is It a Health Hazard?

Bisphenol A (BPA) is a chemical added to plastics, mostly polycarbonate (which is used to make bottled water containers), and to epoxy resins (which are used to line metal-based containers, such as those used for packaging infant formulas). It has been utilized for these purposes and many others since the 1940s. Most studies evaluating the toxicity of BPA demonstrate it does not cause adverse health effects to humans at the levels it exists in for beverage and food containers. However, in January of 2010, the FDA issued an update on BPA uses in the food industry.US Food and Drug Administration. “Update on Bisphenol A (BPA) for Use in Food Contact Applications.” Last updated March 30, 2012. www.fda.gov/NewsEvents/PublicHealthFocus/ucm197739.htm. This update reports that the FDA, along with the IOM and the National Toxicology Program, “have some concern about the potential effects of BPA on the brain, behavior, and prostate gland in fetuses, infants, and young children.”US Food and Drug Administration. “Update on Bisphenol A (BPA) for Use in Food Contact Applications.” Last updated March 30, 2012. To address these potential health concerns studies are currently being conducted to further evaluate the risk of adverse health effects associated with exposure to low levels of BPA. In the interim, the FDA is taking steps to reduce human exposure to BPA. Many bottled water companies have switched to “BPA-free” plastic containers.

Tools for Change

Make a more sustainable choice and enjoy a glass of water from the tap right in your home.

Save some money, reduce your exposure to BPA, and be more sustainable in your water consumption by drinking more tap water than bottled water. If your tap water has a bad smell or taste, purchase a home water filter. If you still prefer bottled water, do not buy purified water. Also, buy larger volumes of bottled water with less packaging and use a reusable bottle for drinking, or better yet try a water glass from the kitchen cupboard. If you have questions about the safety of your tap water, visit the website of the municipality in which you live. They are required by law to provide this information to the public.

Key Takeaways

- Beverages do not make you full rather, they satiate your thirst. Therefore, the fewer calories in a beverage, the better it is for avoiding weight gain.
- In all age groups, the consumption of total beverages provides, on average, 21 percent of daily caloric intake. This is 7 percent higher than the IOM acceptable caloric intake from beverages and 11 percent higher than that recommended by The Beverage Panel.
- In 1974, the US federal government enacted The Safe Drinking Water Act in order to help provide the American public with safe drinking water.
- In the decades immediately following the implementation of water chlorination and disinfection methods, water-borne illnesses, such as cholera and typhoid fever, essentially disappeared in the United States. In fact, the treatment of drinking water is touted as one of the top public-health achievements of the last century.
- There is some evidence from observational studies that consuming hard water is inversely associated with the incidence of some chronic diseases, including cardiovascular disease and some cancers.
- Bottled water is not regulated by the EPA but by the FDA. The contaminant levels set by the EPA for tap water are not different for bottled water, but there is much less testing, monitoring, and oversight of bottled water in comparison to tap water.

Discussion Starters

1. What is your favorite bottled water? Look up its source and treatment and compare your information with others in your class.

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10.E: Water, Electrolytes, Acid-Base Balance (Exercises)

It's Your Turn

1. Make a flow chart of the physiological events that trigger thirst.
2. Calculate your sodium intake in a day. Is it lower, average, or higher than the recommended intake?
3. Tear the labels off of, or bring in the whole can or bottle of, your favorite beverages. Make a chart of the fluid amount, calories, and nutrients in each beverage.
4. Determine how much caffeine you consume each day and its sources (use Table 7.12 to help you). Then, rank your consumption levels based on the guidelines provided in this chapter.

Apply It

1. Make a list of ten things you do that use water and then another of ten things the body does with water.
2. Calculate your daily sodium intake for a week. Is your daily intake lower, average, or higher than the recommended intake? How does it vary during the week?
3. Perform an experiment in class by conducting a taste-test of tap water and bottled waters. Make a chart of the results.

Expand Your Knowledge

1. Diagram two physiological mechanisms that regulate water output.
2. Read this article and summarize in a paragraph if it is or is not the time to "end the war on salt." (http://www.scientificamerican.com/article.cfm?id=its-time-to-end-the-war-on-salt). Can you find a reference that disputes the conclusions of this article?
3. Visit the website of The Beverage Panel and review how they used the knowledge of health and nutrition to set recommendations for particular beverages (http://www.cpc.unc.edu/projects/beverage/panel_recommendations).

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CHAPTER OVERVIEW

11: Nutrients Involved in Hematopoietic System

In this chapter 10, we look at the nutrients important in energy metabolism and blood health, by first looking at blood and at metabolism, and then discussing the B vitamins, vitamin K, magnesium, iron, zinc, and other micronutrients. We also explore iron-deficient anemia and iron toxicity.

11.1: Chapter Introduction

11.2: Blood's Function in the Body and in Metabolism Support

11.3: Vitamins Important for Metabolism and for Blood Function and Renewal

11.4: Minerals Important for Blood Function and Renewal

11.5: Iron-Deficiency Anemia

11.E: Exercises

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11.1: Chapter Introduction

Big Idea

Micronutrients come from many sources and some may surprise you; get them in the right amounts to support metabolism and blood health.

Video 10.1.1

How to Get Iron into Your Diet

(click to see video)

View this video for simple steps you can take to obtain and maintain healthy iron levels in your body.



Figure 10.1.1: Mmm, cornbread cooked in a cast iron skillet—the smell and taste of cooking on the range. Can this also be an iron-friendly meal? © Shutterstock

In a small town in the Appalachian Mountains, Joseph Lodge founded Lodge Iron Cookware in 1896. Today it is still a family-run business that provides Americans with pioneer-style iron cookware. Iron cookware was and still is, prized for its heat retention, even heating, and durability. In fact, many pans sold one hundred years ago are still in use today. Unbeknownst to the American pioneers, the cookware also leaches iron, an essential mineral, into foods as they are cooked in cast-iron hardware.

Iron has several vital functions in the body. Primarily it is the oxygen carrier of the protein hemoglobin, which is found in red blood cells. Oxygen is essential for cellular metabolism. A reduction in the oxygen-carrying capacity of red blood cells hampers the synthesis of energy and consequently cell function. Additionally, iron is required for energy production and enzymatic synthesis of RNA and DNA. Therefore cells that are rapidly dividing are acutely sensitive to an iron deficiency. Since red blood cells are under a constant state of renewal in the body, low iron levels impede their synthesis, eventually causing anemia. A person with anemia experiences fatigue, shortness of breath, dizziness, muscle weakness, and pale skin. In infants and children, iron-deficiency anemia can impair growth, motor control, mental functioning, behavior, and performance in school. Iron deficiency is the number one nutritional deficiency in the world, and even in America, it affects 10 percent of women of childbearing age and many infants, children, and adolescents.

Dietary sources of iron include red meats, poultry, leafy green vegetables, prunes, raisins, egg yolks, lentils, oysters, clams, artichokes, and enriched cereal grains. While there are many food sources of iron, only a small fraction of dietary iron is absorbed. One method of increasing dietary intake of iron is cooking foods in an iron skillet. Acidic foods high in moisture content, such as tomatoes, absorb more iron during cooking than nonacidic foods. For example, cooking spaghetti sauce in iron cookware can increase the iron content ten-fold. How much iron leaches into food is also dependent on cooking times; the longer food is in the pan the more iron is absorbed into the food. Stirring food more often increases contact time and thus more iron is absorbed from the cookware. The utility of iron cookware in increasing dietary intake of iron has prompted some international public health organizations to distribute iron cookware to high-risk populations in developing countries as a strategy to reduce the prevalence of iron-deficiency anemia worldwide.

You Decide

What are the different ways to build iron storehouses in your body without taking a pill?

In this chapter, we will discuss the importance of blood and its vital role in support of metabolism and pull together what we have learned about macronutrient metabolism. You will also learn the important roles micronutrients have in metabolism and how they support blood function and renewal. We will also consider food sources of these valuable nutrients. Read the facts, then decide the best way to supplement your diet with iron friendly eating and cooking.

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11.2: Blood's Function in the Body and in Metabolism Support

Learning Objectives

- List each component of blood and its major role.

You know you cannot live without blood, and that your heart pumps your blood over a vast network of veins and arteries within your body, carrying oxygen to your cells. However, beyond these basic facts, what do you know about your blood?

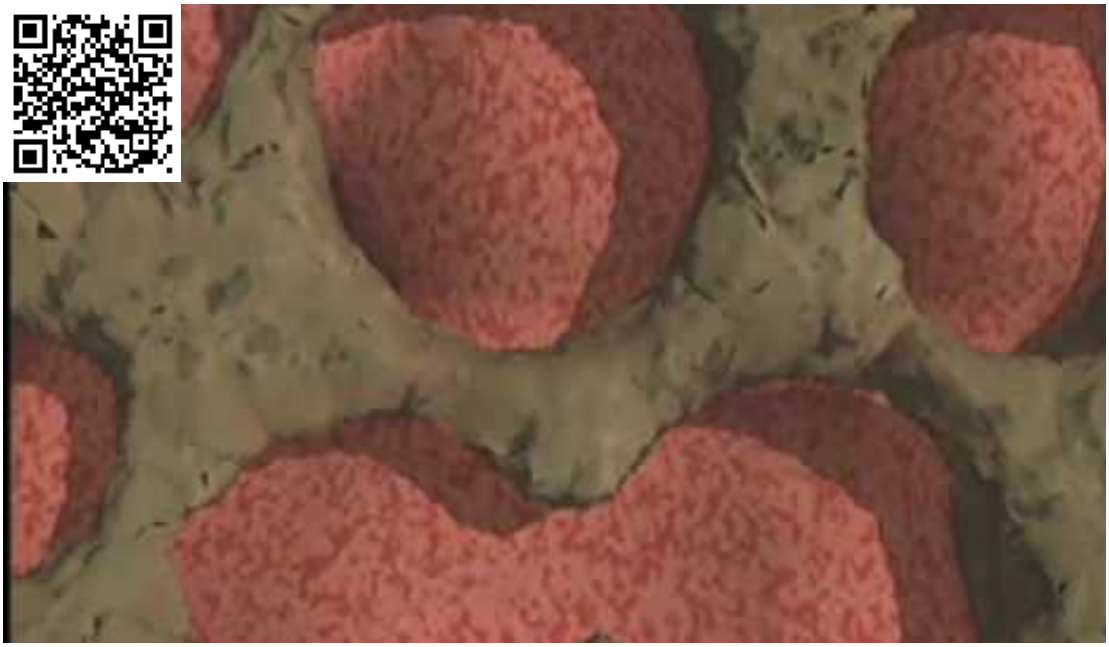
Blood is a connective tissue of the circulatory system, transporting absorbed nutrients to cells like O_2, glucose, and amino acids, and waste products from cells like CO_2 and urea. It supports cellular metabolism by transporting synthesized macromolecules and waste products. Additionally, it transports molecules, such as hormones, allowing for communication between organs. The volume of blood coursing throughout an adult human body is about 5 liters (1.3 gallons) and accounts for approximately 8 percent of human body weight.

What Makes Up Blood and How Do These Substances Support Blood Function?

Blood is about 78 percent water and 22 percent solids by volume. The liquid part of blood is called plasma and it is mostly water (95 percent), but also contains proteins such as albumin and lipoproteins, ions, glucose, amino acids, lipids, vitamins, minerals, waste products like ammonia and urea, gases, enzymes, and hormones. You learned in Chapter 5 that the protein albumin is found in high concentrations in the blood. Albumin helps maintain the fluid balance between blood and tissues, as well as helping to maintain a constant blood pH. In Chapter 11 you will learn that the water component of blood is essential for its actions as a transport vehicle and that the electrolytes carried in blood maintain fluid balance and a constant pH. Furthermore, the high water content of blood helps maintain body temperature, and the constant flow of blood distributes heat throughout the body. Blood is exceptionally good at temperature control, so much so that the many small blood vessels in your nose are capable of warming frigid air to body temperature before it reaches the lungs.

The cellular components of blood include red blood cells, white blood cells, and platelets. Red blood cells are the most numerous of the components. Each drop of blood contains millions of them. Red blood cells are red because they each contain approximately 270 million hemoglobin proteins, which contain the mineral iron, which when bound to oxygen turns red. The most vital duty of red blood cells is to transport oxygen from the lungs to all cells in the body so that they can make energy via aerobic metabolism. The white blood cells that circulate in blood are part of the immune system and they survey the entire body looking for foreign invaders to destroy. They make up about 1 percent of blood volume. Platelets are fragments of cells that are always circulating in the blood in case of an emergency. When blood vessels are injured platelets rush to the site of injury to plug the wound. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow. Red blood cells live for about 120 days, white blood cells live anywhere from eighteen hours to one year, or even longer, and platelets have a lifespan of about ten days.

Bone marrow is the place where many blood cells develop prior to entering the circulatory system.



***Video 10.2.1**: What Is Blood? Watch this brief animation on the importance of blood components (click to see video).*

Nutrients In

Once absorbed from the small intestine, all nutrients require transport to cells in need of their support. Additionally, molecules manufactured in other cells sometimes require delivery to other organ systems. Blood is the conduit and blood vessels are the highways that support nutrient and molecule

transport to all cells. Water-soluble molecules, such as some vitamins, minerals, sugars, and many proteins, move independently in blood. Fat-soluble vitamins, triglycerides, cholesterol, and other lipids are packaged into lipoproteins that allow for transport in the watery milieu of blood. Many proteins, drugs, and hormones are dependent on transport carriers, primarily albumin. In addition to transporting all of these molecules, blood must transfer the oxygen breathed in by the lungs to all cells in the body. As discussed, the iron-containing hemoglobin molecule in red blood cells accomplishes this.

Wastes Out

In the metabolism of macronutrients to energy, cells produce the waste products carbon dioxide and water. As blood travels through smaller and smaller vessels, the rate of blood flow is dramatically reduced allowing for the efficient exchange of nutrients and oxygen for cellular waste products. The kidneys remove any excess water in the blood, and blood delivers the carbon dioxide to the lungs where it is exhaled. Also, the liver produces the waste product urea from the breakdown of amino acids and detoxifies many harmful substances, all of which require transport in the blood to the kidneys for excretion.

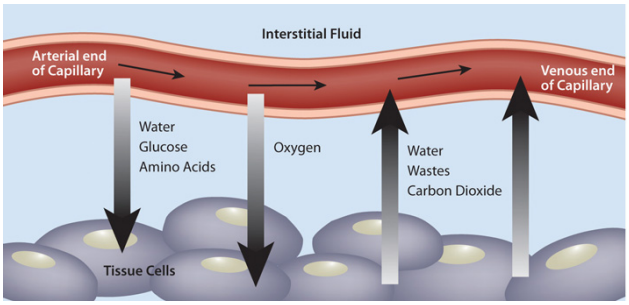


Figure 10.2.2: The Capillary Exchange: Nutrients In and Wastes Out

All for One, One for All

We are not going to talk about the three musketeers, but we will talk about the way our bodies function and work harmoniously to sustain life. The eleven organ systems in the body completely depend on each other for continued survival as a complex organism. Blood allows for transport of nutrients, wastes, water, and heat, and is also a conduit of communication between organ systems. Blood's importance to the rest of the body is aptly presented in its role in glucose delivery, especially to the brain. The brain metabolizes, on average, 6 grams of glucose per hour. In order to avert confusion, coma, and death, glucose must be readily available to the brain at all times. To accomplish this task, cells in the pancreas sense glucose levels in the blood. If glucose levels are low, the hormone glucagon is released into the blood and is transported to the liver where it communicates the signal to ramp-up glycogen breakdown and glucose synthesis. The liver does just that, and glucose is released into the blood, which transports it to the brain. Concurrently, blood transports oxygen to support the metabolism of glucose to energy in the brain. Healthy blood conducts its duties rapidly, avoiding hypoglycemic coma and death. This is just one example of the body's survival mechanisms exemplifying life's mantra, "All for one, one for all."

What Makes Blood Healthy?

Maintaining healthy blood, including its continuous renewal, is essential to support its vast array of vital functions. Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes. As with all other tissues, blood needs macro- and micronutrients to optimally function. In the bone marrow, where blood cells are made, amino acids are required to build the massive amount of hemoglobin packed within every red blood cell, along with all other enzymes and cellular organelles contained in each blood cell. Red blood cells, similar to the brain, use only glucose as fuel, and it must be in constant supply to support red-blood-cell metabolism. As with all other cells, the cells in the blood are surrounded by a plasma membrane, which is composed primarily of lipids. Blood health is also acutely sensitive to deficiencies in some vitamins and minerals more than others, a topic that will be explored in this chapter.

What Can Blood Tests Tell You About Your Health?

Since blood is the conduit of metabolic products and wastes, measuring the components of blood, and particular substances in the blood can reveal not only the health of blood, but also the health of other organ systems. In standard blood tests performed during an annual physical, the typical blood tests conducted can tell your physician about the functioning of a particular organ or about disease risk.

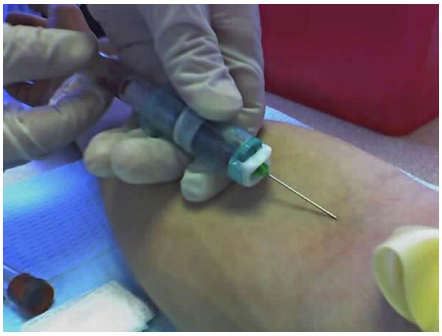


Figure 10.2.3: Blood tests are helpful tools in diagnosing disease and provide much information on overall health.Venipuncture using a vacutainer. from Wikipedia.

A biomarker is defined as a measurable molecule or trait that is connected with a specific disease or health condition. The concentrations of biomarkers in blood are indicative of disease risk. Some biomarkers are cholesterol, triglycerides, glucose, and prostate-specific antigen. The results of a blood test give the concentrations of substances in a person's blood and display the normal ranges for a certain population group. Many factors, such as physical activity level, diet, alcohol intake, and medicine intake can influence a person's blood test levels and cause them to fall outside the normal range, so results of blood tests outside the "normal" range are not always indicative of health problems. The assessment of multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status. See Table 10.1 for a partial list of substances measured in a typical blood test. This table notes only a few of the things that their levels tell us about health.

Table 10.1.1: Blood Tests

Substance Measured	Indicates
Red-blood-cell count	Oxygen-carrying capacity
Hematocrit (red-blood-cell volume)	Anemia risk
White-blood-cell count	Presence of infection
Platelet count	Bleeding disorders, atherosclerosis risk
pH	Metabolic, kidney, respiratory abnormalities
Albumin	Liver, kidney, and Crohn's disease, dehydration
Bilirubin	Liver-function abnormality
Oxygen/Carbon Dioxide	Respiratory or metabolic abnormality
Hemoglobin	Oxygen-carrying capacity
Iron	Anemia risk
Magnesium	Magnesium deficiency
Electrolytes (calcium, chloride, magnesium, potassium)	Many illnesses (kidney, metabolic, etc.)
Cholesterol	Cardiovascular disease risk
Triglycerides	Cardiovascular disease risk
Glucose	Diabetes risk
Hormones	Many illnesses (diabetes, reproductive abnormalities)

Source: National Heart Lung and Blood Institute. "Types of Blood Tests." January 6, 2012. http://www.nhlbi.nih.gov/health/health-topics/topics/bdt/types.html.

Interactive 10.1.1

Visit the websites of the National Heart, Lung, and Blood Institute and Lab Tests Online to find out more on what to expect on blood tests and how to interpret results.

http://www.nhlbi.nih.gov/health/dci/Diseases/bdt/bdt_whatdo.html

http://labtestsonline.org/

Key Takeaways

- Blood is a connective tissue of the circulatory system and the fluid in the body that transports absorbed nutrients to cells and waste products from cells.
- The fluid part of blood, plasma, makes up the largest amount of blood volume and contains proteins, ions, glucose, lipids, vitamins, minerals, waste products, gases, enzymes, and hormones. The cellular components of blood include red blood cells, white blood cells, and platelets. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow.
- As blood travels through smaller and smaller vessels the rate of blood flow is dramatically reduced, allowing for the efficient exchange of nutrients and oxygen for cellular waste products.
- Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes.
- The assessment of multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status.

Discussion Starters

1. Why does the heart pump blood at a faster rate during exercise?
2. Come up with an estimate on how often it is safe to donate blood. Get the facts on donating blood by visiting the website of the Red Cross.

   http://www.redcrossblood.org/donating-blood/eligibility-requirements

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11.3: Vitamins Important for Metabolism and for Blood Function and Renewal

Learning Objectives

- Summarize the role of the B vitamins in blood functions.
- Explain how Vitamin K supports a life-saving function of blood.

In addition to being essential for metabolism, many vitamins and minerals are required for blood renewal and function. At insufficient levels in the diet, these vitamins and minerals impair the health of blood and consequently the delivery of nutrients in and wastes out, amongst its many other functions. In this section, we will focus on the vitamins that take part in metabolism and blood function and renewal.

Vitamins: Functions in Blood

Folate (pteroylglutamic acid)

Folate is a water-soluble vitamin and its primary form is tetrahydrofolate (THF). It is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic, also called megaloblastic, anemia. Macrocytic and megaloblastic mean “big cell,” and anemia refers to fewer red blood cells or red blood cells containing less hemoglobin. Macrocytic anemia is characterized by larger immature red blood cells and fewer mature red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size.

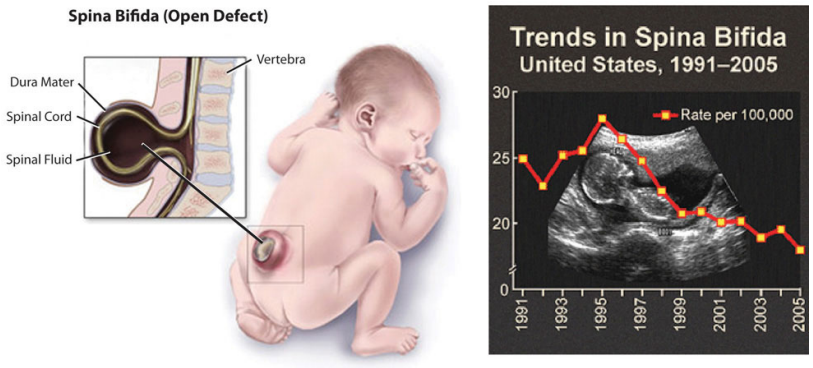


Figure 10.3.1: Spina bifida is a neural-tube defect that can have severe health consequences.

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural tube defect that occurs when the spine does not completely enclose the spinal cord, and anencephalopathy (no brain). Spina bifida can lead to many physical and mental disabilities (Figure 10.3.1). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate (Figure 10.4.3). Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer, however scientific studies refute this hypothesis.

A deficiency in folate can manifest with a variety of different symptoms including mental confusion, headache, glossitis (smooth, red tongue), weakness, fatigue, dyspnea (shortness of breath), and elevated blood levels of homocysteine. Smokers, individuals who consume large amounts of alcohol, oral contraceptive users, pregnant women, infants fed goats' milk, cancer patients receiving some type of chemotherapy, antibiotic users, and chronic consumers of aspirin and antacids are at risk of developing a folate deficiency. Folate can mask a vitamin B_{12} deficiency.

See Table 10.3.1 for a list of foods rich in folate. Folate is easily destroyed by heat and air, so one should be careful when cooking folate-rich foods. Fresh is best.

Cobalamin (B_{12})

Vitamin B12 or cobalamin is water-soluble and the biggest vitamin by weight and size. Cobalamin contains cobalt, making it the only vitamin that contains a metal ion. Cobalamin is an essential part of coenzymes. It is necessary for the maintenance of nerve cells, energy metabolism, hormone production, fat and protein catabolism, for folate coenzyme function (removes methyl group), and for hemoglobin synthesis. An enzyme requiring cobalamin is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in cobalamin has similar consequences to health as folate deficiency. In children and adults cobalamin deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers, there is an increased risk of neural tube defects.

In order for the human body to absorb cobalamin, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for cobalamin absorption, which occurs in the small intestine (illeum). Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Only a small amount of vitamin B_{12} is absorbed passively without the intrinsic factor complex. Pernicious anemia is treated with large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the bloodstream without passing through the intestine. In patients that do not respond to oral or sublingual treatment, vitamin B_{12} is given by injection.

People with stomach dysfunction, vegans and people with bariatric surgery or ileum problems are at risk of developing a vitamin B_{12} deficiency. It can take up to 20 years for the deficiency to manifest if your dietary intake is inadequate but only 3 to 7 years if you are missing intrinsic factor. Dietary folate can disguise a vitamin B_{12} deficiency until irreversible neurological problems develop.

A summary of the prominent functions of the folate and vitamin B_{12} their deficiency syndromes is given in Table 10.3.1.

Table 10.3.1: Vitamin Functions in Blood, and Deficiency Syndromes

B Vitamin	Function	Deficiency: Signs and Symptoms
Folate	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural tube defects
B_{12} (cobalamin)	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural tube defects

Interactive 10.3.1

The USDA has an interactive database of nutrient contents in food. To view reports of single nutrients simply click on the one you are interested in and view the report. http://www.ars.usda.gov/Services/docs.htm?docid=20958

Dietary Sources Rich in Folate and Vitamin B_{12}

To assist you in getting all the folate you need to support blood cell synthesis look over Table 10.3.2 for good dietary sources of these micronutrients. Fifty to ninety percent of folate in foods can be destroyed by food processing and preparation, unltraviolet light, and oxidation.

Vitamin B_{12} is produced by the bacteria in your gut and you can find it in fermented foods, nutritional yeast, and soil contaminants. Foods tend to be a secondary source of vitamin B_{12} with gut microbes being the primary source. A list of foods considered good sources of vitamin B_{12} are shown in Table 10.3.3.

Table 10.3.2: Dietary Sources of Folate

Food	Micrograms per Serving	Percent Daily Value
Liver	185 (3 oz.)	45
Calf liver	650 (3 oz.)	160

Food	Micrograms per Serving	Percent Daily Value
Fortified breakfast cereals	400 (¾ c.)	100
Spinach	100 (½ c., boiled)	25
Northern beans	100 (½ c., boiled)	25
Asparagus	85 (4 spears, boiled)	20
Vegetarian baked beans	60 (1 c.)	15
Broccoli	45 (2 spears)	10
Avocado	45 (½ c.)	10
Bread (enriched)	25 (1 slice)	6

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Folate." Last reviewed April 15, 2009. http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/.

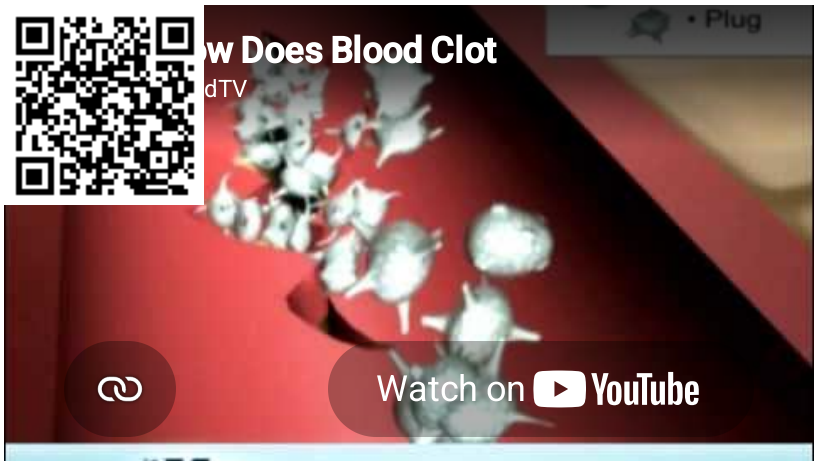
Table 10.3.3: Dietary Sources of Vitamins B_{12}

Food	Micrograms per Serving	Percent Daily Value
Liver	48 (1 slice)	800
Clams	34.2 (3 oz.)	570
Organic calf liver	31 (3 oz.)	520
Fortified breakfast cereals	6.0 (1 serving)	100
Trout (wild)	5.4 (3 oz.)	90
Trout (farmed)	3.5 (3 oz.)	58
Salmon (sockeye)	4.8 (3 oz.)	80
Cheeseburger	2.1	35
Yogurt (plain)	1.4 (1 c.)	23
Beef (top sirloin)	1.4 (3 oz.)	23
Milk	0.9 (1 c.)	15
Egg	0.6 (1 large)	10

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin B_{12}." Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/.

Vitamin K: Functions in Blood

Vitamin K is a fat-soluble vitamin that is critical for the formation of the blood clotting factors, thrombin, and fibrin. Blood-clotting proteins are continuously circulating in the blood. Upon injury to a blood vessel, platelets stick to the wound forming a plug. The clotting factors circulating close by responding in a series of protein-protein interactions resulting in the formation of the fibrous protein, fibrin, which reinforces the platelet plug (Video 10.3.2) for an animation of the blood-clotting cascade of events). Vitamin K is also needed for the formation of the bone matrix proteins osteocalcin and matrix Gla.



Video 10.3.1: *How Does Blood Clot? This video gives a brief description of the blood-clotting process (click to see video).*

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins as discussed in the previous chapter. Vitamin K also plays a role in bone mineralization and a deficiency in this vitamin prevents bone mineralization. People who have fat malabsorption, some infants at birth, and people taking a large amount of non-absorbable antibiotics for a long time are at risk of developing a deficiency.

The rat poison, Warfarin, blocks blood clotting by inhibiting vitamin K. It is used to treat strokes and heart attacks. If one's vitamin K intake is high, this reduces the effectiveness of these drugs. Fluorescent light and sunlight destroy vitamin K.

Dietary Reference Intakes and Sources of Vitamin K

The RDA for vitamin K for adult males is 120 mcg/day and for adult females is 90 mcg/day. Vitamin K is present in many foods and most highly concentrated in green leafy vegetables. See Table 10.3.4 for a list of dietary sources of vitamin K. Bacteria in our large intestine synthesize vitamin K.

Table 10.3.4: Dietary Sources of Vitamin K

Food	Micrograms per Serving	Percent Daily Value
Broccoli (½ c.)	160.0	133
Asparagus (4 spears)	34.0	28
Cabbage (½ c.)	56.0	47
Spinach (½ c.)	27.0	23
Green peas (½ c.)	16.0	13
Cheese (1 oz.)	10.0	8
Ham (3 oz.)	13.0	11
Ground beef (3 oz.)	6.0	5
Bread	1.1	<1
Orange	1.3	1

Key Takeaways

- The water-soluble B vitamins are involved as coenzymes in the breakdown of nutrients and in the building of macromolecules, such as protein, RNA, and DNA.

- B-vitamin deficiencies are relatively rare especially in developed countries; although the health consequences can be severe as with folate deficiency during pregnancy and the increased risk of neural-tube defects in offspring.
- Vitamin K is necessary for blood clotting.

Discussion Starters

1. Discuss how the actions of B vitamins are interdependent; meaning the level of one affects the function of another.
2. Have a classroom debate on whether it is prudent for the federal government to regulate claims on micronutrient supplements, such as those containing B vitamins.

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11.4: Minerals Important for Blood Function and Renewal

Learning Objectives

- List the primary function of each of the minerals involved in metabolism.
- Summarize the roles of minerals important in blood function and renewal.

In a well-balanced diet, minerals are plentiful, and herbs are power-packed with minerals. Eat more plants, spice up your food, and drink herbal teas to obtain optimum mineral nutrition.



Iron

Iron is a trace mineral that we need small quantities every day. It is slightly water soluble and is a cation that exists in two states, +2 (ferrous) or +3 (ferric). Red blood cells contain the oxygen carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 10.4.2). Eighty percent of the body's iron is bound to hemoglobin. In the muscle, iron is part of the oxygen-binding protein, myoglobin. Iron is a key component of hundreds of metabolic enzymes. Many of the proteins of the electron transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

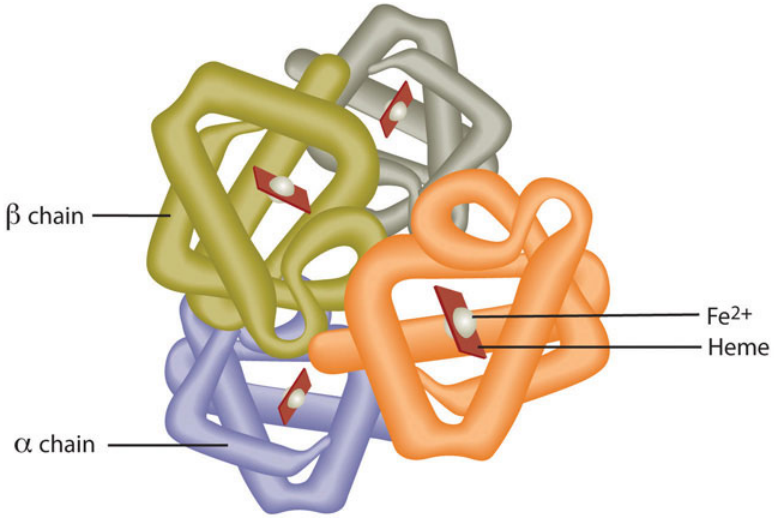


Figure 11.4.1: Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released (see "Video 10.5.1"). If iron levels are low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. Only 2-35% of the iron in your diet is absorbed. Once absorbed, the iron may be incorporated into hemoglobin or myoglobin to transport oxygen, or incorporated into other proteins, or stored in the liver, bone marrow or spleen.

Ferritin is the molecule that stores iron in mucosal cells. When the iron is needed it is released from the ferritin and transported by transferrin to other cells for use. Once in the body, it is difficult to excrete iron but some iron will be lost when mucosal cells of the gut are shedded, a process that occurs about every 3-5 days.

Erythrocytes or RBCs circulate for about 120 days and then they are removed. When blood cells are decommissioned, the liver and spleen degrade the red blood cell and transferrin or recycles the iron back to the liver the bone marrow where red blood cells are made. The heme component is recycled into bile. Hepcidin, a hormone produced by the liver, regulates iron balance by inhibiting its release. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources. Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.



Video 11.4.1***:*** *Oxygen Transport. Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body*.

Dietary iron comes in two forms, as heme iron or as nonheme iron. The bioavailability of iron is highly dependent on dietary sources and the form of iron. In animal-based foods, about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the *American Journal of Clinical Nutrition* reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent and that from vegetarian diets range between 5 and 12 percent.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. Iron deficiency is the most common of all micronutrient deficiencies and will be explored in depth in Section 10.5.

Zinc

Zinc is a trace mineral that is a cation and cofactor for over two hundred enzymes in the human body that play a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. It is important for wound healing, transport of vitamin A, taste perception, growth and development, and cofactor in genetic material and protein (zinc fingers).

As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world’s population has a zinc-deficient diet.Prasad, Ananda. “Zinc deficiency.” BMJ 2003 February 22; 326(7386): 409–410. doi: 10.1136/bmj.326.7386.409. Accessed October 2, 2011. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1125304/?tool=pmcentrez. This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, taste changes, loss of appetite, impaired vision, impaired immune function, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and

severely deficient zinc diets can result in anemia. People at risk of developing a zinc deficiency are people consuming excess iron, copper and/or dietary fiber, people that lack financial access to a nutrient adequate diet, the elderly, pregnant women and children. Zinc is rich in foods high in protein.

Copper

Copper is a trace mineral that is cation and exists in the +1 or +2 state. Like iron, copper assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport, and hemoglobin synthesis. The other important function of copper is an antioxidant, which was also discussed in Chapter 8.

Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves. Groups at risk of developing a copper deficiency are people who consume too much zinc.

Menke's disease is a genetic disorder that causes a copper deficiency. The onset occurs typically during infancy and is characterized by sparse, kinky hair; failure to gain weight and grow at the expected rate (failure to thrive); and deterioration of the nervous system. Often these children do not live past age 3. Early treatment with copper may improve the prognosis in some affected individuals.

Individuals with the rare inherited disease, Wilson's disease, accumulate copper in the liver and brain. Excess copper intake

Table 11.4.1: Mineral Functions in Metabolism and Blood and Deficiency Syndrome

Mineral	Function	Deficiency: Signs and Symptoms
Trace		
Iron	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate
Zinc	Assists in energy production, protein, RNA and DNA synthesis; required for hemoglobin synthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss
Copper	Assists in energy production, iron metabolism, cofactor for enzymes	Anemia: fatigue, paleness, faster heart rate

Dietary Reference Intakes for Minerals and Dietary Sources

The RDA set by the IOM for minerals involved in metabolism are listed for adults in Table 10.4.2 "Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism". The table also lists dietary sources for these micronutrients. The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 11.4.2: Dietary Reference Intakes and Food Sources for Minerals Important for Blood Formation

Mineral	RDA (mg/day)	Food Sources
Trace		
Iron	8 (males)	Heme sources: Animal products such as meat, fish, and poultry Non-heme sources: fortified breakfast cereals, beans (tofu), spinach, peas, dried fruit, whole grains
	18 (females)	
Zinc	11 (males)	Red meat, poultry, seafood, fortified breakfast cereals, beans, nuts, whole grains
* denotes Adequate Intake, **for ages 31–50 only		

Mineral	RDA (mg/day)	Food Sources
Copper	8 (females)	Whole grains, liver, legumes, seeds, cocoa, water if copper pipes
	0.900 (males)	
	0.900 (females)	
* denotes Adequate Intake, **for ages 31–50 only		

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, such as oxalate and phytate, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

Key Takeaways

- Minerals cannot be broken down to release energy.
- Minerals are cofactors for hundreds of enzymes involved in metabolism.
- Iron especially, but also copper and zinc are critical for blood function and renewal.
- Minerals are not as efficiently absorbed as most vitamins and bioavailability can be very low.

Discussion Starters

1. Discuss why "more is not always better," especially how this saying pertains to micronutrient intake.
2. Look up the chemical structure of phytate and explain how it inhibits the absorption of positively charged minerals.

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11.5: Iron-Deficiency Anemia

Learning Objectives

- Discuss why iron-deficiency anemia is the most prevalent nutritional deficiency worldwide, its impacts on human health, and possible solutions to combat it.

Iron-Deficiency Anemia: Signs, Symptoms, and Treatment

Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. Regardless of the cause (be it from low dietary intake of iron or via excessive blood loss), iron-deficiency anemia has the following signs and symptoms, which are linked to the essential functions of iron in energy metabolism and blood health:

- Fatigue
- Weakness
- Pale skin
- Shortness of breath
- Dizziness
- Swollen, sore tongue
- Abnormal heart rate

Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. There are three stages of iron deficiency. The first stage is iron depletion in which iron stores become low, and ferritin levels are reduced. Usually, there are no accompanying signs or symptoms that iron levels are being depleted. In the second stage, iron deficiency erythropoiesis, transferrin levels decrease resulting in reduced iron transport. Production time for heme is reduced. Feelings of a low energy level, reduced capacity to do physical work, slow cognitive function are signs that anemia is developing. In some rare instances, pica may occur which is the appetite for ice, clay, paste, and other non-food items. The last stage is iron deficiency anemia. It is characterized by a low hemoglobin concentration with small (microcytic), pale (hypochromic) RBCs. Symptoms include fatigue upon exertion, weakness, headaches, apathy, pallor, poor resistance to cold temperatures, low physical work capacity, and poor immune function.

Several different blood tests are needed to assess iron status. The clinician must decide if the anemia is the result of an iron deficiency or other nutrients such as folate or vitamin B_{12}. These include the following:

- Serum iron which is poor measure of iron status
- Serum ferritin which indicates storage status and is a good measure of early deficiency
- Transferrin which can provide clues on a progressing deficiency. Total iron-binding capacity and transferrin saturation may be measured
- Hematocrit which is not a good measure of iron status
- Hemoglobin which is late indicator of iron deficiency
- Erythrocyte protoporphyrin which measures the non-heme, non-complexed protoporphyrin in blood. Used to measure if blood has too little iron or too much lead.
- Mean cell volume (MCV) measures the average size of the RBC. Several anemias have smaller RBC.
- Mean corpuscular Hb concentration (MCHC)
- Liver and bone marrow biopsies - very invasive and rarely done to assess iron status.

Several different groups are at risk of developing anemia. Iron is lost through the gastrointestinal tract, urine, sweat or skin. If you have chronic changes in one of these systems, you could be at risk of developing an iron deficiency. Menstruating women and growing individuals such as infants, children, adolescents, and pregnant women have increased needs for iron that are not always met by their diet. A chronic anemia of exercise has been reported but the cause is unknown. It may be due to an increase in blood volume, damage to RBCs (foot-strike hemolysis), or sweat loss. People with excessive blood loss can develop anemia. Ulcers, wounds, surgery, infections and regular blood donation can contribute to excessive blood loss. Vegetarians require more iron than individuals who include animal products in their diet and must be careful to eat enough iron. Finally, people who live in developing countries are more likely to develop an iron deficiency.

Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron. Iron supplements have some adverse side effects including nausea, constipation, diarrhea, vomiting, and abdominal pain. Reducing the dose at first and then gradually increasing to the full dose often minimizes the side effects of iron supplements.

See Table 10.5.1 for good dietary sources of iron. The absorption of iron changes with your body's need; it is higher if your iron stores are low. Even though your body can modulate iron absorption, less than 35% of what you eat is absorbed and ranges between 2 - 35%. Heme iron is more efficiently absorbed, 25%, than non-heme iron, 17%. There are several things you can do to improve non-heme iron absorption. Avoiding foods and beverages high in phytates and also tea (which contains tannic acid and polyphenols, both of which impair iron absorption), is important for people who have iron-deficiency anemia. Eating a dietary source of vitamin C at the same time as iron-containing foods improves absorption of nonheme iron in the gut. Additionally, unknown compounds that likely reside in muscle tissue of meat, poultry, and fish (MFP factor) increase iron absorption from both heme and nonheme sources. These factors have not been identified. See Table 10.6.2 for more enhancers and inhibitors for iron absorption.

Excess dietary calcium, zinc, phosphorus, and manganese can interfere with iron absorption. Antacids increase stomach pH which decreases iron absorption. Remember, acid converts the ferric state of iron to ferrous which improve water solubility and absorption.

Another way to increase iron intake is to cook using iron cookware but the amount of iron leached from the pan into your food depends on several factors. First, the acidity of the food; the more acidic the food, more iron will be released into the food. Second, the longer you leave the food to cook in iron cookware, more iron will be imparted to the food. White flour is fortified with iron which can contribute significant amounts of iron to one's diet if you eat a lot of foods made with fortified white flour. Otherwise, there are better iron sources.

Table 10.5.1: Dietary Sources of Iron

	Milligrams per serving	Percent RDA (males)	Percent RDA (females)
Oysters (3 oz.)	13.20	165	73
Beef liver (3 oz.)	7.50	94	42
Prune juice (½ c.)	5.20	65	29
Clams (2 oz.)	4.20	53	23
Walnuts (½ c.)	3.75	47	21
Chickpeas (½ c.)	3.00	38	19
Bran flakes (½ c.)	2.80	37	16
Pork roast (3 oz.)	2.70	34	15
Raisins (½ c.)	2.55	32	14
Roast beef (3 oz.)	1.80	23	10
Green peas (½ c.)	1.50	19	8
Peanuts (½ c.)	1.50	19	8
Green beans (½ c.)	1.00	13	6
Egg (1)	1.00	13	6

Source: University of Maryland Medical Center. “Iron.” © 2011 University of Maryland Medical Center (UMMC). All rights reserved. www.umm.edu/altmed/articles/iron-000309.htm#ixzz2BIykoCPs.

Table 11.5.2: Enhancers and Inhibitors of Iron Absorption

Enhancer	Inhibitor
Meat	Phosphate

Enhancer	Inhibitor
Fish	Calcium
Poultry	Tea
Seafood	Coffee
Stomach acid	Colas
	Soy protein
	High doses of minerals (antacids)
	Bran/fiber
	Phytates
	Oxalates
	Polyphenols

Iron Deficiency: A Worldwide Nutritional Health Problem

The Centers for Disease Control and Prevention reports that iron deficiency is the most common nutritional deficiency worldwide.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. The WHO estimates that 80 percent of people are iron deficient and 30 percent of the world population has iron-deficiency anemia.The World Bank. “Anemia.” Accessed October 2, 2011. web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743 ~theSitePK:672263,00.html. The main causes of iron deficiency worldwide are parasitic worm infections in the gut causing excessive blood loss, and malaria, a parasitic disease causing the destruction of red blood cells. In the developed world, iron deficiency is more the result of dietary insufficiency and/or excessive blood loss occurring during menstruation or childbirth.

At-Risk Populations

Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes. Infants, children, and even teens require more iron because iron is essential for growth. In these populations, iron deficiency (and eventually iron-deficiency anemia) can also cause the following signs and symptoms: poor growth, failure to thrive, and poor performance in school, as well as mental, motor, and behavioral disorders. Women who experience heavy menstrual bleeding or who are pregnant require more iron in the diet. One more high-risk group is the elderly. Both elderly men and women have a high incidence of anemia and the most common causes are a dietary iron deficiency and/or a chronic disease such as ulcer, inflammatory diseases, and cancer. Additionally, those who have recently suffered from traumatic blood loss, frequently donate blood, or take excessive antacids for heartburn need more iron in their diet.

Iron Toxicity

The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity. In children, death has occurred from ingesting as little as 200 mg of iron and therefore it is critical to keep iron supplements out of children’s reach. The IOM has set tolerable upper intake levels of iron (Table 10.5.3 "Tolerable Upper Intake Levels of Iron"). Mostly a hereditary disease, hemochromatosis is the result of a genetic mutation that leads to abnormal iron metabolism and an accumulation of iron in certain tissues such as the liver, pancreas, and heart. The signs and symptoms of hemochromatosis are similar to those of iron overload in tissues caused by high dietary intake of iron or other nongenetic metabolic abnormalities but are often increased in severity.

Table 11.5.1: Tolerable Upper Intake Levels of Iron

Age	Males (mg/day)	Females (mg/day)	Pregnancy (mg/day)	Lactation (mg/day)
7–12 months	40	40	N/A	N/A

Age	Males (mg/day)	Females (mg/day)	Pregnancy (mg/day)	Lactation (mg/day)
1–13 years	40	40	N/A	N/A
14–18 years	45	45	45	45
19+ years	45	45	45	45

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Thalassemia is an inherited disorder that causes the hemoglobin molecule to be abnormally shaped. People of Asian, Chinese, Mediterranean or African descent have a greater risk of carrying the defective gene. People with this disease are anemic and need transfusions to stay alive. Often the excess iron will be stored in tissues causing an iron toxicity. They require chelation therapy to remove the excess iron.

There are a variety of other conditions that can lead to iron toxicity. Iron toxicity may look display symptoms similar to a deficiency, apathy, lethargy, and fatigue. Consuming more than 45 mg/day can lead to an overload and gastrointestinal distress, constipation, nausea, emesis, and diarrhea. Unchecked, this can lead to intestinal damage, liver damage and or failure. Hemosiderosis is excess storage of iron in the liver, heart, joints and other tissues. Excess iron from blood transfusions or unknown etiologies can cause iron to build up in these tissues. Males tend to experience more hemosiderosis than females. Iron supplements should be kept away from children and iron overload is one of the leading causes of accidental death of children.

Preventing Iron-Deficiency Anemia

In young children, iron-deficiency anemia can cause significant motor, mental, and behavior abnormalities that are long-lasting. In the United States, the high incidence of iron-deficiency anemia in infants and children was a major public-health problem prior to the early 1970s, but now the incidence has been greatly reduced. This achievement was accomplished by implementing the screening of infants for iron-deficiency anemia in the health sector as a common practice, advocating the fortification of infant formulas and cereals with iron, and distributing them in supplemental food programs, such as that within Women, Infants, and Children (WIC). Breastfeeding, iron supplementation, and delaying the introduction of cow's milk for at least the first twelve months of life were also encouraged. These practices were implemented across the socioeconomic spectrum and by the 1980s iron-deficiency anemia in infants had significantly declined. Other solutions had to be introduced in young children, who no longer were fed breast milk or fortified formulas and were consuming cow's milk. The following solutions were introduced to parents: provide a diet rich in sources of iron and vitamin C, limit cow's milk consumption to less than twenty-four ounces per day, and a multivitamin containing iron.



Figure 11.5.1: While supplementation may be necessary in acute situations, the best way to boost your iron intake is through good eating habits. Imag used with permission (Public Domain; This image was released by the National Cancer Institute, an agency part of the National Institutes of Health).

In the third world, iron-deficiency anemia remains a significant public-health challenge. The World Bank claims that a million deaths occur every year from anemia and that the majority of those occur in Africa and Southeast Asia. The World Bank states five key interventions to combat anemia:The World Bank. “Anemia.” Accessed October 2, 2011. web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743 ~theSitePK:672263,00.html

- Provide at-risk groups with iron supplements.
- Fortify staple foods with iron and other micronutrients whose deficiencies are linked with anemia.
- Prevent the spread of malaria and treat the hundreds of millions with the disease.
- Provide insecticide-treated bed netting to prevent parasitic infections.
- Treat parasitic-worm infestations in high-risk populations.

Also, there is an ongoing investigation as to whether supplying iron cookware to at-risk populations is effective in preventing and treating iron-deficiency anemia.

Key Takeaways

- Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body, resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. It is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron.
- The main causes of iron deficiency worldwide are parasitic-worm infections in the gut (causing excessive blood loss), malaria, a parasitic disease causing the destruction of red blood cells, and insufficient iron in the diet.
- Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes.
- In America in the past, iron-deficiency anemia was prevalent in infants and young children. After the introduction of infant screening, fortification of formulas and foods, and educating parents on providing an iron-rich diet, iron-deficiency anemia significantly declined in this country.
- In the third world, iron-deficiency anemia remains a significant public-health challenge. Solutions to reduce the prevalence of iron-deficiency anemia in the developing world include providing supplements to target populations, fortifying foods with iron and other blood-healthy micronutrients, preventing the spread of malaria, treating parasitic infections, and giving iron cookware to high-risk populations.
- The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults, including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity.

Discussion Starters

1. Come up with a hypothesis or two on why it is vital that blood is continuously renewed.
2. Discuss the effectiveness and cost of some possible solutions for eliminating iron-deficiency anemia worldwide.

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11.E: Exercises

It's Your Turn

1. Make a chart of the vitamins and minerals important for metabolism and list their main functions.
2. List four functions of blood.
3. With regard to the functions of iron in metabolism and blood health, describe how low iron levels lead to the characteristic signs and symptoms of iron-deficiency anemia.

Apply It

1. Draw a flow chart of the stages of nutrient catabolism and point out where the B vitamins are required.
2. Summarize in a paragraph why a pregnant woman requires more iron in the diet and why it is important for newborn babies to be screened for iron deficiency.
3. Plan a daily menu that meets the RDA for iron and iron-absorption enhancers.

Expand Your Knowledge

1. Read "Sir Frederick Hopkins—Nobel Lecture" on the history of the discovery of vitamins and summarize in a paragraph or two the importance of continuing scientific investigation to define the functions of vitamins in order to improve the health of humans. http://www.nobelprize.org/nobel_prizes/medicine/laureates/1929/hopkins-lecture.html
2. Go to the USDA database (http://www.ars.usda.gov/Services/docs.htm?docid=20958) and prepare a list of the top ten food sources of vitamin B_6 and vitamin B_{12}.
3. Why would having too many red blood cells decrease the amount of oxygen delivered to cells? To help answer this question visit the website of the National Heart, Lung, and Blood Institute (http://www.nhlbi.nih.gov/health/dci/Diseases/poly/poly_all.html).

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CHAPTER OVERVIEW

12: Maternal, Infant, Childhood, and Adolescent Nutrition

This chapter is the first of two that exploring nutrition through the life cycle and it looks at pregnancy through the toddler years. Topics include pregnancy, breastfeeding, introducing solid foods, and nutrition during the toddler years.

12.1: Chapter Introduction
12.2: The Human Life Cycle
12.3: Pregnancy and Nutrition
12.4: Infancy and Nutrition
12.5: Nutrition in the Toddler Years
12.6: Childhood and Nutrition
12.7: Puberty and Nutrition
12.8: Older Adolescence and Nutrition
12.E: Exercises

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12.1: Chapter Introduction

Big Idea

Breastfeeding promotion and support greatly influences infant health.



Figure 12.1.1: The choice to breastfeed is one that all new mothers face. Support from family members, friends, employers, and others can greatly help with both the decision-making process during pregnancy and the practice of breastfeeding after the baby's birth. (public domain; Yves Picq http://veton.picq.fr)

The World Health Organization (WHO) recommends that infants should be given only breast milk for the first six months of life. Exclusive breastfeeding is one of the best ways a mother can support the growth and protect the health of her infant child. Breast milk contains all of the nutrients that a newborn requires and gives a child the best start to a healthy life. Many women want to breastfeed their babies. Unfortunately, a mother's intention alone may not be enough to make this practice possible. Around the world, less than 40 percent of infants under the age of six months are breastfed exclusively.World Health Organization. "10 Facts on Breastfeeding." Accessed February 21, 2012. http://www.who.int/features/factfiles/breastfeeding/en/. In the United States, about 75 percent of babies start out being breastfed. Yet by the age of six months, when solid foods should begin to be introduced into a child's diet along with breast milk, only 15 percent of infants in the United States were still breastfed exclusively, according to the Centers for Disease Control and Prevention (CDC).Centers for Disease Control and Prevention. "Breastfeeding: Promotion and Support." Last updated August 2, 2011. http://www.cdc.gov/breastfeeding/promotion/index.htm. However, the approval and assistance of family members, friends, employers, health-care providers, and policymakers can make an enormous difference and provide the needed promotion and support for mothers who wish to breastfeed their children.

Education about breastfeeding typically begins with health-care providers. During prenatal care and often soon after a woman has given birth, doctors, nurses, and other clinicians can explain the benefits of breastfeeding and describe the proper technique. Nearly all births in the United States and Canada occur in hospital settings, and hospital practices in labor, delivery, postpartum care, and discharge planning can inform and support women who want to breastfeed. Once a new mother has left the hospital for home, she needs access to a trained individual who can provide consistent information. International Board Certified Lactation Consultants (IBCLCs) are health-care professionals (often a registered nurse or registered dietitian) certified in breastfeeding management that works with new mothers to solve problems and educate families about the benefits of this practice. Research shows that breastfeeding rates are higher among women who had infants in hospitals that make IBCLCs available to new mothers, rather than those who gave birth in institutions without these professionals on staff.US Department of Health and Human Services, Office of the Surgeon General. "Executive Summary: The Surgeon General's Call to Action to Support Breastfeeding." January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf. In addition, spouses, partners, and other family members can play critical roles in helping a pregnant woman make the decision to breastfeed and assisting with feeding after the baby is born.

Employment can also factor into a woman's decision to breastfeed or her ability to maintain the practice. Employed mothers have been less likely to initiate breastfeeding and tend to breastfeed for a shorter period of time than new mothers who are not employed or who have lengthy maternity leaves. In 2010 in the United States, the passage of the Affordable Care Act (ACA) called for

employers to provide accommodations within the workplace for new mothers to pump breast milk. This law requires a private and clean space within the workplace, other than a restroom, along with adequate break time for a woman to express milk.US Department of Health and Human Services, Office of the Surgeon General. “Executive Summary: The Surgeon General’s Call to Action to Support Breastfeeding.” January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf.

Members of a community can also promote and support breastfeeding. New mothers can join peer counseling groups or turn to other women within their community who have previous experience with breastfeeding. In addition, community-based programs can provide education and support. The US Department of Agriculture’s Women, Infants, and Children program provides information on breastfeeding for low-income families. Launched in 2004, the Loving Support program combines peer counseling with breastfeeding promotion efforts to increase duration rates across the United States. La Leche League is an international program that provides mother-to-mother support, encouragement, and education about breastfeeding for women around the world.

You Decide

How can you help to promote and support breastfeeding practices in your community?

Although breastfeeding should be recommended and encouraged for almost all new mothers, it is important to remember that the decision to breastfeed is a personal choice and women should not be made to feel guilty if they cannot or choose not, to breastfeed their infants. In some rare cases, a woman is unable to breastfeed or it is not in the baby’s best interest.

Nutritional choices that parents make, such as the decision to breastfeed or bottle-feed, not only affect early childhood development, but also a child’s health and wellness later in life. Therefore, it is imperative to promote and support the best practices for the well-being of infants and mothers alike. Throughout this chapter, we will examine how dietary choices—from the daily caloric intake for pregnant women to serving sizes for toddlers—impact health and wellness during pregnancy and the early childhood years.

Video 12.1.1: Breastfeeding and Working

This video from the Colorado Breastfeeding Coalition focuses on the importance of making workplace accommodations for employees who are breastfeeding their infants. (click to see video)

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12.2: The Human Life Cycle

Learning Objectives

- Identify and define the different stages of the human lifecycle.
- Explain how the human body develops from infancy through the toddler years.

According to the *American Journal of Clinical Nutrition*, the human life span, or the maximum length of time possible for human life, is 130 years.Ordovas, J. M. “Living Well to 100: Nutrition, Genetics, Inflammation.” *Am J Clin Nutr* 83 (2006): 401S490S. Human bodies change significantly over time, and food is the fuel for those changes. People of all ages need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to sustain life and health. However, the amounts of nutrients needed differ. Throughout the human life cycle, the body constantly changes and goes through different periods known as stages. The major stages of the human lifecycle are defined as follows:

- **Pregnancy.** The development of a zygote into an embryo and then into a fetus in preparation for childbirth.
- **Infancy.** The earliest part of childhood. It is the period from birth through age one.
- **Toddler years.** Occur during ages two and three and are the end of early childhood.
- **Childhood.** Takes place from ages four to eight.
- **Puberty.** The period from ages nine to thirteen, which is the beginning of adolescence.
- **Older adolescence.** The stage that takes place between ages fourteen and eighteen.
- **Adulthood.** The period from adolescence to the end of life and begins at age nineteen.
- **Middle age.** The period of adulthood that stretches from age thirty-one to fifty.
- **Senior years, or old age.** Extend from age fifty-one until the end of life.

Changes during Pregnancy

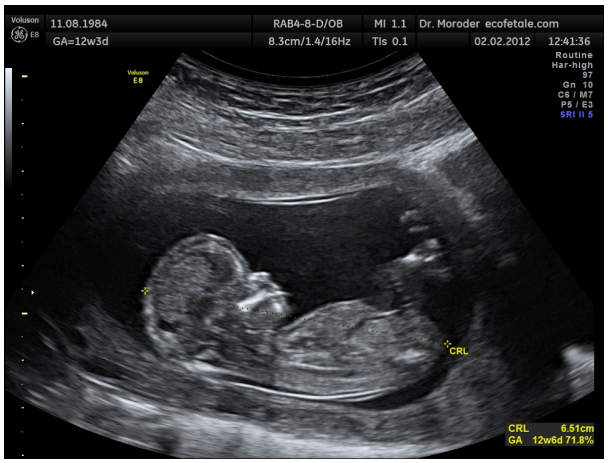


Figure 12.2.1: This ultrasound image shows a four-month-old fetus. Ultrasound image of a fetus in the womb, viewed at 12 weeks of pregnancy (bidimensional-scan). ***Wolfgang Moroder***.

In this chapter, we will focus on the human life cycle from the prenatal period into early childhood. We begin with pregnancy, a developmental marathon that lasts about forty weeks. It begins with the first trimester (weeks one to week twelve), extends into the second trimester (weeks thirteen to week twenty-seven), and ends with the third trimester (week twenty-eight to birth). At conception, a sperm cell fertilizes an egg cell, creating a zygote. The zygote rapidly divides into multiple cells and within two weeks becomes an embryo and implants itself in the uterine wall, where it develops into a fetus. Some of the major changes that occur include the branching of nerve cells to form primitive neural pathways at eight weeks. At the twenty-week mark, physicians typically perform an ultrasound to acquire information about the fetus and check for abnormalities. By this time, it is possible to know the sex of the baby. At twenty-eight weeks, the unborn baby begins to add body fat in preparation for life outside of the womb.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 81–82. Throughout this entire process, a pregnant woman’s nutritional choices affect not only fetal development but also her own health and the future health of her newborn.

Changes during Infancy

A number of major physiological changes occur during infancy. The trunk of the body grows faster than the arms and legs, while the head becomes less prominent in comparison to the limbs. Organs and organ systems grow at a rapid rate. Also during this period, countless new synapses form to link brain neurons. Two soft spots on the baby's skull, known as fontanels, allow the skull to accommodate rapid brain growth. The posterior fontanel closes first, by the age of eight weeks. The anterior fontanel closes about a year later, at eighteen months on average. Developmental milestones include sitting up without support, learning to walk, teething, and vocalizing among many, many others. All of these changes require adequate nutrition to ensure development at the appropriate rate.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 248.

Changes during the Toddler Years

Major physiological changes continue into the toddler years. Unlike in infancy, the limbs grow much faster than the trunk, which gives the body a more proportionate appearance. By the end of the third year, a toddler is taller and more slender than an infant, with a more erect posture. As the child grows, bone density increases and bone tissue gradually replaces cartilage. This process known as ossification is not completed until puberty.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 108. Developmental milestones include running, drawing, toilet training, and self-feeding. How a toddler acts, speaks, learns, and eats offers important clues about their development.



Figure 12.2.2: *As children mature, their friends can exert a strong influence on their nutritional choices. (CC-BY-SA 2.0; USDA)*

Changes during Childhood

Early childhood encompasses infancy and the toddler years, from birth through age three. The remaining part of childhood is the period from ages four through eight and is the time when children enter school. A number of critical physiological and emotional changes take place during this life stage. For example, a child's limbs lengthen steadily, while the growth of other body parts begins to slow down. By age ten, the skull and the brain have grown to near-adult size.Beverly McMillan, *Human Body: A Visual Guide* (Sydney, Australia: Weldon Owen, 2006), 258. Emotional and psychological changes occur as well. Children's attitudes and opinions about food deepen. They not only begin taking their cues about food preferences from family members, but also from peers and the larger culture. All of these factors should impact the nutritional choices parents make for their children. This time in a child's life provides an opportunity for parents and other caregivers to reinforce good eating habits and to introduce new foods into the diet while remaining mindful of a child's preferences. Parents should also serve as role models for their children, who will often mimic their behavior and eating habits.

Changes during Puberty

The onset of puberty is the beginning of adolescence and is the bridge between the childhood years and young adulthood. Medically, adolescence is defined as the period between ages eleven and fourteen for girls and between twelve to fifteen for boys. For the purpose of discussing the influence of nutritional choices during the life cycle, this text will follow the *2010 Dietary Guidelines for Americans*, which divides the adolescent years into two stages: ages nine to thirteen, or puberty, and ages fourteen to eighteen, or late adolescence. We will discuss puberty first. Some of the important physiological changes that take place during this stage include the development of primary sex characteristics, or the reproductive organs, along with the onset of menstruation in females. This life stage is also characterized by the appearance of secondary sex characteristics, such as the growth of facial and body hair, the development of breasts in girls, and the deepening of the voice in boys. Other physical changes include rapid growth

and alterations in body proportions.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 170–71. All of these changes, as well as the accompanying mental and emotional adjustments, should be supported with sound nutrition.

Changes in Late Adolescence

The *Dietary Guidelines* defines the next phase of the human life-cycle, late adolescence, as the period from ages fourteen to eighteen. After puberty, the rate of physical growth slows down. Girls stop growing taller around age sixteen, while boys continue to grow taller until ages eighteen to twenty. One of the psychological and emotional changes that take place during this life stage includes the desire for independence as adolescents develop individual identities apart from their families.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 171–76. As teenagers make more and more of their dietary decisions, parents or other caregivers and authority figures should guide them toward appropriate, nutritious choices.

Key Takeaways

The human body constantly develops and changes throughout the human life cycle, and food provides the fuel for those changes. The major stages of the human lifecycle include pregnancy, infancy, the toddler years, childhood, puberty, older adolescence, adulthood, middle age, and the senior years. Proper nutrition and exercise ensure health and wellness at each stage of the human lifecycle.

Discussion Starter

1. In preparation for this chapter and the next, predict how you think nutrient needs might differ at the beginning of life compared to the end of life. Then, after reading this chapter and the one that follows, discuss if your predictions were correct or incorrect.

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12.3: Pregnancy and Nutrition

Learning Objectives

- Summarize prenatal nutritional requirements and dietary recommendations.
- Discuss the most important nutritional concerns during pregnancy.
- Explore the relationship between fetal development and nutritional choices.

It is crucial to consume healthy foods at every phase of life, beginning in the womb. Good nutrition is vital for any pregnancy and not only helps an expectant mother remain healthy but also impacts the development of the fetus and ensures that the baby thrives in infancy and beyond. During pregnancy, a woman's needs increase for certain nutrients more than for others. If these nutritional needs are not met, infants could suffer from low birth weight (a birth weight less than 5.5 pounds, which is 2,500 grams), among other developmental problems. The best predictor of a successful birth is appropriate maternal weight gain. Therefore, it is crucial to make careful dietary choices.

The Early Days of Pregnancy

For medical purposes, pregnancy is measured from the first day of a woman's last menstrual period until childbirth and typically lasts about forty weeks. Major changes begin to occur in the earliest days, often weeks before a woman even knows that she is pregnant. During this period, adequate nutrition supports cell division, tissue differentiation, and organ development. As each week passes, new milestones are reached. Therefore, women who are trying to conceive should make proper dietary choices to ensure the delivery of a healthy baby. Fathers-to-be should also consider their eating habits. A sedentary lifestyle and a diet low in fresh fruits and vegetables may affect male fertility. Men who drink too much alcohol may also damage the quantity and quality of their sperm.Mayo Clinic. "Healthy Sperm: Improving Your Fertility." © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. http://www.mayoclinic.com/health/fertility/MC00023. For both men and women, adopting healthy habits also boosts general well-being and makes it possible to meet the demands of parenting.

Tools for Change

A pregnancy may happen unexpectedly. Therefore, it is important for all women of childbearing age to get 400 micrograms of folate per day prior to pregnancy and 600 micrograms per day during pregnancy. Folate, which is also known as folic acid, is crucial for the production of DNA and RNA and the synthesis of cells. A deficiency can cause megaloblastic anemia, or the development of abnormal red blood cells, in pregnant women. It can also have a profound effect on the unborn baby. Typically, folate intake has the greatest impact during the first eight weeks of pregnancy, when the neural tube closes. The neural tube develops into the fetus's brain, and adequate folate reduces the risk of brain abnormalities or neural tube defects, which occur in one in a thousand pregnancies in North America each year. This vital nutrient also supports the spinal cord and its protective coverings. Inadequate folic acid can result in birth defects, such as spina bifida, which is the failure of the spinal column to close. The name "folate" is derived from the Latin word *folium* for leaf, and leafy green vegetables such as spinach and kale are excellent sources of it. Folate is also found in legumes, liver, and oranges. Additionally, since 1998, food manufacturers have been required to add folate to cereals and other grain products.MedlinePlus, a service of the National Institutes of Health. "Folic Acid." © 1995–2012 Therapeutic Research Faculty, publishers of Natural Medicines Comprehensive Database, Prescriber's Letter, Pharmacist's Letter. Last reviewed August 7, 2011. http://www.nlm.nih.gov/medlineplus/druginfo/natural/1017.html.

Weight Gain during Pregnancy

During pregnancy, a mother's body changes in many ways. One of the most notable and significant changes is weight gain. If a pregnant woman does not gain enough weight, her unborn baby will be at risk. Poor weight gain, especially in the third trimester, could result not only in low birth weight but also infant mortality and intellectual disabilities. Therefore, it is vital for a pregnant woman to maintain a healthy weight, and her weight prior to pregnancy has a major effect. Infant birth weight is one of the best indicators of a baby's future health. Pregnant women of normal weight should gain between 25 and 35 pounds in total through the entire pregnancy. The precise amount that a mother should gain usually depends on her beginning body mass index (BMI). See Table 12.3.1 for The Institute of Medicine (IOM) recommendations.

Table 12.3.1: Body Mass Index and Pregnancy

Prepregnancy BMI	Weight Category	Recommended Weight Gain

Prepregnancy BMI	Weight Category	Recommended Weight Gain
Below 18.5	Underweight	28–40 lbs.
18.5–24.9	Normal	25–35 lbs.
25.0–29.9	Overweight	15–25 lbs.
Above 30.0	Obese (all classes)	11–20 lbs.

Source: Institute of Medicine. “Weight Gain during Pregnancy: Reexamining the Guidelines.” May 2009. www.iom.edu/~/media/Files/Report%20Files/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines/Resource%20Page%20-%20Weight%20Gain%20During%20Pregnancy.pdf.

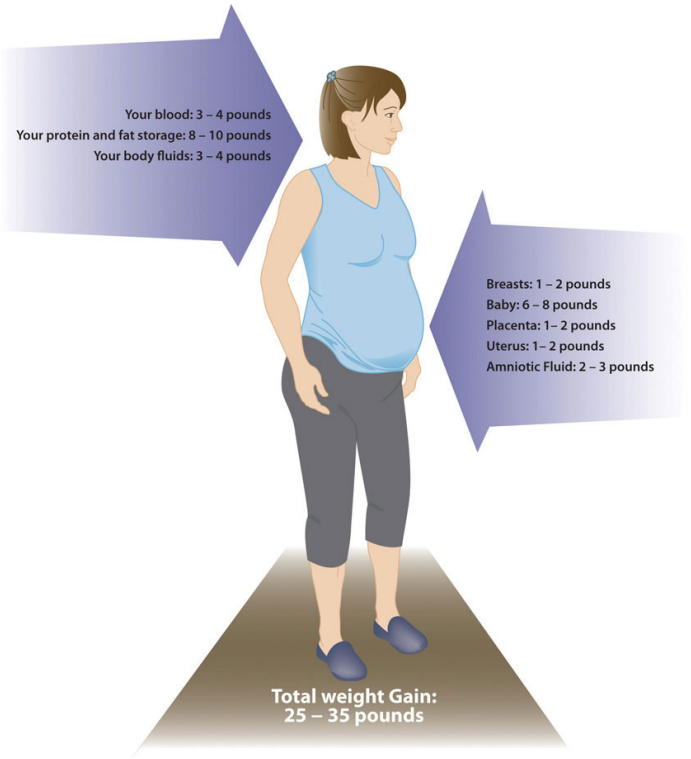


Figure 12.3.1: The weight an expectant mother gains during pregnancy is almost all lean tissue, including the placenta and fetus. Weight gain is not the only major change. A pregnant woman also will find that her breasts enlarge and that she has a tendency to retain water. Source: Utah Department of Health, Baby Your Baby. “Weight Gain during Pregnancy.” © 2012 Baby Your Baby. http://www.babyyourbaby.org/pregnancy/during.

Starting weight below or above the normal range can lead to different complications. Pregnant women with a prepregnancy BMI below twenty are at a higher risk of a preterm delivery and an underweight infant. Also, their nutrient stores may be inadequate. Pregnant women with a prepregnancy BMI above thirty have an increased risk of the need for a cesarean section during delivery. Therefore, it is optimal to have a BMI in the normal range prior to pregnancy. They are also at increased risk of gestational diabetes.

Generally, women gain 2 to 5 pounds in the first trimester. After that, it is best not to gain more than one pound per week. Some of the new weight is due to the growth of the fetus, while some are due to changes in the mother’s body that support the pregnancy. Weight gain often breaks down in the following manner: 6 to 8 pounds of fetus, 1 to 2 pounds for the placenta (which supplies nutrients to the fetus and removes waste products), 2 to 3 pounds for the amniotic sac (which contains fluids that surround and cushion the fetus), 1 to 2 pounds in the breasts, 1 to 2 pounds in the uterus, 3 to 4 pounds of maternal blood, 3 to 4 pounds maternal fluids, and 8 to 10 pounds of extra maternal fat stores that will be needed for breastfeeding and delivery. Women who are pregnant with more than one fetus are advised to gain even more weight to ensure the health of their unborn babies.

The pace of weight gain is also important. If a woman puts on weight too slowly, her physician may recommend nutrition counseling. Low weight gain is considered less than 15 pounds and is linked to an increased risk of birth asphyxia, infections, and

illness. Also, infants may have difficulty regulating their blood glucose and calcium after birth. Babies born prematurely have lung and liver immaturity while full-term babies that are underweight are considered small for gestational age (SGA). These infants are 40 times likely to die during infancy and have trouble regulating blood glucose and body temperature. Growth may be retarded and neural development impaired.

If she gains weight too quickly, especially in the third trimester, it may be the result of edema, or swelling due to excess fluid accumulation. Rapid weight gain may also result from increased calorie consumption or a lack of exercise. This may result in a baby with a high birth weight, greater than 9 lbs. Large babies are difficult to deliver vaginally and may require a cesarean section (C-section). These infants are at a greater risk of poor health and death compared to normal weight babies, and there is a doubled risk of neural tube defects that are not related to a folate deficiency. The mother may experience increased blood pressure that may lead to preeclampsia. On average, a full-term infant at birth weighs 7 to 8 lbs and is about twenty inches long.

Weight Loss Before and After Pregnancy

Weight loss during pregnancy is not recommended, even if you are overweight. Inadequate dietary carbohydrate intake can reduce glucose to the fetus which can impact development particularly the brain. Dieting may slow weight gain which can lead to the same problems discussed in the previous section.

During labor, new mothers lose some of the weight they gained during pregnancy with the delivery of their child. In the following weeks, they continue to shed weight as they lose accumulated fluids and their blood volume returns to normal. Some studies have hypothesized that breastfeeding also helps a new mother lose some of the extra weight, although research is ongoing.Stuebe, A. M., MD, MSc and J. W. Rich-Edwards, Sc. D. “The Reset Hypothesis: Lactation and Maternal Metabolism.” © Thieme Medical Publishers, *Am J Perinatol* 26, no.1 (2009): 81–88. doi: 10.1055/s-0028-1103034. New mothers who gain a healthy amount of weight and participate in regular physical activity during their pregnancies also have an easier time shedding weight post pregnancy. However, women who gain more weight than needed for a pregnancy typically retain that excess weight as body fat. If those few pounds increase a new mother’s BMI by a unit or more, that could lead to complications such as hypertension or Type 2 diabetes in future pregnancies or later in life.

Nutritional Requirements

As a mother’s body changes, so do her nutritional needs. Pregnant women must consume more calories and nutrients in the second and third trimesters than other adult women. However, the average recommended daily caloric intake can vary depending on activity level and the mother’s normal weight. Also, pregnant women should choose a high-quality, diverse diet, consume fresh foods, and prepare nutrient-rich meals. Steaming is the best way to cook vegetables. Vitamins are destroyed by overcooking, whereas uncooked vegetables and fruits have the highest vitamin content. It is also standard for pregnant women to take prenatal supplements to ensure adequate intake of the needed micronutrients.

Energy

During the first trimester, a pregnant woman has the same energy requirements as normal (before pregnancy) and should consume the same number of calories as usual—about 1,800 calories for a woman living a sedentary lifestyle, about 2,000 calories for a woman who is moderately active, and about 2,200 for a woman who is active. However, as the pregnancy progresses, a woman must increase her caloric intake. According to the IOM, she should consume an additional 340 calories per day during the second trimester, and an additional 450 calories per day during the third trimester. This is partly due to an increase in metabolism, which rises during pregnancy and contributes to increased energy needs. A woman can easily meet these increased needs by consuming more nutrient-dense foods. For example, an additional 340 calories could include a medium-sized banana (about 100 calories), a cup of nonfat yogurt with fruit on the bottom (about 140 calories), and a slice of whole-wheat toast (about 75 calories).

Carbohydrates

The recommended daily allowance, or RDA, of carbohydrates during pregnancy is about 175 to 265 grams per day to fuel fetal brain development with a minimum of 135 grams per day. The best food sources for pregnant women include whole-grain bread and cereals, brown rice, root vegetables, legumes, and fruits. These and other unrefined carbohydrates provide nutrients, phytochemicals, antioxidants, and fiber. These foods also help to build the placenta and supply energy for the growth of the unborn baby. Refined carbohydrates, such as white bread, cookies and other baked desserts, pretzels, and chips are nutritionally deficient and should be kept to a minimum.

Protein

During pregnancy, extra protein is needed for the synthesis of new maternal and fetal tissues. Protein builds muscle and other tissues, enzymes, antibodies, and hormones in both the mother and the unborn baby. Additional protein also supports increased blood volume and the production of amniotic fluid. The RDA of protein during pregnancy is 71 grams per day, which is 25 grams (50%) above the normal recommendation. However, in most instances, there is no need for a pregnant woman to make an effort to increase protein intake as long as she has a normal appetite because even nonpregnant women in North America typically eat that much protein. Protein should be derived from healthy sources, such as lean red meat, white-meat poultry, legumes, nuts, seeds, eggs, and fish. Low-fat milk and other dairy products also provide protein, along with calcium and other nutrients.

Fat

There are no specific recommendations for fats in pregnancy, apart from following normal dietary guidelines. Fats should make up 25 to 35 percent of daily calories, and those calories should come from healthy fats, such as avocados. Foods with unhealthy fats, including French fries and other fast food, should be avoided. Also, it is not recommended for pregnant women to be on a very low-fat diet since it would be hard to meet the needs of essential fatty acids and fat-soluble vitamins. Fatty acids are important during pregnancy because they support the baby's brain and eye development. In particular, the brain depends on omega-3 and omega-6 fatty acids, such as the kind found in salmon and sunflower or safflower oil, for function, structure, and growth. Fats can also help the placenta grow and may help to prevent premature birth and low birth weight.

Fiber



Figure 12.3.2: Fresh fruit and whole grains, such as a bowl of muesli, are excellent sources of fiber during a pregnancy. Dry muesli mix served with milk and bananas. (CC SA- BY 3.0; VirtualSteve)

Ideally, a pregnant woman should eat 25 to 30 grams of dietary fiber per day. There are two types of fiber, and pregnant women should consume both. Insoluble fiber acts as a natural laxative, which softens stools and speeds the elimination of waste material through the colon to avoid constipation. Sources of insoluble fiber include whole grains, fruits, vegetables, dried peas, and beans. Soluble fiber has little effect on the intestines, however, it helps to lower blood cholesterol levels and regulate blood glucose. Sources of soluble fiber include fruits, vegetables, and beans, along with oats, barley, and other fiber-filled whole grains.

Fluids

Fluid intake must also be monitored. According to the IOM, pregnant women should drink 2.3 liters (about 10 cups) of liquids per day to provide enough fluid for blood production. It is also important to drink liquids during physical activity or when it is hot and humid outside, to replace fluids lost through perspiration. The combination of a high-fiber diet and lots of liquids also helps to eliminate waste.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes - discomforts.cfm.

Vitamins and Minerals

Pregnancy requires certain conditionally essential nutrients, which are nutrients that are supplied only under special conditions, such as stress, illness, or aging. The daily requirements for nonpregnant women change with the onset of a pregnancy. Taking a daily prenatal supplement or multi vitamin helps to meet many nutritional needs. However, most of these requirements should be fulfilled with a healthy diet. The following table compares the normal levels of required vitamins and minerals to the levels needed during pregnancy. For pregnant women, the RDA of nearly all vitamins and minerals increases these are highlighted in red. The other vitamins (D, E, and K) and minerals (Na, Cl, Ca, P and F) do not change.

Table 12.3.2: Recommended Nutrient Intakes during Pregnancy

Nutrient	Nonpregnant Women	Pregnant Women
Vitamin A (mcg)	700.0	770.0
Vitamin B_6 (mg)	1.5	1.9
Vitamin B_{12} (mcg)	2.4	2.6
Vitamin C (mg)	75.0	85.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Calcium (mg)	1,000.0	1,000.0
Folate (mcg)	400.0	600.0
Iron (mg)	18.0	27.0
Magnesium (mg)	320.0	360.0
Niacin (B_3) (mg)	14.0	18.0
Phosphorus	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4
Thiamine (B_1) (mg)	1.1	1.4
Zinc (mg)	8.0	11.0

Source: Institute of Medicine. “Nutrition during Pregnancy: Part I: Weight Gain, Part II: Nutrient Supplements.” January 1, 1990. iom.edu/Reports/1990/Nutrition-During-Pregnancy-Part-I-Weight-Gain-Part-II-Nutrient-Supplements.aspx.

The micronutrients involved with building the skeleton—vitamin D, calcium, phosphorus, and magnesium—are crucial during pregnancy to support fetal bone development. Although the levels are the same as those for nonpregnant women, many women do not typically consume adequate amounts and should make an extra effort to meet those needs.

There is an increased need for all B vitamins during pregnancy. Adequate vitamin B_6 supports the metabolism of amino acids, while more vitamin B_{12} is needed for the synthesis of red blood cells and DNA. Additional zinc is crucial for cell development and protein synthesis. The need for vitamin A also increases, and extra iron intake is important because of the increase in blood supply during pregnancy and to support the fetus and placenta. Iron is the one micronutrient that is almost impossible to obtain in adequate amounts from food sources only. Therefore, even if a pregnant woman consumes a healthy diet, there still is a need to take an iron supplement, in the form of ferrous salts. Also, remember that folate needs increase during pregnancy to 600 micrograms per day to prevent neural tube defects. This micronutrient is crucial for fetal development because it helps produce the extra blood a woman’s body requires during pregnancy. Vitamin B12 is also important.

For most other minerals, recommended intakes are similar to those for nonpregnant women, although it is crucial for pregnant women to make sure to meet the RDAs to reduce the risk of birth defects. In addition, pregnant mothers should avoid exceeding any recommendations. Taking megadose supplements can lead to excessive amounts of certain micronutrients, such as vitamin A and zinc, which may produce toxic effects that can also result in birth defects.

Guide to Eating during Pregnancy

While pregnant women have an increased need for energy, vitamins, and minerals, energy increases are proportionally less than other macronutrient and micronutrient increases. So, nutrient-dense foods, which are higher in proportion of macronutrients and micronutrients relative to calories, are essential to a healthy diet. Examples of nutrient-dense foods include fruits, vegetables, whole grains, peas, beans, reduced-fat dairy, and lean meats. Notice, these are also lower fat choices. Pregnant women should be able to meet almost all of their increased needs via a healthy diet as long as they choose wisely. However, expectant mothers should take a prenatal supplement to ensure an adequate intake of iron and folate. Here are some additional dietary guidelines for pregnant women: US Department of Health and Human Services, Office on Women's Health. "Healthy Pregnancy: Do's and Don'ts." Last updated March 5, 2009. www.womenshealth.gov/publications/our-publications/pregnancy-dos -donts.pdf.

- Eat iron-rich or iron-fortified foods, including meat or meat alternatives, breads, and cereals, to help satisfy increased need for iron and prevent anemia.
- Include vitamin C-rich foods, such as orange juice, broccoli, or strawberries, to enhance iron absorption.
- Eat a well-balanced diet, including fruits, vegetables, whole grains, calcium-rich foods, lean meats, and a variety of cooked seafood (excluding fish that are high in mercury, such as swordfish and shark).
- Drink additional fluids, water especially.

Foods to Avoid

A number of substances can harm a growing fetus. Therefore, it is vital for women to avoid them throughout a pregnancy. Some are so detrimental that a woman should avoid them even if she suspects that she might be pregnant. For example, consumption of alcoholic beverages results in a range of abnormalities that fall under the umbrella of fetal alcohol spectrum disorders. They include learning and attention deficits, heart defects, and abnormal facial features. Alcohol enters the unborn baby via the umbilical cord and can slow fetal growth, damage the brain, or even result in miscarriage. The effects of alcohol are most severe in the first trimester when the organs are developing. As a result, there is no safe amount of alcohol that a pregnant woman can consume. Although pregnant women in the past may have participated in behavior that was not known to be risky at the time, such as drinking alcohol or smoking cigarettes, today we know that it is best to avoid those substances completely to protect the health of the unborn baby.

Pregnant women should also limit caffeine intake, which is found not only in coffee, but also tea, colas, cocoa, chocolate, and some over-the-counter painkillers. Some studies suggest that very high amounts of caffeine have been linked to babies born with low birth weights. The *American Journal of Obstetrics and Gynecology* released a report, which found that women who consume 200 milligrams or more of caffeine a day (which is the amount in 10 ounces of coffee or 25 ounces of tea) increase the risk of miscarriage.Weng X, Odouli R, and Li D-K. "Maternal caffeine consumption during pregnancy and the risk of miscarriage: a prospective cohort study." *Am J Obstet Gynecol* 2008;198:279.e1-279.e8. Consuming large quantities of caffeine affects the pregnant mother as well, leading to irritability, anxiety, and insomnia. Most experts agree that small amounts of caffeine each day are safe (about one 8-ounce cup of coffee a day or less).American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 495. However, that amount should not be exceeded.

One should keep sugar substitutes to a minimum although there are no direct scientific links to birth defects.

Vegetarianism

Lacto-ovo and lactovegetarians have not special problems beyond those common to vegetarians. Women who are vegans need to be concerned about their protein, vitamin B_6 and zinc intake because these nutrients may be low. She may need to take a supplement to boost her intake of vitamin B6, zinc as well as iron, calcium, vitamin D and vitamin B12.

Foodborne Illness

For both mother and child, foodborne illness can cause major health problems. For example, the foodborne illness caused by the bacteria *Listeria monocytogenes* can cause spontaneous abortion and fetal or newborn meningitis. According to the CDC, pregnant women are twenty times more likely to become infected with this disease, which is known as listeriosis, than nonpregnant, healthy adults. Symptoms include headaches, muscle aches, nausea, vomiting, and fever. If the infection spreads to the nervous system, it can result in a stiff neck, convulsions, or a feeling of disorientation.American Pregnancy Association. "Listeria and Pregnancy." © 2000–2012 American Pregnancy Association. http://www.americanpregnancy.org/pregnancycomplications/listeria.html.

Foods more likely to contain the bacteria are unpasteurized dairy products, especially soft cheeses and blue-veined cheeses, and also smoked seafood, hot dogs, paté, cold cuts, and uncooked meats. To avoid consuming contaminated foods, women who are

pregnant or breastfeeding should take the following measures:

- Thoroughly rinse fruits and vegetables before eating them
- Keep cooked and ready-to-eat food separate from raw meat, poultry, and seafood
- Store food at 40° F (4° C) or below in the refrigerator and at 0° F (−18° C) in the freezer
- Refrigerate perishables, prepared food, or leftovers within two hours of preparation or eating
- Clean the refrigerator regularly and wipe up any spills right away
- Check the expiration dates of stored food once per week

You will learn more about foodborne illness and its consequences in other chapters

Food Contaminants

It is always important to avoid consuming contaminated food to prevent food poisoning. This is especially true during pregnancy. Heavy metal contaminants, particularly mercury, lead, and cadmium, pose risks to pregnant mothers. As a result, vegetables should be washed thoroughly or have their skins removed to avoid heavy metals.

Pregnant women can eat fish, ideally 8 to 12 ounces of different types each week. Expectant mothers are able to eat cooked shellfish such as shrimp, farm-raised fish such as salmon, and a maximum of 6 ounces of albacore, or white, tuna. However, they should avoid fish with high methyl mercury levels, such as shark, swordfish, tilefish, and king mackerel. Pregnant women should also avoid consuming raw shellfish to avoid foodborne illness. The Environmental Defense Fund eco-rates fish to provide guidelines to consumers about the safest and most environmentally friendly choices. You can find ratings for fish and seafood at http://www.edf.org.

Physical Activity during Pregnancy

For most pregnant women, physical activity is a must and is recommended in the *2010 Dietary Guidelines for Americans*. Regular exercise of moderate intensity, about thirty minutes per day most days of the week, keeps the heart and lungs healthy. It also helps to improve sleep and boosts mood and energy levels. In addition, women who exercise during pregnancy report fewer discomforts and may have an easier time losing excess weight after childbirth. Low to moderate exercises like brisk walking, swimming, or an aerobics class geared toward expectant mothers are all great ways to get exercise during a pregnancy. Healthy women who already participate in vigorous activities, such as running, can continue doing so during pregnancy provided they discuss an exercise plan with their physicians.



Figure 12.3.3: Walking is an excellent way for an expectant mother to get moderate exercise.

However, pregnant women should avoid pastimes that could cause injuries, such as soccer, football, and other contact sports, or activities, or that could lead to falls, such as horseback riding and downhill skiing. It may be best for pregnant women not to participate in certain sports, such as tennis, that require you to jump or change direction quickly. Scuba diving should also be avoided because it might result in the fetus developing decompression sickness. This potentially fatal condition results from a rapid decrease in pressure when a diver ascends too quickly.National Institutes of Health, and Friends of the National Library of Medicine. "Should I Exercise During My Pregnancy?" *NIH Medline Plus 3*, no. 1 (Winter 2008): 26. http://www.nlm.nih.gov/medlineplus/magazine/issues/winter08/articles/winter08pg26.html.

When exercising, the warm-up should be 5-10 minutes followed low to moderate exercises 30-40 minutes in length at a heart rate below 150 beats per minute. Cool-down should be 5-10 minutes. Plenty of fluids should be consumed and a hot, humid climate avoided. Three to four days of exercise is recommended with adequate rest between exercise. Pregnant women should avoid exercising if they are sick; avoid exercising on their back after the first trimester; and avoid standing for prolonged periods of time to prevent venous pooling.

Common Discomforts during Pregnancy

Pregnancy can lead to certain discomforts, from back strain to swollen ankles. Also, a pregnant woman is likely to experience constipation because increased hormone levels can slow digestion and relax muscles in the bowels. Constipation and pressure from the growth of the uterus can result in hemorrhoids, which are another common discomfort.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm. Getting mild to moderate exercise and drinking enough fluids can help prevent both conditions. Also, eating a high-fiber diet softens the stools and reduces the pressure on hemorrhoids.

Heartburn can occur during the early months of pregnancy due to an increase in the hormone progesterone, and during the later months due to the expanding size of the fetus, which limits stomach contraction. Avoiding chocolate, mint, and greasy foods, and remaining upright for an hour after meals can help pregnant women avoid heartburn. In addition, it can be helpful to drink fluids between meals, instead of with food.

Other common complaints can include leg cramps and bloating. Regular exercise can help to alleviate these discomforts. A majority of pregnant women develop gastrointestinal issues, such as nausea and vomiting. Many also experience food cravings and aversions. All of these can impact a pregnant woman's nutritional intake and it is important to protect against adverse effects.

Nausea and Vomiting

Nausea and vomiting are gastrointestinal issues that strike many pregnant women, typically in the first trimester. Nausea tends to occur more frequently than vomiting. These conditions are often referred to as "morning sickness," although that's something of a misnomer because nausea and vomiting can occur all day long, although it is often the worst in the first part of the day.

Increased levels of the pregnancy hormone human chorionic gonadotropin may cause nausea and vomiting, although that is speculative. Another major suspect is estrogen because levels of this hormone also rise and remain high during pregnancy. Given that a common side effect of estrogen-containing oral contraceptives is nausea this hormone likely has a role. Nausea usually subsides after sixteen weeks, possibly because the body becomes adjusted to higher estrogen levels.

It can be useful for pregnant women to keep a food diary to discover which foods trigger nausea, so they can avoid them in the future. Other tips to help avoid or treat nausea and vomiting include the following:

- Avoid spicy foods
- Avoid strong or unusual odors
- Eat dry cereal, toast, or crackers
- Eat frequent, small meals
- Consume more unrefined carbohydrates
- Get moderate aerobic exercise
- Drink ginger tea, which aids in stomach upset
- Seek fresh air when a bout of nausea comes on

A severe form of nausea and vomiting is a condition known as hyperemesis gravidarum. It is marked by prolonged vomiting, which can result in dehydration and require hospitalization. This disorder is relatively rare and impacts only 0.3 to 2 percent of all

pregnant women.Eliakim, R., O. Abulafia, and D. M. Sherer. “Hyperemesis Gravidarum: A Current Review.” *Am J Perinatol* 17, no. 4 (2000): 207–18.

Food Cravings and Aversions, and Pica

Food aversions and cravings do not have a major impact unless food choices are extremely limited. The most common food aversions are milk, meats, pork, and liver. For most women, it is not harmful to indulge in the occasional craving, such as the desire for pickles and ice cream. However, a medical disorder known as pica is willingly consuming foods with little or no nutritive value, such as dirt, clay, and laundry starch. In some places, this is a culturally accepted practice. However, it can be harmful if these substances take the place of nutritious foods or contain toxins. This is not a real physiological need. For example, craving pickles does not mean the women needs salt and craving ice cream does not mean the woman or fetus needs calcium. Instead, food cravings and aversions are due to the effect of pregnancy on taste and smell sensitivity.

Complications during Pregnancy

Expectant mothers may face different complications during the course of their pregnancy. They include certain medical conditions that could greatly impact a pregnancy if left untreated, such as gestational hypertension and gestational diabetes, which have diet and nutrition implications.

Gastrointestinal

Heartburn can occur during pregnancy. Here are a number of suggestions to relieve the condition:

- Relax and eat slowly
- Chew food thoroughly
- Eat small frequent meals
- Drink liquids between meals not during the meal
- Avoid spicy and greasy foods
- Sit up while eating and keep one's head elevated while sleeping
- Wait an hour before lying down
- Wait two hours before exercising

Constipation and hemorrhoids are also gastrointestinal problems that occur during pregnancy. Exercising regularly, eating foods high in fiber, increasing your food intake to at least 8 glasses per day, and responding promptly to the urge to defecate are ways to improve constipation and hemorrhoids. Mineral oil as a laxative is not recommended because it interferes with the absorption of the fat-soluble vitamins.

Morning sickness which includes nausea and/or vomiting occurs during the first semester for some pregnant women due to hormonal imbalances. Morning sickness can affect one's food intake for the day. There are several measures one can take to minimize morning sickness such as rising slow when you first get up in the morning, eating dry toast or crackers, eating small, frequent meals, and chewing gum or sucking hard candies. Pregnant women should avoid disagreeable smelly foods. If she feels nauseated, carbonated beverages instead of citrus fruit, water, milk, coffee, or tea, may help relieve the upset stomach,

Gestational Hypertension

Gestational hypertension is a condition of high blood pressure during the second half of pregnancy. Also referred to as pregnancy-induced hypertension, this condition affects about 6 to 8 percent of all pregnant women. First-time mothers are at a greater risk, along with women who have mothers or sisters who had gestational hypertension, women carrying multiple fetuses, women with a prior history of high blood pressure or kidney disease, and women who are overweight or obese when they become pregnant.

Hypertension can prevent the placenta from getting enough blood, which would result in the baby getting less oxygen and nutrients. This can result in low birth weight, although most women with gestational hypertension can still deliver a healthy baby if the condition is detected and treated early. Some risk factors can be controlled, such as diet, while others cannot, such as family history. If left untreated, gestational hypertension can lead to a serious complication called preeclampsia, which is sometimes referred to as toxemia. This disorder is marked by elevated blood pressure (hypertension) and protein in the urine (proteinuria) and is associated with swelling (whole body edema). This can lead to reduced blood flow to the fetus and maternal organs, cerebral hemorrhage, convulsion and coma (eclampsia). Preeclampsia and eclampsia are very serious health problems that lead to the mother and/or fetuses death. To prevent preeclampsia, the WHO recommends increasing calcium intake for women consuming diets low in that micronutrient, administering a low dosage of aspirin (75 milligrams), and increasing prenatal check-ups.World

Health Organization. “WHO Recommendations for Prevention and Treatment of Preeclampsia and Eclampsia.” 2011. Accessed June 8, 2012. http://whqlibdoc.who.int/publications/2011/9789241548335_eng.pdf.

Video 12.3.1: Gestational Hypertension and Preeclampsia

This video focuses on the signs and risk factors of gestational hypertension and preeclampsia. (click to see video)

Gestational Diabetes

About 4 percent of pregnant women suffer from a condition known as gestational diabetes, which is abnormal glucose tolerance during pregnancy. It is most common in women with a family history of diabetes. The body becomes resistant to the hormone insulin, which enables cells to transport glucose from the blood. Gestational diabetes is usually diagnosed around twenty-four to twenty-six weeks, although it is possible for the condition to develop later into a pregnancy. Signs and symptoms of this disease include extreme hunger, thirst, or fatigue. If blood sugar levels are not properly monitored and treated, the baby might gain too much weight and require a cesarean delivery. Diet and regular physical activity can help to manage this condition. Most patients who suffer from gestational diabetes also require daily insulin injections to boost the absorption of glucose from the bloodstream and promote the storage of glucose in the form of glycogen in liver and muscle cells. Gestational diabetes usually resolves after childbirth, although some women who suffer from this condition develop Type 2 diabetes later in life, particularly if they are overweight.

Key Takeaways

During pregnancy, it is imperative that a woman meets the nutritional needs both she and her unborn child require, which includes an increase in certain micronutrients, such as iron and folate. Starting BMI determines how much weight a woman needs to gain throughout her pregnancy. In an average pregnancy, a woman gains an extra 30 pounds. During the second and third trimesters, a woman’s energy requirements increase by 340 calories per day for the second trimester and 450 calories per day for the third trimester. Common discomforts that can impact nutritional intake during pregnancy include nausea and vomiting, heartburn, and constipation. Gestational hypertension is a condition that impacts about 6 to 8 percent of pregnant women and results in a rise in blood pressure levels. This condition can lead to preeclampsia during a pregnancy. Gestational diabetes is a condition that impacts about 4 percent of pregnant women and results in a rise in blood glucose levels. This condition can lead to Type 2 diabetes later in life.

Discussion Starter

1. Discuss the changing nutritional requirements for iron and vitamin A during pregnancy. Use what you know about each kind of micronutrient and its impact on the body to explain why the increase in RDA might be exponentially greater for one of these nutrients than for the other.

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12.4: Infancy and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for infants.
- Describe the physiologic basis for lactation and the specific components of breast milk.
- Discuss the benefits and barriers related to breastfeeding.
- Examine feeding problems that parents and caregivers may face with their infants.

Diet and nutrition have a major impact on a child's development from infancy into the adolescent years. A healthy diet not only affects growth, but also immunity, intellectual capabilities, and emotional well-being. One of the most important jobs of parenting is making sure that children receive an adequate amount of needed nutrients to provide a strong foundation for the rest of their lives.

Infancy (Birth to Age One)

The term infant is derived from the Latin word *infans*, which means "unable to speak." Healthy infants grow steadily, but not always at an even pace. For example, during the first year of life, height increases by 50 percent, while weight triples. Physicians and other health professionals can use growth charts to track a baby's development process. Because infants cannot stand, length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age. Nationally-accepted growth charts are based on data collected by the National Center for Health Statistics. These charts allow for tracking trends over time and comparing with other infants among percentiles within the United States. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as failure-to-thrive (FTT), which is characterized by poor growth. FTT can happen at any age, but in infancy, it typically occurs after six months. Some causes include poverty, lack of enough food, feeding inappropriate foods, and excessive intake of fruit juice. The greatest changes in weight and length occur during the first year of life.

Nutritional Requirements

Requirements for macronutrients and micronutrients on a per-kilogram basis are higher during infancy than at any other stage in the human life cycle. These needs are affected by the rapid cell division that occurs during growth, which requires energy and protein, along with the nutrients that are involved in DNA synthesis. During this period, babies are entirely dependent on their parents or other caregivers to meet these needs. For almost all infants six months or younger, breast milk is the best source to fulfill nutritional requirements. An infant may require feedings eight to twelve times a day or more in the beginning. After six months, infants can gradually begin to consume solid foods to help meet nutrient needs.

Energy

Energy needs relative to size are much greater in an infant than an adult because of the large surface area of its body. A baby's resting metabolic rate is two times that of an adult. The RDA to meet energy needs changes as an infant matures and puts on more weight. The IOM uses a set of equations to calculate the total energy expenditure and resulting energy needs. For example, the equation for the first three months of life is *(89 x weight [kg] −100) + 175 kcal*.

Based on these equations, the estimated energy requirement for infants from zero to six months of age is 472 to 645 kilocalories per day for boys and 438 to 593 kilocalories per day for girls (100-120 kcal per kg body weight per day). For infants ages six to twelve months, the estimated requirement is 645 to 844 kilocalories per day for boys and 593 to 768 kilocalories per day for girls. From the age one to age two, the estimated requirement rises to 844–1,050 kilocalories per day for boys and 768–997 kilocalories per day for girls.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, Institute of Medicine of the National Academies (Washington, D.C.: The National Academies Press, 2005), 169–70. How often an infant wants to eat will also change over time due to growth spurts, which typically occur at about two weeks and six weeks of age, and again at about three months and six months of age.

Macronutrients

The dietary recommendations for infants are based on the nutritional content of human breast milk. Carbohydrates make up about 45 to 65 percent of the caloric content in breast milk, which amounts to a RDA of about 130 grams. Almost all of the carbohydrate in human milk is lactose, which infants digest and tolerate well. In fact, lactose intolerance is practically nonexistent in infants. Protein makes up about 5 to 20 percent of the caloric content of breast milk, which amounts to 13 grams per day (or 1.52 grams per kg body weight per day). Infants have a high need for protein to support growth and development, though excess protein (which is only a concern with bottle-feeding) can cause dehydration, diarrhea, fever, and acidosis in premature infants. About 30 to 40 percent of the caloric content in breast milk is made up of fat. A high-fat diet is necessary to encourage the development of neural pathways in the brain and other parts of the body. However, saturated fats and trans fatty acids inhibit this growth. Infants who are over the age of six months, which means they are no longer exclusively breastfed, should not consume foods that are high in these types of fats.

Micronutrients

Almost all of the nutrients that infants require can be met if they consume an adequate amount of breast milk. There are a few exceptions, though. Human milk is low in vitamin D, which is needed for calcium absorption and building bone, among other things. Therefore, breastfed children often need to take a vitamin D supplement in the form of drops. Infants at the highest risk for vitamin D deficiency are those with darker skin and no exposure to sunlight. Breast milk is also low in vitamin K, which is required for blood clotting, and deficits could lead to bleeding or hemorrhagic disease. Babies are born with limited vitamin K, so supplementation may be needed initially and some states require a vitamin K injection after birth. Also, breast milk is not high in iron, but the iron in breast milk is well absorbed by infants. After four to six months, however, an infant needs an additional source of iron other than breast milk.

Fluids

Infants have a high need for fluids, 1.5 milliliters per kilocalorie (150 - 170 ml per kg body weight per day) consumed compared to 1.0 milliliters per kilocalorie consumed for adults. This is because children have larger body surface area per unit of body weight and a reduced capacity for perspiration. Therefore, they are at greater risk of dehydration. However, parents or other caregivers can meet an infant's fluid needs with breast milk or formula. As solids are introduced, parents must make sure that young children continue to drink fluids throughout the day.

Breastfeeding

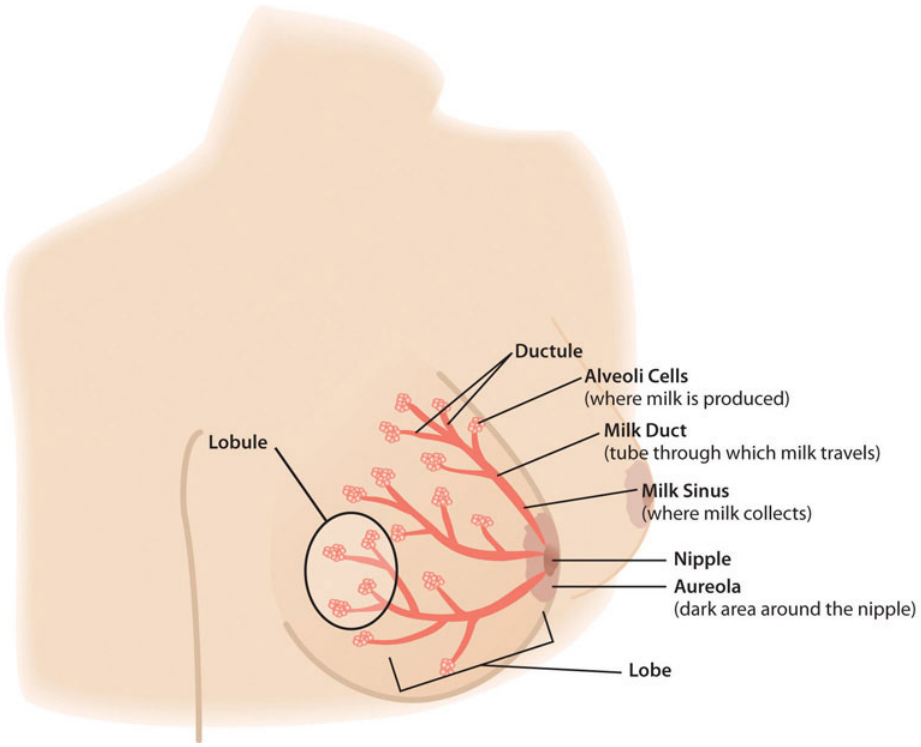


Figure 12.4.1: Anatomy of the breast.

The alveoli cells produce milk. To secrete it, they contract and push milk into the ductules and the milk sinus, which collects the milk. When a nursing infant's gums press on the areola and nipple, the sinuses squeeze the milk into the baby's mouth. The nipple tissue becomes firmer with stimulation, which makes it more flexible and easier for the baby to grasp in the mouth.

After the birth of the baby, nutritional needs must be met to ensure that an infant not only survives but thrives from infancy into childhood. Breastfeeding provides the fuel a newborn needs for rapid growth and development. As a result, the WHO recommends that breastfeeding is done exclusively for the first six months of an infant's life. New mothers must also pay careful consideration to their own nutritional requirements to help their bodies recover in the wake of the pregnancy. This is particularly true for women who breastfeed their babies, which calls for an increased need for certain nutrients.

Lactation

Lactation is the process that makes breastfeeding possible and is the synthesis and secretion of breast milk. Early in a woman's pregnancy, her mammary glands begin to prepare for milk production. Hormones play a major role in this, particularly during the second and third trimesters. At that point, levels of the hormone prolactin increase to stimulate the growth of the milk duct system, which initiates and maintains milk production. Levels of the hormone oxytocin also rise to promote the release of breast milk when the infant suckles, which is known as the milk ejection reflex or let-down reflex. However, levels of the hormone progesterone need to decrease for successful milk production, because progesterone inhibits milk secretion. Shortly after birth, the expulsion of the placenta triggers progesterone levels to fall, which activates lactation.King, J. "Contraception and Lactation: Physiology of Lactation." *Journal of Midwifery and Women's Health* 52, no. 6 (2007): 614–20. © 2007 Elsevier Science, Inc.

New mothers need to adjust their caloric and fluid intake to make breastfeeding possible. The RDA is 330 additional calories during the first six months of lactation and 400 additional calories during the second six months of lactation. The energy needed to support breastfeeding comes from both increased intake and from stored fat. For example, during the first six months after her baby is born, the daily caloric cost for a lactating mother is 500 calories, with 330 calories derived from increased intake and 170 calories derived from maternal fat stores. This helps explain why breastfeeding may promote weight loss in new mothers. Lactating women should also drink 3-4 liters of liquids per day (about 13 cups) to maintain milk production, according to the IOM. Carbohydrate and protein needs are higher during lactation. An additional 25 grams of protein is needed per day. Fluid needs increase to 3-4 liters while vitamins and minerals are not a concern if the woman is eating an adequate diet. A lack of nutrients will reduce the quantity in breast milk, not the quality.

As is the case during pregnancy, the RDA of nearly all vitamins and minerals increases for women who are breastfeeding their babies. The following table compares the recommended vitamins and minerals for lactating women to the levels for nonpregnant and pregnant women from Table 12.2. The DRI is higher is for vitamins A, E, B_1, B_2, biotin, pantothenic acid, B_6, B_{12}, choline, zinc, iodine, and selenium during lactation than pregnancy and before pregnancy. The mother may need to take an iron supplement.

Table 12.4.1: Recommended Nutrient Intakes during Lactation

Nutrient	Nonpregnant Women	Pregnant Women	Lactating Women
Vitamin A (mcg)	700.0	770.0	1,300.0
Vitamin B_6 (mg)	1.5	1.9	2.0
Vitamin B_{12} (mcg)	2.4	2.6	2.8
Vitamin C (mg)	75.0	85.0	120.0
Vitamin D (mcg)	5.0	5.0	5.0
Vitamin E (mg)	15.0	15.0	19.0
Calcium (mg)	1,000.0	1,000.0	1,000.0
Folate (mcg)	400.0	600.0	500.0
Iron (mg)	18.0	27.0	9.0
Magnesium (mg)	320.0	360.0	310.0
Niacin (B_3) (mg)	14.0	18.0	17.0
Phosphorus	700.0	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4	1.6
Thiamine (B_1) (mg)	1.1	1.4	1.4
Zinc (mg)	8.0	11.0	12.0

Source: Institute of Medicine, www.iom.edu.

Calcium requirements do not change during breastfeeding because of more efficient absorption, which is the case during pregnancy, too. However, the reasons for this differ. During pregnancy, there is enhanced absorption within the gastrointestinal tract. During lactation, there is enhanced retention by the kidneys. The RDA for phosphorus, fluoride, and molybdenum also remains the same.

Components of Breast Milk

Human breast milk not only provides adequate nutrition for infants, it also helps to protect newborns from disease. In addition, breast milk is rich in cholesterol, which is needed for brain development. It is helpful to know the different types and components of breast milk, along with the nutrients they provide to enable an infant to survive and thrive. The amount of milk produced generally is determined by the infant's demand.

Colostrum

Colostrum is produced immediately after birth, prior to the start of milk production, and lasts for several days after the arrival of the baby. Colostrum is thicker than breast milk and is yellowish or creamy in color. This protein-rich liquid fulfills an infant’s nutrient needs during those early days. Although low in volume, colostrum is packed with concentrated nutrition for newborns. This special milk is high in fat-soluble vitamins, minerals, and immunoglobulins (antibodies) that pass from the mother to the baby. Immunoglobulins provide passive immunity for the newborn and protect the baby from bacterial and viral diseases.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm. Bifidus factors promote the growth of friendly bacteria such as L*actobacillus*, that protect against infection. Colostrum also contains lactoferrin, a protein that protects iron from

digestion by harmful bacteria, and lactaherin, a protein that binds viruses responsible for infant diarrhea. Antibodies are also present that protect against intestinal infections.

Transitional Milk

Two to four days after birth, colostrum is replaced by transitional milk. Transitional milk is a creamy liquid that lasts for approximately two weeks and includes high levels of fat, lactose, and water-soluble vitamins. It also contains more calories than colostrum. After a new mother begins to produce transitional milk, she typically notices a change in the volume and type of liquid secreted and an increase in the weight and size of her breasts.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

Mature Milk

Mature milk is the final fluid that a new mother produces. In most women, it begins to secrete at the end of the second week post childbirth. There are two types of mature milk that appear during a feeding. Foremilk occurs at the beginning and includes water, vitamins, and protein. Hind-milk occurs after the initial release of milk and contains higher levels of fat, which is necessary for weight gain. Combined, these two types of milk ensure that a baby receives adequate nutrients to grow and develop properly.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

About 90 percent of mature milk is water, which helps an infant remain hydrated. The other 10 percent contains carbohydrates, proteins, and fats, which support energy and growth. Similar to cow’s milk, the main carbohydrate of mature breast milk is lactose. Breast milk contains vital fatty acids, such as docosahexaenoic acid (DHA) and arachidonic acid (ARA). In terms of protein, breast milk contains more whey than casein (which is the reverse of cow’s milk). Whey is much easier for infants to digest than casein. Complete protein, which means all of the essential amino acids, is also present in breast milk. Complete protein includes lactoferrin, an iron-gathering compound that helps to absorb iron into an infant’s bloodstream.

In addition, breast milk provides adequate vitamins and minerals. Although absolute amounts of some micronutrients are low, they are more efficiently absorbed by infants. Other essential components include digestive enzymes that help a baby digest the breast milk. Human milk also provides the hormones and growth factors that help a newborn to develop.

Diet and Milk Quality

A mother’s diet can have a major impact on milk production and quality. As during pregnancy, lactating mothers should avoid illegal substances and cigarettes. Some legal drugs and herbal products can be harmful as well, so it is helpful to discuss them with a health-care provider. Some mothers may need to avoid certain things, such as spicy foods, that can produce gas in sensitive infants. Lactating women can drink alcohol, though they must avoid breastfeeding until the alcohol has completely cleared from their milk. Typically, this takes two to three hours for 12 ounces of beer, 5 ounces of wine, or 1.5 ounces of liquor, depending on a woman’s body weight.Harms, R., MD. “Breast-Feeding and Alcohol: Is It Okay to Drink?” © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. www.mayoclinic.com/health/breast-feeding-and-alcohol/AN02131. Precautions are necessary because exposure to alcohol can disrupt an infant’s sleep schedule.

Benefits of Breastfeeding

Breastfeeding has a number of benefits, both for the mother and for the child. Breast milk is the ideal food and contains immunoglobulins, enzymes, immune factors, and white blood cells. As a result, breastfeeding boosts the baby’s immune system and lowers the incidence of diarrhea, along with respiratory diseases, gastrointestinal problems, and ear infections. Breastfed babies also are less likely to develop asthma and allergies, and breastfeeding lowers the risk of sudden infant death syndrome. In addition, human milk encourages the growth of healthy bacteria in an infant’s intestinal tract. All of these benefits remain in place after an infant has been weaned from breast milk. Some studies suggest other possible long-term effects. For example, breast milk may improve an infant’s intelligence and protect against Type 1 diabetes and obesity, although research is ongoing in these areas.Healthy Children.org. “Breastfeeding Benefits Your Baby’s Immune System.” © 2012 American Academy of Pediatrics. Accessed February 21, 2012. http://www.healthychildren.org/English/ages-stages/baby/breastfeeding/pages/Breastfeeding-Benefits-Your-Baby%27s-Immune-System.aspx.

Breastfeeding has a number of other important benefits. It is easier for babies to digest breast milk than bottle formula, which contains proteins made from cow’s milk that require an adjustment period for infant digestive systems. Breastfed infants are sick less often than bottle-fed infants. Breastfeeding is more sustainable and results in less plastic waste and other trash. Breastfeeding

can also save families money because it does not incur the same cost as purchasing formula. Other benefits include that breast milk is always ready. It does not have to be mixed, heated, or prepared. Also, breast milk is sterile and is always at the right temperature.

In addition, the skin-to-skin contact of breastfeeding promotes a close bond between mother and baby, which is an important emotional and psychological benefit. The practice also provides health benefits for the mother. Breastfeeding helps a woman's bones stay strong, which protects against fractures later in life. Studies have also shown that breastfeeding reduces the risk of breast and ovarian cancers.National Cancer Institute. "Reproductive History and Breast Cancer Risk." Accessed February 6, 2012. http://www.cancer.gov/cancertopics/factsheet/Risk/reproductive-history.

Other benefits for the mother include a low-cost feeding option, convenient way to feed their baby and a more rapid weight loss for the mother (up to 1-2 pounds per month while lactating) targeted at the specific areas she gained weight. The quality and quantity of milk are not affected by moderate exercise. Along with bone protection, breastfeeding can reduce the risk of breast, ovarian and type II diabetes. During breastfeeding, the uterus shrinks and amenorrhea (no menstruation) occurs which conserves iron stores.

The Baby-Friendly Hospital Initiative

In 1991, the WHO and UNICEF launched the Baby-Friendly Hospital Initiative (BFHI), which works to ensure that all maternities, including hospitals and free-standing facilities, become centers of breastfeeding support. A maternity can be denoted as "baby-friendly" when it does not accept substitutes to human breast milk and has implemented ten steps to support breastfeeding. These steps include having a written policy on breastfeeding communicated to health-care staff on a routine basis, informing all new mothers about the benefits and management of breastfeeding, showing new mothers how to breastfeed their infants, and how to maintain lactation, and giving newborns no food or drink other than breast milk, unless medically indicated. Since the BFHI began, more than fifteen thousand facilities in 134 countries, from Benin to Bangladesh, have been deemed "baby friendly." As a result, more mothers are breastfeeding their newborns and infant health has improved, in both the developed world and in developing nations.United Nations Children's Fund. "The Baby-Friendly Hospital Initiative." Accessed June 8, 2012. http://www.unicef.org/programme/breastfeeding/baby.htm.

Barriers to Breastfeeding

Although breast milk is ideal for almost all infants, there are some challenges that nursing mothers may face when starting and continuing to breastfeed their infants. These obstacles include painful engorgement or fullness in the breasts, sore and tender nipples, milk leakage that can be embarrassing, inverted nipples, infection, and inadequate storage for milk. There are societal barriers too and these include lack of comfort or confidence to breastfeed in public and lack of accommodation to breastfeed or express milk in the workplace.

One of the first challenges nursing mothers face is learning the correct technique. It may take a little time for a new mother to help her baby properly latch on to her nipples. Improper latching can result in inadequate intake, which could slow growth and development. However, International Board Certified Lactation Consultants (IBCLCs), OB nurses, and registered dietitians are all trained to help new mothers learn the proper technique. Education, the length of maternity leave, and laws to protect public breastfeeding, among other measures, can all help to facilitate breastfeeding for many lactating women and their newborns.

Contraindications to Breastfeeding

Although there are numerous benefits to breastfeeding, in some cases there are also risks that must be considered. In the developed world, a new mother with HIV should not breastfeed, because the infection can be transmitted through breast milk. These women typically have access to bottle formula that is safe and can be used as a replacement for breast milk. However, in developing nations where HIV infection rates are high and acceptable infant formula can be difficult to come by, many newborns would be deprived of the nutrients they need to develop and grow. Also, inappropriate or contaminated bottle formulas cause 1.5 million infant deaths each year. As a result, the WHO recommends that women infected with HIV in the developing world should nurse their infants while taking antiretroviral medications to lower the risk of transmission.World Health Organization. "Infant and Young Child Feeding." July 2010. http://www.who.int/mediacentre/factsheets/fs342/en/index.html

Breastfeeding also is not recommended for women undergoing radiation or chemotherapy treatment for cancer. Additionally, if an infant is diagnosed with galactosemia, meaning an inability to process the simple sugar galactose, the child must be on a galactose-free diet, which excludes breast milk. This genetic disorder is a very rare condition, however, and only affects 1 in thirty- to sixty thousand newborns.Genetics Home Reference, a service of the US National Library of Medicine. "Galactosemia." July 9, 2012. http://ghr.nlm.nih.gov/condition/galactosemia. When breastfeeding is contraindicated for any reason, feeding a baby formula enables parents and caregivers to meet their newborn's nutritional needs.

Lactation Guidelines

Babies cry for many reasons and one reason may be that they are hungry. It is a late indicator of hunger. About 10-15 minutes per breast is recommended. It is best if you allow the infant to feed on both breasts. Food flavors from the foods mom eats can appear in breast milk, for example, spicy foods. These flavors may annoy the baby. Also, mom's cow milk intake may bother the infant. Alcohol enters breast milk so it is best to avoid alcohol during lactation or wait at least 2 hours after drinking an alcoholic beverage to breastfeed. Alcohol can reduce the infant's intake of breast milk. Chemicals from cigarette smoke and caffeine also pass into milk. One should limit their caffeine-containing beverage intake to no more than 1-2 cups per day. Caffeine can cause the infant to be irritable and wakeful. Estrogen-containing oral contraceptive can reduce milk output and protein content.

Bottle-Feeding

Most women can and should breastfeed when given sufficient education and support. However, as discussed, a small percentage of women are unable to breastfeed their infants, while others choose not to. For parents who choose to bottle-feed, infant formula provides a balance of nutrients. However, not all formulas are the same and there are important considerations that parents and caregivers must weigh. Standard formulas use cow's milk which is very different from human milk as a base although soy-based are available too. They have 20 calories per fluid ounce, similar to breast milk, with vitamins and minerals added. Soy-based formulas are usually given to infants who develop diarrhea, constipation, vomiting, colic, or abdominal pain, or to infants with a cow's milk protein allergy. Hypoallergenic protein hydrolysate formulas are usually given to infants who are allergic to cow's milk and soy protein. This type of formula uses hydrolyzed protein, meaning that the protein is broken down into amino acids and small peptides, which makes it easier to digest. Preterm infant formulas are given to low birth weight infants if breast milk is unavailable. Preterm infant formulas have 24 calories per fluid ounce and are given until the infant reaches the desired weight.

Infant formula comes in three basic types:

1. Powder that requires mixing with water. This is the least expensive type of formula.
2. Concentrates, which are liquids that must be diluted with water. This type is slightly more expensive.
3. Ready-to-use liquids that can be poured directly into bottles. This is the most expensive type of formula. However, it requires the least amount of preparation. Ready-to-use formulas are also convenient for traveling.

Most babies need about 2.5 ounces of formula per pound of body weight each day. Therefore, the average infant should consume about 24 fluid ounces of breast milk or formula per day. When preparing formula, parents and caregivers should carefully follow the safety guidelines, since an infant has an immature immune system. All equipment used in formula preparation should be sterilized. Prepared, unused formula should be refrigerated to prevent bacterial growth. Parents should make sure not to use contaminated water to mix formula in order to prevent foodborne illnesses. Follow the instructions for powdered and concentrated formula carefully—formula that is over diluted would not provide adequate calories and protein, while over-concentrated formula provides too much protein and too little water which can impair kidney function.

It is important to note again that both the American Academy of Pediatrics and the WHO state that breast milk is far superior to infant formula. This table compares the advantages of giving a child breast milk to the disadvantages of using bottle formula.

Table 12.4.2: Breast Milk versus Bottle Formula

Breast Milk	Bottle Formula
Antibodies and lactoferrin in breast milk protect infants.	Formula does not contain immunoprotective factors.
The iron in breast milk is absorbed more easily.	Formula contains more iron than breast milk, but it is not absorbed as easily.
The feces that babies produce do not smell because breastfed infants have different bacteria in the gut.	The feces that bottle-fed infants produce tends to have a foul-smelling odor.
Breast milk is always available and is always at the correct temperature.	Formula must be prepared, refrigerated for storage, and warmed before it is given to an infant.
Breastfed infants are less likely to have constipation.	Bottle-fed infants are more likely to have constipation.
Breastfeeding ostensibly is free, though purchasing a pump and bottles to express milk does require some expense.	Formula must be purchased and is expensive.

Breast Milk	Bottle Formula
Breast milk contains the fatty acids DHA and ARA, which are vital for brain and vision development.	Some formulas contain DHA and ALA.

Source: American Pregnancy Association. “Breastfeeding versus Bottle Feeding.” November 5, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandbottle.html.

There are problems if a powdered formula is not correctly diluted with water. If it is too dilute, i.e. too much water is added, then the infant will have inadequate nutrient intake and may fail to grow as well as experience water intoxication. If the dry powder is mixed with too little water, then the infant may become dehydrated. The source of water used to make the formula should be free of contamination, for example, lead, to prevent infection or diarrhea which is common in developing countries that have poor water sanitation.

Video 12.4.1: Breastfeeding Mothers—La Leche League Canada

This video explains the benefits of breastfeeding for both mothers and infants. (click to see video)

Introducing Solid Foods

Infants should be breastfed or bottle-fed exclusively for the first six months of life according to the WHO. (The American Academy of Pediatrics recommends breast milk or bottle formula exclusively for at least the first four months, but ideally for six months.) Infants should not consume solid foods prior to six months because solids do not contain the right nutrient mix that infants need. Also, eating solids may mean drinking less breast milk or bottle formula. If that occurs, an infant may not consume the right quantities of various nutrients. If parents try to feed an infant who is too young or is not ready, their tongue will push the food out, which is called an extrusion reflex. After six months, the suck-swallow reflexes are not as strong, and infants can hold up their heads and move them around, both of which make eating solid foods more feasible.

Solid baby foods can be bought commercially or prepared from regular food using a food processor, blender, food mill, or grinder at home. Usually, an infant cereal can be offered from a spoon between four to six months. By nine months to a year, infants are able to chew soft foods and can eat solids that are well chopped or mashed.

Infants who are fed solid foods too soon are susceptible to developing food allergies. Therefore, as parents and caregivers introduce solids, they should feed their child only one new food at a time (starting with rice cereal, followed by fruits or vegetables), to help identify allergic responses or food intolerances. An iron supplement or iron-fortified cereal is also recommended at this time because iron stores are depleted by about six months.

Nutrient dense foods should be offered that are iron-rich foods like fortified cereals, pureed meat and vitamin C-rich foods that will help with iron absorption. Fruit juices should be limited to 4-6 ounces per day because they can cause diarrhea. One food should be introduced per week and it does not matter if fruit or vegetables are introduced first. Wheat cereal should be offered last.

Here are simple dietary guidelines for the last half of the infant's first year of life.

- Build up variety
- Avoid under or overfeeding
- Don't restrict fat or cholesterol
- Don't overdo fiber rich foods
- Moderate sugar and sodium intake is fine
- Focus on iron rich foods

Learning to Self-Feed

Solid foods should be introduced when the infant is physiologically, immunologically, and developmentally ready which is around 6 months. At this time starch digestion capacity has developed and the kidneys can handle the increased protein found in food. Also, fat digestion is increased with bile acid secretion. Immunologically, the gastrointestinal tract lining has closed decreasing antigen access and the gut immune system is better developed reducing the risk of infection and food allergies. Developmentally, body weight has doubled and the baby can hold their head up and sit. The extrusion reflex has diminished and the infant is interacting with their environment. They may be asking for food and can indicate satiety by turning away and leaning back. They may be able to chew and bring the food to their mouth.

With the introduction of solid foods, young children begin to learn how to handle food and how to feed themselves. At six to seven months, infants can use their whole hand to pick up items (this is known as the palmer grasp). They can lift larger items, but picking up smaller pieces of food is difficult. At eight months, a child might be able to use a pincer grasp, which uses fingers to pick up objects. After the age of one, children slowly begin to use utensils to handle their food. Unbreakable dishes and cups are essential, since very young children may play with them or throw them when they become bored with their food.

Feeding Problems during Infancy

Parents and caregivers should be mindful of certain diet-related problems that may arise during infancy. Certain foods are choking hazards, including foods with skins or foods that are very small, such as grapes. Other examples of potential choking hazards include raw carrots and apples, raisins, hard candy, hot dogs, gum, marshmallows, whole grapes, cherries, popcorn, raw carrots, celery, whole beans, nuts and peanut butter. These foods should be avoided.

Egg whites, chocolate, nuts and unprocessed cow's milk should be avoided until after the first year of life. Honey, Corn syrup can contain the botulism toxin so should be avoided as well as unpasteurized juices or milk products, and raw or undercooked eggs, meat, fish poultry, and shellfish. Parents should also avoid adding salt or seasonings to an infant's food as well as canned vegetables because the sodium can present a problem. Sugar alcohols can cause diarrhea so these foods should be avoided too. Baby desserts or concentrated sweets are not recommended.

Heating an infant's food presents a risk of accidental injury or burns, which may occur if the food is heated unevenly or excessively. Keep in mind that an infant cannot communicate that the food is too hot. Also, parents and caregivers should never leave a baby alone at mealtime, because an infant can accidentally choke on pieces of food that are too big or have not been adequately chewed. Raw honey and corn syrup both contain spores of *Clostridium botulinum*. They produce a poisonous toxin in a baby's intestines, which can cause the foodborne illness botulism. After the age of one, it is safe to give an infant honey or corn syrup. However, honey as an ingredient in food, such as in cereal, is safe for all ages because it has been adequately heat-treated.

Overnutrition

Overnutrition during infancy is a growing problem. Overfed infants may develop dietary habits and metabolic characteristics that last a lifetime. According to the *American Journal of Clinical Nutrition*, the consequences of overnutrition and growth acceleration in infancy include long-term obesity, along with Type 2 diabetes and cardiovascular disease later in life.Singhal, A. et al. "Nutrition in Infancy and Long-Term Risk of Obesity: Evidence from Two Randomized Control Trials." *Am J Clin Nutr* 92 (2010): 1133–44. Therefore, parents and other caregivers should restrain from overfeeding, and ideally give their infants breast milk to promote health and well-being.

Food Allergies

Food allergies impact four to six percent of young children in America. Common food allergens that can appear just before or after the first year include peanut butter, egg whites, wheat, cow's milk, and nuts. For infants, even a small amount of a dangerous food can prove to be life-threatening. If there is a family history of food allergies, it is a good idea to delay giving a child dairy products until one year of age, eggs until two years of age, and shellfish, fish, and nuts until three years of age.

However, lactating women should not make any changes to their diets. Research shows that nursing mothers who attempt to ward off allergies in their infants by eliminating certain foods may do more harm than good. According to the American Academy of Allergy, Asthma, and Immunology, mothers who avoided certain dairy products showed decreased levels in their breast milk of an immunoglobulin specific to cow's milk. This antibody is thought to protect against the development of allergies in children. Even when an infant is at higher risk for food allergies, there is no evidence that alterations in a mother's diet make a difference.Gever, J. "Nursing Mom's Diet No Guard Against Baby Allergies." Medpage Today. © 2012 Everyday Health, Inc. March 7, 2012. http://www.medpagetoday.com/MeetingCoverage/AAAAIMeeting/31527?utm_content=&utm_medium=email&utm_campaign=DailyHeadlines&utm_source=WC&eun=g330425d0r&userid=330425& email=mzimmerman@cox.net&mu_id=. Approximately one percent of formula-fed infants develop a food allergy.

Early Childhood Caries

Primary teeth are at risk for a disorder known as early childhood caries from breast milk, formula, juice, or other drinks fed through a bottle. Liquids can build up in a baby's mouth, and the natural or added sugars lead to decay. Early childhood caries is caused not only by the kinds of liquids given to an infant but also by the frequency and length of time that fluids are given. Giving a child a bottle of juice or other sweet liquids several times each day, or letting a baby suck on a bottle longer than a mealtime, either when

awake or asleep, can also cause early childhood caries. Bacteria in the mouth feed on the carbohydrate and cause teeth decay. In addition, this practice affects the development and position of the teeth and the jaw. The risk of early childhood caries continues into the toddler years as children begin to consume more foods with a high sugar content. Therefore, parents should avoid giving their children sugary snacks and beverages.

Gastroesophageal Reflux

Small amounts of spitting up during a feeding are normal. However, there is cause for concern if it is too difficult to feed an infant due to gastroesophageal reflux. This condition occurs when stomach muscles open at the wrong times and allow milk or food to back up into the esophagus. Symptoms of gastroesophageal reflux in infants include severe spitting up, projectile vomiting, arching of the back as though in pain, refusal to eat or pulling away from the breast during feedings, gagging or problems with swallowing, and slow weight gain. For most infants, making adjustments in feeding practices addresses the issue. For example, a parent can feed their baby in an upright position, wait at least an hour after eating for play time, burp more often, or give a child smaller, more frequent feedings.

Diarrhea and Constipation

Diarrhea is often caused by a gastrointestinal infection and can dehydrate an infant. It is characterized by stool frequency and consistency that deviates substantially from the norm. Diarrhea may indicate a bacterial or viral infection or food intolerance. Chronic diarrhea can cause growth failure. If an infant has had several bouts of this condition, they will need to replace lost fluids and electrolytes. A common recommendation is to give a child an oral rehydration solution. Because of the immunoprotective factors in breast milk, breastfed infants are less likely to contract gastrointestinal viral illness and experience diarrhea.

Infant constipation—which is the passage of hard, dry bowel movements, but not necessarily the absence of daily bowel movements—is another common problem. This condition frequently begins when a baby transitions from breast milk to formula or begins eating solid foods. Pediatricians can provide the best guidance for handling the problem. Common recommendations include applying a small amount of water-based lubricant to an infant's anus to ease the passage of hard stools, and feeding an infant on solid foods pureed pears or prunes, or providing barley cereal in place of rice cereal.Mayo Clinic. "Infant and Toddler Health." March 16, 2011. © 1998–2012 Mayo Foundation for Medical Education and Research. www.mayoclinic.com/health/infant-and-toddler-health/MY00362. Parents can also offer their child a little more water in between feedings to help alleviate the condition.

Colic

Colic is a common problem during infancy, characterized by crankiness and crying jags. It is defined as crying that lasts longer than three hours per day for at least three days per week and for at least three weeks (which is commonly known as the "rule of 3's"), and is not caused by a medical problem. About one-fifth of all infants develop colic, usually between the second and third weeks. Crying spells can occur around the clock but often worsen in the early evening. Also, colicky babies may have stomachs that are enlarged or distended with gas.

There is no definitive explanation for colic. Often, colic occurs when a child is unusually sensitive to stimulation. In breastfed babies, colic can be a sign of sensitivity to the mother's diet. Lactating mothers can try to eliminate caffeine, chocolate, and any other potentially irritating foods from their meals.Medline Plus, a service of the US National Library of Medicine. "Colic and Crying." Last updated August 2, 2011. www.nlm.nih.gov/medlineplus/ency/article/000978.htm. However, since colic usually subsides over time, any improvement that occurs with food elimination may coincide with the natural healing process.

Parents and caregivers who are feeding bottle formula to colicky babies should talk with pediatricians about replacing it with a protein hydrolysate formula.American Academy of Pediatrics. "Colic." HealthyChildren.org. © American Academy of Pediatrics. Last updated May 12, 2011. http://www.healthychildren.org/English/ages-stages/baby/crying-colic/pages/Colic.aspx. Whether breastfeeding or bottle-feeding, it is also important not to overfeed infants, which could make them uncomfortable and more likely to have crying fits. In general, it is best to wait between two and three hours from the start of one feeding to the start of the next. If food sensitivity is the cause, colic should cease within a few days of making changes. Eventually, the problem goes away. Symptoms usually begin to dissipate after six weeks and are gone by twelve weeks.Medline Plus, a service of the US National Library of Medicine. "Colic and Crying." Last updated August 2, 2011. www.nlm.nih.gov/medlineplus/ency/article/000978.htm.

Newborn Jaundice

Newborn jaundice is another potential problem during infancy. This condition can occur within a few days of birth and is characterized by yellowed skin or yellowing in the whites of the eyes, which can be harder to detect in dark-skinned babies.

Jaundice typically appears on the face first, followed by the chest, abdomen, arms, and legs. This disorder is caused by elevated levels of bilirubin in a baby's bloodstream. Bilirubin is a substance created by the breakdown of red blood cells and is removed by the liver. Jaundice develops when a newborn's liver does not efficiently remove bilirubin from the blood. There are several types of jaundice associated with newborns:

- **Physiologic jaundice.** The most common type of newborn jaundice and can affect up to 60 percent of full-term babies in the first week of life.
- **Breast-milk jaundice.** The name for a condition that persists after physiologic jaundice subsides in otherwise healthy babies and can last for three to twelve weeks after birth. Breast-milk jaundice tends to be genetic and there is no known cause, although it may be linked to a substance in the breast milk that blocks the breakdown of bilirubin. However, that does not mean breastfeeding should be stopped. As long as bilirubin levels are monitored, the disorder rarely leads to serious complications.
- **Breastfeeding jaundice.** Occurs when an infant does not get enough milk. This may happen because a newborn does not get a good start breastfeeding, does not latch on to the mother's breast properly, or is given other substances that interfere with breastfeeding (such as juice). Treatment includes increased feedings, with help from a lactation consultant to ensure that the baby takes in adequate amounts.



Figure 12.4.2: Yellowing skin is one sign of newborn jaundice. IMage used with permission (CC BY-SA 3.0; Martybugs).

Newborn jaundice is more common in a breastfed baby and tends to last a bit longer. If jaundice is suspected, a pediatrician will run blood tests to measure the amount of bilirubin in an infant's blood. Treatment often involves increasing the number of feedings to increase bowel movements, which helps to excrete bilirubin. Within a few weeks, as the baby begins to mature and red blood cell levels diminish, jaundice typically subsides with no lingering effects.American Pregnancy Association. "Breastfeeding and Jaundice." © 2000–2012 American Pregnancy Association. Accessed February 21, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandjaundice.htm.

Iron Deficiency Anemia

A poor transition from breast milk, which is a poor source of iron, to solid foods can cause an iron deficiency or anemia. Remember, during the first six months of life, the infant is drawing on his/her iron stores which were accumulated *in utero*. By six months of age, the infant's iron stores are low so it is important they are given iron-rich foods for their first foods. In children drinking cow's milk, milk anemia may develop if 2-3 cups of cow's milk is consumed per day. The milk displaces the iron making it unavailable for absorption.

Vegetarian Diets

For the first six months of life, infants are lactovegetarian because the consume milk. After six months, maintaining a vegan status becomes more challenging. Vegans should consult a pediatrician and a registered dietitian if they want to continue their infant as a vegan. Continued breastfeeding or formula feeding may be recommended with supplementary feeding to assure adequate iron and energy intake.

Key Takeaways

Parents and other caregivers should use growth charts to track an infant's development and determine how to best meet their child's nutritional needs. For the first four to six months of life, children should consume breast milk exclusively. For the next six months, solid foods should be introduced gradually into an infant's diet as parents and caregivers continue to provide breast milk. Breast milk is ideal for infants and provides all of the nutrients they need to grow and develop. Breastfeeding provides a number of benefits for both a mother and her infant. For babies, breast milk boosts the immune system to protect against disease. For mothers, breastfeeding has several health benefits, such as reducing the risk of breast cancer and ovarian cancer. For both, breastfeeding promotes an emotional bond between mother and child. Some problems related to food and nutrition that may occur during infancy include overnutrition, early childhood caries, gastroesophageal reflux, diarrhea, constipation, and colic.

Discussion Starter

1. Why do some women choose to breastfeed their infants? Why do others decline to breastfeed? Discuss this crucial decision that parents make in the first stages of an infant's life and the possible consequences of each choice.

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12.5: Nutrition in the Toddler Years

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for toddlers.
- Explore the introduction of solid foods into a toddler's diet.
- Examine feeding problems that parents and caregivers may face with their toddlers.

By the age of two, children have advanced from infancy and are on their way to becoming school-aged children. Their physical growth and motor development slow compared to the progress they made as infants. However, toddlers experience enormous intellectual, emotional, and social changes. Of course, food and nutrition continue to play an important role in a child's development. During this stage, the diet completely shifts from breastfeeding or bottle-feeding to solid foods along with healthy juices and other liquids. The toddler's metabolism slows compared to the infant so their appetite decreases. Parents of toddlers also need to be mindful of certain nutrition-related issues that may crop up during this stage of the human lifecycle. For example, fluid requirements relative to body size are higher in toddlers than in adults because children are at greater risk of dehydration. Toddlers should drink about 1.3 liters of fluids per day, ideally liquids that are low in sugar. Compared to infants, toddler fluid, energy and protein requirements per kilogram are lower.

Several assessments will be used to determine if the child is the appropriate size for their age. These include charts of height and weight: height-for-age and weight-for-age. If the child is less than the fifth percentile they would be considered stunted or underweight, respectively. BMI may also be calculated as a screening tool to give an indirect measurement of body fatness. If it is less than the fifth percentile the child would be considered underweight. If it is greater than the 95th percentile then the child is overweight. Head circumference will be measured too.

The Toddler Years (Ages Two to Three)

During this phase of human development, children are mobile and grow more slowly than infants, but are much more active. Their nutritional needs increase with age but decrease per kg body weight. The toddler years pose interesting challenges for parents or other caregivers, as children learn how to eat on their own and begin to develop personal preferences. However, with the proper diet and guidance, toddlers can continue to grow and develop at a healthy rate.

Nutritional Requirements

MyPlate may be used as a guide for the toddler's diet (www.choosemyplate.gov/preschoolers.html). A toddler's serving sizes should be approximately one-quarter that of an adult's. One way to estimate serving sizes for young children is one tablespoon for each year of life. For example, a two-year-old child would be served 2 tablespoons of fruits or vegetables at a meal, while a four-year-old would be given 4 tablespoons or a quarter cup. Here is an example of a toddler-sized meal:

- 1 ounce of meat or chicken, or 2 to 3 tablespoons of beans
- One-quarter slice of whole-grain bread
- 1 to 2 tablespoons of cooked vegetable
- 1 to 2 tablespoons of fruit

Energy

The energy requirements for ages two to three are about 1,000 to 1,400 calories a day. The following formula can also be used to calculate energy needs: kcal/d = ((89*weight in kg)-100_+20. In general, a toddler needs to consume about 40 calories for every inch of height. For example, a young child who measures 32 inches should take in an average of 1,300 calories a day. However, the recommended caloric intake varies with each child's level of activity. Toddlers require small, frequent, nutritious snacks and meals to satisfy energy requirements. The amount of food a toddler needs from each food group depends on daily calorie needs. See Table 12.5 for some examples.

Table 12.5.1: Serving Sizes for Toddlers

Food Group	Daily Serving	Examples
Grains	About 3 ounces of grains per day, ideally whole grains	• 3 slices of bread • 1 slice of bread, plus ⅓ cup of cereal, and ¼ cup of cook
Proteins	2 ounces of meat, poultry, fish, eggs, or legumes	• 1 ounce of lean meat or chicken, plus one egg • 1 ounce of fish, plus ¼ cup of cooked beans
Fruits	1 cup of fresh, frozen, canned, and/or dried fruits, or 100 percent fruit juice	• 1 small apple cut into slices • 1 cup of sliced or cubed fruit • 1 large banana
Vegetables	1 cup of raw and/or cooked vegetables	• 1 cup of pureed, mashed, or finely chopped vegetables (s broccoli, or tomato sauce)
Dairy Products	2 cups per day	• 2 cups of fat-free or low-fat milk • 1 cup of fat-free or low-fat milk, plus 2 slices of cheese • 1 cup of fat-free or low-fat milk, plus 1 cup of yogurt

Source: Academy of Nutrition and Dietetics. "It's about Eating Right: Size-Wise Nutrition for Toddlers." © 1995–2012, Academy of Nutrition and Dietetics, all rights reserved. www.eatright.org/public/content.aspx?id=8055.

Macronutrients

For carbohydrate intake, the Acceptable Macronutrient Distribution Range (AMDR) is 45 to 65 percent of daily calories (113 to 163 grams for 1,000 daily calories). Toddlers' needs increase to support their body and brain development. Brightly-colored unrefined complex carbohydrates, such as peas, orange slices, tomatoes, and bananas are not only nutrient-dense, they also make a plate look more appetizing and appealing to a young child. Low sugar snacks over snacks with added sugar should be emphasized. The RDA of protein is 5 to 20 percent of daily calories (13 to 50 grams for 1,000 daily calories). The AMDR for fat for toddlers is 30 to 40 percent of daily calories (33 to 44 grams for 1,000 daily calories). Essential fatty acids are vital for the development of the eyes, along with nerve and other types of tissue. However, toddlers should not consume foods with high amounts of trans fats and saturated fats. Instead, young children require the equivalent of 3 teaspoons of healthy oils, such as canola oil, each day.

Micronutrients

As a child grows bigger, the demands for micronutrients increase. Generally, well-nourished children do not need supplements but there are three exceptions: fluoride, iron, and vitamin D. These needs for vitamins and minerals can be met with a balanced diet, with a few exceptions. According to the American Academy of Pediatrics, toddlers and children of all ages need 600 international units of vitamin D per day. Vitamin D-fortified milk and cereals can help to meet this need. However, toddlers who do not get enough of this micronutrient should receive a supplement otherwise. Pediatricians may also prescribe a fluoride supplement for toddlers who live in areas with fluoride-poor water. Iron deficiency is also a major concern for children between the ages of two and three. You will learn about iron-deficiency anemia later in this section.

If the child does not eat enough fruits and vegetables, their intake of vitamin A and C may be inadequate. If they avoid dairy or don't eat and drink enough dairy, then their calcium intake may be low.

Learning How to Handle Food

As children grow older, they enjoy taking care of themselves, which includes self-feeding. During this phase, it is important to offer children foods that they can handle on their own and that helps them avoid choking and other hazards. Examples include fresh fruits that have been sliced into pieces, orange or grapefruit sections, peas or potatoes that have been mashed for safety, a cup of yogurt,

and whole-grain bread or bagels cut into pieces. Even with careful preparation and training, the learning process can be messy. As a result, parents and other caregivers can help children learn how to feed themselves by providing the following:

- small utensils that fit a young child's hand
- small cups that will not tip over easily
- plates with edges to prevent food from falling off
- small servings on a plate
- high chairs, booster seats, or cushions to reach a table

Feeding Problems in the Toddler Years

During the toddler years, parents may face a number of problems related to food and nutrition. Possible obstacles include difficulty helping a young child overcome a fear of new foods, or fights over messy habits at the dinner table. Even in the face of problems and confrontations, parents and other caregivers must make sure their preschooler has nutritious choices at every meal. For example, even if a child stubbornly resists eating vegetables, parents should continue to provide them. Before long, the child may change their mind, and develop a taste for foods once abhorred. It is important to remember this is the time to establish or reinforce healthy habits.

Nutritionist Ellyn Satter states that feeding is a responsibility that is split between parent and child. According to Satter, parents are responsible for *what* their infants eat, while infants are responsible for *how much* they eat. In the toddler years and beyond, parents are responsible for *what* children eat, *when* they eat, and *where* they eat, while children are responsible for *how much* food they eat and *whether* they eat. Satter states that the role of a parent or a caregiver in feeding includes the following:

- selecting and preparing food (including the toddler can be fun)
- providing regular meals and snacks
- making meal times interactive and enjoyable
- showing children what they must learn about mealtime behavior
- Introducing new foods at the beginning of the meal when the child is hungry
- avoiding letting children eat in between meal- or snack-times (Ellyn Satter Associates. "Ellyn Satter's Division of Responsibility in Feeding." © 2012 by Ellyn Satter. www.ellynsatter.com/ellyn-satters-division-of-responsibility -in-feeding-i-80.html.)

High-Risk Choking Foods

Certain foods are difficult for toddlers to manage and pose a high risk of choking. Big chunks of food should not be given to children under the age of four. Also, globs of peanut butter can stick to a younger child's palate and choke them. Popcorn and nuts should be avoided as well because toddlers are not able to grind food and reduce it to a consistency that is safe for swallowing. Certain raw vegetables, such as baby carrots, whole cherry tomatoes, whole green beans, and celery are also serious choking hazards. However, there is no reason that a toddler cannot enjoy well-cooked vegetables cut into bite-size pieces.

Picky Eaters

The parents of toddlers are likely to notice a sharp drop in their child's appetite. Children at this stage are often picky about what they want to eat. They may turn their heads away after eating just a few bites. Or, they may resist coming to the table at mealtimes. They also can be unpredictable about what they want to consume for specific meals or at particular times of the day. Although it may seem as if toddlers should increase their food intake to match their level of activity, there is a good reason for picky eating. A child's growth rate slows after infancy, and toddlers ages two and three do not require as much food.

Food Jags

For weeks, toddlers may go on a food jag and eat one or two preferred foods—and nothing else. It is important to understand that preferences will be inconsistent as a toddler develops eating habits. This is one way that young children can assert their individuality and independence. However, parents and caregivers should be concerned if the same food jag persists for several months, instead of several weeks. Options for addressing this problem include rotating acceptable foods while continuing to offer diverse foods, remaining low-key to avoid exacerbating the problem and discussing the issue with a pediatrician. Also, children should not be forced to eat foods that they do not want. It is important to remember that food jags do not have a long-term effect on a toddler's health, and are usually temporary situations that will resolve themselves.

Toddler Obesity

Another potential problem during the early childhood years is toddler obesity. According to the US Department of Health and Human Services, in the past thirty years, obesity rates have more than doubled for all children, including infants and toddlers.Head Start, US Department of Health and Human Services. "Prevention of Overweight and Obesity in Infants and Toddlers." 2005. Accessed February 21, 2012. http://eclkc.ohs.acf.hhs.gov/hslc/tta-system/family Almost 10 percent of infants and toddlers weigh more than they should considering their length, and slightly more than 20 percent of children ages two to five are overweight or obese.Institute of Medicine of the National Academies. "Early Childhood Obesity Prevention Policies." June 23, 2011. www.iom.edu/Reports/2011/Early-Childhood -Obesity-Prevention-Policies.aspx Obesity during early childhood tends to linger as a child matures and cause health problems later in life.

There are a number of reasons for this growing problem. One is a lack of time. Parents and other caregivers who are constantly on the go may find it difficult to fit home-cooked meals into a busy schedule and may turn to fast food and other conveniences that are quick and easy, but not nutritionally sound. Another contributing factor is a lack of access to fresh fruits and vegetables. This is a problem particularly in low-income neighborhoods where local stores and markets may not stock fresh produce or may have limited options. Physical inactivity is also a factor, as toddlers who live a sedentary lifestyle are more likely to be overweight or obese. Another contributor is a lack of breastfeeding support. Children who were breastfed as infants show lower rates of obesity than children who were bottle-fed.

To prevent or address toddler obesity parents and caregivers can do the following:

- Eat at the kitchen table instead of in front of a television to monitor what and how much a child eats.
- Offer a child healthy portions. The size of a toddler's fist is an appropriate serving size.
- Plan time for physical activity, about sixty minutes or more per day. Toddlers should have no more than sixty minutes of sedentary activity, such as watching television, per day.

Early Childhood Caries

Early childhood caries remains a potential problem during the toddler years. The risk of early childhood caries continues as children begin to consume more foods with a high sugar content. According to the National Health and Nutrition Examination Survey, children between ages of two and five consume about 200 calories of added sugar per day.US Department of Health and Human Services. "Consumption of Added Sugar among US Children and Adolescents." *NCHS Data Brief*, No. 87 (March 2012). Therefore, parents with toddlers should avoid processed foods, such as snacks from vending machines, and sugary beverages, such as soda. Parents also need to instruct a child on brushing their teeth at this time to help a toddler develop healthy habits and avoid tooth decay.

Iron-Deficiency Anemia

An infant who switches to solid foods, but does not eat enough iron-rich foods, can develop iron-deficiency anemia. This condition occurs when an iron-deprived body cannot produce enough hemoglobin, a protein in red blood cells that transports oxygen throughout the body. The inadequate supply of hemoglobin for new blood cells results in anemia. Iron-deficiency anemia causes a number of problems including weakness, pale skin, shortness of breath, and irritability. It can also result in intellectual, behavioral, or motor problems. In infants and toddlers, iron-deficiency anemia can occur as young children are weaned from iron-rich foods, such as breast milk and iron-fortified formula. They begin to eat solid foods that may not provide enough of this nutrient. As a result, their iron stores become diminished at a time when this nutrient is critical for brain growth and development.

There are steps that parents and caregivers can take to prevent iron-deficiency anemia, such as adding more iron-rich foods to a child's diet, including lean meats, fish, poultry, eggs, legumes, and iron-enriched whole-grain breads and cereals. A toddler's diet should provide 7 to 10 milligrams of iron daily. Although milk is critical for the bone-building calcium that it provides, intake should not exceed the RDA to avoid displacing foods rich with iron. Children may also be given a daily supplement, using infant vitamin drops with iron or ferrous sulfate drops. If iron-deficiency anemia does

occur, treatment includes a dosage of 3 milligrams per kilogram once daily before breakfast, usually in the form of a ferrous sulfate syrup. Consuming vitamin C, such as orange juice, can also help to improve iron absorption.Kazal Jr., L. A., MD. “Prevention of Iron Deficiency in Infants and Toddlers.” *American Academy of Family Physicians* 66, no. 7 (October 1, 2002): 1217—25. www.aafp.org/afp/2002/1001/p1217.html.

Toddler Diarrhea

As with adults, a variety of conditions or circumstances may give a toddler diarrhea. Possible causes include bacterial or viral infections, food allergies, or lactose intolerance, among other medical conditions. Excessive fruit juice consumption (more than one 6-ounce cup per day) can also lead to diarrhea.American Academy of Pediatrics, Committee on Nutrition 1999–2000. “The Use and Misuse of Fruit Juice in Pediatrics.” *Pediatrics* 119, no. 2 (February 2007): 405. doi:10.1542/peds.2006-3222. Diarrhea presents a special concern in young children because their small size makes them more vulnerable to dehydration. Parents should contact a pediatrician if a toddler has had diarrhea for more than twenty-four hours, if a child is also vomiting, or if they exhibit signs of dehydration, such as a dry mouth or tongue, or sunken eyes, cheeks, or abdomen. Preventing or treating dehydration in toddlers includes the replacement of lost fluids and electrolytes (sodium and potassium). Oral rehydration therapy, or giving special fluids by mouth, is the most effective measure.

Developing Habits

Eating habits develop early in life. They are typically formed within the first few years and it is believed that they persist for years, if not for life. So it is important for parents and other caregivers to help children establish healthy habits and avoid problematic ones. Children begin expressing their preferences at an early age. Parents must find a balance between providing a child with an opportunity for self-expression, helping a child develop healthy habits, and making sure that a child meets all of their nutritional needs. Following Ellyn Satter’s division of responsibility in feeding (see above) can help a child eat the right amount of food, learn mealtime behavior, and grow at a healthy and predictable rate.

Bad habits and poor nutrition have an accrual effect. The foods you consume in your younger years will impact your health as you age, from childhood into the later stages of life. As a result, good nutrition today means optimal health tomorrow. In the next chapter, you will learn about how nutritional needs change from the later childhood years, through adolescence and adulthood, and into old age. The choices that you make at every age accumulate over time and greatly impact your health into the golden years.

Video 12.4: Introducing Your Toddler to New Foods

This video focuses on ways to encourage toddlers to try new foods. (click to see video)

Lead Poisoning

Lead poisoning is a leading cause of poisoning in this age and usually occurs from ingesting lead paint. Lead is a heavy metal and it accumulates in the bones, brain, teeth, and kidneys. lead poisoning causes iron deficiency, learning disabilities and behavioral changes, paralysis, nerve damage, and death with severe toxicity.

Effect of Food on Behavior

Sugar and food additives have been promoted to cause hyperactivity. There is no scientific evidence to support these claims. Eating sugar laden foods will increase short-term activity, but that will decrease quickly. A high dose of sugar can act as a sedative after the initial stimulation.

Caffeine can be found in a variety of different foods, not just coffee. Sodas and chocolate can contain caffeine so you need to read the ingredient list to if it is present in the product. Caffeine is a stimulant and may cause hyperactivity in some children. Other children are sensitive to caffeine.

Scientific studies have shown that breakfast improves school performance. Children who skip breakfast have a shorter attention span and poorer concentration.

Key Takeaways

By the toddler years, young children are able to self-feed and begin to develop eating habits and preferences. The energy requirements for ages two to three are about 1,000 to 1,400 calories per day, and in general, a toddler needs to consume about 40 calories for every inch of height. Growth slows during the toddler years, but children are more active at this stage and undergo a great deal of intellectual, emotional, and social development. Some food- and nutrition-related problems that can occur during the toddler years include choking, picky eating, food jags, early childhood caries, iron-deficiency anemia, and toddler diarrhea.

Discussion Starter

1. How do the nutritional needs of a child change from infancy into the toddler years? Discuss the changing needs for energy, macronutrients, and micronutrients as young children mature.

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12.6: Childhood and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for school-aged children.
- Discuss the most important nutrition-related concerns during childhood.

Nutritional needs change as children leave the toddler years. From ages four to eight, school-aged children grow consistently, but at a slower rate than infants and toddlers. They also experience the loss of deciduous, or “baby,” teeth and the arrival of permanent teeth, which typically begins at age six or seven. As new teeth come in, many children have some malocclusion, or malposition, of their teeth, which can affect their ability to chew food. Other changes that affect nutrition include the influence of peers on dietary choices and the kinds of foods offered by schools and afterschool programs, which can make up a sizable part of a child’s diet. Food-related problems for young children can include tooth decay, food sensitivities, and malnourishment. Also, excessive weight gain early in life can lead to obesity into adolescence and adulthood.

Childhood (Ages Four to Eight): “Growing Pains”



Figure 12.6.1: In school-aged children, muscle mass and strength increase and motor skills show improvement. (Public Domain; Tysto)

At this life stage, a healthy diet facilitates physical and mental development and helps to maintain health and wellness. School-aged children experience steady, consistent growth, with an average growth rate of 2–3 inches (5–7 centimeters) in height and 4.5–6.5 pounds (2–3 kilograms) in weight per year. In addition, the rate of growth for the extremities is faster than for the trunk, which results in more adult-like proportions. Long-bone growth stretches muscles and ligaments, which results in many children experiencing “growing pains,” at night time in particular.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 150–51.

Energy

Children’s energy needs vary, depending on their growth and level of physical activity. Energy requirements also vary according to gender. Girls ages four to eight require 1,200 to 1,800 calories a day, while boys need 1,200 to 2,000 calories daily, and, depending on their activity level, maybe more. Also, recommended intakes of macronutrients and most micronutrients are higher relative to body size, compared with nutrient needs during adulthood. Therefore, children should be provided nutrient-dense food at meal- and snack-time. However, it is important not to overfeed children, as this can lead to childhood obesity, which is discussed in the next section. Parents and other caregivers can turn to the MyPlate website for guidance: http://www.choosemyplate.gov/.

Macronutrients

For carbohydrates, the Acceptable Macronutrient Distribution Range (AMDR) is 45–65 percent of daily calories (which is a recommended daily allowance of 135–195 grams for 1,200 daily calories). Carbohydrates high in fiber should make up the bulk of intake. The AMDR for protein is 10–30 percent of daily calories (30–90 grams for 1,200 daily calories). Children have a high need

for protein to support muscle growth and development. High levels of essential fatty acids are needed to support growth (although not as high as in infancy and the toddler years). As a result, the AMDR for fat is 25–35 percent of daily calories (33–47 grams for 1,200 daily calories). Children should get 17–25 grams of fiber per day.

Micronutrients

Micronutrient needs should be met with foods first. Parents and caregivers should select a variety of foods from each food group to ensure that nutritional requirements are met. Because children grow rapidly, they require foods that are high in iron, such as lean meats, legumes, fish, poultry, and iron-enriched cereals. Adequate fluoride is crucial to support strong teeth. One of the most important micronutrient requirements during childhood is adequate calcium and vitamin D intake. Both are needed to build dense bones and a strong skeleton. Children who do not consume adequate vitamin D should be given a supplement of 10 micrograms (400 international units) per day. Table 12.6.1 shows the micronutrient recommendations for school-aged children. (Note that the recommendations are the same for boys and girls. As we progress through the different stages of the human life cycle, there will be some differences between males and females regarding micronutrient needs.)

Table 12.6.1: Micronutrient Levels during Childhood

Nutrient	Children, Ages 4–8
Vitamin A (mcg)	400.0
Vitamin B_6 (mcg)	600.0
Vitamin B_{12} (mcg)	1.2
Vitamin C (mg)	25.0
Vitamin D (mcg)	5.0
Vitamin E (mg)	7.0
Vitamin K (mcg)	55.0
Calcium (mg)	800.0
Folate (mcg)	200.0
Iron (mg)	10.0
Magnesium (mg)	130.0
Niacin (B_3) (mg)	8.0
Phosphorus (mg)	500.0
Riboflavin (B_2) (mcg)	600.0
Selenium (mcg)	30.0
Thiamine (B_1) (mcg)	600.0
Zinc (mg)	5.0

Source: Institute of Medicine. www.iom.edu.

Factors Influencing Intake

A number of factors can influence children's eating habits and attitudes toward food. Family environment, societal trends, taste preferences, and messages in the media all impact the emotions that children develop in relation to their diet. Television commercials can entice children to consume sugary products, fatty fast foods, excess calories, refined ingredients, and sodium. Therefore, it is critical that parents and caregivers direct children toward healthy choices.

One way to encourage children to eat healthy foods is to make meal- and snack-time fun and interesting. Parents should include children in food planning and preparation, for example selecting items while grocery shopping or helping to prepare part of a meal, such as making a salad. At this time, parents can also educate children about kitchen safety. It might be helpful to cut sandwiches, meats, or pancakes into small or interesting shapes. In addition, parents should offer nutritious desserts, such as fresh fruits, instead

of calorie-laden cookies, cakes, salty snacks, and ice cream. Also, studies show that children who eat family meals on a frequent basis consume more nutritious foods. Dakota County, Minnesota. “Research on the Benefits of Family Meals.” © 2006. Last revised April 30, 2012. www.co.dakota.mn.us/Departments/PublicHealth/Projects/ResearchFamilyMeals.htm.

Children and Malnutrition

Malnutrition is a problem many children face, in both developing nations and the developed world. Even with the wealth of food in North America, many children grow up malnourished, or even hungry. The US Census Bureau characterizes households into the following groups:

- food secure
- food insecure without hunger
- food insecure with moderate hunger
- food insecure with severe hunger

Millions of children grow up in food-insecure households with inadequate diets due to both the amount of available food and the quality of food. In the United States, about 20 percent of households with children are food insecure to some degree. In half of those, only adults experience food insecurity, while in the other half both adults and children are considered to be food insecure, which means that children did not have access to adequate, nutritious meals at times.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

Growing up in a food-insecure household can lead to a number of problems. Deficiencies in iron, zinc, protein, and vitamin A can result in stunted growth, illness, and limited development. Federal programs, such as the National School Lunch Program, the School Breakfast Program, and Summer Feeding Programs, work to address the risk of hunger and malnutrition in school-aged children. They help to fill the gaps and provide children living in food-insecure households with greater access to nutritious meals.

The National School Lunch Program

Beginning with preschool, children consume at least one of their meals in a school setting. Many children receive both breakfast and lunch outside of the home. Therefore, it is important for schools to provide meals that are nutritionally sound. In the United States, more than thirty-one million children from low-income families are given meals provided by the National School Lunch Program. This federally-funded program offers low-cost or free lunches to schools, and also snacks to after school facilities. School districts that take part receive subsidies from the US Department of Agriculture (USDA) for every meal they serve. School lunches must meet the *2010 Dietary Guidelines for Americans* and need to provide one-third of the RDAs for protein, vitamin A, vitamin C, iron, and calcium. However, local authorities make the decisions about what foods to serve and how they are prepared.US Department of Agriculture. “National School Lunch Program Fact Sheet.” 2011. Accessed March 5, 2012. www.fns.usda.gov/cnd/lunch/AboutLunch/NSLPFactSheet.pdf. The Healthy School Lunch Campaign works to improve the food served to children in school and to promote children’s short- and long-term health by educating government officials, school officials, foodservice workers, and parents. Sponsored by the Physicians Committee for Responsible Medicine, this organization encourages schools to offer more low-fat, cholesterol-free options in school cafeterias and in vending machines.Physicians Committee for Responsible Medicine. “Healthy School Lunches.” Accessed March 5, 2012. http://healthyschoollunches.org/.



Video 12.6.1: *The USDA Introduces New School Lunch Standards. (click to see video). This video focuses on changes to the National School Lunch Program in the United States.*

Children and Vegetarianism

Another issue that some parents face with school-aged children is the decision to encourage a child to become a vegetarian or a vegan. Some parents and caregivers decide to raise their children as vegetarians for health, cultural, or other reasons. Preteens and teens may make the choice to pursue vegetarianism on their own, due to concerns about animals or the environment. No matter the reason, parents with vegetarian children must take care to ensure vegetarian children get healthy, nutritious foods that provide all the necessary nutrients.

Types of Vegetarian Diets

There are several types of vegetarians, each with certain restrictions in terms of diet:

- **Ovo-vegetarians.** Ovo-vegetarians eat eggs but do not eat any other animal products.
- **Lacto-ovo-vegetarians.** Lacto-ovo-vegetarians eat eggs and dairy products but do not eat any meat.
- **Lacto-vegetarians.** Lacto-vegetarians eat dairy products but do not eat any other animal products.
- **Vegans.** Vegans eat food only from plant sources, no animal products at all.

Children who consume some animal products, such as eggs, cheese, or other forms of dairy, can meet their nutritional needs. For a child following a strict vegan diet, planning is needed to ensure adequate intake of protein, iron, calcium, vitamin B_{12}, and vitamin D. Legumes and nuts can be eaten in place of meat, soy milk fortified with calcium and vitamins D and B_{12} can replace cow's milk.

Food Allergies and Food Intolerance

The development of food allergies is a concern during the toddler years. This remains an issue for school-aged children. Recent studies show that three million children under age eighteen are allergic to at least one type of food.American Academy of Allergy, Asthma and Immunology. "Allergy Statistics." Accessed on March 5, 2012. http://www.aaaai.org/about-the-aaaai/newsroom/allergy-statistics.aspx. Some of the most common allergenic foods include peanuts, milk, eggs, soy, wheat, and shellfish. An allergy occurs when a protein in food triggers an immune response, which results in the release of antibodies, histamine, and other defenders that attack foreign bodies. Possible symptoms include itchy skin, hives, abdominal pain, vomiting, diarrhea, and nausea. Symptoms usually develop within minutes to hours after consuming a food allergen. Children can outgrow a food allergy, especially allergies to wheat, milk, eggs, or soy.

Anaphylaxis is a life-threatening reaction that results in difficulty breathing, swelling of the mouth and throat, decreased blood pressure, shock, or even death. Milk, eggs, wheat, soybeans, fish, shellfish, peanuts, and tree nuts are the most likely to trigger this type of response. A dose of the drug epinephrine is often administered via a "pen" to treat a person who goes into anaphylactic shock.National Institutes of Health, US Department of Health and Human Services. "Food Allergy Quick Facts." Accessed March 5, 2012. http://www.niaid.nih.gov/topics/foodallergy/understanding/pages/quickfacts.aspx.

Some children experience a food intolerance, which does not involve an immune response. A food intolerance is marked by unpleasant symptoms that occur after consuming certain foods. Lactose intolerance, though rare in very young children, is one example. Children who suffer from this condition experience an adverse reaction to the lactose in milk products. It is a result of the small intestine's inability to produce enough of the enzyme lactase, which is produced by the small intestine. Symptoms of lactose intolerance usually affect the GI tract and can include bloating, abdominal pain, gas, nausea, and diarrhea. An intolerance is best managed by making dietary changes and avoiding any foods that trigger the reaction.National Digestive Disease Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Lactose Intolerance." *NIH Publication No. 09–2751* (June 2009). Last updated April 23, 2012. digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/.

The Threat of Lead Toxicity

There is a danger of lead toxicity, or lead poisoning, among school-aged children. Lead is found in plumbing in old homes, in lead-based paint, and occasionally in the soil. Contaminated food and water can increase exposure and result in hazardous lead levels in the blood. Children under age six are especially vulnerable. They may consume items tainted with lead, such as chipped, lead-based paint. Another common exposure is lead dust in carpets, with the dust flaking off of paint on walls. When children play or roll around on carpets coated with lead, they are in jeopardy. Lead is indestructible, and once it has been ingested it is difficult for

the human body to alter or remove it. It can quietly build up in the body for months, or even years, before the onset of symptoms. Lead toxicity can damage the brain and central nervous system, resulting in impaired thinking, reasoning, and perception.

Treatment for lead poisoning includes removing the child from the source of contamination and extracting lead from the body. Extraction may involve chelation therapy, which binds with lead so it can be excreted in urine. Another treatment protocol, EDTA therapy, involves administering a drug called ethylenediaminetetraacetic acid to remove lead from the bloodstream of patients with levels greater than 45 mcg/dL.Mayo Foundation for Medical Education and Research. “Lead poisoning.” ©1998–2012 Accessed March 5, 2012. www.mayoclinic.com/health/lead-poisoning/FL00068. Fortunately, lead toxicity is highly preventable. It involves identifying potential hazards, such as lead paint and pipes, and removing them before children are exposed to them.

Key Takeaways

The recommended intakes of macronutrients and micronutrients for children are higher relative to body size compared with nutrient needs during adulthood. Also, children’s daily energy needs vary depending on their level of physical activity and their gender. Girls ages four to eight require 1,200 to 1,800 calories, while boys ages four to eight need 1,200 to 2,000 calories. Some food- and nutrition-related problems that can affect school-aged children include malnutrition, food allergies, food intolerances, and lead toxicity.

Discussion Starter

1. Which nutritional issues should parents who raise their children as vegans consider? Examine the vegan lifestyle and its impact on childhood development. Visit the following websites for more information on veganism:

   http://www.vrg.org/nutshell/kids.htm

   http://kidshealth.org/parent/nutrition_center/healthy_eating/vegan.html

   www.fcs.uga.edu/ext/pubs/html/FDNS-E-18.html

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12.7: Puberty and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for preteens.
- Discuss the most important nutrition-related concerns at the onset of puberty.
- Discuss the growing rates of childhood obesity and the long-term consequences of it.

Puberty is the beginning of adolescence. The onset of puberty brings a number of changes, including the development of primary and secondary sex characteristics, growth spurts, an increase in body fat, and an increase in bone and muscle development. All of these changes must be supported with adequate intake and healthy food choices.

The Onset of Puberty (Ages Nine to Thirteen)

This period of physical development is divided into two phases. The first phase involves height increases from 20 to 25 percent. Puberty is second to the prenatal period in terms of rapid growth as the long bones stretch to their final, adult size. Girls grow 2–8 inches (5–20 centimeters) taller, while boys grow 4–12 inches (10–30 centimeters) taller. The second phase involves weight gain related to the development of bone, muscle, and fat tissue. Also in the midst of puberty, the sex hormones trigger the development of reproductive organs and secondary sexual characteristics, such as pubic hair. Girls also develop “curves,” while boys become broader and more muscular.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 258.



Figure 12.7.1: Puberty typically begins slightly earlier in girls than in boys. For girls, puberty often begins around age eleven, while for boys it begins around age twelve. (Public Domain; Leifern)

Energy

The energy requirements for preteens differ according to gender, growth, and activity level. Energy requirements during this time are the highest based on daily need, not body weight. For ages nine to thirteen, girls should consume about 1,400 to 2,200 calories per day and boys should consume 1,600 to 2,600 calories per day. Physically active preteens who regularly participate in sports or exercise need to eat a greater number of calories to account for increased energy expenditures.

Macronutrients

For carbohydrates, the AMDR is 45 to 65 percent of daily calories (which is a recommended daily allowance of 158–228 grams for 1,400–1,600 daily calories). Carbohydrates that are high in fiber should make up the bulk of intake. Protein is needed for rapid growth. The AMDR for protein is 10 to 30 percent of daily calories (35–105 grams for 1,400 daily calories for girls and 40–120 grams for 1,600 daily calories for boys). The AMDR for fat is 25 to 35 percent of daily calories (39–54 grams for 1,400 daily calories for girls and 44–62 grams for 1,600 daily calories for boys), depending on caloric intake and activity level.

Micronutrients

Key vitamins needed during puberty include vitamins D, K, and B_{12}. Adequate calcium intake is essential for building bone and preventing osteoporosis later in life. Young females need more iron at the onset of menstruation, while young males need additional

iron for the development of lean body mass. Almost all of these needs should be met with dietary choices, not supplements (iron is an exception). Table 12.7.1 shows the micronutrient recommendations for young adolescents.

The B vitamins are needed for energy and protein metabolism. Folate and vitamin B_{12} are needed for DNA and cell growth. Many adolescents avoid milk which puts them at risk of developing a riboflavin, vitamin D, and calcium deficiency. Vitamin D and calcium are of particular concern since the bones are lengthening and this is a critical time to lay down bone mass. Iron is also at risk of deficiency; females because menstruation starts and males to do increase muscle mass.

Table 12.7.1: Micronutrient Levels during Puberty

Nutrient	Preteens, Ages 9–13
Vitamin A (mcg)	600.0
Vitamin B_6 (mg)	1.0
Vitamin B_{12} (mcg)	1.8
Vitamin C (mg)	45.0
Vitamin D (mcg)	5.0
Vitamin E (mg)	11.0
Vitamin K (mcg)	60.0
Calcium (mg)	1,300.0
Folate (mcg)	300.0
Iron (mg)	8.0
Magnesium (mg)	240.0
Niacin (B_3) (mg)	12.0
Phosphorus (mg)	1,250.0
Riboflavin (B_2) (mcg)	900.0
Selenium (mcg)	40.0
Thiamine (B_1) (mcg)	900.0
Zinc (mg)	8.0
Source: Institute of Medicine. www.iom.edu.	

Childhood Obesity

Children need an adequate caloric intake for growth, and it is important not to impose very restrictive diets. However, exceeding caloric requirements on a regular basis can lead to childhood obesity, which has become a major problem in North America. Nearly one of three US children and adolescents are overweight or obese. Let's Move. "Learn the Facts." Accessed March 5, 2012. www.letsmove.gov/learn-facts/epidemic-childhood-obesity. In Canada, approximately 26 percent of children and adolescents are overweight or obese.Childhood Obesity Foundation. "Statistics." Accessed March 5, 2012. http://www.childhoodobesityfoundation.ca/statistics.



Figure 12.7.2: *A sedentary lifestyle along with poor diet contributes to childhood obesity. (CC SA-By 2.5; Robert Lawton);*

There are a number of reasons behind the problem of childhood obesity, including:

- larger portion sizes
- limited access to nutrient-rich foods
- increased access to fast foods and vending machines
- lack of breastfeeding support
- declining physical education programs in schools
- insufficient physical activity and a sedentary lifestyle
- media messages encouraging the consumption of unhealthy foods
- high fat, high energy snacks

Children who suffer from obesity are more likely to become overweight or obese adults. Obesity has a profound effect on self-esteem, energy, and activity level. Even more importantly, it is a major risk factor for a number of diseases later in life, including cardiovascular disease, Type 2 diabetes, stroke, hypertension, and certain cancers.World Health Organization. “Obesity and Overweight Fact Sheet.” Last revised March 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

A percentile for body mass index (BMI) specific to age and sex is used to determine if a child is overweight or obese. This is more appropriate than the BMI categories used for adults because the body composition of children varies as they develop, and differs between boys and girls. If a child gains weight inappropriate to growth, parents and caregivers should limit energy-dense, nutrient-poor snack foods. Also, children ages three and older can follow the National Cholesterol Education Program guidelines of no more than 35 percent of calories from fat (10 percent or less from saturated fat), and no more than 300 milligrams of cholesterol per day. In addition, it is extremely beneficial to increase a child’s physical activity and limit sedentary activities, such as watching television, playing video games, or surfing the Internet.

Programs to address childhood obesity can include behavior modification, exercise counseling, psychological support or therapy, family counseling, and family meal-planning advice. For most, the goal is not weight loss, but rather allowing height to catch up with weight as the child continues to grow. Rapid weight loss is not recommended for preteens or younger children due to the risk of deficiencies and stunted growth.



Video 12.7.1: Voice of America: Adolescent Obesity Raises Risk of Severe Obesity in Adulthood. This video provides information about the link between adolescent obesity and adult obesity.

Avoiding Added Sugars

One major contributing factor to childhood obesity is the consumption of added sugars. Added sugars include not only sugar added to food at the table, but also are ingredients in items such as bread, cookies, cakes, pies, jams, and soft drinks. The added sugar in store-bought items may be listed as white sugar, brown sugar, high-fructose corn syrup, honey, malt syrup, maple syrup, molasses, anhydrous dextrose, crystal dextrose, and concentrated fruit juice. (Not included are sugars that occur naturally in foods, such as the lactose in milk or the fructose in fruits.) In addition, sugars are often "hidden" in items added to foods after they're prepared, such as ketchup, salad dressing, and other condiments. According to the National Center for Health Statistics, young children and adolescents consume an average of 322 calories per day from added sugars or about 16 percent of daily calories.National Center for Health Statistics. "Consumption of Added Sugar among US Children and Adolescents, 2005–2008." *NCHS Data Brief*, no. 87, (March 2012). http://www.cdc.gov/nchs/data/databriefs/db87.pdf. The primary offenders are processed and packaged foods, along with soda and other beverages. These foods are not only high in sugar, they are also light in terms of nutrients and often take the place of healthier options. Intake of added sugar should be limited to 100–150 calories per day to discourage poor eating habits.

Tools for Change

The *2008 Physical Activity Guidelines for Americans* call for sixty minutes of moderate to vigorous physical activity daily for preteens and teens. This includes aerobic activity, along with bone- and muscle-strengthening exercises.US Department of Health and Human Services. "2008 Physical Activity Guidelines for Americans." Accessed March 5, 2012. http://www.health.gov/paguidelines/pdf/paguide.pdf. However, many young people fall far short of this goal. Preteens must be encouraged to lead more active lifestyles to prevent or treat childhood obesity. In the United States, the Let's Move! campaign inspires kids to start exercising. This program, launched in 2010 by First Lady Michelle Obama, works to solve the problem of rising obesity rates among children, preteens, and teens. It offers information to parents and educators, works to provide healthier food choices in schools and afterschool programs, and helps children become more active. One way the program promotes physical activity is by encouraging preteens and teens to find something they love to do. When kids find an activity they enjoy, whether riding a bike, playing football, joining a soccer team, or participating in a dance crew, they are more likely to get moving and stay healthy. You can learn more about Let's Move! and efforts to encourage physical activity among adolescents at this website: www.letsmove.gov/.

Concluding Comments

During puberty, preteens experience growth spurts, along with the development of primary and secondary sex characteristics. The daily energy requirements for preteens differ according to gender, growth, and activity level. Girls ages nine to thirteen should consume 1,400 to 2,200 calories per day, and boys should consume 1,600 to 2,600 calories per day. Nutritional concerns for older children include malnutrition and obesity. Preteens should be encouraged to develop good habits, including consuming a healthy diet and regularly participating in sports or an exercise program.

Discussion Starter

1. What would you recommend to help families prevent obesity among their children? What tips would you provide? What lifestyle changes might help? Use the dietary guidelines at this website to discuss suggestions. http://www.choosemyplate.gov/.

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12.8: Older Adolescence and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for teens.
- Discuss the most important nutrition-related concerns during adolescence.
- Discuss the effect of eating disorders on health and wellness.

In this section, we will discuss the nutritional requirements for young people ages fourteen to eighteen. One way that teenagers assert their independence is by choosing what to eat. They have their own money to purchase food and tend to eat more meals away from home. Older adolescents also can be curious and open to new ideas, which includes trying new kinds of food and experimenting with their diet. For example, teens will sometimes skip a main meal and snack instead. That is not necessarily problematic. Their choice of food is more important than the time or place.

However, too many poor choices can make young people nutritionally vulnerable. Teens should be discouraged from eating fast food, which has a high fat and sugar content, or frequenting convenience stores and using vending machines, which typically offer poor nutritional selections. Other challenges that teens may face include obesity and eating disorders. At this life stage, young people still need guidance from parents and other caregivers about nutrition-related matters. It can be helpful to explain to young people how healthy eating habits can support activities they enjoy, such as skateboarding or dancing, or connect to their desires or interests, such as a lean figure, athletic performance, or improved cognition.

Adolescence (Ages Fourteen to Eighteen): Transitioning into Adulthood

As during puberty, growth and development during adolescence are different in males than in females. In teenage girls, fat assumes a larger percentage of body weight, while teenage boys experience greater muscle and bone increases, and a decrease in body fat. For both, primary and secondary sex characteristics have fully developed and the rate of growth slows with the end of puberty. Also, the motor functions of an older adolescent are comparable to those of an adult.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 171–173. Again, adequate nutrition and healthy choices support this stage of growth and development. Acne, substance use and abuse, obesity and adolescent pregnancy put the adolescent at risk of developing a nutrient deficiency that can have last lifetime effect.

Energy

Adolescents have increased appetites due to increased nutritional requirements. Nutrient needs are greater in adolescence than at any other time in the life cycle, except during pregnancy. The energy requirements for ages fourteen to eighteen are 1,800 to 2,400 calories for girls and 2,000 to 3,200 calories for boys, depending on activity level. The extra energy required for physical development during the teenage years should be obtained from foods that provide nutrients instead of “empty calories.” Also, teens who participate in sports must make sure to meet their increased energy needs.

Macronutrients

Older adolescents are more responsible for their dietary choices than younger children, but parents and caregivers must make sure that teens continue to meet their nutrient needs. For carbohydrates, the AMDR is 45 to 65 percent of daily calories (203–293 grams for 1,800 daily calories). Adolescents require more servings of grain than younger children and should eat whole grains, such as wheat, oats, barley, and brown rice. The Institute of Medicine recommends higher intakes of protein for growth in the adolescent population. The AMDR for protein is 10 to 30 percent of daily calories (45–135 grams for 1,800 daily calories), and lean proteins, such as meat, poultry, fish, beans, nuts, and seeds are excellent ways to meet those nutritional needs.

The AMDR for fat is 25 to 35 percent of daily calories (50–70 grams for 1,800 daily calories), and the AMDR for fiber is 25–34 grams per day, depending on daily calories and activity level. It is essential for young athletes and other physically active teens to intake enough fluids because they are at a higher risk for becoming dehydrated.

Micronutrients

Micronutrient recommendations for adolescents are mostly the same as for adults, though children this age need more of certain minerals to promote bone growth (e.g., calcium and phosphorus, along with iron and zinc for girls). Again, vitamins and minerals

should be obtained from food first, with supplementation for certain micronutrients only (such as iron).

The most important micronutrients for adolescents are calcium, vitamin D, vitamin A, and iron. Adequate calcium and vitamin D are essential for building bone mass. The recommendation for calcium is 1,300 milligrams for both boys and girls. Low-fat milk and cheeses are excellent sources of calcium and help young people avoid saturated fat and cholesterol. It can also be helpful for adolescents to consume products fortified with calcium, such as breakfast cereals and orange juice. Iron supports the growth of muscle and lean body mass. Adolescent girls also need to ensure sufficient iron intake as they start to menstruate. Girls ages twelve to eighteen require 15 milligrams of iron per day. Increased amounts of vitamin C from orange juice and other sources can aid in iron absorption. Also, adequate fruit and vegetable intake allows for meeting vitamin A needs. Table 12.8.1 shows the micronutrient recommendations for older adolescents, which differ slightly for males and females, unlike the recommendations for puberty.

Table 12.8.1: Micronutrient Levels during Older Adolescence

Nutrient	Males, Ages 14–18	Females, Ages 14–18
Vitamin A (mcg)	900.0	700.0
Vitamin B_6 (mg)	1.3	1.2
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	75.0	65.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	75.0	75.0
Calcium (mg)	1,300.0	1,300.0
Folate mcg)	400.0	400.0
Iron (mg)	11.0	15.0
Magnesium (mg)	410.0	360.0
Niacin (B_3) (mg)	16.0	14.0
Phosphorus (mg)	1,250.0	1,250.0
Riboflavin (B_2) (mg)	1.3	1.0
Selenium (mcg)	55.0	55.0
Thiamine (B_1) (mg)	1.2	1.0
Zinc (mg)	11.0	9.0
Source: Institute of Medicine. www.iom.edu.		

Acne

Some teens develop acne which is not caused by eating chocolate, sugary or greasy foods. Instead, it is caused by an infection of the sebaceous gland in the skin. The gland duct becomes clogged and skin oils accumulate. When this happens, the gland becomes irritated, inflamed and the associated "heads" occur. Acne is worsened by stress and tends to run in families (hereditary link). Treatment includes reducing the factors that are causing the stress, antibiotics, topical ointments and/or the drug Accutane. Accutane is similar to vitamin A so toxicity from the drug will be monitored closely.

Eating Disorders

Do you know any of these people: Demi Lovato, Paula Abdul, Russell Brand, Lady Gaga, Alanis Morissette, Diana, Princess of Wales, Elton John, or Jane Fonda? They all have an eating disorder.

Many teens struggle with an eating disorder, which can have a detrimental effect on diet and health. A study published by North Dakota State University estimates that these conditions impact twenty-four million people in the United States and seventy million worldwide.North Dakota State University. “Eating Disorder Statistics.” Accessed March 5, 2012. http://www.ndsu.edu/fileadmin/counseling/Eating_Disorder_Statistics.pdf. These disorders are more prevalent among adolescent girls but have been increasing among adolescent boys in recent years. Because eating disorders often lead to malnourishment, adolescents with an eating disorder are deprived of the crucial nutrients their still-growing bodies need.

The cause of eating disorders is unknown and most likely multiple factors contribute to its development. These factors may be biological, psychological and/or social and several factors may interact to cause the condition. Biological factors appear as a consequence of pubertal hormone changes and may be genetic. Personality and behavioral changes occur during puberty and these may promote the development of an eating disorder. Finally, mass media influences our perception of body weight and sets unrealistic notions of desirable body weight. Often, adolescent athletes have the misconception that less weight is better performance.

Eating disorders involve extreme behavior related to food and exercise. Sometimes referred to as “starving or stuffing,” they encompass a group of conditions marked by undereating or overeating. Some of these conditions include:

- **Anorexia Nervosa.** Anorexia nervosa is a potentially fatal condition characterized by under eating and excessive weight loss. People with this disorder are preoccupied with dieting, calories, and food intake to an unhealthy degree. Anorexics have a poor body image, which leads to anxiety, avoidance of food, a rigid exercise regimen, fasting, and a denial of hunger. The condition predominantly affects females. Between 0.5 and 1 percent of American women and girls suffer from this eating disorder. Five percent are men. Two to five percent of adolescent girls experience anorexia nervosa.
  The American Psychiatry Association sets standards to diagnosis eating disorders. The DMS-IV criteria for anorexia nervosa are 1) refusal to maintain body mass over a minimal weight for age and height (15% below expected body mass).; 2) intense fear of gaining weight or becoming fat despite being underweight, 3) distorted self-image and/or denial of the severity of low body mass (satisfied with certain body parts but critical of other areas); and 4) absence of at least three consecutive menstrual cycles. The individual may have an emaciated physical appearance with rough, dry, cold skin, hair loss, and tooth loss. Psychologically they may be competitive, obsessive, and have very high standards. Their family may be over-involved, rigid, over protective, and conflictive.
  Protein-energy malnutrition is a common nutritional complication of anorexia nervosa. Medical complications are a lower immune function (reduced white blood cells); lower basal metabolic rate, body temperature, heart rate, and bone mass; anemia; constipation; amenorrhea; multiple organ failures; and an increased risk of suicide.
  Therapy should involve a medical team trained to treat anorexia nervosa. The nutrition goal is a slow weight gain and this is done by gradually increasing food intake (approximately 200 kcal per day) Supplements may be required to make sure the diet is nutritionally adequate. Food habits need to be changed so it is important to identify the emotional factors and ways to control their behavior. This may be done using family, group/individual, and/or relapse therapy.
- **Binge-Eating Disorder (also called compulsive overeating).** People who suffer from binge-eating disorder experience regular episodes of eating an extremely large amount of food in a short period of time but don't purge. This eating disorder is the most common and is common in the severely obese. Binge eating is a compulsive behavior, and people who suffer from it typically feel it is beyond their control. This behavior often causes feelings of shame and embarrassment and leads to obesity, high blood pressure, high cholesterol levels, Type 2 diabetes, and other health problems. Both males and females suffer from binge-eating disorder. It affects 1 to 5 percent of the population.
  The diagnosis of binge eating includes recurrent binges at least two days per week for six months. The individual feels they are eating out of control and eat large amounts of food even when they are not hungry. Often, they eat alone because they are embarrassed about the amount of food they ate and feel disgusted and guilty for overeating. Most people with this eating disorder are overweight or obese. They have a low self-esteem and may be depressed. Medical complications are related to their excess adipose stores and treatment involves weight loss and changing their lifestyle to maintain the weight lost.
- **Bulimia Nervosa.** Bulimia nervosa is more prevalent than anorexia nervosa and is characterized by alternating cycles of overeating and undereating. People who suffer from it partake in binge eating, followed by compensatory behavior, such as self-induced vomiting, laxative use, diuretics, enemas, medications, fasting, and compulsive exercise. Most experience a loss of control over eating during their binge episode. As with anorexia, most people with this condition are female and may be single, well-educated and near ideal body weight. Approximately 1 to 2 percent of American women and girls have this eating disorder.National Eating Disorders Association. “Learn Basic Terms and Information on a Variety of Eating Disorder Topics.” Accessed March 5, 2012. www.nationaleatingdisorders.org/information-resources/general -information.php.

The DMS-IV criteria for bulimia nervosa are 1) recurrent episodes of binge-eating, 2) recurrent, inappropriate, compensatory behavior in order to prevent weight gain; 3) binge eating and compensatory behavior both occur on average at least twice a week for three months; 4) dissatisfaction and/or distortion of body image, and 5) disturbance does not occur in episodes of anorexia nervosa. People with this eating disorder may have normal weight or experience a rapid change in weight by twenty percent.

This eating disorder may develop after unsuccessful dieting. The individual may be a perfectionist, have low self-esteem, a high-stress level, be depressed, and/or passive. usually, they know the behavior is abnormal. Their family may be disengaged and permissive. Medical complications can include poor kidney function, decreased immune function, increased number of urinary tract infections, low blood potassium (hypokalemia) and irregular heart beat. If they purge by vomiting, they may experience infections of the esophagus and salivary glands, rupturing their esophagus and/or stomach, erosion of their teeth, and loss of potassium. Treatment includes developing normal eating habits, meal planning, food diaries and maintaining constant body weight and food intake. Psychologically they must break the purge cycle, develop a better body image, build self-esteem, treat depression, and develop a healthy attitude about their body image and food.

Eating disorders stem from stress, low self-esteem, and other psychological and emotional issues. It is important for parents to watch for signs and symptoms of these disorders, including sudden weight loss, loose clothing, lethargy, drop in grades, social isolation like eating alone, vomiting after meals, and the use of appetite suppressants. Eating disorders can lead to serious complications or even be fatal if left untreated. Treatment includes cognitive, behavioral, and nutritional therapy and requires a trained professional.



Video 12.8.1: Eating Disorders: Anorexia. This video provides more information about the eating disorder anorexia nervosa.

Muscle Dysmorphia (Adonis Complex)

Adonis Complex is the preoccupation with not being sufficiently lean and muscular. It has many similarities to anorexia nervosa but clearly, the individual has a distorted image of their body. Most people with this eating disorder are large and muscular. They have a preoccupation with being lean and muscular and frequently weigh themselves and/or look at themselves in the mirror (narcissistic). They like to wear baggy clothes or modify their clothes to enhance their muscularity. To achieve the muscularity, they engage in excessive exercise and abuse dietary supplements or adhere to a strict dietary regime. Amazingly, they view themselves as frail and small, even though they are not, and they may spend greater than three hours thinking about their muscularity.

Concluding Comments

Older adolescents experience numerous physical changes and must increase their energy intake to support these changes and meet nutrient needs. Nutrient needs are greater during adolescence than at any other time in the life cycle, except during pregnancy. The daily energy requirements for ages fourteen to eighteen are 1,800 to 2,400 calories for girls, and 2,000 to 3,200 calories for boys, depending on activity level. Nutritional concerns for older adolescents include eating disorders.

Discussion Starter

1. Research the biological, social, and psychological aspects of eating disorders at this website. Then, brainstorm a list of risk factors and warning signs for parents, teachers, and physicians.

http://www.nationaleatingdisorders.org/

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12.E: Exercises

It's Your Turn

1. Plan a day's worth of meals for a pregnant woman that contain the RDA of vitamin C. To help determine the vitamin C content in foods, visit the USDA National Nutrient Database: www.nal.usda.gov/fnic/foodcomp/search.
2. Create a brochure or plan a peer-to-peer campaign that encourages pregnant women to breastfeed their newborns and includes the major benefits of this practice.
3. After watching the video, which recommends snacks for adults and older children, use these ideas and what you have learned to create a list of toddler-friendly healthy snacks for parents. Take into account potential problems for young children, such as foods that are choking hazards.

   Eating Healthy Snacks

   (click to see video)

Apply It

1. Create a chart that compares the energy requirements and fluid recommendations for the following phases: the second trimester of pregnancy, the third trimester of pregnancy, the first six months of lactation, and the second six months of lactation.
2. Visit a store and study the labels of three different brands of infant formula. Record the nutrition facts for each brand, such as the calories, amount of carbohydrates, amount of protein, and so on.
3. Research ways to adjust the behavior of picky eaters at this website: http://www.healthychildren.org. Then, create a list of four to five tips for parents of toddlers. Apply Ellyn Satter's division of responsibility as you create your suggestions.

Expand Your Knowledge

1. How might statistics regarding unplanned pregnancies relate to the recommendation that all women should regularly take a multivitamin with folic acid? Use your knowledge of the impact of folate to explain your response.
2. Write a short speech that you would give to local government officials to recommend ways that they can promote and support the practice of breastfeeding in your community. Or prepare an email or letter to explain to a friend or family member why you have made the choice to breastfeed your child or to support your partner in the practice of breastfeeding.
3. Visit http://www.healthychildren.org and research ways to introduce solid foods into an infant's diet. Then create an eating plan to help parents gradually introduce solids to their babies, beginning at the age of six months.

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13: Nutrition From Adulthood to the Elderly Years

In this Chapter. we continue to explore nutrition through the life cycle, this time looking at adulthood to the elderly years.

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13.1: Chapter Introduction

Big Idea

The human lifespan, the maximum number of years of human life, has remained unchanged and is around 130 years. Very few people have reached that age and the records show the oldest person lived 122 years and 164 days. Good nutritional choices reduce the risk of chronic disease during the middle-aged and elderly years.

One hundred years ago, when many families sat down to dinner, they might have eaten boiled potatoes or corn, leafy vegetables such as cabbage or collards, fresh-baked bread, and, if they were fortunate, a small amount of beef or chicken. Young and old alike benefited from a sound diet that packed a real nutritional punch. Times have changed. Many families today fill their dinner plates with fatty foods, such as French fries cooked in vegetable oil, a hamburger that contains several ounces of ground beef, and a white-bread bun, with a single piece of lettuce and a slice or two of tomato as the only vegetables served with the meal.



Figure 13.1.1: The emergence of the obesity epidemic not only relates to what we eat and drink but also how much we consume on a daily basis. (CC-BY-SA 2.0; XP-ert).

Our diet has changed drastically as processed foods, which did not exist a century ago, and animal-based foods now account for a large percentage of our calories. Not only has what we eat changed, but the amount of it that we consume has greatly increased as well, as plates and portion size have grown much larger. All of these choices impact our health, with short- and long-term consequences as we age. Possible effects in the short-term include excess weight gain and constipation. The possible long-term effects, primarily related to obesity, include the risk of cardiovascular disease, Type 2 diabetes, hypertension, stroke, osteoarthritis, sleep apnea, respiratory problems, liver and gallbladder disease, and certain cancers (endometrial, breast, and colon) among middle-aged and elderly adults.Centers for Disease Control and Prevention. “Overweight and Obesity: Health Consequences.” Last updated March 3, 2011. www.cdc.gov/obesity/causes/health.html.

It is best to start making healthy choices from a young age and maintain them as you mature. However, a recent report published in the *American Journal of Clinical Nutrition*, suggests that adopting good nutritional choices later in life, during the forties, fifties, and even the sixties, may still help to reduce the risk of chronic disease as you grow older.Rivlin, R. S. “Keeping the Young-Elderly Healthy: Is It Too Late to Improve Our Health through Nutrition?” *Am J Clin Nutr* 86, supplement (2007): 1572S–6S. Even if past nutritional and lifestyle choices were not aligned with dietary guidelines, older adults can still do a great deal to reduce their risk of disability and chronic disease. As we age, we tend to lose lean body mass. This loss of muscle and bone can have critical health implications. For example, a decrease in body strength can result in an increased risk for fractures because older adults with weakened muscles are more likely to fall and to sustain serious injuries when they do. However, improving your diet while increasing physical activity helps to control weight, reduce fat mass, and maintain muscle and bone mass.

There are a number of changes middle-aged adults can implement, even after years of unhealthy choices. Choices include eating more dark, green, leafy vegetables, substituting high-fat proteins with lean meats, poultry, fish, beans, and nuts, and engaging in moderate physical activity for thirty minutes per day, several days per week. The resulting improvements in body composition will go a long way toward providing greater protection against falls and fractures and helping to ward off cardiovascular disease and

hypertension, among other chronic conditions.Rivlin, R. S. “Keeping the Young-Elderly Healthy: Is It Too Late to Improve Our Health through Nutrition?” *Am J Clin Nutr* 86, supplement (2007): 1572S–6S.

Life Expectancy

Life expectancy has increased over time. Now, in the USA, women can expect to live on average 81 years while the life expectancy for men on average is 71 years. In the last few years, life expectancy has decreased due to the obesity epidemic. For our forefathers, death was usually due to an infectious disease but the discovery of antibiotics, advances in medical treatment, improvement in nutrition and an abundant food supply has doubled life expectancy in the twentieth century.

Demographics have been changing. In 1900, only one out of twenty-five people were 65 years or older. Now, the number of people over the age of sixty-five has tripled and by 2060, the number will double again to 98 million people in the USA. The fastest growing group are those over the age of 85 years. This group has increased seven-fold since the 1950s. Amazingly, in the last decade, the number of centurions has doubled. Only 20-30% of the longevity is contributed to genes, most are due to health-related behaviors. Most of the elderly have chronic diseases that are related to nutrition. These include heart disease, diabetes, hypertension, osteoporosis, and obesity.

Causes of Aging

Scientists have proposed a number of theories to explain why the human body ages but one single theory has not immerged. The rate and manner in which humans age is influenced by genes, the environment, and lifestyle. A complex interplay between each of these determines life expectancy.

Characteristics of Longer Life Expectancy

Why do some people live longer? There are common characteristics among those that live longer. They sleep regularly and adequately. They are physically active on a regular basis which is a powerful predictor of mobility. They don't smoke and they maintain a healthy body weight. Their diets are charactered by well-balanced, regular meals, including breakfast. They eat between 18-27% of their calories from fat. Their meat consumption is low, and their fruit and vegetable intake is high. They don't drink alcohol or they drink in moderation.

You Decide:

What is one nutritional choice that you can make today to reduce your risk of chronic disease tomorrow?

Previously, we focused on the effects of dietary choices during pregnancy, infancy, and the toddler years. Our examination of nutrition through the human life cycle continues as we study the remainder of childhood into adulthood and the elderly years. Nutritional choices remain critical throughout a person’s life and influence overall health and wellness. The nutritional choices we make today affect not only our present health but also our future well-being.

Video 13.1.1: Weight Gain and Body-Composition Changes, Midlife into Older Age

This video focuses on the consequences of changing body composition from the middle-aged years into old age. (click to see video)

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13.2: The Human Life Cycle Continues

Learning Objectives

- Identify and define the different stages of the human lifecycle.
- Explain how the human body develops from childhood through the elderly years.

As discussed previously, all people need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to maintain life and health. However, the amounts of needed nutrients change as we pass from one stage of the human lifecycle to the next. Young children require a higher caloric intake relative to body size to facilitate physical and mental development. On the other hand, inactive senior citizens need fewer calories than other adults to maintain their weight and stay healthy. Psychological, emotional, and social issues over the span of a human life can also influence diet and nutrition. For example, peer pressure during adolescence can greatly affect the nutritional choices a teenager makes. Therefore, it is important to weigh a number of considerations when examining how nutrient needs change. In this chapter, we will focus on diet, nutrition, and the human life cycle from adulthood into the elderly years.

Changes in Young Adulthood

The phase after adolescence is young adulthood, and this period spans ages nineteen to thirty. It is a stable time compared to childhood and adolescence. Physical growth has been completed and all of the organs and body systems are fully developed. Typically, a young adult who is active has reached his or her physical peak and is in prime health. For example, vital capacity, or the maximum amount of air that the lungs can inhale and exhale, is at its peak between the ages of twenty and forty.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–93. Proper nutrition and adequate physical activity at this stage not only promote wellness in the present but also provide a solid foundation for the future.

Changes in Middle Age

Nutritionally speaking, middle age is defined as the period from age thirty-one to fifty. The early period of this stage is very different from the end. For example, during the early years of middle age, many women experience pregnancy, childbirth, and lactation. In the latter part of this life stage, women face perimenopause, which is a transition period that leads up to menopause, or the end of menstruation. A number of physical changes take place in the middle-age years, including the loss of bone mass in women due to dropping levels of estrogen during menopause. In both men and women, visual acuity declines, and by age forty there can be a decreased ability to see objects at a close distance, a condition known as presbyopia.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–93. All of these are signs of aging, as the human body begins to change in subtle and not-so-subtle ways. However, a middle aged person can remain vital, healthy, and near his or her physical peak with proper diet and adequate exercise.

Changes in the Older Adult Years

The senior, or elderly, years are the period from age fifty-one until the end of life. A number of physiological and emotional changes take place during this life stage. For example, many elderly adults face serious health challenges, such as cancer, heart disease, diabetes, or dementia. Both men and women experience a loss of muscle mass and strength and undergo changes in body composition. Fat deposits build up in the abdominal area, which increases the risk for Type 2 diabetes and cardiovascular disease. The skin becomes thinner and may take longer to heal after an injury. Around age seventy, men begin to experience bone loss when estrogen and testosterone levels begin to decline.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 512. Healthy nutritional choices can help to prevent or manage disability and chronic conditions.

In addition, disorders of the nervous system can have profound effects. Dementia is the umbrella term for changes in the normal activity of the brain. Elderly adults who suffer from dementia may experience memory loss, agitation, and delusions. One in eight people over age sixty-four and almost half of all people over eighty-five suffer from the brain disorder Alzheimer's disease, which is the most common form of dementia.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 421. Neurological disorder and psychological conditions, such as depression, can influence attitudes toward food, along with the ability to prepare or ingest food. They might lead some adults to overindulge to compensate

for stress or emotions that are difficult to handle. Other adults might eat less or pay less attention to their diet and nutritional needs. Elderly adults may also need guidance from dietitians and healthcare professionals to make the best dietary choices for this stage of life.

Changing Needs and Nutrition

Nutritional needs continue to change at each stage of life. It is important to adjust your diet and physical activity to meet these changing needs and ensure health and wellness throughout your life. Parents must continue to help their school-aged children and adolescents establish healthy eating habits and attitudes toward food. Their primary role is to bring a wide variety of health-promoting foods into the home so that their children can make good choices. As children become adults, they must be mindful of the choices they make and how those choices affect their health, not only in the present but also in the future.

Key Takeaways

The human body constantly changes throughout the life cycle, from childhood into adulthood and old age. Proper nutrition and physical activity ensure health and wellness at each stage of the human lifecycle.

Discussion Starter

1. In preparation for this chapter, predict how nutrient needs might change as a healthy young adult matures into old age. Then, after reading the text, discuss if your predictions were correct or incorrect.

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13.3: Young Adulthood and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for young adults.
- Discuss the most important nutrition-related concerns during young adulthood.
- Explain how nutritional and lifestyle choices can affect current and future health.

With the onset of adulthood, good nutrition can help young adults enjoy an active lifestyle. For most people, this is the time when their bodies are in the best condition. The body of an adult does not need to devote its energy and resources to support the rapid growth and development that characterizes youth. However, the choices made during those formative years can have a lasting impact. Eating habits and preferences developed during childhood and adolescence influence health and fitness into adulthood. Some adults have gotten a healthy start and have established a sound diet and regular activity program, which helps them remain in good condition from young adulthood into the later years. Others carry childhood obesity into adulthood, which adversely affects their health. However, it is not too late to change course and develop healthier habits and lifestyle choices. Therefore, adults must monitor their dietary decisions and make sure their caloric intake provides the energy that they require, without going into excess.

Young Adulthood (Ages Nineteen to Thirty): At Your Peak

At this time, growth is completed and people reach their physical peak. Major organs and body systems have fully matured by this stage of the life cycle. For example, the human body reaches maximum cardiac output between ages twenty and thirty. Also, bone and muscle mass are at optimal levels, and physical activity helps to improve muscle strength, endurance, and tone.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–193. In order to maintain health and fitness at this age, it is important to continue to practice good nutrition. Healthy eating habits promote metabolic functioning, assist repair and regeneration, and prevent the development of chronic conditions. In addition, the goals of a young adult, such as beginning a career or seeking out romantic relationships, can be supported with good habits.

Energy

Young men typically have higher nutrient needs than young women. For ages nineteen to thirty, the energy requirements for women are 1,800 to 2,400 calories, and 2,400 to 3,000 calories for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding, who require a higher energy intake.

Macronutrients

For carbohydrates, the AMDR is 45 to 65 percent of daily calories. All adults, young and old, should eat fewer energy-dense carbohydrates, especially refined, sugar-dense sources, particularly for those who lead a more sedentary lifestyle. The AMDR for protein is 10 to 35 percent of total daily calories, and should include a variety of lean meat and poultry, eggs, beans, peas, nuts, and seeds. The guidelines also recommend that adults eat two 4-ounce servings (or one 8-ounce serving) of seafood per week.

It is also important to replace proteins that are high in trans fats and saturated fat with ones that are lower in solid fats and calories. All adults should limit total fat to 20 to 35 percent of their daily calories and keep saturated fatty acids to less than 10 percent of total calories by replacing them with monounsaturated and polyunsaturated fatty acids. Avoid trans fats by limiting foods that contain synthetic sources, such as partially hydrogenated oils. The AMDR for fiber is 22 to 28 grams per day for women and 28 to 34 grams per day for men. Soluble fiber may help improve cholesterol and blood sugar levels, while insoluble fiber can help prevent constipation.

Tools for Change

A healthy diet of nutrient-rich meals incorporates a variety of whole foods. Whole foods are unprocessed or unrefined, or have been created with as little processing as possible. They do not include a lot of added ingredients, such as sugar, sodium, or fat, and are free of preservatives or other chemicals that are often added to food products. Examples of whole foods with no processing include legumes and fresh fruits and vegetables. Examples of whole foods with minimal processing include whole-grain breads and cereals. Dietitians recommend consuming whole foods for a variety of reasons. Whole foods provide nutrients in their natural state,

with all of the vitamins and minerals intact. Food processing can remove some nutrients during manufacturing. Also, diets rich in whole foods contain high concentrations of fiber and antioxidants, and can protect against chronic disease.

Micronutrients

Micronutrient needs in adults differ slightly according to sex. Young men and women who are very athletic and perspire a great deal also require extra sodium, potassium, and magnesium. Males require more of vitamins C and K, along with thiamine, riboflavin, and niacin. Females require extra iron due to menstruation. Therefore, it can be beneficial for some young adults to follow a daily multivitamin regimen to help meet nutrient needs. But as always, it is important to remember "food first, supplements second." Table 13.3.1 shows the micronutrient recommendations for adult men and women.

Table 13.3.1: Micronutrient Levels during Adulthood

Nutrient	Adult Males	Adult Females
Vitamin A (mcg)	900.0	700.0
Vitamin B_6 (mg)	1.3	1.3
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	90.0	75.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	120.0	90.0
Calcium (mg)	1,000.0	1,000.0
Folate (mcg)	400.0	400.0
Iron (mg)	8.0	18.0
Magnesium (mg)	400.0	310.0
Niacin (B_3) (mg)	16.0	14.0
Phosphorus (mg)	700.0	700.0
Riboflavin (B_2) (mg)	1.3	1.1
Selenium (mcg)	55.0	55.0
Thiamine (B_1) (mg)	1.2	1.1
Zinc (mg)	11.0	8.0

Source: Institute of Medicine. www.iom.edu.

Nutritional Concerns in Young Adulthood

There are a number of intake recommendations for young adults. According to the IOM, an adequate intake (AI) of fluids for men is 3.7 liters per day, from both food and liquids. The AI for women is 2.7 liters per day, from food and liquids.Institute of Medicine. "Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate." Accessed March 5, 2012. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx. It is best when fluid intake is from water, instead of sugary beverages, such as soda. Fresh fruits and vegetables, including watermelon and cucumbers, are excellent food sources of fluid. In addition, young adults should avoid consuming excessive amounts of sodium. The health consequences of high sodium intake include high blood pressure and its complications. Therefore, it is best to limit sodium to less than 2,300 milligrams per day.

Gastrointestinal Integrity

Good nutrition during the young adult years can help to support gastrointestinal integrity and prevent digestive disorders, such as constipation and diarrhea. Dietary fiber helps bind indigestible food together and normalize bowel movements. It also holds more water in the stool to make it softer for those who suffer from constipation. Excellent sources of fiber include oats, barley, rye, wheat, brown rice, celery, carrots, nuts, seeds, dried beans, oranges, and apples. In addition, healthy intestinal microflora can be supported by prebiotics which are found in fruits and vegetables and stimulate the growth of beneficial bacteria already in the colon and by probiotics which are live bacteria in the food you eat that change or improve the bacterial balance in the gut. An example of a prebiotic is walnuts and an example of a probiotic is yogurt.

Obesity during Adulthood

Obesity remains a major concern into young adulthood. For adults, a BMI above 25 is considered overweight, and a BMI of 30 or higher is obese. By that measurement, about two-thirds of all adults in the United States are overweight or obese, with 35.7 percent considered to be obese.Centers for Disease Control, National Center for Health Statistics. “Prevalence of Obesity in the United States, 2009–2010.” *NCHS Data Brief*, No. 82, January 2012, accessed on March 5, 2012. http://www.cdc.gov/nchs/data/databriefs/db82.pdf. As during childhood and adolescence, physical inactivity and poor dietary choices are major contributors to obesity in adulthood. Solid fats, alcohol, and added sugars (SoFAAS) make up 35 percent of total calories for most people, leading to high levels of saturated fat and cholesterol and insufficient dietary fiber. Therefore, it is important to limit unrefined carbohydrates and processed foods.

Concluding Comments

Young adults typically have reached their physical peak and can support health and wellness with adequate nutrition and exercise. For ages nineteen to thirty, the daily energy requirements are 1,800 to 2,400 calories for women and 2,400 to 3,000 calories for men, depending on activity level. Nutritional concerns for young adults include adequate energy and fluid intake, sodium intake, and the consumption of fiber. Young adults should avoid consuming solid fats, added sugars, and alcohol in excess.

Discussion Starter

1. How do your intake of carbohydrates, proteins, and fats compare to the AMDR? What can you do to make changes and meet the nutritional recommendations?

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13.4: Middle Age and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for middle-aged adults.
- Discuss the most important nutrition-related concerns during middle age.
- Define “preventive nutrition” and give an applied example.

During this stage of the human life cycle, adults begin to experience the first outward signs of aging. Wrinkles begin to appear, joints ache after a highly active day, and body fat accumulates. There is also a loss of muscle tone and elasticity in the connective tissue.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 212–213. Throughout the aging process, good nutrition can help middle-aged adults maintain their health and recover from any medical problems or issues they may experience.

Middle Age (Ages Thirty-One to Fifty): Aging Well

Many people in their late thirties and in their forties notice a decline in endurance, the onset of wear-and-tear injuries (such as osteoarthritis), and changes in the digestive system. Wounds and other injuries also take longer to heal. Body composition changes due to fat deposits in the trunk. To maintain health and wellness during the middle-aged years and beyond, it is important to:

- maintain a healthy body weight
- consume nutrient-dense foods
- drink alcohol moderately or not at all
- be a non-smoker
- engage in moderate physical activity at least 150 minutes per week

Energy

The energy requirements for ages thirty-one to fifty are 1,800 to 2,200 calories for women and 2,200 to 3,000 calories for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding (see Chapter 12). Middle-aged adults must rely on healthy food sources to meet these needs. In many parts of North America, typical dietary patterns do not match the recommended guidelines. For example, five foods—iceberg lettuce, frozen potatoes, fresh potatoes, potato chips, and canned tomatoes—account for over half of all vegetable intake.Adam Drewnowski and Nicole Darmon. “Food Choices and Diet Cost: an Economic Analysis.” *The Journal of Nutrition*. © 2005 The American Society for Nutritional Sciences. Accessed March 5, 2012. http://jn.nutrition.org/content/135/4/900.full. Following the dietary guidelines in the middle-aged years provides adequate but not excessive energy, macronutrients, vitamins, and minerals.

Video 13.4.1: Caloric Restriction

This video focuses on the possible connection between caloric restriction and longevity. (click to see video)

Macronutrients and Micronutrients

The AMDRs for carbohydrate, protein, fat, fiber, and fluids remain the same from young adulthood into middle age (see Section 13.3 of this chapter). It is important to avoid putting on excess pounds and limiting an intake of SoFAAS to help avoid cardiovascular disease, diabetes, and other chronic conditions.

There are some differences, however, regarding micronutrients. For men, the recommendation for magnesium increases to 420 milligrams daily, while middle-aged women should increase their intake of magnesium to 320 milligrams per day. Other key vitamins needed during the middle-aged years include folate and vitamins B_6 and B_{12} to prevent elevation of homocysteine, a byproduct of metabolism that can damage arterial walls and lead to atherosclerosis, a cardiovascular condition. Again, it is important to meet nutrient needs with food first, then supplementation, such as a daily multivitamin, if you can’t meet your needs through food.

Preventive/Defensive Nutrition

During the middle-aged years, preventive nutrition can promote wellness and help organ systems to function optimally throughout aging. Preventive nutrition is defined as dietary practices directed toward reducing disease and promoting health and well-being.

Healthy eating in general—such as eating unrefined carbohydrates instead of refined carbohydrates and avoiding trans fats and saturated fats—helps to promote wellness. However, there are also some things that people can do to target specific concerns. One example is consuming foods high in antioxidants, such as strawberries, blueberries, and other colorful fruits and vegetables, to reduce the risk of cancer.



Figure 13.4.1: Brightly colored tomatoes are another example of foods that are high in antioxidants. (CC BY-SA, 3.0; Aravind Sivaraj).

Phytochemicals are compounds in fruits and vegetables that act as defense systems for plants. Different phytochemicals are beneficial in different ways. For example, carotenoids, which are found in carrots, cantaloupes, sweet potatoes, and butternut squash, may protect against cardiovascular disease by helping to prevent the oxidation of cholesterol in the arteries, although research is ongoing.Sari Voutilainen, Tarja Nurmi, Jaakko Mursu, and Tiina H. Rissanen. "Carotenoids and Cardiovascular Health." *Am J Clin Nutr* 83 (2006): 1265–71. http://www.ajcn.org/content/83/6/1265.full.pdf. According to the American Cancer Society, some studies suggest that a phytochemical found in watermelons and tomatoes called lycopene may protect against stomach, lung, and prostate cancer, although more research is needed.American Cancer Society. "Lycopene." Last revised May 13, 2010. http://www.cancer.org/Treatment/TreatmentsandSideEffects/ComplementaryandAlternativeMedicine/DietandNutrition/lycopene.

Omega-3 fatty acids can help to prevent coronary artery disease. These crucial nutrients are found in oily fish, including salmon, mackerel, tuna, herring, cod, and halibut. Other beneficial fats that are vital for healthy functioning include monounsaturated fats, which are found in plant oils, avocados, peanuts, and pecans.

Menopause

In the middle-aged years, women undergo a specific change that has a major effect on their health. They begin the process of menopause, typically in their late forties or early fifties. The ovaries slowly cease to produce estrogen and progesterone, which results in the end of menstruation. Menopausal symptoms can vary, but often include hot flashes, night sweats, and mood changes. The hormonal changes that occur during menopause can lead to a number of physiological changes as well, including alterations in body composition, such as weight gain in the abdominal area. Bone loss is another common condition related to menopause due to the loss of female reproductive hormones. Bone thinning increases the risk of fractures, which can affect mobility and the ability to complete everyday tasks, such as cooking, bathing, and dressing.Academy of Nutrition and Dietetics. "Eating Right During Menopause." © 1995–2012. Accessed March 5, 2012. www.eatright.org/Public/content.aspx?id=6809. Recommendations for women experiencing menopause or perimenopause (the stage just prior to the end of the menstruation) include:

- consuming a variety of whole grains, and other nutrient-dense foods
- maintaining a diet high in fiber, low in fat, and low in sodium
- avoiding caffeine, spicy foods, and alcohol to help prevent hot flashes
- eating foods rich in calcium, or taking physician-prescribed calcium supplements and vitamin D
- doing stretching exercises to improve balance and flexibility and reduce the risk of falls and fractures

Key Takeaways

Middle-aged adults begin to experience signs of aging and must continue to support their health and wellness with nutrition and exercise. The daily energy requirements for ages thirty-one to fifty are 1,800 to 2,200 calories for women and 2,200 to 3,000

calories for men, depending on activity level. Nutritional concerns for middle-aged adults relate to menopause and the prevention of chronic disease.

Discussion Starter

1. Visit the following websites to learn more about nutrition during the years of perimenopause and menopause. Discuss with classmates what you believe to be the three most important nutritional concerns for women during this phase of life. http://www.medicinenet.com/script/main/art.asp?articlekey=59895 and http://www.webmd.com/menopause/guide/staying-healthy-through-good-nuitrition

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13.5: Old Age and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for elderly adults.
- Discuss the most important nutrition-related concerns during the senior years.
- Discuss the influence of diet on health and wellness in old age.

Beginning at age fifty-one, requirements change once again and relate to the nutritional issues and health challenges that older people face. After age sixty, blood pressure rises and the immune system may have more difficulty battling invaders and infections. The skin becomes more wrinkled and hair has turned gray or white or fallen out, resulting in hair thinning. Older adults may gradually lose an inch or two in height. Also, short-term memory might not be as keen as it once was.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 260.

In addition, many people suffer from serious health conditions, such as cardiovascular disease and cancer. Being either underweight or overweight is also a major concern for the elderly. However, many older adults remain in relatively good health and continue to be active in their golden years. Good nutrition is often the key to maintaining health later in life. In addition, the fitness and nutritional choices made earlier in life set the stage for continued health and happiness.

Older Adulthood (Ages Fifty-One and Older): The Golden Years

An adult's body changes during old age in many ways, including a decline in hormone production, muscle mass, and strength. Also in the later years, the heart has to work harder because each pump is not as efficient as it used to be. Kidneys are not as effective in excreting metabolic products such as sodium, acid, and potassium, which can alter water balance and increase the risk for over- or underhydration. In addition, immune function decreases and there is lower efficiency in the absorption of vitamins and minerals.

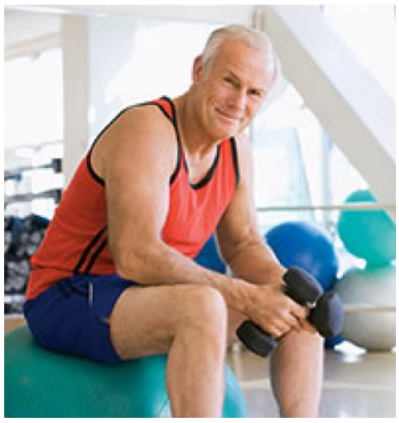


Figure 13.5.1: Regular exercise, along with a nutritious diet, can help older adults maintain their health. (Public Domain; National Institutes of Health).

Older adults should continue to consume nutrient-dense foods and remain physically active. However, deficiencies are more common after age sixty, primarily due to reduced intake or malabsorption. The loss of mobility among frail, homebound elderly adults also impacts their access to healthy, diverse foods.

Energy

Due to reductions in lean body mass and metabolic rate, older adults require less energy than younger adults. An energy deficit and weight loss are common problems. The energy requirements for people ages fifty-one and over are 1,600 to 2,200 calories for women and 2,000 to 2,800 calories for men, depending on activity level. The decrease in physical activity that is typical of older adults also influences nutritional requirements. Including physical activity in their daily routine allows for a higher energy intake and a greater likely hood they will meet their other nutrient requirements. It also helps maintain body composition and weight.

Macronutrients

The AMDRs for carbohydrates, protein, and fat remain the same from middle age into old age. Older adults should substitute more unrefined carbohydrates for refined ones, such as whole grains and brown rice. Fiber is especially important in preventing

constipation and diverticulitis, and may also reduce the risk of colon cancer. Protein should be lean, and healthy fats, such as omega-3 fatty acids, are part of any good diet. Fat intake should be lower to increase nutrient density.

Micronutrients

An increase in certain micronutrients can help maintain health during this life stage. Iron needs increase because of lower absorption due to lower stomach acid. The recommendations for calcium increase to 1,200 milligrams per day for both men and women to slow bone loss. Also to help protect bones, vitamin D recommendations increase to 10–15 micrograms per day for men and women. Vitamin B_6 recommendations rise to 1.7 milligrams per day for older men and 1.5 milligrams per day for older women to help lower levels of homocysteine and protect against cardiovascular disease. As adults age, the production of stomach acid can decrease and lead to an overgrowth of bacteria in the small intestine. This can affect the absorption of vitamin B_{12} and cause a deficiency. As a result, older adults need more B_{12} than younger adults and require an intake of 2.4 micrograms per day, which helps promote healthy brain functioning. For elderly women, higher iron levels are no longer needed post menopause and recommendations decrease to 8 milligrams per day. People over age fifty should eat foods rich with all of these micronutrients and antioxidants.

Nutritional Concerns for Older Adults

Dietary choices can help improve health during this life stage, postpone some chronic diseases, and address some of the nutritional concerns that many older adults face. In addition, there are specific concerns related to nutrition that affect adults in their later years. They include medical problems, such as disability and disease, which can impact diet and activity level. For example, dental problems can lead to difficulties with chewing and swallowing, which in turn can make it hard to maintain a healthy diet. The use of dentures (not as effective as real teeth) or the preparation of pureed or chopped foods can help solve this problem. There also is a decreased thirst response in the elderly, and the kidneys have a decreased ability to concentrate urine, both of which can lead to dehydration. Adequate fluid intake is necessary to facilitate excretion of metabolic waste. At least six cups of fluid are recommended a day and some medications may increase the need for more fluids.

Other factors can affect an older person's decision to eat and thus their nutritional status. These factors can include medications, emotional state such as depression, confusion or memory loss, availability of money, physical hindrances and loss of friends and spouse. Many older people take multiple drugs that are important to maintain their health. These drugs can interact with each other or by themselves causing nutritional deficiencies. For example, diuretics cause water loss and some nutrient losses, while other drugs can decrease appetite. Depression occurs in about ten to fourteen percent of older people and lowers food intake.

Here are guidelines for improving nutrient intake in the elderly. Meals should be regular, small and frequent. Quick, easily prepared foods like convenience foods may be appropriate to assure the elderly are eating. Different flavorings and seasonings should be encouraged to make food more interesting. Eating is a social event so eating with others should be encouraged as well as sharing meal preparation and responsibilities with others. Community resources are available to help with shopping and cooking and their use encouraged. Physical activity improves appetite and independence.

Sensory Issues

At about age sixty, taste buds begin to decrease in size and number. As a result, the taste threshold is higher in older adults, meaning that more of the same flavor must be present to detect the taste. Many elderly people lose the ability to distinguish between salty, sour, sweet, and bitter flavors. This can make food seem less appealing and decrease the appetite. An intake of foods high in sugar and sodium can increase due to an inability to discern those tastes. The sense of smell also decreases, which impacts attitudes toward food. Sensory issues may also affect the digestion because the taste and smell of food stimulate the secretion of digestive enzymes in the mouth, stomach, and pancreas.

Gastrointestinal Problems

A number of gastrointestinal issues can affect food intake and digestion among the elderly. Saliva production decreases with age, which affects chewing, swallowing, and taste. Digestive secretions decline later in life as well, which can lead to atrophic gastritis (inflammation of the lining of the stomach). This interferes with the absorption of some vitamins and minerals. Reduction of the digestive enzyme lactase results in a decreased tolerance for dairy products. Slower gastrointestinal motility can result in more constipation, gas, and bloating, and can also be tied to low fluid intake, decreased physical activity, and a diet low in fiber, fruits, and vegetables.

Other gastrointestinal problems include atrophic gastritis which is a chronic inflammation of the stomach mucosa. Most often this is caused by a bacterial overgrowth and leads to a loss of HCl and intrinsic factor impairing absorption of several important nutrients. About thirty percent of those over 60 suffer from this condition. Some older people experience ulcers and this can increase their need for iron.

Dysphagia

Some older adults have difficulty getting adequate nutrition because of the disorder dysphagia, which impairs the ability to swallow. Any damage to the parts of the brain that control swallowing can result in dysphagia, therefore stroke is a common cause. Dysphagia is also associated with advanced dementia because of overall brain function impairment. To assist older adults suffering from dysphagia, it can be helpful to alter food consistency. For example, solid foods can be pureed, ground, or chopped to allow more successful and safe swallow. This decreases the risk of aspiration, which occurs when food flows into the respiratory tract and can result in pneumonia. Typically, speech therapists, physicians, and dietitians work together to determine the appropriate diet for dysphagia patients.

Video 13.5.1: Dysphagia

This video provides information about the symptoms and complications of dysphagia. (click to see video)

Obesity in Old Age

Similar to other life stages, obesity is a concern for the elderly. Being moderately overweight if over sixty-five may be okay; being obese is not. Adults over age sixty are more likely to be obese than young or middle-aged adults. As explained throughout this chapter, excess body weight has severe consequences. Being overweight or obese increases the risk for potentially fatal conditions that can afflict the elderly. They include cardiovascular disease, which is the leading cause of death in the United States, and Type 2 diabetes, which causes about seventy thousand deaths in the United States annually.Centers for Disease Control, National Center for Health Statistics. “Deaths and Mortality.” Last updated January 27, 2012. http://www.cdc.gov/nchs/fastats/deaths.htm. Obesity is also a contributing factor for a number of other conditions, including arthritis.

For older adults who are overweight or obese, dietary changes to promote weight loss should be combined with an exercise program to protect muscle mass. This is because dieting reduces muscle as well as fat, which can exacerbate the loss of muscle mass due to aging. Although weight loss among the elderly can be beneficial, it is best to be cautious and consult with a healthcare professional before beginning a weight-loss program.

Anorexia of Aging

In addition to concerns about obesity among senior citizens, being underweight can be a major problem. A condition known as the anorexia of aging is characterized by poor food intake, which results in dangerous weight loss. This major health problem among the elderly leads to a higher risk for immune deficiency, frequent falls, muscle loss, and cognitive deficits. Reduced muscle mass and physical activity mean that older adults need fewer calories per day to maintain a normal weight. It is important for health care providers to examine the causes of anorexia of aging among their patients, which can vary from one individual to another. Understanding why some elderly people eat less as they age can help health-care professionals assess the risk factors associated with this condition. Decreased intake may be due to disability or the lack of a motivation to eat. Also, many older adults skip at least one meal each day. As a result, some elderly people are unable to meet even reduced energy needs.

Nutritional interventions should focus primarily on a healthy diet. Remedies can include increasing the frequency of meals and adding healthy, high-calorie foods (such as nuts, potatoes, whole-grain pasta, and avocados) to the diet. Liquid supplements between meals may help to improve caloric intake.Morley, J. E. “Anorexia of Aging: Physiologic and Pathologic.” *Am J Clin Nutr* 66 (1997): 760–73. http://www.ajcn.org/content/66/4/760.full.pdf. Healthcare professionals should consider a patient’s habits and preferences when developing a nutritional treatment plan. After a plan is in place, patients should be weighed on a weekly basis until they show improvement.

Bone Health

Bone mass and density decrease with age because calcium and other minerals are lost. The spine compresses shrinking our stature while the long bones remain the same length but become more brittle as minerals are lost. Because of the changes in bones, posture and walking are affected, for example, the walking gait becomes slower. Diet can contribute to the loss of bone mass and density because good sources of calcium and vitamin D are lacking in the diet.

Vision Problems

Many older people suffer from vision problems and a loss of vision. Age-related macular degeneration is the leading cause of blindness in Americans over age sixty.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 413. This disorder can make food planning and preparation extremely difficult and people who suffer from it often must depend on caregivers for their meals. Self-feeding also may be difficult if an elderly person cannot see his or her food clearly. Friends and family members can help older adults with shopping and cooking. Food-assistance programs for older adults (such as Meals on Wheels) can also be helpful.

Diet may help reduce the risk of macular degeneration. Consuming colorful fruits and vegetables, rich in antioxidants, increases the intake of lutein and zeaxanthin. Several studies have shown that these antioxidants provide protection for the eyes. Lutein and zeaxanthin are found in green, leafy vegetables such as spinach, kale, and collard greens, and also corn, peaches, squash, broccoli, Brussels sprouts, orange juice, and honeydew melon.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 415.

Cataracts is the thickening of the lenses of the eye and develops when aging or injury causes changes in the lenses of your eye. There are many causes, for example, UV light exposure and oxidative stress can contribute to its development. Even obesity can increase the risk of developing cataracts. Eating foods rich in vitamin C, E and carotenoids may reduce the risk.

Neurological Conditions

Elderly adults who suffer from dementia may experience memory loss, agitation, and delusions. One in eight people over the age sixty-four and almost half of all people over eighty-five suffer from Alzheimer's, which is the most common form of dementia. These conditions can have serious effects on diet and nutrition as a person increasingly becomes incapable of caring for himself or herself, which includes the ability to buy and prepare food, and to self-feed.

Nutrient insufficiencies can also contribute to diminished brain function. For example, inadequate intake of vitamin B_{12}, vitamin C, and vitamin E have been linked to short-term memory. Changes in problem-solving performance have been observed with inadequate intake of vitamin B_2, folate, vitamin B_{12} and vitamin C while changes in cognition have been observed with insufficient intake of folate, vitamin B_6, vitamin B_{12}, iron and vitamin E. Several neurotransmitters are synthesized from nutrients, for example, tyrosine is the precursor for dopamine and tryptophan is the precursor for serotonin. Choline is also important for the production of the neurotransmitter acetylcholine. Chronically low consumption of vitamin B_1, vitamin B_3, zinc and folate can alter brain health.

Arthritis

Arthritis is the painful inflammation and stiffness of the joints. It is many diseases, not just one. There are several different types of arthritis: degenerative, inflammatory, infectious, and metabolic. Osteoarthritis is the most common degenerative arthritis and is associated with being overweight. Rheumatoid arthritis is an example of inflammatory arthritis. If this form of arthritis is caught early, drug therapy can help put it in remission. Eating foods rich in omega-3 fatty acids, and/or the antioxidants vitamin C, vitamin E, and carotenoids may help relieve the pain associated with this type of arthritis. Gout is a type of metabolic arthritis where uric acid crystals are deposited in the joints. The old wives tale is that rich food causes gout is not true. Foods rich in purines, for example, meat and seafood, increase the risk.

Longevity and Nutrition

The foods you consume in your younger years influence your health as you age. Good nutrition and regular physical activity can help you live longer and healthier. Conversely, poor nutrition and a lack of exercise can shorten your life and lead to medical problems. The right foods provide numerous benefits at every stage of life. They help an infant grow, an adolescent develop mentally and physically, a young adult achieve his or her physical peak, and an older adult cope with aging. Nutritious foods form the foundation of a healthy life at every age.

Key Takeaways

As adults age, physical changes impact nutrient needs and can result in deficiencies. The daily energy requirements for adults ages fifty-one and over are 1,600 to 2,200 calories for women and 2,000 to 2,800 calories for men, depending on activity level. Older adults are more susceptible to medical problems, such as disability and disease, which can impact appetite, the ability to plan and prepare food, chewing and swallowing, self-feeding, and general nutrient intake. A nutrient-dense, plant-based diet can help prevent or support the healing of a number of disorders that impact the elderly, including macular degeneration and arthritis.

Discussion Starter

1. Revisit the predictions you made at the beginning of this chapter about how nutrient needs might change as a healthy young adult matures into old age. Which predictions were correct? Which were incorrect? What have you learned?

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13.E: Exercises

It's Your Turn

1. Create a list of nutritional tips for adults who are caring for their elderly parents after watching the following video:

   Nutrition for Senior Citizens

   (click to see video)

Apply It

1. After watching the video, hold a small group discussion to discuss the influence of environment, economics, culture, and lifestyle on dietary choices.

   The Obesity Epidemic

   (click to see video)

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CHAPTER OVERVIEW

14: Alcohol

Alcohol is produced when yeast in the absence of oxygen ferment a food source like grains or grapes. The sugar in these food sources is converted to alcohol. Humankind has been drinking beverages that contain alcohol for thousands of years. In fact, the ancient Egyptians paid their slaves with beer. Along with a low alcohol content, these ancient beers were a good source of vitamins and antibiotics like tetracycline, the reason some mummies glow under ultraviolet lights. Today, alcohol containing beverages do not have the plethora of vitamins and tetracycline because society has focused on maximizing the alcohol content.

14.1: Introduction to Alcohol

14.2: Alcohol Absorption and Metabolism

14.3: Pros and Cons of Drinking Alcohol

14.4: How Much to Drink?

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14.1: Introduction to Alcohol

Learning Objectives

- Explain the impacts of excessive alcohol intake (both acutely and chronically) on health.

Alcohol is both a beverage providing some sustenance and a drug. For thousands of years, alcohol has been consumed in a medicinal, celebratory, and ritualistic manner. It is drunk in just about every country and often in excessive amounts. Alcohol is a psychoactive drug. A psychoactive drug is any substance that crosses the blood-brain barrier primarily affecting the functioning of the brain, be it altering mood, thinking, memory, motor control, or behavior. Alcohols in chemistry refer to a group of similar organic compounds, but in beverages the only alcohol consumed is ethanol. Ethanol is an organic compound that contains a hydroxyl (OH) group. It is the byproduct of yeast fermentation of sugars, like maltose, in an anaerobic environment.

The Behavioral Risk Factor Surveillance System survey reported that more than half of the adult US population drank alcohol in the past thirty days (Centers for Disease Control and Prevention. “Alcohol and Public Health.” Last updated March 5, 2012. http://www.cdc.gov/alcohol/). The 2015 National Survey on Drug Use and Health (NSDUH) estimated that 86.4% of people 18 and older drank at some time during their life and 70.1% reported they drank in the last year[1]. Of the total population who drank alcohol, approximately 7 percent drank heavily, while 26.9 percent of people ages 18 or older reported they engaged in binge drinking at some point in their life.[2] Binge drinking (as defined by the National Institute on Alcohol Abuse and Alcoholism) is when men consume five or more drinks, and when women consume four or more drinks, in two hours or less (Centers for Disease Control and Prevention. “Alcohol and Public Health.” Last updated March 5, 2012. http://www.cdc.gov/alcohol/). Alcohol in excess is detrimental to health; however, since its beginnings, it has been suspected and promoted as a benefit to the body and mind when consumed in moderation. In the United States, the *Dietary Guidelines* define moderate alcohol intake as no more than one drink per day for women and up to two drinks per day for men (US Department of Agriculture and US Department of Health and Human Services. “Alcoholic Beverages.” In *Dietary Guidelines for Americans 2015*. (Washington D. C.: US Department of Health and Human Services and US Department of Agriculture, 2015). https://health.gov/dietaryguidelines/2015/guidelines/appendix-9/). Although drunkenness has pervaded many cultures, drinking in moderation has long been a mantra of multiple cultures with access to alcohol.



Figure 14.1.1: One-half ounce of hard liquor.

Beer, wine, and hard liquor are the alcohol types familiar to most people and each contains pure ethanol in different amounts. Beer and wine will give the amount of alcohol in a percent based on volume. So if a beer is labeled as 5.9% alcohol that means a 12 ounce can contain 0.71 ounces of alcohol. On average, one can of beer contains about 15 grams of ethanol which does not seem like much except it will take the liver approximately one hour to metabolize and clear that amount.

Example 14.1.1: Beer 12 fluid ounces

Alcohol % varies. If alcohol content is 5.0% by volume:

$$(12 \text{ ounces of beer}) \times \left(29.5735 \frac{milliliters}{ounce}\right) \times \left(0.05 \frac{milliliters}{milliliters}\right) \times \left(0.789 \frac{grams}{milliliters}\right) \approx 14 \text{ grams of alcohol}$$

1. 29.5735 is the conversion factor for ounces to grams
2. 0.05 is the percent alcohol
3. 0.789 is the density of alcohol

The ethanol content of hard liquor is stated as proof which is half the percentage of alcohol. So, one ounce of hard liquor is 30 grams of ethanol or 200 proof or 100% alcohol.

Discussion Starters

1. Weekends seem to be the time to party on campus. How many people do you know that drink? How much do they drink and why?

References

1. Substance Abuse and Mental Health Services Administration (SAMHSA). 2015 National Survey on Drug Use and Health (NSDUH). Table 2.41B—Alcohol Use in Lifetime, Past Year, and Past Month among Persons Aged 12 or Older, by Demographic Characteristics: Percentages, 2014 and 2015. Available at: https://www.samhsa.gov/data/sites/default/files/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015.htm#tab2-41b. Accessed 1/18/17.
2. Substance Abuse and Mental Health Services Administration (SAMHSA). 2015 National Survey on Drug Use and Health (NSDUH). Table 2.46B—Alcohol Use, Binge Alcohol Use, and Heavy Alcohol Use in Past Month among Persons Aged 12 or Older, by Demographic Characteristics: Percentages, 2014 and 2015. Available at: https://www.samhsa.gov/data/sites/default/files/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015.htm#tab2-46b. Accessed 1/18/17.

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14.2: Alcohol Absorption and Metabolism

Learning Objectives

- Explain the digestion and metabolism of alcohol

In this section, we will discuss how alcohol is absorbed and metabolized.

Absorption

Alcohol is passively absorbed primarily in the small intestine although small amounts may be absorbed in the mouth, stomach and large intestine. The rate of absorption depends on body size; the larger the person, the slower absorption. So a person who weighs 180 lbs will take longer to absorb one beer than someone who weighs 120 lbs. For example, someone who weighs 180 lbs will absorb 9-16 grams of alcohol per hour while someone weighing 120 lbs will absorb 6-10 grams of alcohol per hour. Other factors also affect alcohol absorption. Eating food, particularly fat, protein and fiber, while drinking alcohol will slow absorption while carbonated alcoholic beverages are absorbed faster. Women are more proficient at absorbing alcohol than men. Once absorbed, alcohol reaches the brain quickly where it alters mental and physical functions.

Metabolism

More than 90 percent of ingested alcohol is metabolized in the liver at a rate of approximately half an ounce per hour, but the rate varies from person to person. The rate of degradation and clearance in the liver depends on a variety of genetic and environmental factors including body size, previous alcohol exposure, food intake and one's general health. While waiting to be degraded, alcohol stays in the blood and some will be excreted through the breath (which is how Breathalyzers work), urine, saliva, and sweat.

There are three systems in the liver for degrading or detoxifying alcohol (14.2.1). These are the alcohol dehydrogenase (ADH) system, the microsomal ethanol-oxidizing system (MEOS), and the acetaldehyde dehydrogenase (ALDH) system. ADH and ALDH work together to break alcohol down to acetate which is easier to remove from the body. ADH degrades ethanol to acetaldehyde, a known carcinogen. Some ADH exists in the stomach and levels of this enzyme are diminished by fasting. ALDH quickly degrades the acetaldehyde to acetate which is further broken down to carbon dioxide and water in extrahepatic tissues. People of Asian descent have reduced levels of ALDH and this contributes to the flushing commonly experienced after drinking alcohol. Other side effects of acetaldehyde build up is rapid heartbeat and hyper ventalation. One fifth of the alcohol absorbed is degraded by MEOS to acetaldehyde.

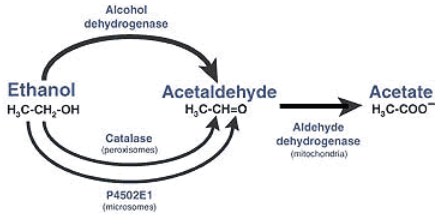


Figure 14.2.1: Break down of alcohol into acetaldehyde and acetate.

The chemical pathways involved in degrading ethanol use NAD^+ and take it from other pathways such as glycolysis (the breakdown of glucose) and the TCA (tricarboxylic acid) cycle (also known as the Krebs cycle) which generates energy from glucose. As a result, $NADH_2$ accumulates and slows the TCA cycle causing acetyl CoA to accumulate. Excess acetyl CoA is diverted to fatty acid synthesis and the fatty acids are incorporated into triglycerides. These triglycerides can accumulate in the liver and over time clog the liver and impair function. This is one of the proposed mechanisms by which fatty accumulates in the liver following alcohol intake.

When alcohol is consumed in excess, ethanol circulates in the blood until liver enzymes are available to degrade it. The byproduct of degradation, acetaldehyde, is harmful. Also, alcohol decreases the production of antidiuretic hormone (ADH) and decreased levels of ADH prevents the retention of water so water and water soluble vitamin losses are increased. Alcoholic beverages do not hydrate and excess intake can lead to dehydration.

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14.3: Pros and Cons of Drinking Alcohol

Learning Objectives

- Explain the impacts of excessive alcohol intake (both acutely and chronically) on health.

Pros and Cons

Alcohol, when drunk in moderation, has beneficial effects. However, drinking any type of alcoholic beverage, beer, wine or hard liquor, can lead to dependency on the substance and the level of tolerance is different for everyone. Here we explore the beneficial and harmful effects of so that you will be better able to make wise decisions about drinking beverages that contain alcohol. It is important to remember when you consume alcohol, you are also consuming calories, seven calories per gram, that do not contain other beneficial nutrients. So alcohol is a source of "empty" or "naked" calories.

Health Benefits of Moderate Alcohol Intake

In contrast to excessive alcohol intake, moderate alcohol intake has been shown to provide health benefits. The data is most convincing for preventing heart disease in middle-aged and older people. A review of twenty-nine studies concluded that moderate alcohol intake reduces the risk of coronary heart disease by about 30 percent in comparison to those who do not consume alcohol.*Ronksley, P. E.* et al. “Association of Alcohol Consumption with Selected Cardiovascular Disease Outcomes: A Systematic Review and Meta-Analysis.” *BMJ* 342, no. d671 (2011). doi: 10.1136/bmj.d671. Several other studies demonstrate that moderate alcohol consumption reduces the incidences of stroke and heart attack, and also death caused by cardiovascular and heart disease. The drop in risk for these adverse events ranges between percent. Moreover, there is some scientific evidence that moderate alcohol intake reduces the risk for metabolic syndrome, Type 2 diabetes, and gallstones. In addition to providing some health benefits, moderate alcohol intake has long served as a digestive aid and a source of comfort and relaxation, and it induces social interaction, thereby benefiting all aspects of the health triangle. It has not been clearly demonstrated that moderate alcohol consumption benefits younger populations, and the risks of any alcohol consumption do not outweigh the benefits for pregnant women, those who are taking medications that interact with alcohol, and those who are unable to drink in moderation.

Health Consequences of Alcohol Abuse

Distilled spirits have exceptionally few nutrients, but beer and wine do provide some nutrients, vitamins, minerals, and beneficial plant chemicals along with calories. A typical beer is 150 kilocalories, a glass of wine contains approximately 80 kilocalories, and an ounce of hard liquor (without a mixer) is around 65 kilocalories. Alcoholic drinks in excess contribute to weight gain by substantially increasing caloric intake. However, alcohol displays its two-faced character again in its effects on body weight, making many scientific studies contradictory. Multiple studies show high intakes of hard liquor are linked to weight gain, although this may be the result of the regular consumption of hard liquor with sugary soft drinks, juices, and other mixers. On the other hand drinking beer and, even more so, red wine, is not consistently linked to weight gain and in some studies actually, decreases weight gain. The contradictory results of scientific studies that have examined the association of alcohol intake with body weight are partly due to the fact that alcohol contributes calories to the diet, but when drunk in excess reduces the secretion of pancreatic juice and damages the lining of the gastrointestinal system, impairing nutrient digestion and absorption. The impaired digestion and absorption of nutrients in alcoholics contributes to their characteristic “skinniness” and multiple associated micronutrient deficiencies. The most common macro nutrient deficiency among alcoholics is water, as it is excreted in excess. Commonly associated micronutrient deficiencies include thiamine, pyridoxine, folate, vitamin A, magnesium, calcium, and zinc. Furthermore, alcoholics typically replace calories from alcohol with those of nutritious foods, sometimes getting 50 percent or more of their daily caloric intake from alcoholic beverages. Alcohol can also interfere with the ability of organs to use nutrients.

Effects of Alcohol Abuse on the Brain

Alcohol can adversely affect nearly every area of the brain. When BAC rises, the central nervous system is depressed. Alcohol disrupts the way nerve cells communicate with each other by interfering with receptors on certain cells. The immediate impact of alcohol on the brain can be seen in the awkwardly displayed symptoms of confusion, blurred vision, slurred speech, and other signs of intoxication. These symptoms will go away once drinking stops, but abusive alcohol consumption over time can lead to long-lasting damage to the brain and nervous system. This is because alcohol and its metabolic byproducts kill brain cells. Excessive alcohol intake has the following effects on specific areas of the brain:

1. **Medulla.** This area controls automatic functions, such as heart rate. When alcohol first limits its functioning, people feel sleepy. With greater BAC levels, unconsciousness, comas, and death can result.
2. **Cerebellum.** This is where conscious movement is coordinated. With too much alcohol, balance and motor skills are impaired.
3. **Cerebral cortex.** Senses and thoughts are processed here, and this is where action is initiated. When BAC levels increase, the ability to think, exercise good judgment and feel pain decrease.
4. **Hypothalamus and pituitary gland.** Alcohol increases sexual desire but decreases sexual performance. It also prompts signals which increase urine production.
5. **Limbic system.** When alcohol affects this area, individuals may become very emotional and lose memory function.

Effects of Alcohol Abuse on the Liver

According to the CDC, 19,388 Americans died from alcohol-related liver diseases in 2014. Although not every alcoholic or heavy drinker will die from liver problems, the liver is one of the body's main filtering organs and is severely stressed by alcohol abuse. The term Alcoholic Liver Disease (ALD) is used to describe liver problems linked to excessive alcohol intake. ALD can be progressive, with individuals first suffering from a fatty liver and going on to develop cirrhosis. It is also possible to have different forms of ALD at the same time.

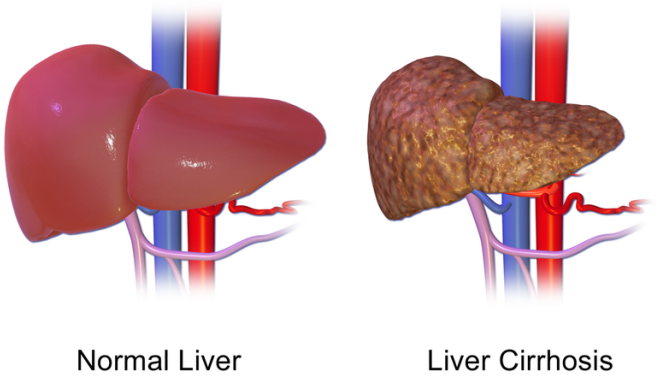


Figure 14.3.1*: Liver Cirrhosis. Excessive alcohol consumption causes the destruction of liver cells. In an attempt to repair itself, the liver initiates an inflammatory and reparation process causing scar tissue to form. In the liver's attempt to replace the dead cells, surviving liver cells multiply. The result is clusters of newly formed liver cells, also called regenerative nodules, within the scar tissue. This state is called cirrhosis of the liver.* See a full animation of this medical topic. from BruceBlaus (via Wikipedia).

The three most common forms of ALD are:

- **Fatty liver.** A rather benign disorder that develops after excessive alcohol consumption; however, it can progress to more fatal diseases. Fatty liver is reversible if alcohol use is brought under control. Large fat droplets occur in the liver due to increased triglyceride synthesis, decreased fatty acid breakdown, and decreased VLDL release from the liver to transport the triglyceride to extrahepatic tissues. Fatty liver is associated with chronic alcohol consumption, generally, not one night of binge-drinking.
- **Alcoholic hepatitis.** The symptoms of this alcohol-induced liver inflammation are a swollen liver, abdominal pain, nausea, fever, jaundice, and vomiting. Although linked to alcohol use, even people who drink moderately can sometimes develop this condition, and not all alcohol abusers do. If a person stops drinking alcohol, the liver damage can be reversed. But if they continue, cirrhosis may develop and death can result.
- **Cirrhosis.** Long term excessive alcohol consumption can cause cirrhosis. This serious and sometimes fatal form of ALD develops when liver cells die and form scar tissue, which blocks blood flow and causes wastes and toxins, like ammonia, to build up in the system. Normal liver function is disrupted and causes damage to the brain. Strictly speaking, cirrhosis cannot be cured. It can, however, be stopped with medical treatment and complications can be managed if the individual stops drinking, and many do survive. Not all cases of cirrhosis are strictly due to alcoholism or chronic consumption of alcohol, and not all alcoholics develop the disease. Symptoms of cirrhosis include the buildup of abdominal fluid (ascites), abdominal pain, fever, thirst, confusion, and fatigue.

Fetal Alcohol Spectrum Disorders

Fetal alcohol spectrum disorders (FASDs) are a group of conditions that can occur in a person whose mother drank alcohol during pregnancy. These symptoms can include physical problems and problems with behavior and learning. Often, a person with FASD

has a mix of these problems. Different terms are used to describe FASD depending on the symptoms.

Fetal alcohol syndrome (FAS) is growth, mental, and physical problems that may occur in a baby when a mother drinks alcohol during pregnancy.The Institute of Medicine estimated 1996 that fetal alcohol syndrome (FAS) was between 0.5 and 3.0 cases per 1,000 (Stratton, K.; Howe, C.; Battaglia, F.; Eds. *Fetal Alcohol Syndrome: Diagnosis, Epidemiology, Prevention, and Treatment)*. Washington, DC: Institute of Medicine, National Academy Press, 1996). More recent reports from other sites suggest the prevalence may be 2 to 7 cases per 1,000 or as high as 20 to 50 cases per 1,000 (May, P.A.; Gossage, J.P.; Kalberg, W.O.; et al. Prevalence and epidemiologic characteristics of FASD from various research methods with an emphasis on recent in-school studies. *Developmental Disabilities Research Reviews* 15(3):176–192, 2009. PMID: 19731384; May, P.A.; Keaster, C.; Bozeman, R.; et al. Prevalence and characteristics of fetal alcohol syndrome and partial fetal alcohol syndrome in a Rocky Mountain Region City. *Drug and Alcohol Dependence* 155:118–127, 2015. PMID: 26321671)

There is no safe level of alcohol during pregnancy. If you are planning on becoming pregnant, you should stop drinking 4 to 6 weeks before conception. Alcohol consumed during the first trimester causes physical damage to developing tissues and organs. During the second trimester, the risk of spontaneous abortion increases and during the third trimester, both body and brain growth problems develop. the impact on the fetus and subsequent baby can manifest in a variety of symptoms including poor growth while in the womb and after birth, decreased muscle tone and poor coordination, and delayed developmental milestones. Characteristic facial features can occur with chronic alcoholism and these include small head circumference; narrow, receding forehead; flattened (low) nasal bridge; short, upturned nose; underdeveloped jaw and receding chin; extra skin folds on eyelids, drooping eyelids, or downward slant of eyes; short-sightedness, and inability focus; uneven or poorly formed ears; and absence of a groove in the upper lip.

Alcohol-related neurodevelopmental disorder (ARND) is another alcohol related disorder which is associated with behavioral, cognitive, or central nervous system abnormalities. It is associated with prenatal alcohol exposure. Often women do not know they are pregnant and continue to drink. People with ARND tend to do poorly at school.

Also, prenatal alcohol exposure can result in skeletal and organ malformation termed alcohol-related birth defects (ARBD).

Key Takeaways

- Alcohol in excess is detrimental to health; in moderation, however, it is promoted as a benefit to the body and mind. The US *Dietary Guidelines* define moderate alcohol intake as no more than one drink per day for women and no more than two drinks per day for men.
- Moderate intake of alcohol has been shown in multiple scientific studies to provide health benefits, including reducing the risks of heart disease, cardiovascular disease, metabolic syndrome, Type 2 diabetes, and gallstones.

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14.4: How Much to Drink?

Learning Objectives

- Knowledge of different levels of alcohol intake and ways people consume alcohol
- Understanding of the mental and physical effects of alcohol at different levels of intake

How Much to Drink?

Most likely, you have observed people drinking alcohol, or been with people who are drinking, or drank alcohol yourself. What did you observe? People can consume alcohol in a variety of different ways for a variety of different reasons. The National Institute on Alcohol Abuse and Alcoholism (NIAAA) has defined different levels of drinking. Where do you or those around you fit in?

Table 14.4.1: Definitions of different levels of drinking

Type of drinking	Definition
Moderate alcohol consumption	Moderate drinking is up to 1 drink per day for women and up to 2 drinks per day for men ("Dietary Guidelines for Americans 2015-2020," U.S. Department of Health and Human Services and U.S. Department of Agriculture)
Binge Drinking	NIAAA defines binge drinking as a pattern of drinking that brings blood alcohol concentration (BAC) levels to 0.08 g/dL. This typically occurs after 4 drinks for women and 5 drinks for men—in about 2 hours. The Substance Abuse and Mental Health Services Administration (SAMHSA), which conducts the annual National Survey on Drug Use and Health (NSDUH), defines binge drinking as 5 or more alcoholic drinks for males or 4 or more alcoholic drinks for females on the same occasion (i.e., at the same time or within a couple of hours of each other) on at least 1 day in the past month.
Heavy Alcohol Use	SAMHSA defines heavy alcohol use as binge drinking on 5 or more days in the past month.
NIAAA's Definition of Drinking at Low Risk for Developing Alcohol Use Disorder (AUD)	For women, low-risk drinking is defined as no more than 3 drinks on any single day and no more than 7 drinks per week. For men, it is defined as no more than 4 drinks on any single day and no more than 14 drinks per week. NIAAA research shows that only about 2 in 100 people who drink within these limits have AUD.
Those who should avoid alcohol:	• Individuals plan to drive a vehicle or operate machinery • Take medications that interact with alcohol • Have a medical condition that alcohol can aggravate • Are pregnant or trying to become pregnant

The blood alcohol concentration (BAC) is measured in milligrams percent, comparing units of alcohol to units of blood. BAC is a measurement used legally to assess intoxication and the impairment and ability to perform certain activities, as in driving a car. As a general rule, the liver can metabolize one standard drink (defined as 12 ounces of beer, 5 ounces of wine, or 1 ½ ounces of hard liquor) per hour. Drinking more than this, or more quickly, will cause BAC to rise to potentially unsafe levels. Table 14.4.2 summarizes the mental and physical effects associated with different BAC levels.

Table 14.4.2: Mental and Physical Effects of Different BAC Levels

BAC Percent	Typical Effects
0.02	Some loss of judgment, altered mood, relaxation, increased body warmth

BAC Percent	Typical Effects
0.05	Exaggerated behavior, impaired judgment, may have some loss of muscle control (focusing eyes), usually good feeling, lowered alertness, release of inhibition
0.08	Poor muscle coordination (balance, speech, vision, reaction time), difficulty detecting danger, and impaired judgment, self-control, reasoning, and memory
0.10	Clear deterioration of muscle control and reaction time, slurred speech, poor coordination, slowed thinking
0.15	Far less muscle control than normal, major loss of balance, vomiting

In addition to the one drink per hour guideline, the rate at which an individual's BAC rises is affected by the following factors:

- Sex (A woman's BAC will rise more quickly than a man's.)
- Weight (BAC will rise more slowly for heavier people.)
- Genetics
- Length of time as a heavy drinker
- Type of alcohol consumed
- Amount of alcohol consumed
- Consumption rate
- Consumption before or after a meal (food in the stomach slows absorption)
- Mixture (carbonated mixers speed absorption)
- Medications may increase the bioavailability of alcohol.



Figure 14.4.2: In moderation, alcohol promotes some aspects of health. However, caution is necessary because excessive alcohol intake can have detrimental effects on health.

Giving the liver enough time to fully metabolize the ingested alcohol is the only effective way to avoid alcohol toxicity. Drinking coffee or taking a shower will not help. The legal limit for intoxication in many states is a BAC of 0.08. Taking into account the rate at which the liver metabolizes alcohol after drinking stops, and the alcohol excretion rate, it takes at least five hours for a legally intoxicated person to achieve sobriety.

Myths About Drinking

- Alcohol does not warm you up.
- Mixing drinks does not lead to a hangover. Ethanol causes hangovers.
- Vitamins, tranquilizers, aspirin, drinking more water, breathing pure oxygen, exercising, and eating do not prevent a hangover or make it less worse.
- Drinking caffeinated beverages does not keep you from getting drunk or slow the intoxication process.
- Alcohol is a depressant
- Alcohol is a legal DRUG

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CHAPTER OVERVIEW

15: Nutrition and Exercise

Nutrition can improve athletic performance. What you eat and when you eat can make or break your workout or competition. if you eat the right types of foods at the right time, your body will have the nutrients it needs during physically demanding activities like running, bicycling, or lifting weights. This chapter will introduce you to the concepts of sports nutrition.

15.1: Chapter Introduction
15.2: Introduction to Nutrition and Physical Fitness
15.3: Aerobic Exercise
15.4: Anaerobic Exercise
15.5: Nutrients that are critical to athletes
15.6: Fitness Supplements and Steroids
15.7: Fitness and Health
15.8: Supplemental- Creating your own fitness plan

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15.1: Chapter Introduction



Physical activity is divided into three types: inactivity, non-exercise activity, and exercise. Sitting and laying down comprise physical inactivity. Many people spend a substantial portion of their day inactive or sedentary. How about you? Have you ever counted how many hours a day you spend inactive?

Non-exercise activity (also known as NEAT) includes activities that are not sleeping, eating or sports-like activities like walking, standing, gardening, typing, performing yard work, fidgeting, and cleaning house. Exercise is the third type of physical activity and includes anything that is a sport-like exercise, for example, swimming, running, and bicycling. Exercise activities can be further divided into aerobic and anaerobic which will be explained in this chapter.

Physical activity confers many benefits. It improves our mental outlook and capacity, our self-image, our self-confidence, and provides independence for the elderly. Moving can also increase lean body mass and decrease body fat. Research studies find people who are obese spend significantly more time during the day physically inactive than people who are not overweight or obese. Engaging in physical activity also increases bone mass, and heart, lung, and muscle function. Morbidly and mortality is lower in people who are physically active compared to people who are sedentary. Also, the risk is reduced for cardiovascular disease, hypertension, stroke, type II diabetes, cancer, particularly colon and breast, osteoporosis and gall bladder disease.

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15.2: Introduction to Nutrition and Physical Fitness

Physical fitness is a general state of health and well-being and, more specifically, the ability to perform aspects of sports, occupations and daily activities. Physical fitness is generally achieved through proper nutrition, moderate-vigorous physical exercise, physical activity, and sufficient rest. Before the industrial revolution, fitness was defined as the capacity to carry out the day's activities without undue fatigue. However, with automation and changes in lifestyles physical fitness is now considered a measure of the body's ability to function efficiently and effectively in work and leisure activities, to be healthy, to resist hypokinetic diseases, and to meet emergency situations.

Components of fitness include body composition, flexibility muscle strength and endurance, and cardiovascular endurance.

Figure 15.2.1: *Physical fitness can be achieved through exercise. Photo shows Rich Froning Jr. – four-time winner of "Fittest Man on Earth" title.*

Fitness

Fitness is defined as the quality or state of being fit. Around 1950, perhaps consistent with the Industrial Revolution and the treatise of World War II, the term "fitness" increased in western vernacular by a factor of ten. The modern definition of fitness describes either a person or machine's ability to perform a specific function or a holistic definition of human adaptability to cope with various situations. This has led to an interrelation of human fitness and attractiveness which has mobilized global fitness and fitness equipment industries. Regarding specific function, fitness is attributed to personnel who possess significant aerobic or anaerobic ability, i.e. strength or endurance. A holistic definition of fitness is described by Greg Glassman in the CrossFit journal as an increased work capacity across broad times and modal domains; mastery of several attributes of fitness including strength, endurance, power, speed, balance and coordination and being able to improve the amount of work done in a given time with any of these domains. A well-rounded fitness program will improve a person in all aspects of fitness, rather than one, such as only cardio/respiratory endurance or only weight training.

Figure 15.2.2: *A woman performs plank exercise for strengthening of muscles*

A comprehensive fitness program tailored to an individual typically focuses on one or more specific skills, and on age- or health-related needs such as bone health. Many sources also cite mental, social and emotional health as an important part of overall fitness. This is often presented in textbooks as a triangle made up of three points, which represent physical, emotional, and mental fitness. Physical fitness can also prevent or treat many chronic health conditions brought on by unhealthy lifestyle or aging. Working out can also help some people sleep better and possibly alleviate some mood disorders in certain individuals.

Developing research has demonstrated that many of the benefits of exercise are mediated through the role of skeletal muscle as an endocrine organ. That is, contracting muscles release multiple substances known as myokines which promote the growth of new tissue, tissue repair, and various anti-inflammatory functions, which in turn reduce the risk of developing various inflammatory diseases.

Activity guidelines

The Physical Activity Guidelines for Americans was created by the Office of Disease Prevention and Health Promotion. This publication suggests that all adults should avoid inactivity to promote good health mentally and physically. For substantial health benefits, adults should participate in at least 150 minutes (two hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week. For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount. Adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

Training

Specific or task-oriented fitness is a person's ability to perform a specific activity with a reasonable efficiency: for example, sports or military service. Specific training prepares athletes to perform well in their sports. Examples are:

- 100 m sprint: in a sprint, the athlete must be trained to work anaerobically throughout the race, an example of how to do this would be interval training.
- Middle distance running: athletes require both speed and endurance to gain benefit out of this training. The hard-working muscles are at their peak for a longer period of time as they are being used at that level for a longer period of time.
- Marathon: in this case, the athlete must be trained to work aerobically and their endurance must be built-up to a maximum.
- Many firefighters and police officers undergo regular fitness testing to determine if they are capable of the physically demanding tasks required of the job.
- Members of armed forces will often be required to pass a formal fitness test – for example, soldiers of the US Army must be able to pass the Army Physical Fitness Test (APFT).
- Hill sprints: requires a level of fitness, to begin with, the exercise is particularly good for the leg muscles. The army often trains doing mountain climbing and races.
- Sand running creates less strain on leg muscles than running on grass or concrete. This is because sand collapses beneath the foot softening the landing. Sand training is an effective way to lose weight and become fit as its proven you need more effort (one and a half times more) to run on the soft sand than on a hard surface.
- Aquajogging is a form of exercise that decreases strain on joints and bones. The water supplies minimal impact to muscles and bones which is good for those recovering from injury. Furthermore, the resistance of the water as one jogs through it provides an enhanced effect of exercise (the deeper you are the greater the force needed to pull your leg through).

Figure 15.2.3: *Swimmers perform squats prior to entering the pool in a U.S. military base, 2011*

- Swimming: Squatting exercise helps in enhancing a swimmer's start.

In order for physical fitness to benefit the health of an individual, an unknown response in the person called a stimulus will be triggered by the exertion. When exercise is performed with the correct amount of intensity, duration, and frequency, a significant amount of improvement can occur. The person may overall feel better but the physical effects on the human body take weeks or months to notice and possibly years for full development. For training purposes, exercise must provide a stress or demand on either a function or tissue. To continue improvements, this demand must eventually increase little over an extended period of time. This sort of exercise training has three basic principles: overload, specificity, and progression. These principles are related to health but also enhancement of physical working capacity.[22]

High-Intensity Interval Training (HIIT)

High-Intensity Interval Training consists of repeated, short bursts of exercise, completed at a high level of intensity. These sets of intense activity are followed by a predetermined time of rest or low-intensity activity. Studies have shown that exercising at a higher intensity has increased cardiac benefits for humans, compared to when exercising at a low or moderate level. When your workout consists of an HIIT session, your body has to work harder to replace the oxygen it lost. Research into the benefits of HIIT has revealed that it can be very successful for reducing fat, especially around the abdominal region. Furthermore, when compared to continuous moderate exercise, HIIT proves to burn more calories and increase the amount of fat burned post- HIIT session. Lack of time is one of the main reasons stated for not exercising; HIIT is a great alternative for those people because the duration of an HIIT session can be as short as 10 minutes, making it much quicker than conventional workouts.

Cardiovascular (Cardio-respiratory) training

Cardiovascular capacity can be measured using VO_2 max, a measure of the amount of oxygen the body can uptake and utilize. Cardiorespiratory training involves movement that increases the heart rate to improve the body's oxygen consumption. This form of exercise is an important part of all training regiments ranging from professional athletes to the everyday person. Also, it helps increase stamina.

Examples are:

- Jogging – Running at a steady and gentle pace. This form of exercise is great for maintaining weight.
- Elliptical Training – This is a stationary exercise machine used to perform walking, or running without causing excessive stress on the joints. This form of exercise is perfect for people with achy hips, knees, and ankles.

- Walking – Moving at a fairly regular pace for a short, medium or long distance.
- Treadmill training – Many treadmills have programs set up that offers a numerous amount of different workout plans. One effective cardiovascular activity would be to switch between running and walking. Typically warm up first by walking and then switch off between walking for three minutes and running for three minutes.
- Swimming – Using the arms and legs to keep oneself afloat and moving either forwards or backwards. This is a good full body exercise for those who are looking to strengthen their core while improving cardiovascular endurance.
- Cycling – Riding a bicycle typically involves longer distances than walking or jogging. This is another low-stress exercise on the joints and is great for improving leg strength.

Benefits of Fitness

Controlling blood pressure

Physical fitness has proven to result in positive effects on the body's blood pressure because staying active and exercising regularly builds up a stronger heart. The heart is the main organ in charge of systolic blood pressure and diastolic blood pressure. Engaging in a physical activity will create a rise in blood pressure, once the activity is stopped, however, the individual's blood pressure will return to normal. The more physical activity that one engages in, the easier this process becomes, resulting in a more 'fit' individual. A "normal" blood pressure is considered to be 120/80 or below. Through regular physical fitness, the heart does not have to work as hard to create a rise in blood pressure, which lowers the force on the arteries, and lowers the over all blood pressure.

Cancer prevention

Centers for disease control and prevention provide lifestyle guidelines of maintaining a balanced diet and engaging in physical activity to reduce the risk of disease. The WCRF/ American Institute for Cancer Research (AICR) published a list of recommendations that reflect the evidence they have found through consistency in fitness and dietary factors that directly relate to Cancer prevention. The WCRF/AICR recommendations include the following:

- "Be as lean as possible without becoming underweight
- Each week, adults should engage in at least 150 minutes of moderate intensity physical activity or 75 minutes of vigorous intensity physical activity
- Children should engage in at least one hour of moderate or vigorous physical activity each week
- Be physically active for at least thirty minutes every day
- Avoid sugar, limit the consumption of energy packed foods
- Balance your diet with a variety of vegetables, grains, fruits, legumes, etc.
- Limit sodium intake, the consumption of red meats and the consumption of processed meats
- Limit alcoholic drinks to two for men and one for women a day"

These recommendations are also widely supported by the American Cancer Society. The guidelines have been evaluated and individuals that have higher guideline adherence scores substantially reduce cancer risk as well as help towards control with a multitude of chronic health problems. Regular physical activity is a factor that helps reduce an individual's blood pressure and improves cholesterol levels, two key components that correlate with heart disease and Type 2 Diabetes. The American Cancer Society encourages the public to "adopt a physically active lifestyle" by meeting the criteria in a variety of physical activities such as hiking, swimming, circuit training, resistance training, lifting, etc. It is understood that cancer is not a disease that can be cured by physical fitness alone, however, because it is a multifactorial disease, physical fitness is a controllable prevention. The large associations tied with being physically fit and reduced cancer risk are enough to provide a strategy to reduce cancer risk. The American Cancer Society asserts different levels of activity ranging from moderate to vigorous to clarify the recommended time spent on a physical activity. These classifications of physical activity consider the intentional exercise and basic activities are done on a daily basis and give the public a greater understanding by what fitness levels suffice as future disease prevention.

Inflammation

Studies have shown an association between increased physical activity and reduced inflammation It produces both a short-term inflammatory response and a long-term anti-inflammatory effect. Physical activity reduces inflammation in conjunction with or independent of changes in body weight. However, the mechanisms linking physical activity to inflammation are unknown.

Immune system

Physical activity boosts the immune system. This is dependent on the concentration of endogenous factors (such as sex hormones, metabolic hormones and growth hormones), body temperature, blood flow, hydration status and body position. Physical activity has shown to increase the levels of natural killer (NK) cells, NK T cells, macrophages, neutrophils and eosinophils, complements, cytokines, antibodies and T cytotoxic cells. However, the mechanism linking physical activity to the immune system is not fully understood.

Cardiovascular disease prevention

Physical activity affects one's blood pressure, cholesterol levels, blood lipid levels, blood clotting factors and the strength of blood vessels. All factors that directly correlate to cardiovascular disease. It also improves the body's use of insulin. People who are at risk for diabetes, Type 2 (insulin resistant) especially, benefit greatly from physical activity because it activates a better usage of insulin and protects the heart. Those who develop diabetes have an increased risk of developing cardiovascular disease. In a study where a sample of around ten thousand adults from the Third National Health and Nutrition Examination Survey, physical activity and metabolic risk factors such as insulin resistance, inflammation, dyslipidemia were assessed. The study adjusted basic confounders with moderate/vigorous physical activity and the relation with CVD mortality. The results displayed physical activity is associated with a lower risk of CVD mortality that was independent of traditional metabolic risk factors.

The American Heart Association recommendations include the same findings as provided in the WCRF/ AICR recommendations list for people who are healthy. In regards to people with lower blood pressure or cholesterol, the association recommends that these individuals aim for around forty minutes of moderate to vigorous physical activity around three or four times a week.

Weight control

Achieving resilience through physical fitness promotes a vast and complex range of health related benefits. Individuals who keep up physical fitness levels generally regulate their distribution of body fat and stay away from obesity. Abdominal fat, specifically visceral fat, is most directly affected by engaging in aerobic exercise. Strength training has been known to increase the amount of muscle in the body, however, it can also reduce body fat. Sex steroid hormones, insulin, and an appropriate immune response are factors that mediate metabolism in relation to the abdominal fat. Therefore, physical fitness provides weight control through regulation of these bodily functions.

Neuropsychological effects

Regular exercise is effective for preventing the age-related decline in cognition and improving overall neuropsychological function. The increased synthesis of neurotrophic factors in the body and brain and the resulting neurogenesis in various brain structures are largely responsible for these effects. Exercise also has persistent antidepressant effects and has been found to serve as both a means to prevent and treat drug addictions, particularly psychostimulant addictions.

Menopause and physical fitness

Menopause is the term that is used to refer to the stretch of both before and after a woman's last menstrual cycle. there are an instrumental amount of symptoms connected to menopause, most of which can affect the quality of life of the women involved in this stage of her life. One way to reduce the severity of the symptoms is exercise and keeping a healthy level of fitness. Pre or during menopause as the women body changes there can be physical, physiological or internal changes to the body. These changes can be prevented or the reduced with the use of regular exercise. these changes include:

- Prevention of weight gain: around menopause women tend to lose their muscle mass and have it replaced with abdominal fat. Slight increases in physical exercise can help to prevent this.
- Reduce the risk of breast cancer: due to the weight loss from regular exercise, it may offer protection from breast cancer.
- Strengthen the bones of the body: Physical activity can slow the bone loss after menopause reducing the chance of bone fractures and osteoporosis.
- Reduce the risk of disease: Excess weight can increase the risk of heart disease and type 2 diabetes, and the regular physical activity can counter these effects.
- Boost the mood: By being involved in regular activities it can improve the psychological health, this can be the case at any age and not only for times during or after menopause.

The Melbourne Women's Midlife Health Project provided evidence that showed over an eight-year time period 438 were followed. Even though the physical activity was not associated with VMS in this cohort at the beginning. Women that reported they were

physically active every day at the beginning were 49% less likely to have reported bothersome hot flushes. This is in contrast to women who level of activity decreased were more likely to experience bothersome hot flushes.

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15.3: Aerobic Exercise

Aerobic exercise (also known as cardio) is physical exercise of low to high intensity that depends primarily on the aerobic energy-generating process. Aerobic literally means "relating to, involving, or requiring free oxygen", and refers to the use of oxygen to adequately meet energy demands during exercise. Generally, light-to-moderate intensity activities that are sufficiently supported by aerobic metabolism can be performed for extended periods of time. When practiced in this way, examples of cardiovascular/aerobic exercise are medium to long distance running/jogging, swimming, cycling, and walking, according to the first extensive research on aerobic exercise, conducted in the 1960s on over 5,000 U.S. Air Force personnel by Dr. Kenneth H. Cooper.

Figure 15.3.1: *Example of cardio exercise that is aerobic.*

Kenneth Cooper was the first person to introduce the concept of aerobic exercise. In the 1960s, Cooper started research into preventive medicine. He became intrigued by the belief that exercise can preserve one's health. In 1970 he created his own institute (the Cooper Institute) for non-profit research and education devoted to preventive medicine. He sparked millions into becoming active and is now known as the "father of aerobics".

Aerobic versus anaerobic exercise

Aerobic exercise and fitness can be contrasted with anaerobic exercise, of which strength training and short-distance running are the most salient examples. The two types of exercise differ by the duration and intensity of muscular contractions involved, as well as by how energy is generated within the muscle. Anaerobic exercise becomes necessary when the heart and lungs can not keep up with the oxygen demands of the muscle.

Remember from the chapter on energy metabolism that ATP is the energy needed for the cells in our body to live and function which includes muscle cells contraction. Within the muscle, ATP is not stored and it is quickly used in 3-10 seconds. Phosphocreatine is a very short term energy store used to regenerate ATP but it is depleted within 30 seconds. Glucose circulating in the blood or released from muscle glycogen stores is used to generate ATP and depending on availability and for intermediate exercise (65% of VO_2 max) provides energy for two hours. This process is called glycolysis.

When the amount of oxygen is inadequate as seen with high-intensity exercise, glucose can only be broken down to lactic acid because of a shortage of oxygen. The lactic acid accumulates in the muscle and decreases performance.

Fatty acids can be used to generate ATP but this process requires oxygen to be a fuel source. Muscle cells obtain fatty acids from two sources, small stores within the muscle and circulating fatty acids released from adipose stores. Remember, fatty acids are not water soluble so they are transported on albumin or within lipoproteins as triglycerides. Low to intermediate intensity exercise for a prolonged period burns fat.

Amino acids can be used as an energy source although they are not the preferred source. Amino acids are obtained from the intramuscular amino acid pool via the glucose-alanine cycle. At the most, amino acids can provide 10% of total energy.

New research on the endocrine functions of contracting muscles has shown that both aerobic and anaerobic exercise promote the secretion of myokines, which are beneficial hormones, with attendant benefits including the growth of new tissue, tissue repair, and various anti-inflammatory functions, which in turn reduce the risk of developing various inflammatory diseases. Myokine secretion, in turn, is dependent on the amount of muscle contracted, and the duration and intensity of contraction. As such, both types of exercise (aerobic and anaerobic) produce quite a number of health benefits.

Figure 15.3.2: *Fox and Haskell formula showing the split between aerobic (light orange) and anaerobic (dark orange) exercise and heart rate*

In almost all conditions, anaerobic exercise is accompanied by aerobic exercises because the less efficient anaerobic metabolism must supplement the aerobic system due to energy demands that exceed the aerobic system's capacity. What is generally called aerobic exercise might be better termed "solely aerobic", because it is designed to be low-intensity enough not to generate lactate (or lactic acid), so that all carbohydrate is aerobically turned into energy.

Initially, during increased exertion, muscle glycogen is broken down to produce glucose, which undergoes glycolysis producing pyruvate which then reacts with oxygen (Krebs cycle, Chemiosmosis) to produce carbon dioxide and water and releases energy. If there is a shortage of oxygen (anaerobic exercise, explosive movements), carbohydrate is consumed more rapidly because the

pyruvate ferments into lactate. If the intensity of the exercise exceeds the rate with which the cardiovascular system can supply muscles with oxygen, it results in a buildup of lactate and quickly makes it impossible to continue the exercise. Unpleasant effects of lactate buildup initially include the burning sensation in the muscles, and may eventually include nausea and even vomiting if the exercise is continued without allowing lactate to clear from the bloodstream.glycolysis producing pyruvate which then reacts with oxygen (Krebs cycle, Chemiosmosis) to produce carbon dioxide and water and releases energy. If there is a shortage of oxygen (anaerobic exercise, explosive movements), carbohydrate is consumed more rapidly because the pyruvate ferments into lactate. If the intensity of the exercise exceeds the rate with which the cardiovascular system can supply muscles with oxygen, it results in a buildup of lactate and quickly makes it impossible to continue the exercise. Unpleasant effects of lactate buildup initially include the burning sensation in the muscles, and may eventually include nausea and even vomiting if the exercise is continued without allowing lactate to clear from the bloodstream.

As glycogen levels in the muscle begin to fall, glucose is released into the bloodstream by the liver, and fat metabolism is increased so that it can fuel the aerobic pathways. Aerobic exercise may be fueled by glycogen reserves, fat reserves, or a combination of both, depending on the intensity. Prolonged moderate-level aerobic exercise at 65% VO_2 max (the heart rate of 150 bpm for a 30-year-old human) results in the maximum contribution of fat to the total energy expenditure. At this level, fat may contribute 40% to 60% of the total, depending on the duration of the exercise. Oxygen is required to burn fat. Vigorous exercise above 75% VO_2 max (160 bpm) primarily burns glycogen.

Major muscles in a rested, untrained human typically contain enough energy for about 2 hours of vigorous exercise. Exhaustion of glycogen is a major cause of what marathon runners call "hitting the wall". Training, lower intensity levels, and carbohydrate loading may allow postponement of the onset of exhaustion beyond 4 hours.

Aerobic exercise comprises innumerable forms. In general, it is performed at a moderate level of intensity over a relatively long period of time. For example, running a long distance at a moderate pace is an aerobic exercise, but sprinting is not. Playing singles tennis, with near-continuous motion, is generally considered aerobic activity, while golf or two people team tennis, with brief bursts of activity punctuated by more frequent breaks, may not be predominantly aerobic. Some sports are thus inherently "aerobic", while other aerobic exercises, such as fartlek training or aerobic dance classes, are designed specifically to improve aerobic capacity and fitness. It is most common for aerobic exercises to involve the leg muscles, primarily or exclusively. There are some exceptions. For example, rowing to distances of 2,000 m or more is an aerobic sport that exercises several major muscle groups, including those of the legs, abdomen, chest, and arms. Common kettle bell exercises combine aerobic and anaerobic aspects.

Among the recognized health benefits of doing regular aerobic exercise are:

- Strengthening the muscles involved in respiration, to facilitate the flow of air in and out of the lungs
- Strengthening and enlarging the heart muscle, to improve its pumping efficiency and reduce the resting heart rate, known as aerobic conditioning
- Improving circulation efficiency and reducing blood pressure
- Increasing the total number of red blood cells in the body, facilitating transport of oxygen
- Improved mental health, including reducing stress and lowering the incidence of depression, as well as increased cognitive capacity.
- Reducing the risk for diabetes. One meta-analysis has shown, from multiple conducted studies, that aerobic exercise does help lower Hb A_{1C}levels for type 2 diabetics.

As a result, aerobic exercise can reduce the risk of death due to cardiovascular problems. In addition, high-impact aerobic activities (such as jogging or using a skipping rope) can stimulate bone growth, as well as reduce the risk of osteoporosis for both men and women. In addition to the health benefits of aerobic exercise, there are numerous performance benefits:

- Increased storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance
- Neovascularization of the muscle sarcomeres to increase blood flow through the muscles
- Increasing speed at which aerobic metabolism is activated within muscles, allowing a greater portion of energy for intense exercise to be generated aerobically
- Improving the ability of muscles to use fats during exercise, preserving intramuscular glycogen
- Enhancing the speed at which muscles recover from high-intensity exercise
- Neurobiological effects: improvements in brain structural connections and increased gray matter density, new neuron growth, improved cognitive function (cognitive control and various forms of memory), and improvement or maintenance of mental health

Some drawbacks of aerobic exercise include:

- Overuse injuries because of repetitive, high-impact exercise such as distance running.
- Is not an effective approach to building muscle.
- Only effective for fat loss when used consistently.

Both the health benefits and the performance benefits, or "training effect", require a minimum duration and frequency of exercise. Most authorities suggest at least twenty minutes performed at least three times per week.

Supplementary Reading

https://www.sciencelearn.org.nz/reso...y-for-exercise

Aerobic Capacity

Aerobic capacity describes the functional capacity of the cardiorespiratory system, (the heart, lungs and blood vessels). Aerobic capacity refers to the maximum amount of oxygen consumed by the body during intense exercises, in a given time frame. It is a function both of cardiorespiratory performance and the maximum ability to remove and utilize oxygen from circulating blood. To measure maximal aerobic capacity, an exercise physiologist or physician will perform a VO_2 max test, in which a subject will undergo progressively more strenuous exercise on a treadmill, from an easy walk through to exhaustion. The individual is typically connected to a respirometer to measure oxygen consumption, and the speed is increased incrementally over a fixed duration of time. The higher the measured cardiorespiratory endurance level, the more oxygen has been transported to and used by exercising muscles, and the higher the level of intensity at which the individual can exercise. More simply put, the higher the aerobic capacity, the higher the level of aerobic fitness. The Cooper and multi-stage fitness tests can also be used to assess functional aerobic capacity for particular jobs or activities.

Figure 15.3.3: *Aerobic workout*

The degree to which aerobic capacity can be improved by exercise varies very widely in the human population: while the average response to training is an approximately 17% increase in VO_2max, in any population there are "high responders" who may as much as double their capacity, and "low responders" who will see little or no benefit from training. Studies indicate that approximately 10% of otherwise healthy individuals cannot improve their aerobic capacity with exercise at all. The degree of an individual's responsiveness is highly heritable, suggesting that this trait is genetically determined.

Table 15.3.1: Varieties of Aerobic Exercises

Indoor	Outdoor
• Stair climbing • Elliptical trainer • Indoor rower • Stairmaster • Stationary bicycle • Treadmill	• Walking • Cycling • Running • Cross-country skiing • Cross-country running • Nordic walking • Inline skating • Rowing

Alternatives

Higher intensity exercise, such as high-intensity interval training (HIIT), increases the resting metabolic rate (RMR) in the 24 hours following high-intensity exercise, ultimately burning more calories than lower intensity exercise; low-intensity exercise burns more calories during the exercise, due to the increased duration, but fewer afterward.

Aerobic exercise has long been a popular approach to achieving weight loss and physical fitness, often taking a commercial form.

- In the 1970s Judi Sheppard Missett helped create the market for commercial aerobics with her Jazzercise program
- In the 1980s Richard Simmons hosted an aerobic exercise show on television, and also released a series of exercise videos

- In the 1990s Billy Blanks's Tae Bo helped popularize cardio-boxing workouts that incorporated martial arts movements

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15.4: Anaerobic Exercise

Anaerobic exercise is a physical exercise intense enough to cause lactate to form. It is used by athletes in non-endurance sports to promote strength, speed and power and by body builders to build muscle mass. Muscle energy systems trained using anaerobic exercise develop differently compared to aerobic exercise, leading to greater performance in short duration, high-intensity activities, which last from mere seconds to up to about 2 minutes. Any activity lasting longer than about two minutes has a large aerobic metabolic component.

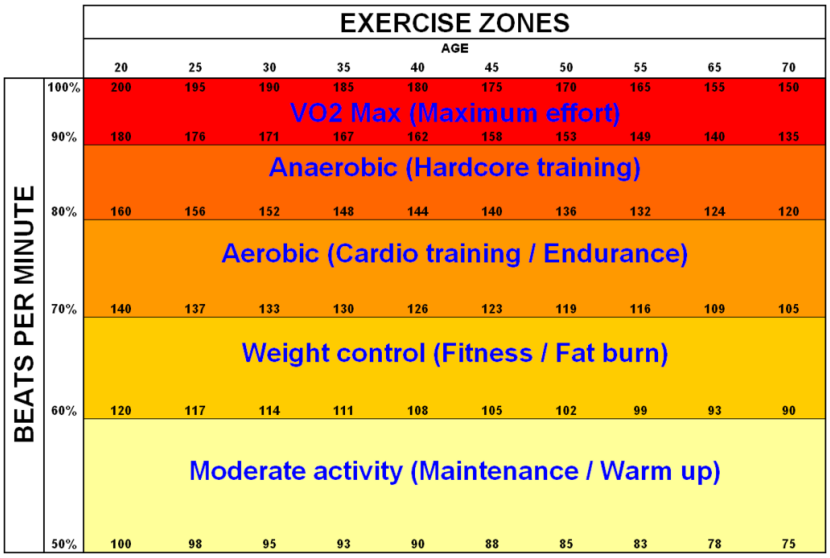


Figure 15.4.1: *Exercise work zones (Fox and Haskell formula between 20 and 70-year-old): VO2Max (red zone), anaerobic, aerobic, weight control and moderate activity. (CC BY-Sa 3.0;* Morgoth666 *)*

Metabolism

Anaerobic metabolism, or anaerobic energy expenditure, is a natural part of whole-body metabolic energy expenditure. Fast twitch muscle (as compared to slow twitch muscle) operates using anaerobic metabolic systems, such that any recruitment of fast twitch muscle fibers leads to increased anaerobic energy expenditure. Intense exercise lasting upwards of about four minutes (e.g., a mile race) may still have a considerable anaerobic energy expenditure component. High-intensity interval training, although based on aerobic exercises like running, cycling and rowing, effectively becomes anaerobic when performed in excess of 90% maximum heart rate. Anaerobic energy expenditure is difficult to accurately quantify, although several reasonable methods to estimate the anaerobic component to exercise are available.

In contrast, aerobic exercise includes lower intensity activities performed for longer periods of time. Activities such as walking, long slow runs, rowing, and cycling require a great deal of oxygen to generate the energy needed for prolonged exercise (i.e., aerobic energy expenditure). In sports which require repeated short bursts of exercise however, the anaerobic system enables muscles to recover for the next burst. Therefore training for many sports demands that both energy producing systems be developed.

The two types of anaerobic energy systems are:

1. high energy phosphates, adenosine triphosphate and creatine phosphate; and
2. anaerobic glycolysis.

The former is called **alactic anaerobic** and the latter **lactic anaerobic** system. High energy phosphates are stored in limited quantities within muscle cells. Anaerobic glycolysis exclusively uses glucose (and glycogen) as a fuel in the absence of oxygen, or more specifically when ATP is needed at rates that exceed those provided by aerobic metabolism. The consequence of such rapid glucose breakdown is the formation of lactic acid (or more appropriately, its conjugate base lactate at biological pH levels). Physical activities that last up to about thirty seconds rely primarily on the former, ATP-CP phosphagen system. Beyond this time both aerobic and anaerobic glycolysis-based metabolic systems begin to predominate.

The by-product of anaerobic glycolysis, lactate, has traditionally been thought to be detrimental to muscle function. However, this appears likely only when lactate levels are very high. Elevated lactate levels are only one of many changes that occur within and around muscle cells during intense exercise that can lead to fatigue. Fatigue, that is muscle failure, is a complex subject. Elevated muscle and blood lactate concentrations are a natural consequence of any physical exertion. The effectiveness of anaerobic activity can be improved through training

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15.5: Nutrients that are critical to athletes

Diet Needs

Physical activity requires energy and the type of activity, your body size, training and type of activity will determine your total daily energy expenditure. Obviously, non-exercise burns fewer calories and most people tend to spend more hours a day doing these types of activities than exercise. Tere are three energy macro nutrients as you have learned - carbohydrate, fat, and protein. Carbohydrate and fat are the preferred fuel sources. Both meal composition and timing relative to exercise are important for the athlete.

For athletes, an intake of more than 55% of calories from carbohydrate is recommended daily as carbohydrate is the preferred energy source. In some cases, athletes may carbohydrate load their muscles glycogen which may be useful for activities lasting more than 90 minutes. To carbohydrate load, one eats 7 -10 grams carbohydrate per kg body mass three days prior to the competitive event and after strenuous exercise that depletes the glycogen stores. Carbohydrate loading seems to work best in untrained people, not well-trained athletes and does not work in women. Recent scientific evidence suggests a better way to ensure adequate glycogen stores is to eat adequate amounts of carbohydrate (55% or greater) daily.

In the chapter on protein, you learned the RDA for protein is approximately 0.8 grams/kg body weight. Athletes need more protein (1.0 to 1.5 grams/kg/day or 10 to 15% of calories) but these levels may be less than they are currently consuming. The American diet generally contains more protein than required to build or maintain tissue. If carbohydrate is 55% or calories and protein is 10-15% of calories, then the remainder of the calories will be from fat (20-35%).

The timing of meals is important for the athlete. Any food should be eaten at least 30 minutes and best if 1-2 hours, before an event or workout. The foods selected should be rich in carbohydrates, low in fat, fiber, and protein. Within two hours after the event or workout, a post-meal should be eaten that is rich in carbohydrate to replace lost muscle glycogen, modest in protein to help rebuild used muscle and some fat.

Several minerals can be a concern for athletes. These minerals include calcium and iron. Weight bearing exercises will increase calcium retention in bones but many athletes avoid eating calcium rich foods like dairy so their calcium intake is inadequate. Depending on the type of exercise, iron deficiency can be a problem. a number of factors can contribute to this deficiency including inadequate iron intake, increased red blood breakdown, sweat loss and gastrointestinal damage that occurs in 8-23% of ultra-endurance athletes.

Vitamins are important for the athlete too but are generally not a concern with the athlete unless they are not eating a well-balanced diet such as that recommended by MyPlate.

Hydration

Hydration is important for the athlete. Water is essential to keep the body cool and thirst is not a reliable indicator of our body's need for water during exercise. During exercise, athletes may sweat and this water and electrolyte losses need to be replaced. Sweat is composed of water, sodium chloride, iron, zinc, copper, potassium, calcium, magnesium and other trace minerals. Depending on the length of the event and the intensity of sweating, the athlete should drink water during the workout or competition. Sodium, potassium, and chloride may not need to be replaced too. Water, which does not contain electrolytes, or a carbohydrate/electrolyte drink may be an appropriate selection. The recommendation is 6-12 oz every 15-20 minutes. After approximately two cups of water, electrolytes should be consumed for every pound of body weight lost.

Consuming too much water can dilute blood sodium concentration resulting in hyponatremia, a condition that leads to neurological dysfunction and possible death. Excessive sweating can also cause hyponatremia.

Female Athlete Triad

Ballet, gymnastics, and women long distance running are three sports that suffer from the female athlete triad. This condition is very serious and is characterized by disordered eating behavior, amenorrhea (because body fat stores are too low), and osteoporosis (usually manifested as stress fractures). Female athlete triad requires a medical team specifically trained to diagnose and treat.

Supplemental Reading

http://extension.colostate.edu/topic...athlete-9-362/

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15.6: Fitness Supplements and Steroids

Bodybuilding supplements are dietary supplements specifically marketed to those involved in bodybuilding, weightlifting, and athletics. Among the most widely used are vitamins, protein, branched-chain amino acids (BCAA), glutamine, essential fatty acids, meal replacement products, creatine, weight loss products and testosterone boosters. Supplements are sold either as single ingredient preparations or in the form of "stacks" - proprietary blends of various supplements marketed as offering "synergistic advantages". While many bodybuilding supplements are also consumed by the general public, their salience and frequency of use may differ when used specifically by bodybuilders. They may be marketed as a product to replace meals, enhance weight gain, promote weight loss or improve athletic performance. Annual sales of sport nutrition products in the US is over $2.7 billion (US) according to Consumer Reports.

History

Athletes in ancient Greece were advised to consume large quantities of meat and wine. A number of herbal concoctions and tonics have been used by strong men and athletes since ancient times across cultures for the enhancement of strength, vigor, prowess, and stamina. In the 1910s, Eugen Sandow, widely considered to be the first modern bodybuilder in the West, advocated the use of dietary control to enhance muscle growth. Later, bodybuilder Earle Liederman advocated the use of "beef juice" or "beef extract" (basically, consomme) as a way to enhance muscle recovery. In the 1950s with recreational and competitive bodybuilding becoming increasingly popular Irvin P. Johnson began to popularize and market egg-based protein powders marketed specifically at bodybuilders and physical athletes. The 1970s and 1980s marked a dramatic increase in the growth of the bodybuilding supplement industry, fueled by the widespread use of modern marketing techniques and a marked increase in recreational bodybuilding.

In October 1994, the Dietary Supplement Health and Education Act (DSHEA) was signed into law in the USA. Under DSHEA, responsibility for determining the safety of the dietary supplements changed from government to the manufacturer and supplements no longer required approval from the U.S. Food and Drug Administration (FDA) before distributing the product. Since that time manufacturers did not have to provide FDA with the evidence to substantiate safety or effectiveness unless a new dietary ingredient was added. It is widely believed that the 1994 DSHEA further consolidated the position of the supplement industry and lead to additional product sales.

Controversies of Fitness Supplements

Mislabeling: According to University of Helsinki food safety professor Marina Heinonen, more than 90% of dietary supplement health claims are incorrect. While many of the claims are based on scientifically based physiological or biochemical processes, their use in bodybuilding parlance is often heavily colored by bodybuilding lore and industry marketing and as such may deviate considerably from traditional scientific usages of the terms. In addition, ingredients listed have been found at times to be different from the contents. In 2015, Consumer Reports reported unsafe levels of arsenic, cadmium, lead, and mercury in several of the protein powders that were tested. Other studies in 2013 showed that one-third of the supplements tested contained unlisted steroids. In 2015 a CBC investigative report found that protein spiking (the addition of amino acid filler to manipulate analysis) was not uncommon, however many of the companies involved challenged these claims.

Health problems: The US FDA reports 50,000 health problems a year due to dietary supplements and these often involve bodybuilding supplements. For example, the "natural" best-seller Craze, 2012's "New Supplement of the Year" by bodybuilding.com, sold in Walmart, Amazon etc., was found to contain undisclosed amphetamine-like compounds. Also, other products by Matt Cahill have contained dangerous substances causing blindness or liver damages, and experts say that Cahill is emblematic for the whole industry.

Liver damage: The incidence of liver damage from dietary supplements has tripled in a decade, the majority of these involved bodybuilding supplements. This resulted in liver transplants and, in some cases, death to the patient. Some have argued that the liver damage is more often caused by prescription drugs rather than supplements.

Lack of effectiveness: In addition to being potentially harmful, some have argued that there is little evidence to indicate any benefit to using bodybuilding supplements. For example, according to the IOC, no consensus had been reached in determining whether an individual in exercise training benefits from protein and amino acid supplements. "In view of the lack of compelling evidence to the contrary, no additional dietary protein is suggested for healthy adults undertaking resistance or endurance exercise".

Protein

Bodybuilders may supplement their diets with protein for reasons of convenience, lower cost (relative to meat and fish products) and to avoid the concurrent consumption of carbohydrates and fats. In addition, some argue that bodybuilders, by virtue of their unique training and goals, require higher-than-average quantities of protein to support maximal muscle growth; however, there is no compelling evidence and no scientific consensus for bodybuilders to consume more protein than the recommended dietary allowance.



Figure 15.6.1: *Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement. (CC BY-SA 3.0;* Sandstein).

Protein supplements are sold in ready-to-drink shakes, bars, meal replacement products (see below), bites, oats, gels and powders. Protein powders are the most popular and may have flavoring added for palatability. The powder is usually mixed with water, milk or juice and is generally consumed immediately before and after exercising, or in place of a meal. The sources of protein are as follows, and differ in protein quality depending on their amino acid profile and digestibility:

- Whey protein contains high levels of all the essential amino acids and branched-chain amino acids. It also has the highest content of the amino acid cysteine, which aids in the biosynthesis of glutathione. For bodybuilders, whey protein provides amino acids used to aid in muscle recovery. Whey protein is derived from the process of making cheese from milk. There are three types of whey protein: whey concentrate, whey isolate, and whey hydrolysate. Whey concentrate is 29–89% protein by weight whereas whey isolate is 90%+ protein by weight. Whey hydrolysate is enzymatically predigested and therefore has the highest rate of digestion of all protein types. Whey protein is usually taken immediately before and after a workout
- Casein protein (or milk protein) has glutamine, and casomorphin. Casein is usually taken before going to bed.
- Soy protein from soybeans contain isoflavones, a type of phytoestrogen.
- Egg-white protein is a lactose- and dairy-free protein.
- Hemp protein from hemp seed contains highly-digestible protein, and hemp oil is high in essential fatty acids.
- Rice protein, when made from the whole grain, is a protein source that is highly digestible and allergen free. Since rice protein is low in the amino acid lysine, it is often combined with pea protein powder to achieve a superior amino acid profile.
- Pea protein is a hypoallergenic protein with a lighter texture than most other protein powders. Pea protein has an amino acid profile similar to that of soy, but pea protein does not elicit concerns about unknown effects of phytoestrogens. Pea protein is also less allergenic than soy. Pea protein has high fiber content and has no allergic ingredients and therefore is easy for digestion as compared to whey protein. Pea protein is a slow digesting protein and is able to keep you full longer.

Figure 15.6.2*: Shaker Bottle commonly used to mix supplements. Often has mesh or a metal whisk inside to break down lumps in the mixture.*

Some nutritionists claim that osteoporosis may occur from excessive protein intake because protein can put pressure on the kidneys and lead to bone loss due to calcium leaching. However, some have suggested that higher calcium excretion may be due to a corresponding increase in protein-induced calcium absorption in the intestines. In addition to complete proteins, some supplements will contain protein fragments such as branched-chain amino acids or individual amino acids (such as glutamine). Amino acids are considered to be inferior to whole protein and have been used by some companies to artificially inflate and falsify protein values in their product (protein spiking). Many protein supplements explicitly indicate on the label that no protein spiking has occurred.

Branched-chain amino acids

Amino acids are the building blocks of protein; the body breaks consumed protein into amino acids in the stomach and intestines. Amino acids are classified as essential, conditionally essential and non-essential. There are three branched-chain amino acids

(BCAAs): leucine, isoleucine, and valine. All three branched-chain amino acids are essential amino acids. Each has numerous benefits on various biological processes in the body. Unlike other amino acids, BCAAs are metabolized in the muscle and have an anabolic/anti-catabolic effect on it. There is some evidence that BCAA's may enhance muscle recovery after intense physical activity and no side effects have been reported at this time.

Glutamine

Glutamine is the most abundant amino acid found in human muscle and is commonly found in supplements or as a micronized, instantly soluble powder because supplement manufacturers claim the body's natural glutamine stores are depleted during anaerobic exercise. Some studies have shown there to be no significant effect of glutamine on bench press strength, knee-extension torque or lean muscle mass when compared to controls taking a placebo, though another study found that glutamine is beneficial in raising T-helper/suppressor cell ratio in long-distance runners.

Essential fatty acids

The essential fatty acids (alpha-linolenic acid and linoleic acid) may be important to supplement while bodybuilding; these cannot readily be made in the body, but are required for various functions within the body to take place. Fatty fish, such as fresh salmon and trout are rich in essential fatty acids and fish oils can also be taken in supplement form. Flaxseed oil, often sold as a supplement on its own, is an ideal source of alpha-linolenic acid, which can also be found in walnuts and pumpkin seeds.

Ergogenic Aids

Ergogenic Aids or supplements are substances purposefully taken to improve athletic performance. Not all ergogenic aids or supplements confer such benefits. Below, several substances that have some scientific evidence to support their athletic performance benefit are discussed.

Creatine

Creatine is an organic acid naturally occurring in the body that supplies energy to muscle cells for short bursts of energy (as required in lifting weights) via creatine phosphate replenishment of ATP. A number of scientific studies have shown that creatine can improve strength, energy, muscle mass, and recovery times. In addition, recent studies have also shown that creatine improves brain function. and reduces mental fatigue.Unlike steroids or other performance-enhancing drugs, creatine can be found naturally in many common foods such as herring, tuna, salmon, and beef.

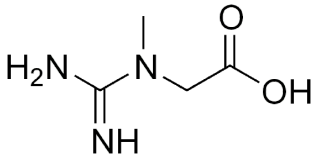


Figure 15.6.3: Skeletal formula of creatine

Creatine increases what is known as *cell volumization* by drawing water into muscle cells, making them larger. This *intracellular* retention should not be confused with the common myth that creatine causes bloating (or *intercellular* water retention). Creatine is sold in a variety of forms, including creatine monohydrate and creatine ethyl ester, amongst others. Though all types of creatine are sold for the same purposes, there are subtle differences between them, such as price and necessary dosage.

In *The New Encyclopedia of Modern Bodybuilding, 2nd ed.*, author Arnold Schwarzenegger states:

> *Creatine monohydrate is regarded as a necessity by most bodybuilders. Creatine monohydrate is the most cost-effective dietary supplement in terms of muscle size and strength gains. … There is no preferred creatine supplement, but it is believed that creatine works best when it is consumed with simple carbohydrates. This can be accomplished by mixing powdered creatine with grape juice, lemonade, or many high glycemic index drinks.*

Some studies have suggested that consumption of creatine with protein and carbohydrates can have a greater effect than creatine combined with either protein or carbohydrates alone.

β-Hydroxy β-methylbutyrate (HMB)

HMB is a metabolite of the amino acid leucine and leucines' keto acid, alpha-ketoisocaproate (KIC). It occurs naturally in small amounts in grapefruit, alfalfa, and catfish, and is naturally synthesized in the human body in the liver and muscle, probably in response to protein synthesis. When combined with an appropriate exercise program, dietary supplementation with β-hydroxy β-methylbutyrate (HMB) may augment gains in muscle hypertrophy (i.e., the size of a muscle), muscle strength, and lean body mass, reduce exercise-induced skeletal muscle damage, and expedite recovery from high-intensity exercise; however, there is insufficient scientific evidence to support these claims. HMB is believed to produce these effects by increasing muscle protein synthesis and decreasing muscle protein breakdown by various mechanisms, including activation of the mechanistic target of rapamycin (mTOR) and inhibition of the proteasome in skeletal muscles. The inhibition of exercise-induced skeletal muscle damage by HMB is affected by the time that it is used relative to exercise. The greatest reduction in skeletal muscle damage from a single bout of exercise appears to occur when calcium HMB is ingested 1–2 hours prior to exercise.

Meal Replacement Products (MRP)

Meal replacement products (MRPs) are either pre-packaged powdered drink mixes or edible bars designed to replace prepared meals. MRPs are generally high in protein, low in fat, have a low to moderate amount of carbohydrates, and contain a wide array of vitamins and minerals. The majority of MRPs use whey protein, casein (often listed as calcium caseinate or micellar casein), soy protein, and/or egg albumin as protein sources. Carbohydrates are typically derived from maltodextrin, oat fiber, brown rice, and/or wheat flour. Some MRPs also contain flax oil powder as a source of essential fatty acids.

MRPs can also contain other ingredients, such as creatine monohydrate, glutamine peptides, L-glutamine, calcium alpha-ketoglutarate, additional amino acids, lactoferrin, conjugated linoleic acid, and medium-chain triglycerides. A sub-class of MRPs are called 'weight gainers' and have a high ratio of carbohydrate:protein. Where a MRP would have a 0.25-2:1 ratio of carbohydrate:protein a weight gainer would have in the order of between 3-5:1 ratios.

The effect of HMB on skeletal muscle damage has been assessed in studies using four different biomarkers of muscle damage or protein breakdown: serum creatine kinase, serum lactate dehydrogenase, urinary urea nitrogen, and urinary 3-methylhistidine. When exercise intensity and volume are sufficient to cause skeletal muscle damage, such as during long-distance running or progressive overload, HMB supplementation has been demonstrated to attenuate the rise in these biomarkers by 20–60%.

Thermogenic products

A thermogenic is a broad term for any supplement that the manufacturer claims will cause thermogenesis, resulting in increased body temperature, increased metabolic rate, and consequently an increased rate in the burning of body fat and weight loss. Until 2004 almost every product found in this supplement category comprised the "ECA stack": ephedrine, caffeine, and aspirin. However, on February 6, 2004, the Food and Drug Administration (FDA) banned the sale of ephedra and its alkaloid, ephedrine, for use in weight loss formulas. Several manufacturers replaced the ephedra component of the "ECA" stack with bitter orange or citrus aurantium (containing synephrine) instead of the ephedrine.

Caffeine

Caffeine is a chemical called xanthine found in the seeds, leaves, and fruit of many plants, where it acts as a natural pesticide. It is the most widely consumed psychoactive substance and is such an important part of many people’s lives that they might not even think of it as a drug. Up to 90 percent of adults around the world use it on a daily basis. According to both the FDA and the American Medical Association, the moderate use of caffeine is “generally recognized as safe.” It is considered a legal psychoactive drug and, for the most part, is completely unregulated.

Typical Doses and Dietary Sources

What is a “moderate intake” of caffeine? Caffeine intakes are described in the following manner:

- **Low–moderate intake.** 130–300 milligrams per day
- **Moderate intake.** 200–300 milligrams per day
- **High intake.** 400 or more milligrams per day

The average caffeine consumption for American adults is considered moderate at 280 milligrams per day, although it is not uncommon for people to consume up to 600 milligrams per day. This works out to almost 4 ½ cups of coffee per day. The bitter taste of caffeine is palatable for many and coffee is the most readily available source of it, accounting for 70 percent of daily

caffeine consumption. The second readily available source of caffeine is soft drinks, delivering 16 percent of daily caffeine. (In this case, the bitter caffeine taste is usually masked by a large amount of added sugar.) Tea is the third common source of caffeine, at 12 percent.

Just how much caffeine is there in a cup of coffee? It varies. The caffeine content of an average cup of coffee can range from 102 to 200 milligrams, and the range of tea is 40 to 120 milligrams. Table 15.6.2 provides useful information on the levels of caffeine found in common beverages. When estimating your total caffeine consumption remember its not only in beverages but also some foods and medicine.

Table 15.6.1: Caffeine Content in Various Beverages and Foods

Beverage/Food	Milligrams
Starbuck's Grande Coffee (16 oz.)	380
Plain brewed coffee (8 oz.)	102–200
Espresso (1 oz.)	30–90
Plain, decaffeinated coffee (8 oz.)	3–12
Tea, brewed (8 oz.)	40–120
Green tea (8 oz.)	25–40
Coca-Cola Classic (12 oz.)	35
Dr. Pepper (12 oz.)	44
Jolt Cola (12 oz.)	72
Mountain Dew (12 oz.)	54
Mountain Dew, MDX (12 oz.)	71
Pepsi-Cola (12 oz.)	38
Red Bull (8.5 oz.)	80
Full Throttle (16 oz.)	144
Monster Energy (16 oz.)	160
Spike Shooter (8.4 oz.)	300

Source: MedicineNet.com. "Caffeine." Accessed October 2, 2011. http://www.medicinenet.com/caffeine/article.htm.

Health Benefits of Caffeine

The most renowned effects of caffeine on the body are increased alertness and delay of fatigue and sleep. How does caffeine stimulate the brain? Watch "Video 15.6.1" to see a graphic account of a brain on caffeine. Caffeine is chemically similar to a chemical in our brains (adenosine). Caffeine interacts with adenosine's specific protein receptor. It blocks the actions of the adenosine, and affects the levels of signaling molecules in the brain, leading to an increase in energy metabolism. At the molecular level, caffeine stimulates the brain, increasing alertness and causing a delay of fatigue and sleep. At high doses caffeine stimulates the motor cortex of the brain and interferes with the sleep-wake cycle, causing side effects such as shakiness, anxiety, and insomnia. People's sensitivity to the adverse effects of caffeine varies and some people develop side effects at much lower doses. The many effects caffeine has on the brain do not diminish with habitual drinking of caffeinated beverages.



Video 15.6.1: *A Brain on Caffeine. Watch this graphic account of the brain on caffeine.*

Scientific studies suggest caffeine can improve endurance capacity by increasing energy available during exercise. The effect may only work in non-caffeine drinkers and it only takes 1-3 days for the body to become "caffeine-naive."

Bicarbonate

The term bicarbonate refers to sodium bicarbonate a salt that disassociates in water to form sodium and bicarbonate ions. Remember, the small intestine produces and uses bicarbonate to neutralize the acid in your stomach. Baking soda is sodium bicarbonate. There is limited scientific evidence that bicarbonate can improve athletic performance. The mechanism of action is through increased buffering of the blood which may be beneficial for high-intensity exercise.

Growth Hormone

Growth hormone (GH) is a hormone our body produces. In sports, athletes use this the abbreviations GH or HGH (human growth hormone) to refer to growth hormone. GH is a prescription medication so possession and use of it without a prescription is illegal. There is limited scientific evidence that it will increase muscle mass and improve athletic performance. Adverse effects of inappropriately using GH include weakened heart wall and premature death.

Anabolic Steroids

While the use of anabolic steroids is prohibited in sports, there is scientific evidence that anabolic steroids can increase muscle mass and thus improve athletic performance. Anabolic steroids come in both synthetic and natural form so the athlete must be careful as these compounds can be hidden in foods from unsuspecting athletes. Anabolic steroids mimic the effects see in adolescents with muscle growth but have adverse effects and in some cases, these effects are irreversible. Side effects include extreme aggression, breathing difficulty, heart disease, blood clots, liver tumors, loss of libido, baldness, testicular atrophy, clitoral enlargement and muscularization in women.

Prohormone

Prohormones are precursors to hormones and are most typically sold to bodybuilders as a precursor to the natural hormone testosterone. This conversion requires naturally occurring enzymes in the body. Side effects are not uncommon, as prohormones can also convert further into DHT and estrogen. To deal with this, many supplements also have aromatase inhibitors and DHT blockers such as chrysin and 4-androstene-3,6,17-trione. To date, most prohormone products have not been thoroughly studied, and the health effects of prolonged use are unknown. Although initially available over the counter, their purchase was made illegal without a prescription in the US in 2004, and they hold similar status in many other countries. They remain legal, however, in the United Kingdom and the wider European Union. Their use is prohibited by most sporting bodies.

Sports Drinks

Scientific studies under certain circumstances show that consuming sports drinks (instead of plain water) during high-intensity exercise lasting longer than one hour significantly enhances endurance, and some evidence indicates it additionally enhances performance. There is no consistent evidence that drinking sports drinks instead of plain water enhance endurance or performance in individuals exercising less than one hour and at low to moderate intensities. A well-concocted sports drink contains sugar, water, and sodium in the correct proportions so that hydration is optimized. The sugar is helpful in maintaining blood-glucose levels

needed to fuel muscles, the water keeps an athlete hydrated, and the sodium enhances fluid absorption and replaces some of that lost in sweat. The American College of Sports Medicine states that the goal of drinking fluids during exercise is to prevent dehydration, which compromises performance and endurance.

The primary source of water loss during intense physical activity is sweat. Perspiration rates are variable and dependent on many factors including body composition, humidity, temperature, and type of exercise. The hydration goal for obtaining optimal endurance and performance is to replace what is lost, not to over-hydrate. A person's sweating rate can be approximated by measuring weight before and after exercise—the difference in weight will be the amount of water weight you lost.

The primary electrolyte lost in sweat is sodium. One liter of sweat can contain between 1,000–2,000 milligrams of sodium. Potassium, magnesium, and calcium are also lost, but in much lower amounts. If you are exercising at high intensity for greater than ninety minutes, it is important to replace sodium as well as water. This can be partly accomplished by consuming a sports drink. The highest content of sodium in commercial sports drinks is approximately 450 milligrams per liter and thus will not replace all lost sodium unless a person drinks several liters. This is NOT recommended, as water intoxication not only compromises performance but may also be deadly. The sodium in sports drinks enhances fluid absorption so that rehydration is more efficiently accomplished. If you are not exercising for more than ninety minutes at a high intensity, dietary intake of sodium and other electrolytes should be sufficient for replacing lost electrolytes.

Who Needs Sports Drinks?

Children and adult athletes exercising for more than one hour at high-intensity (tennis, rowing, rugby, soccer, etc.) may benefit endurance-wise and possibly performance-wise from consuming a sports drink rather than water. However, consuming sports drinks provides no benefit over water to endurance, performance, or exercise recovery for those exercising less than an hour. In fact, as with all other sugary drinks containing few to no nutrients, they are only another source of calories. Drinking sports drinks when you are doing no exercise at all is not recommended.

Sports Drink Alternatives

Instead of a sports drink, you can replenish lost fluids and obtain energy and electrolytes during exercise by drinking plain water and eating a sports bar or snack that contains carbohydrates, protein, and electrolytes. Post exercise, low-fat milk has been scientifically shown to be just as effective as a sports drink as a rehydration beverage and it is more nutrient-dense, containing carbohydrates, protein, and electrolytes, in addition to other vitamins.

Contributors and Attributions

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15.7: Fitness and Health

Learning Objectives

- Define fitness and explain the essential elements of physical fitness.
- List the physical, mental, and emotional benefits of physical activity.

Becoming physically fit is an important part of achieving optimal health. A well-rounded exercise program is crucial to become and remain healthy. Physical activity improves your health in a number of ways. It promotes weight loss, strengthens muscles and bones, keeps the heart and lungs strong, and helps to protect against chronic disease. There are four essential elements of physical fitness: cardiorespiratory endurance, muscle strength, muscle endurance, and flexibility. Some enthusiasts might argue the relative importance of each, but optimal health requires some degree of balance between all four. Neither a muscle-bound weight lifter unable to bend down to tie his shoes nor a flexible yoga enthusiast who cannot lift her suitcase can be considered completely fit. All four elements of physical fitness are vital.

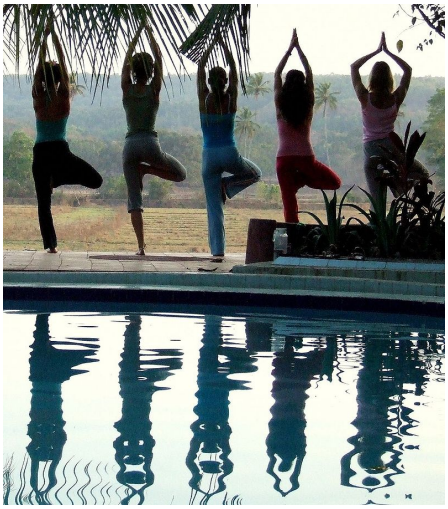


Figure 15.7.1: What does it mean to be physically fit? What does physical fitness encompass? A group of women demonstrating Vrksasana, the tree posture. from Judith on Flickr,

The Essential Elements of Physical Fitness

Building cardiorespiratory endurance through aerobic exercise is an excellent way to maintain a healthy weight. Working on this element of physical fitness also improves your circulatory system. It boosts your ability to supply the body's cells with oxygen and nutrients, and to remove carbon dioxide and metabolic waste. In addition, aerobic exercise makes you breathe faster and more deeply, which maximizes oxygen levels in the blood. Regular, moderate aerobic activity, about thirty minutes at a time for five days per week, trains the body to deliver oxygen more efficiently, which strengthens the heart and lungs and reduces the risk of cardiovascular disease.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

The most common standard for evaluating cardiorespiratory endurance is the **VO_2 max** test. VO_2 max is your maximal oxygen uptake, and the VO_2 max test measures the amount of oxygen (in relation to body weight) that you can use per minute. A test subject usually walks or runs on a treadmill with an air mask over their face to measure oxygen consumption as exercise intensity increases (Video 15.2). At some point, the amount of oxygen consumed no longer increases despite an increase in exercise intensity. This value of oxygen consumption is referred to as VO_2 max, 'V' meaning volume, and 'max' meaning the maximum amount of oxygen (O_2) consumed independent of exercise intensity. The higher the number, the more oxygen you can consume, and the faster or longer you can walk, run, bike, or swim, among other aerobic activities.Ed Eyestone, "How to Improve Your VO_2 Max," *Runner's World*, 9 January 2008. http://www.runnersworld.com/article/0,7120,s6-238-244--12408-0,00.html.



***Video 15.7.1**: VO_2 Max Test: The Human Body—A User's Guide. Watch two athletes take a VO_2 max test to measure their cardiorespiratory endurance. (click to see video).*

Muscle strength and muscle endurance are two other essential elements of physical activity. They are not just crucial for athletes and bodybuilders—building muscle strength and endurance is important for children, seniors, and everyone in between. The support that your muscles provide allows you to work, play, and live more efficiently. Strength training involves the use of resistance machines, resistance bands, free weights, or other tools. However, you do not need to pay for a gym membership or expensive equipment to strengthen your muscles. Homemade weights, such as plastic bottles filled with sand, can work just as well. You can also use your own body weight and do push-ups, leg squats, abdominal crunches, and other exercises to build your muscles. If strength training is performed at least twice a week, it can help to improve muscle strength and endurance and to increase bone strength. Strength training can also help you to maintain muscle mass during a weight-loss program.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

Flexibility is the range of motion available to your joints. Yoga, tai chi, Pilates, and stretching exercises work to improve this element of fitness. Stretching not only improves your range of motion, it also promotes better posture, and helps you perform activities that can require greater flexibility, such as chores around the house. In addition to working on flexibility, older adults should include balance exercises in their regular routine. Balance tends to deteriorate with age, which can result in falls and fractures.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

Some forms of exercise confer multiple benefits, which can help you to balance the different elements of physical fitness. For example, riding a bicycle for thirty minutes or more not only builds cardiorespiratory endurance, it also improves muscle strength and muscle endurance. Some forms of yoga can also build muscle strength and endurance, along with flexibility. However, addressing fitness standards in all four categories generally requires incorporating a range of activities into your regular routine.

Metabolic Fitness

Being fit also encompasses metabolic fitness. It relates to the number of calories you require to survive and the number of calories you burn during physical activity. Recall from Chapter 11 that **metabolism** is the sum of all chemical reactions that occur in the human body to conduct life's processes. Some are catabolic reactions that break down nutrients to supply the body with cellular energy. The rate at which a person burns calories depends on body shape, body composition, sex, age, nutritional status, and genetics.

One measurement of metabolic fitness is **resting metabolic rate**, or RMR, which is a measurement of the amount of energy required for the body to maintain its basic functions while at rest, i.e. breathing, heart beats, liver and kidney function, and so on. On average, RMR accounts for between 50 and 70 percent of a person's total daily energy expenditure. Different factors can affect the RMR, and as a result, it is not a perfect measurement for metabolic fitness. For example, a slender person who is tall has more body surface area and therefore has a higher RMR. Also, muscle utilizes more energy at rest than fat, and a person with more muscle mass has a higher RMR.Moninger, J. "Metabolism Hacks: Tap into Your Calorie-Burning Power." Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/metabolism-hacks.

A second measurement of metabolic fitness is the number of calories burned during physical activity. The amount of calories burned depends on the rate at which the heart beats, how much oxygen is delivered to tissues, and how efficiently metabolic reactions consume oxygen and burn calories. One of the best estimates of energy expenditure during exercise is how much oxygen a person consumes. Recall that VO_2 max is used to measure cardiorespiratory endurance. Greater VO_2 max is indicative of better oxygen metabolism and cardiovascular fitness, meaning more calories burned.

In contrast to RMR, VO_2 max increases significantly with exercise training, from increasing blood flow to tissues to increase the strength of heart muscle contraction. Greater blood flow into the tissues means more oxygen to muscle, which means more calories burned.

Increasing your daily activity and shedding excess weight helps to improve metabolic fitness. However, you do not have to be the perfect weight to be metabolically fit. Metabolic fitness is highly individualized. Also, any improvement to metabolic fitness is beneficial and means a decrease in the risk of developing diabetes, or other chronic conditions.

Keeping Fit: The Benefits of Physical Activity

Regular physical activity is one of the best things you can do to achieve optimal health. Individuals who are physically active for about seven hours per week lower the risk of dying early by 40 percent compared to those who are active for less than thirty minutes per week.Centers for Disease Control and Prevention. "Physical Activity and Health: The Benefits of Physical Activity." Last updated February 16, 2011. http://www.cdc.gov/physicalactivity/everyone/health/index.html. Improving your overall fitness involves sticking with an exercise program on a regular basis. If you are nervous or unsure about becoming more active, the good news is that moderate-intensity activity, such as brisk walking, is safe for most people. Also, the health advantages of becoming active far outweigh the risks. Physical activity not only helps to maintain your weight, it also provides a wealth of benefits—physical, mental, and emotional.

Physical Benefits

Getting the recommended amount of physical activity each week, about 150 minutes of moderate, aerobic exercise, such as power walking or bicycling, does not require joining a gym, wearing spandex, or taking expensive, complicated classes. If you can't commit to a formal workout four to five days per week, you can become more active in simple ways—by taking the stairs instead of the elevator, by walking more instead of driving, by going out dancing with your friends, or by doing your household chores at a faster pace. It is not necessary to perform at the level of a professional dancer or athlete, or to work out for several hours every day, to see real gains from exercise. Even slightly increased activity can lead to physical benefits, such as:

- **Longer life.** A regular exercise program can reduce your risk of dying early from heart disease, certain cancers, and other leading causes of death.
- **Healthier weight.** Exercise, along with a healthy, balanced eating plan, can help you lose extra weight, maintain weight loss, or prevent excessive weight gain.
- **Cardiovascular disease prevention.** Being active boosts HDL cholesterol and decreases unhealthy triglycerides, which reduces the risk of cardiovascular diseases.
- **Management of chronic conditions.** A regular routine can help to prevent or manage a wide range of conditions and concerns, such as metabolic syndrome, Type 2 diabetes, depression, arthritis, and certain types of cancer.
- **Energy boosts.** Regular physical activity can improve muscle tone and strength and provide a boost to your cardiovascular system. When the heart and lungs work more efficiently, you have more energy.
- **Strong bones.** Research shows that aerobic activity and strength training can slow the loss of bone density that typically accompanies aging.

Mental and Emotional Benefits

The benefits of an exercise program are not just physical, they are mental and emotional as well. Anyone who has gone for a walk to clear their head knows the mental benefits of exercise firsthand. Also, you do not have to be a marathoner on a "runner's high" to enjoy the emotional benefits of becoming active. The mental and emotional benefits of physical activity include:

- **Mood improvement.** Aerobic activity, strength-training, and more contemplative activities such as yoga, all help break cycles of worry, absorption, and distraction, effectively draining tension from the body.
- **Reduced risk of depression, or limited symptoms of it.** Some people have called exercise "nature's antidepressant," and studies have shown that physical activity reduces the risk of and helps people cope with the symptoms of depression.
- **Cognitive skills retention.** Regular physical activity can help people maintain thinking, learning, and judgment as they age.
- **Better sleep.** A good night's sleep is essential for clear thinking, and regular exercise promotes healthy, sound sleep. It can also help you fall asleep faster and deepen your rest.

Changing to a More Active Lifestyle

A physically active lifestyle yields so many health benefits that it is recommended for everyone. Change is not always easy, but even small changes such as taking the stairs instead of the elevator, or parking farther away from a store to add a bit more walking into your day can lead to a more active lifestyle and set you on the road to optimal health. When people go one step further by walking or biking on a regular basis or becoming active by growing and maintaining a garden, they do more than promoting their own health—they safeguard the health of the planet, too.

As you change to a more active lifestyle, select an activity that you can integrate into your schedule smoothly, so you can maintain it. For example, instead of making time to get coffee with friends, you might suggest a walk, roller blading, or going for a swim in the campus pool. Also, find an activity that you will be motivated to do. Some people decide to participate in team sports, such as local soccer or softball leagues because they enjoy being active with others or like knowing that a team relies on them. Others prefer to take a class, such as spinning or yoga, that is led by an instructor who will motivate them. Still, others prefer more solitary pursuits, such as taking a jog alone in their neighborhood. No matter what your preference, you are more likely to stick to a workout program if you enjoy it.

Whatever activities people choose to do, if they expend an extra 500 calories per day, they will lose 1 pound per week, become more physically fit, and maintain a healthy nutritional profile. The exact number of calories expended per hour will vary, depending on an individual's weight and level of exertion. However, it can be helpful to keep these numbers in mind (which are for an adult who weighs about 160 pounds) when considering a program of aerobic activity:

- Walking at two miles per hour burns 204 calories per hour
- Bicycling burns 292 calories per hour
- Jogging burns 606 calories per hour
- Golf burns 314 calories per hour if players carry their clubs
- Ballroom dance burns 219 calories per hour
- Tennis burns 584 calories per hour Mayo Clinic. "Exercise for Weight Loss: Calories Burned in 1 Hour." © 1998–2012 Mayo Foundation for Medical Education and Research. Last updated August 2, 2011. http://www.mayoclinic.com/health/exercise/SM00109.

Key Takeaways

Physical fitness is an important part of the pursuit of optimal health. Regular exercise yields multiple benefits in terms of preventing disease and promoting health. The four essential elements of physical fitness are cardiorespiratory endurance, muscle strength, muscle endurance, and flexibility.

Discussion Starter

1. If exercise helps people feel better, why don't more people do it regularly? Discuss some ways to motivate more people to exercise. What are some of the ways that a regular routine could benefit someone currently leading a sedentary lifestyle?

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15.8: Supplemental- Creating your own fitness plan

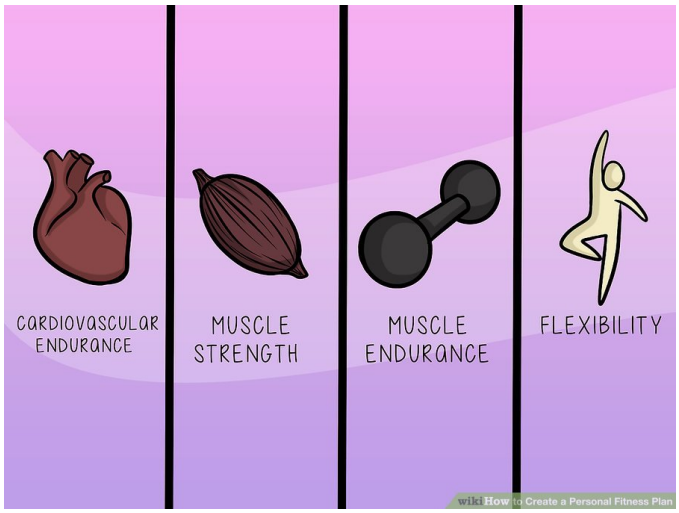
If you'd like to get stronger or faster, lose weight, or just improve the quality of your life, consider creating a personal fitness plan to meet your goals. There are many kinds of possible plans and most incorporate a mix of aerobic, resistance, and flexibility exercises. Assess your level of fitness and craft a plan suited to you

Part 1: Assessing your Fitness Level



Start with the basics. You've decided to get fit — that's a great first step. But don't just jump in without giving it some thought. Start with simple things: Is there anything stopping you from getting fit? Do you have any health issues? Should you talk to a doctor first?

- You probably don't need to talk to a doctor if you're under 50 and in good health, but it is always recommended before starting a new exercise program.
- If you're over 50 or have health issues — like high blood pressure, heart problems, dizzy spells, or arthritis — talk to your doctor first.
- Keep in mind that balance and strength decrease as you age. This can limit your ability to exercise or make injuries more likely, and harder to heal. But, by exercising with caution and a little guidance, you can improve these things through exercise.
- When in doubt, talk to a physician. Your physician can indicate any activities you should steer away from.



Test your current fitness level. Basic fitness is a mix of four things: cardiovascular endurance, muscle strength, muscle endurance, and flexibility. How do you measure up? Test yourself to see where you're fit and where you stand to improve. You'll need a watch, a measuring tape, a yardstick, tape, and a scale.

- Take a brisk 1 mile (1.6 km) walk to test your cardio health. Before you start, take your pulse rate in beats per minute and record the time. Take your pulse again afterward and note how long it took you.
- To get your pulse rate, just put your index and middle fingers on the side of your neck. Count the beats for 10 seconds and multiply by six.
- To test muscular strength, count how many push-ups you can do until you are unable to perform any more push-ups with correct form. If you are a woman, you can do modified push-ups (bend your knees) or classic push-ups. Men should do classic push-ups from the plank position. Record the number.
- For flexibility, secure a yardstick to the floor with some tape at the 15-inch mark. Sit next to the yardstick, with your feet roughly even with the tape. Reach forward as far as you can, holding the position long enough to note how far you were able to reach. Do this exercise three times, recording your farthest reach.
- Now for body composition: waist and Body Mass Index. First, measure and record your waist circumference around the body at the level of your belly button — where your waist is most narrow. To get your BMI (a rough indicator of body fat percentage), use an online calculator or divide your weight in lbs. by your height in inches, squared, times 703. If you're using metric, BMI = (Weight in Kilograms / (Height in Meters x Height in Meters))

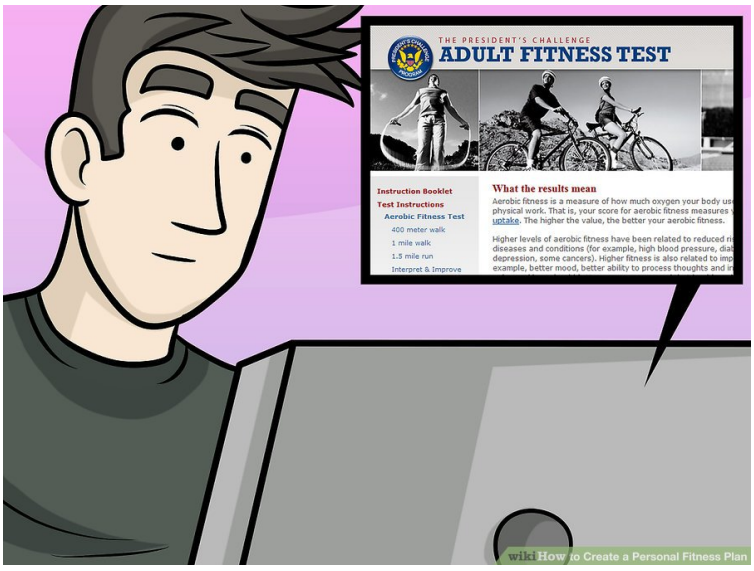


Figure out your goals. What to make of these test results? Well, they should give a rough guide to health based on averages for your age and sex, and also what your fitness plan should focus on. Plug in your results on the President's Challenge Adult Fitness Test website to see where you stand. The website will show you your results and your score in terms of your percentile score, which represents the average achievement of people in your age group performing the test.

- The mile walk measures your cardio fitness. Healthy adults should reach at least the 25 percentile. If you score below this, you may want a fitness plan with an emphasis on aerobic exercise.
- Scoring in the bottom quarter for push-ups means that you probably do not have developed upper body muscle strength — consider adding resistance training to your plan.
- The reach-and-stretch exercise measures how much flexibility your joints and muscles have. A poor result means that you should consider doing stretching exercises like yoga or pilates as part of your program. Ladies usually have a bit more flexibility than men. A woman aged 32 who stretches 12 inches scores in the 5th percentile, where a similar score for a man is in the 25th percentile.
- Finally, a BMI of 25 or more may mean that you are overweight and at higher risk for things like heart disease, high blood pressure, or diabetes. General weight loss might be a goal for your program.



Plan it out. Give yourself added encouragement by planning your program in detail. You can either do this on your own or with outside help. A structured plan will allow you to set goals and stay on track.

- Try writing out your plan on paper, for example. Ask specific questions: What are my goals? What do I want to get out of this fitness program? How will I do it? Is it achievable?
- Be specific in your answers. For instance, do you want to be able to run for 30 minutes four times per week? Or do you want to lose 5 pounds in a month? Just saying "I want to get fit" doesn't give you a concrete, measurable goal to work toward. The more specific you can be, the easier it will be for you to know when you've met your goals.
- Post your plan where you'll see it every day, like in your office or on the bathroom mirror.
- If you want, you can also get a personal trainer. Personal trainers are fitness experts who will make sure you are using proper form while exercising, doing exercises that are appropriate for your fitness level, help you set goals and motivate you to reach them.

Part 2: Creating a Cardio Plan

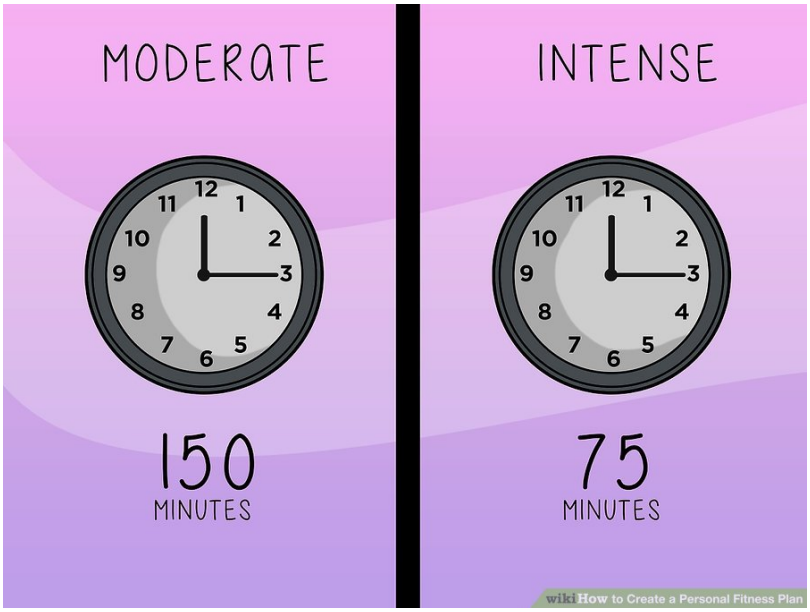
Pick exercises you can do and enjoy. Cardio is the bread and butter of fitness plans. When you do cardio, you work big muscle groups in your body, your heart rate rises, and you breathe faster and more deeply.



Cardio exercise will strengthen your heart, increase your endurance, and burn calories. It will also boost your mood and help you sleep better.

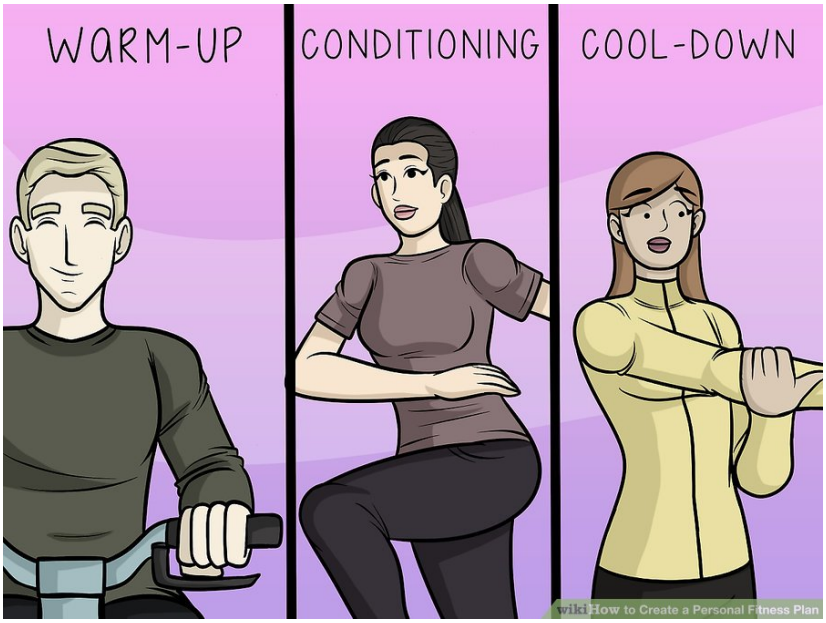
- Cardio is also known as aerobic exercise. The idea is to elevate your heart rate and breathing rate.

- Walking, running, rowing, swimming, bicycling, and dancing are all cardio exercises. So are most team sports, martial arts, and even golfing.
- Choose exercises that you like, but also make sure you are physically able to do them. Running is hard on the knees and feet, for instance, so you if you have bad knees you might need a lower impact exercise like brisk walking, cycling or swimming.
- Also keep in mind that you'll be working out often, so you may want to have several exercises and alternate. For instance, you might ride your bike, swim, and play golf on different days one week. Or, you might play soccer, run, and in-line skate.



Start slowly. Ease your way into the routine until you have more endurance. The US government recommends at least 150 minutes of moderate aerobic activity or 75 minutes of intense activity per week. You don't need to do all of this in two, three, or four sessions, however. Instead, spread it out through the week.

- Aerobic exercise should pass the "talk test," meaning you should be able to talk and carry on a conversation while exercising. If not, your heart rate is too high.
- Ideally, you should do at least 30 minutes of activity per day. If you can't manage that, try breaking up your exercise into smaller chunks. For example, go for a 10 minute walk several times per week in the beginning. As your body gets used to this, lengthen the walk to 15 minutes, then to 20, and then to 30.
- Don't feel the need to do high-intensity exercise at the beginning. Go at your own pace. Otherwise, you might get injured.



Use a three-pronged approach. Cardio isn't all-out exertion all the time. To get the most out of each session, incorporate three elements into your routine: warm-up, conditioning, and cool-down. Ease into the workout, ride your plateau, and then slow down.

- Before each session, warm up for about five to 10 minutes to get your heart going and to increase blood flow to your muscles.
- A low-intensity version of your exercise should do this. If you are riding a bike, for example, take a leisurely ride for a few blocks. If you're swimming, do two or three laps at half pace.
- Aim for around 30 minutes of conditioning after your warm-up. Conditioning is about reaching a "sweet spot" — a level that you can maintain but where your breathing and heart rate are higher than normal.
- End with another five to 10 minutes of cool-down. Slow yourself to a stop and let your heart rate come down. You can also stretch your main muscle groups, like your hamstrings, calf muscles, chest, shoulders, quadriceps, and back.



Work up to ideal length and frequency. Take stock of your progress after a few weeks and make adjustments. Chances are that you will be able to work out longer and harder, gaining aerobic capacity and endurance. Try to work up to doctor recommended guidelines: again, at least 150 minutes of moderate aerobic activity or at 75 minutes of vigorous activity per week. Ideally, you should aim for at least 30 minutes of cardio activity every day.

- Adding five minutes to your workout per week is a modest and doable goal. This means that at the end of a month, you'll be exercising 20 minutes more.

- If your goal is weight loss, you may have to push yourself harder or adopt harder exercises. Rather than working out for 30 minutes three or four times per week, go for 45 minutes five or six times per week.
- Some cardio exercises are better than others if your goal is weight loss. Aerobic dance (like Zumba) and cross-country skiing burn about 700 and 600 calories per hour, for example, compared to brisk walking (150) or golfing (350).
- That said, listen to your body. Take a break and let your body recover if you feel run down. **Stop** exercising and talk to a doctor if you feel pain, dizziness, or shortness of breath.

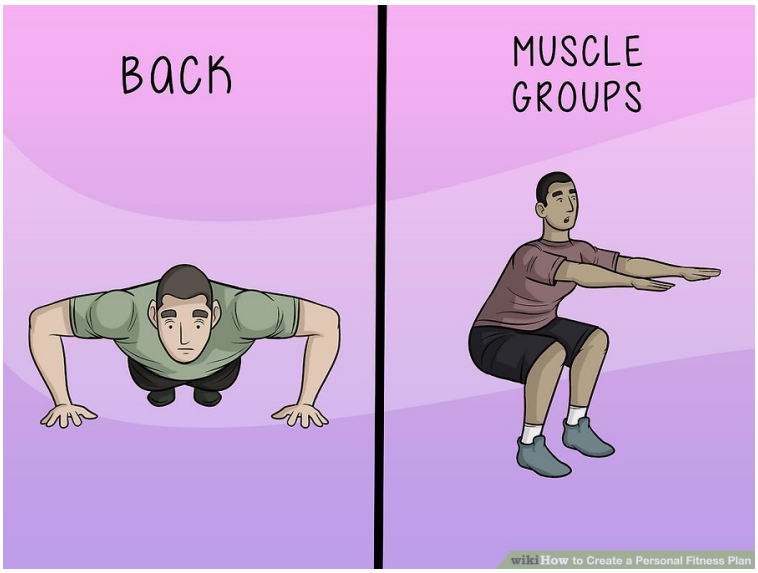
Part 3: Training for Strength

Learn good form. Strength training, also called weight or resistance training, is a different kind of exercise. Strength training builds up muscles and endurance. It will make you stronger, strengthen your bones, raise your stamina, and give you other mental and mood boosts.



The key to a good strength program is to work big muscle groups like the legs, arms, and core.

- In strength training, you use weights to create resistance and make your muscles work harder. You can do this with weight machines, free weights, exercise bands, or even just your own body weight.
- The resistance puts stress on your muscles and joints, so it’s important to learn and always use proper form. Otherwise, you are at risk for sprains, strains, breaks, or overuse injuries. In general, you’ll want to maintain good posture to protect your spine.
- Start with a weight that you can lift comfortably 12–15 times (whether that's on a machine or free weights) and move the joint through its full range of motion. Breathe out when you lift the weight and in when you lower it.
- Talk to people at your gym. A sports trainer or fitness specialist will be able to walk you through each exercise to be sure you’re doing it right.



Pick exercises for major muscle groups. A good strength program will work for all the major muscle groups. Choose exercises that isolate these or work for several groups together. Tailor your program to your own needs, but also to your physical limits. Take into account your strength, balance, and age.

- For example, good exercises for your upper body include push-ups. You can strengthen your arms and shoulders with bent over dumbbell rows and overhead presses. Bench presses will work your chest muscles.
- Exercises that use several muscle groups at once are really useful. For instance, squats will exercise your quadriceps and gluteal muscles at the same time. Lunges are another good example of this kind of exercise.

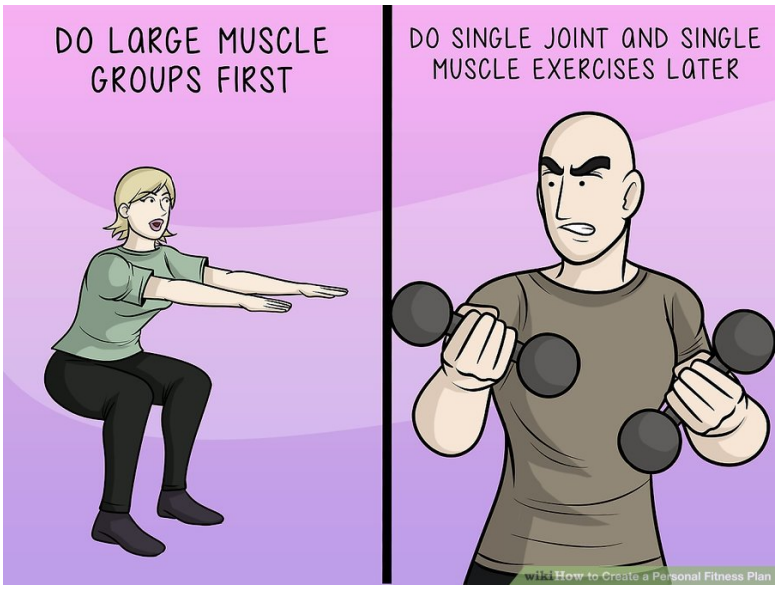
Split the program into rotations, sets, and reps. Your training program should be a cycle. Plan to focus on certain muscle groups on different days, and each day doing a number of specific exercises. You don't need to do a whole body workout every time.

- Your rotation might look something like this: bench-presses, rear flyes, pushups, and planks one day for your back, bicep and tricep curls another day to work your arms, and squats, lunges, bridges, calf raises, balance exercises, and leg curls for your legs the third day.
- During each rotation day, split up the exercises into sets and reps. A "rep" is one full motion of the exercise. A "set" is a series of consecutive reps.
- How many reps and sets should you do? Answers vary. The Mayo Clinic recommends one set of 12 reps for each exercise. Another rule of thumb is that light weight with many reps builds endurance and muscle tone, while heavy weight and fewer reps — but lots of sets (five or more) — builds strength.
- How long should you exercise? The answer is not that long. Most people will see results after about eight weeks with two or three 20 to 30-minute sessions per week, covering all groups. Prevent plateaus by changing up your routine every eight weeks or so.
- Remember to give your body time to rest and heal: always schedule at least 48–72 hours between sessions for each muscle group.



Use the three-pronged approach. Like cardio, use a three-stage approach in your resistance training: aerobic warm-up, post-lift stretching, and cool-down. These will help to get the blood flowing, the joints limber, and to stretch and relax the muscles after you are finished.

- Do a few minutes of low-intensity cardio before you hit the weights, like walking or jogging. “Warm” muscles are less prone to injury than “cold” ones.
- Do not stretch before resistance training.
- After your workout, take some time to cool down and stretch (one or two minutes for each muscle group).

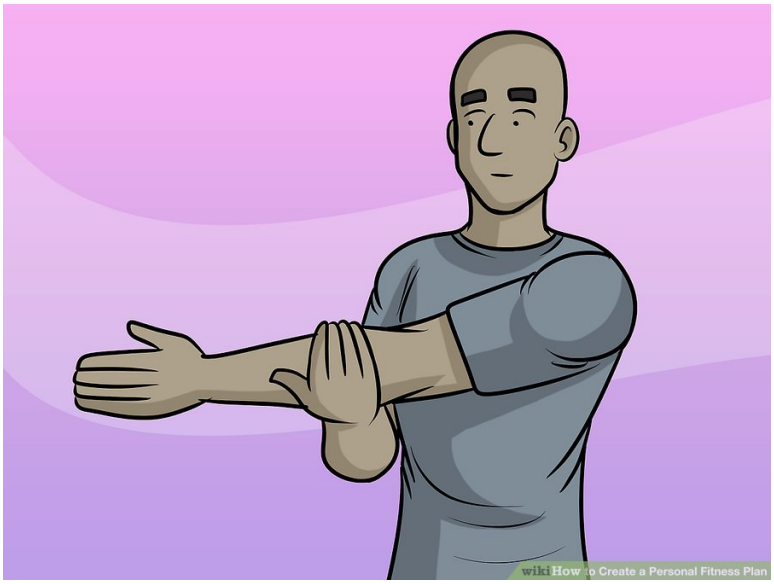


Do large muscle groups first. Experts recommend that your order of exercise should start with large or multiple muscle groups. That way, you’ll be able to do these harder exercises will more energy. You can isolate smaller or individual muscles afterward.

- Prioritize exercises that use several muscle groups at once. Also, do exercises that use multiple joints before those that use one joint.
- You might work out your legs and back first, for instance. Squats, for example, use your legs but also your gluteal and core muscles, and should be done early in the workout.
- Do single joint and single muscle exercises later. Bicep curls or shoulder shrugs can come later in the workout session.

Part 4: Adding Stretching and Flexibility Exercises

Focus on major muscles and joints. Flexibility sometimes gets a back seat in exercise programs. Still, you should be sure to add basic stretches to your program.



Stretching makes you limber, increases the range of motion in joints, increases blood flow to muscles, and can prevent injury. It can also help prevent postural problems and joint misalignment problems.

- Stretch major joints and muscle groups that you use every day, either during your workout or daily activities. The legs, arms, back, chest, shoulders, and hips are some common ones.



Warm-up beforehand. Don’t stretch cold muscles. You can injure yourself. Instead, do a few minutes of warm-up cardio to get the blood flowing before you start stretching.

- For example, walk, bike, or jog at a low intensity for five to 10 minutes beforehand. You can also stretch after your workout when you’re already warmed up.
- You might want to hold off on stretching before strength training or intense activity like running or other track and field sports. Some research shows that pre-event stretching can actually reduce your performance.



Hold the stretch. When you stretch, gently pull the muscle and joint in a smooth movement and hold it for about 30 seconds. You might need to hold for 60 seconds in problem areas, i.e. areas that are inflexible or tight.

- Try some yoga poses, too. In the simple balasana pose (or child's pose), kneel on the floor with your knees slightly apart. Then, lean your hips forward, touch your forehead to the ground, and hold your abdomen to the thighs for 20 to 30 seconds. Reach your arms out in front of you. This pose will gently stretch your lower back and upper body. Older adults should be cautious about this stretch, as it can be harmful to the spine.
- Don’t hold your breath when you stretch, but instead breathe into the movement. Also, don’t bounce. You should not be bouncing to reach farther. This “ballistic” stretching can tighten the muscle or, worse, cause injury.
- Be aware of your spine and don’t stretch it too far in an abnormal direction. The same goes for other joints – keep them soft and do not lock them in position.
- You should not feel pain when you stretch. Some tension or discomfort is normal, but if it hurts you’ve stretched too far.

Contributors and Attributions

- Wikihow: http://www.wikihow.com/Create-a-Personal-Fitness-Plan

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CHAPTER OVERVIEW

16: Additional Reading

This chapter contains additional topics you may find interesting. The topics are not required for this class.

16.1: Food Politics and Perspectives
16.2: The Politics of Food
16.3: The Food Industry
16.4: Food Cost and Inflation
16.5: Sustainability
16.6: A Fresh Perspective- Sustainable Food Systems
16.7: Start Your Sustainable Future Today
16.8: The Issue of Food Security
16.9: Diets around the World
16.10: Why Make Dietary Changes?
16.11: Nutrition and Your Health
16.12: Diet Trends and Health
16.13: Threats to Health
16.14: Careers in Nutrition

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16.1: Food Politics and Perspectives

In this chapter, food politics, sustainability, the food industry, food security, and diets from around the world are explored.

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16.2: The Politics of Food

Learning Objectives

- Discuss how food has become politicized, and give specific examples of how food choices are related to food politics

Some people have begun to view their choices regarding diet and nutrition in light of their political views. More and more, consumers weigh their thoughts on the environment and the world, while making decisions about what to purchase in the grocery store. For example, many people choose to eat free-range chickens due to concerns about animal welfare. Others worry about the higher cost of organically produced food or find that those products are not available in their communities. As a result, feelings about food have become a political mine field.

Food Politics

The production and sale of food is an extremely big business and touches people in all industries and walks of life. Food is not only crucial for day-to-day survival, but also strongly affects overall health and well-being, as well as the economy and culture of a region or a country. So, it is no wonder that more and more producers and consumers alike are speaking out about food to ensure that their interests are protected. Food politics can influence many stakeholders and interests, but always involve the production, regulation, inspection, distribution, and/or retail of food.

Stakeholders

Stakeholders in food politics include large and small farmers, along with large and small food companies. Other important stakeholders include restaurants and other food-service providers, food distributors, grocery stores and other retail outlets, consumers, and trade associations. Antihunger advocates, nutrition advocates, and food-industry lobbyists also have important roles to play. Nongovernmental organizations, such as the American Cancer Society and the WHO, also work to promote good health and nutrition. Each group has its own perspective and its own agenda in disputes related to food.

Disputes

Food politics can be influenced by ethical, cultural, medical, and environmental disputes over agricultural methods and regulatory policies. They are also greatly influenced by manufacturing processes, marketing practices, and the pursuit of the highest possible profit margin by food manufacturers and distributers. Common disputes and controversies include the genetic modification of plants, the potential dangers of food additives, chemical run-off from large-scale farms, and the reliance on factory-farming practices, such as the use of pesticides in crop cultivation and antibiotics in livestock feed. Additional issues and concerns include the use of sugar, salt, and other potentially unhealthy ingredients, the promotion of fast food and junk food to children, and sanitary standards related to livestock.

The Nitrate Dispute

One current dispute relates to the use of nitrates in agriculture. At the dawn of the twentieth century, German chemists Fritz Haber and Carl Bosch invented a system that synthesizes ammonia to produce nitrates on an industrial scale. The compound could then be used to make fertilizers, which along with pesticides and herbicides, made large-scale, modern agriculture possible. However, when nitrates are used in excess, they can create runoff that pollutes surface- and groundwater. For example, chemical runoff has had a profound effect on the Aral Sea and the surrounding area in Kazakhstan and Uzbekistan. The Aral Sea, which was once one of the four largest lakes in the world, was crucial to irrigation projects in the former Soviet Union. But when the lake became contaminated by farm runoff, salinity increased and the lake dramatically shrank, crippling the area's fishing industry. Also, as the lakebed became exposed, dust storms spread contaminated soil, and thousands of people were forced out of the region.Grant, L. "Nitrates: Dangerous Necessity." Environmentalism @ Suite 101.com. May 7, 2011. larry-grant.suite101.com/nitrates-dangerous-necessity-a369949. Contaminated runoff from the use of nitrates not only leads to serious consequences for the environment, but also to human health. Nitrate poisoning reduces the oxygen-carrying capacity of the blood and can be fatal to infants.US Environmental Protection Agency. "Ag 101: Nitrate." Last updated September 10, 2009. http://www.epa.gov/agriculture/ag101/impactnitrate.html. Therefore, significant efforts are being made to use nitrates and other agricultural chemicals in more environmentally friendly ways and to monitor drinking water for dangerous levels of contamination.

The Role of Government

Federal and state policy plays a major role in the politics of food production and distribution. As previously discussed, government agencies regulate the proper processing and preparation of foods, as well as overseeing shipping and storage. They pay particular attention to concerns related to public health. As a result, the enforcement of regulations has been strongly influenced by public concern over food-related events, such as outbreaks of food-bourne illnesses.

Food Production, Distribution, and Safety

Many consumers have concerns about safety practices during the production and distribution of food. This is especially critical given recent outbreaks of food-borne illnesses. For example, during fall 2011 in the United States, there was an eruption of the bacteria *Listeria monocytogenes* in cantaloupe. It was one of the deadliest outbreaks in over a decade and resulted in a number of deaths and hospitalizations.Centers for Disease Control and Prevention. "Multistate Outbreak of Listeriosis Associated with Jensen Farms Cantaloupe—United States." August–September, 2011. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6039a5.htm?s_cid= mm6039a5_w.



Figure 16.1.1: Whole chickens are suspended in a public market. (CC-BY-SA; 3.0; Tomás Castelazo)

In January 2011, the Food Safety Modernization Act was passed to grant more authority to the FDA to improve food safety. The FDA and other agencies also address consumer-related concerns about protecting the nation's food supply in the event of a terrorist attack.

Addressing Hunger

Government agencies also play an important role in addressing hunger via federal food-assistance programs. The agencies provide debit cards (formerly distributed in the form of food vouchers or food stamps) to consumers to help them purchase food and they also provide other forms of aid to low-income adults and families who face hunger and nutritional deficits. This topic will be discussed in greater detail later in this chapter.

The Dual Role of the USDA

The USDA has a dual role in the advancement of American agribusiness and the promotion of health and nutrition among the public. This can create conflicts of interest, and some question whether the USDA values the interests of the agriculture and food industries over consumer health.

However, there is no question that the USDA makes a great deal of effort to educate the public about diet and nutrition. Working with the US Department of Health and Human Services, the agency codeveloped the *Dietary Guidelines for Americans* to inform consumers about the ways their dietary habits affect their health. The USDA also implements all federal nutrition programs.

The Farm Bill

The Farm Bill (introduced in 1990) is a massive piece of legislation that determines the farm and food policy of the federal government. It addresses policy related to federal food programs and other responsibilities of the USDA. The Farm Bill also covers a wide range of agricultural programs and provisions, including farm subsidies and rural development. And, it influences international trade, commodity prices, environmental preservation, and food safety.

The massive Farm Bill is updated and renewed every five years. Over the decades, it has expanded to incorporate new issues, such as conservation and bioenergy. The Farm Bill passed in 2008, known as the Food, Conservation, and Energy Act, included new policy on horticulture and livestock provisions. The 2008 bill also differed from previous legislation in terms of the large number

and scope of proposals that were raised.Johnson, R. and J. Monke, “What Is the ‘Farm Bill’?” Congressional Research Service. *CRS Report for Congress*, no. RS22131 (January 3, 2011). www.nationalaglawcenter.org/assets/crs/RS22131.pdf.

Tools for Change

Start paying attention to the news when you hear about the next upcoming Farm Bill to learn about proposals that could affect the food that arrives in your local supermarket or that is served in your favorite restaurant. To learn more about the upcoming legislation, visit http://www.usda.gov/farmbill. You may also wish to “vote with your fork” and make choices about what you eat based on practices you approve of, such as choosing a vegetarian, vegan, organic, locavore, sustainable, slow-food movement or other type of diet.

Agricultural Subsidies

The Farm Bill can directly and indirectly have wide-ranging effects. For example, the bill dictates subsidies and other forms of agricultural funding or support. Farmers rely on this kind of support to offset varying crop yields and unfavorable weather conditions. The agricultural industry also depends on the federal government to provide some form of price control to guard against flooding the market and dragging down prices. As an example, major changes in the policy of agricultural subsidies were implemented in the 1970s to increase farm incomes and produce cheaper food. As a result of these policies and subsidies, much more corn was grown, giving rise to high fructose corn syrup as a primary sweetener in a number of products today, since corn syrup is cheaper to produce. It is also sweeter than cane sugar, which encouraged its widespread use.

Historically, Congress has pursued farm support programs to ensure that the US population has continued access to abundant and affordable food. However, some leaders worry about the effectiveness of government programs as well as the cost to taxpayers and consumers. Others question if continued farm support is even needed and wonder if it remains compatible with current economic objectives, domestic policy, trade policy, and regulatory restrictions.Johnson, R. and J. Monke, “What Is the ‘Farm Bill’?” Congressional Research Service. *CRS Report for Congress*, no. RS22131 (January 3, 2011). www.nationalaglawcenter.org/assets/crs/RS22131.pdf. For example, federal dairy policies can raise the price of milk and other dairy products, which can detrimentally affect school lunch and food stamp programs. Regarding all of these issues, Congress must heed the demands of its constituents. In the end, it is inevitable that consumers’ growing interest in food issues will affect not only the choices they make in the grocery store, but also the decisions they make in the voting booth.

Key Takeaways

Food politics reflect changing perspectives and policies in the areas of production, distribution, marketing, regulation, and consumption. Over the years, there have been a number of controversies and disputes over food, including concerns about additives and GM foods, the push for sustainable agriculture, and the need to alleviate hunger. In the United States, a massive piece of legislation known as the Farm Bill determines the agricultural and food policy of the federal government.

Discussion Starter

1. Debate a controversial issue related to food politics, such as sustainable agriculture, farm subsidies, or the Farm Bill. Identify the stakeholders involved with the issue and discuss the pros and cons of the differing sides.

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16.3: The Food Industry

Learning Objectives

- Explain what is meant by the term “the food industry” and identify the food technologies and innovations that have shaped the current food system

Agriculture is one of the world’s largest industries. It encompasses trillions of dollars and employs billions of people. In the United States alone, customers spent about $500 billion annually on food products at grocery stores and supermarkets.Plunkett Research, Ltd. “US Food Industry Overview.” Accessed December 5, 2011, http://www.plunkettresearch.com/food%20beverage%20grocery%20market %20research/industry%20statistics. The food industry includes a complex collective of businesses that touches on everything from crop cultivation to manufacturing and processing, from marketing and advertising to distribution and shipment, to food regulation.

The Food System

The food system is a network of farmers and related operations, including food processing, wholesale and distribution, retail, industry technology, and marketing. The milk industry, for example, includes everything from the farm that raises livestock, to the milking facility that extracts the product, to the processing company that pasteurizes milk and packages it into cartons, to the shipping company that delivers the product to stores, to the markets and groceries that stock and sell the product, to the advertising agency that touts the product to consumers. All of these components play a part in a very large system.



Figure 16.2.1: These cows are lined up at a Rotary milking parlor. (CC BY-SA 3.0; Gunnar Richter Namenlos.net).

Food Preservation and Processing

Two important aspects of a food system are preservation and processing. Each provides for or protects consumers in different ways. Food preservation includes the handling or treating of food to prevent or slow down spoilage. Food processing involves transforming raw ingredients into packaged food, from fresh-baked goods to frozen dinners. Although there are numerous benefits to both, preservation and processing also pose some concerns, in terms of both nutrition and sustainability.

Food Preservation

Food preservation protects consumers from harmful or toxic food. There are different ways to preserve food. Some are ancient methods that have been practiced for generations, such as curing, smoking, pickling, salting, fermenting, canning, and preserving fruit in the form of jam. Others include the use of modern techinques and technology, including drying, vacuum packing, pasteurization, and freezing and refrigeration. Preservation guards against food-bourne illnesses, and also protects the flavor, color, moisture content, or nutritive value of food.

Irradiation

Another method of preservation is irradiation, which reduces potential pathogens to enhance food safety. This process involves treating food with ionizing radiation, which kills the bacteria and parasites that cause toxicity and disease. Similar technology is used to sterilize surgical instruments to avoid infection.Centers for Disease Control and Prevention. “Food Irradiation.” Accessed October 11, 2005. www.cdc.gov/ncidod/dbmd/diseaseinfo/foodirradiation.htm. Foods currently approved for irradiation by the FDA include flour, fruits and vegetables, juices, herbs, spices, eggs, and meat and poultry.

Most forms of preservation can affect the quality of food. For example, freezing slightly affects the nutritional content, curing and smoking can introduce carcinogens, and salting greatly increases the sodium. There are also concerns about the effects of using irradiation to preserve food. Studies have shown that this process can change the flavor, texture, color, odor, and nutritional content of food. For example, the yolks of irradiated eggs have less color than nonirradiated eggs.nonirradiated eggs.

Food Processing

Food processing includes the methods and techniques used to transform raw ingredients into packaged food. Workers in this industry use harvested crops or slaughtered and butchered livestock to create products that are marketed to the public. There are different ways in which food can be processed, from a one-off product, such as a wedding cake, to a mass-produced product, such as a line of cupcakes packaged and sold in stores.

The Pros and Cons of Food Processing

Food processing has a number of important benefits, such as creating products that have a much longer shelf life than raw foods. Also, food processing protects the health of the consumer and allows for easier shipment and the marketing of foods by corporations. However, there are certain drawbacks. Food processing can reduce the nutritional content of raw ingredients. For example, canning involves the use of heat, which destroys the vitamin C in canned fruit. Also, certain food additives that are included during processing, such as high fructose corn syrup, can affect the health of a consumer. However, the level of added sugar can make a major difference. Small amounts of added sugar and other sweeteners, about 6 to 9 teaspoons a day or less, are not considered harmful.American Heart Association. “Sugar and Carbohydrates.” Last updated October 12, 2010. http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Sugars-and-Carbohydrates_UCM_303296_Article.jsp#.



Figure 16.2.2: *Industrial cheese production. 10,000 l milk in the left tank, the milk was mixed with rennet and is now broken for the production of Emmentaler.. (CC BY-SA 3.0; MatthiasKabel).*

Food Regulation and Control

Food regulatory agencies work to protect the consumer and ensure the safety of our food. Food and drug regulation in the United States began in the late nineteenth century when state and local governments began to enact regulatory policies. In 1906, Congress passed the Pure Food and Drugs Act, which led to the creation of the US Food and Drug Administration (FDA). Today, a number

of agencies are in charge of monitoring how food is produced, processed, and packaged.EH.Net Encyclopedia. “History of Food and Drug Regulation in the United States.” February 4, 2010. eh.net/encyclopedia/article/Law.Food.and.Drug.Regulation.

Regulatory Agencies

Food regulation is divided among different agencies, primarily the FDA and the US Department of Agriculture (USDA). Regulatory agencies in Canada include the Canadian Food Inspection Agency and Health Canada. The North American public depends on these and other agencies to ensure that the food they purchase and consume from supermarkets, restaurants, and other sources is safe and healthy to eat. It can be confusing to know which agency monitors and manages which regulatory practice. For example, the FDA oversees the safety of eggs when they’re in the shells, while the USDA is in charge of the eggs once they are out of their shells.

The Food and Drug Administration

The FDA enforces the safety of domestic and imported foods. It also monitors supplements, food labels, claims that corporations make about the benefits of products, and pharmaceutical drugs. Sometimes, the FDA must recall contaminated foods and remove them from the market to protect public health. For example, in 2011 contaminated peanut butter led to the recall of thousands of jars of a few popular brands.US Food and Drug Administration. “FDA 101: Product Recalls—From First Alert to Effectiveness Checks.” Last updated September 9, 2011. http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm049070.htm. Recalls are almost always voluntary and often are requested by companies after a problem has been discovered. In rare cases, the FDA will request a recall. But no matter what triggers the removal of a product, the FDA’s role is to oversee the strategy and assess the adequacy and effectiveness of the recall. You will read more about this practice in Chapter 15.

Video 16.2.1: FDA 101: Product Recalls

This video explains how the FDA recalls contaminated products to protect consumers. (click to see video)

The US Department of Agriculture

Headed by the Secretary of Agriculture, the USDA develops and executes federal policy on farming and food. This agency supports farmers and ranchers, protects natural resources, promotes trade, and seeks to end hunger in the United States and abroad. The USDA also assures food safety, and in particular oversees the regulation of meat, poultry, and processed egg products.

The Environmental Protection Agency

A third federal government agency, the Environmental Protection Agency (EPA), also plays a role in the regulation of food. The EPA works to protect human health and the environment. Founded in 1970, the agency conducts an environmental assessment, education, research, and regulation. The EPA also works to prevent pollution and protect natural resources. Two of its many regulatory practices in the area of agriculture include overseeing water quality and the use of pesticides.

Food Safety and Hazard Analysis

Government regulatory agencies utilize HACCP programs to ensure food safety. HACCP, or hazard analysis and critical control points, is a system used to identify potential hazards and prevent foodbourne illnesses. Some of the seven aspects of an HACCP program include identifying the points in a manufacturing process during which potential hazards could be introduced, establishing corrective actions, and maintaining record-keeping procedures. The USDA uses HACCP to regulate meat, while the FDA uses the seven-point system to monitor seafood and juice. In these industries, HACCP systems are used in all stages of production, processing, packaging, and distribution.US Food and Drug Administration. “Hazard Analysis & Critical Control Points (HACCP).” Last updated April 27, 2011. www.fda.gov/food/foodsafety/hazardanalysiscriticalcontrolpointshaccp/default.htm. Currently, the use of HACCP is voluntary for all other food products.

Food Additives

If you examine the label for a processed food product, it is not unusual to see a long list of added materials. These natural or synthetic substances are food additives and there are more than three hundred used during food processing today. The most popular additives are benzoates, nitrites, sulfites, and sorbates, which prevent molds and yeast from growing on food.How Stuff Works. “The Dangers of Food Additives.” Accessed October 5, 2011. http://health.howstuffworks.com/wellness/food-nutrition/facts/dangers-of-food -additives.htm.

Food additives are introduced in the processing stage for a variety of reasons. Some control acidity and alkalinity, while others enhance the color or flavor of food. Some additives stabilize food and keep it from breaking down, while others add body or texture. Table 14.1 lists some common food additives and their uses:

Table 16.2.1: Food Additives

Additive	Reason for Adding
Beta-carotene	Adds artificial coloring to food
Caffeine	Acts as a stimulant
Citric acid	Increases tartness to prevent food from becoming rancid
Dextrin	Thickens gravies, sauces, and baking mixes
Gelatin	Stabilizes, thickens, or texturizes food
Modified food starch	Keeps ingredients from separating and prevents lumps
MSG	Enhances flavor in a variety of foods
Pectin	Gives candies and jams a gel-like texture
Polysorbates	Blends oil and water and keep them from separating
Soy lecithin	Emulsifies and stabilizes chocolate, margarine, and other items
Sulfites	Prevent discoloration in dried fruits
Xanthan gum	Thickens, emulsifies, and stabilizes dairy products and dressings

Source: Center for Science in the Public Interest. “Chemical Cuisine: Learn about Food Additives.” ©2012. Center for Science in the Public Interest. http://www.cspinet.org/reports/chemcuisine.htm.

The Pros and Cons of Food Additives

The FDA works to protect the public from potentially dangerous additives. Passed in 1958, the Food Additives Amendment states that a manufacturer is responsible for demonstrating the safety of an additive before it can be approved. The Delaney Clause that was added to this legislation prohibits the approval of any additive found to cause cancer in animals or humans. However, most additives are considered to be “generally recognized as safe,” a status that is determined by the FDA and referred to as GRAS.

Food additives are typically included in the processing stage to improve the quality and consistency of a product. Many additives also make items more “shelf stable,” meaning they will last a lot longer on store shelves and can generate more profit for store owners. Additives can also help to prevent spoilage that results from changes in temperature, damage during distribution, and other adverse conditions. In addition, food additives can protect consumers from exposure to rancid products and food-bourne illnesses.

Food additives aren’t always beneficial, however. Some substances have been associated with certain diseases if consumed in large amounts. For example, the FDA estimates that sulfites can cause allergic reactions in 1 percent of the general population and in 5 percent of asthmatics. Similarly, the additive monosodium glutamate, which is commonly known as MSG, may cause headaches, nausea, weakness, difficulty breathing, rapid heartbeat, and chest pain in some individuals.Sustainable Table. “The Issues: Additives.” Accessed October 10, 2011. www.sustainabletable.org/issues/additives/#fn14.

The Effect of New Technologies

As mentioned earlier, new technology has had a tremendous effect on the food we eat and the customs and culture related to food consumption. For example, microwaves are used to reduce cooking time or to heat up leftover food. Refrigerators and freezers allow produce to travel great distances and last longer. On the extreme end of making food last longer, there is special food for astronauts that is appropriate for consumption in space. It is safe to store, easy to prepare in the low-gravity environment of a spacecraft, and contains balanced nutrition to promote the health of people working in space. In the military, soldiers consume Meals Ready-to-Eat (MREs), which contain an entire meal in a single pouch.

Genetically Modified Foods

Genetically modified foods (also known as GM or GMO foods), are plants or animals that have undergone some form of genetic engineering. In the United States, much of the soybean, corn, and canola crop is genetically modified. The process involves the alteration of an organism's DNA, which allows farmers to cultivate plants with desirable characteristics.Genomics.Energy.gov. "What Are Genetically Modified Foods?" Last modified November 5, 2008. http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml. For example, scientists could extract a gene that produces a chemical with antifreeze properties from a fish that lives in an arctic region (such as a flounder). They could then splice that gene into a completely different species, such as a tomato, to make it resistant to frost, which would enable farms to grow that crop year-round.Whitman, D. B. "Genetically Modified Foods: Harmful or Helpful?" *ProQuest Discovery Guides* (April 2000). www.csa.com/discoveryguides/gmfood/overview.php.

Certain modifications can be beneficial in resisting pests or pesticides, improving the ripening process, increasing the nutritional content of food, or providing resistance to common viruses. Although genetic engineering has improved productivity for farmers, it has also stirred up debate about consumer safety and environmental protection. Possible side effects related to the consumption of GM foods include an increase in allergenicity, or tendencies to provoke allergic reactions. There is also some concern related to the possible transfer of the genes used to create genetically engineered foods from plants to people. This could influence human health if antibiotic-resistant genes are transferred to the consumer. Therefore, the World Health Organization (WHO) and other groups have encouraged the use of genetic engineering without antibiotic-resistance genes. Genetically modified plants may adversely affect the environment as well and could lead to the contamination of nongenetically engineered organisms.World Health Organization. "Food Safety: 20 Questions on Genetically Modified Foods." © 2011. http://www.who.int/foodsafety/publications/biotech/20questions/en/.

Genetically modified foods fall under the purview of the EPA, the USDA, and the FDA. Each agency has different responsibilities and concerns in the regulation of GM crops. The EPA ensures that pesticides used for GM plants are safe for the environment. The USDA makes sure genetically engineered seeds are safe for cultivation prior to planting. The FDA determines if foods made from GM plants are safe to eat. Although these agencies act independently, they work closely together and many products are reviewed by all three.Whitman, D. B. "Genetically Modified Foods: Harmful or Helpful?" *ProQuest Discovery Guides* (April 2000).

Video 16.2.2: Too Much Controversy Over Genetically Modified Foods?

(click to see video)

Food Enrichment and Fortification

Many foods are enriched or fortified to boost their nutritional value. Enrichment involves adding nutrients to restore those that were lost during processing. For example, iron and certain B vitamins are added to white flour to replace the nutrients that are removed in the process of milling wheat. Fortification is slightly different than enrichment and involves adding new nutrients to enhance a food's nutritive value. For example, folic acid is typically added to cereals and grain products, while calcium is added to some orange juice.

The Health of the Population

Certain enrichment and fortification processes have been instrumental in protecting public health. For example, adding iodine to salt has virtually eliminated iodine deficiencies, which protects against thyroid problems. Adding folic acid to wheat helps increase intake for pregnant women, which decreases the risk of neural tube defects in their children. Also, vegans or other people who do not consume many dairy products are able to drink orange juice or soy milk that has been fortified with calcium to meet the daily recommendations. However, there is some concern that foods of little nutritive value will be fortified in an effort to improve their allure, such as soft drinks with added vitamins.

Key Takeaways

The food industry encompasses all aspects of food production: manufacturing, distribution, marketing, retail, regulation, and consumption. Food preservation and processing have a number of benefits including improving the quality of food products, making them more shelf-stable, and aiding the marketing and advertising of food. There are more than three hundred additives used during food processing today. Food preservation and processing also have some drawbacks, including potentially damaging the nutritive value of food. The cultivation and consumption of genetically modified foods are also highly controversial, with many

people opposed to the genetic modification of crops. There are three key government agencies that regulate food in the United States: the US Department of Agriculture, the US Food and Drug Administration, and the US Environmental Protection Agency.

Discussion Starter

1. Discuss the debate about the use of food additives, such as beta-carotene and citric acid. What are the benefits to using them? What are the drawbacks? Do you believe that food additives are more helpful or more harmful, and why?

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16.4: Food Cost and Inflation

Learning Objectives

- Cite a recent event that has had a profound effect on how consumers feel about the food supply.
- Give a historical overview of the era of cheap food.

Statistics show that Americans spend more than $1.5 trillion on food each year at supermarkets, in restaurants, and from other food providers.Plunkett Research, Ltd. “US Food Industry Overview.” 2011. http://www.plunkettresearch.com/food%20beverage%20grocery%20market %20research/industry%20statistics. According to the USDA, a thrifty family of four spends about $540-$620 per month on groceries.US Department of Agriculture. “Official USDA Food Plans: Cost of Food at Home at Four Levels, US Average, August 2011.” Issued September 2011. www.cnpp.usda.gov/Publications/FoodPlans/2011/CostofFoodAug2011.pdf. A number of factors affect the rising cost of food. They include agricultural production, processing and manufacturing, wholesale distribution, retail distribution, and consumption.

Around the world, commodity prices rose sharply in 2010 as crop production shortfalls led to reduced supplies and a higher volatility in agricultural markets. Other factors that played a role in increasing food prices include a population boom that has drastically increased demand, droughts and other natural disasters that have crippled farmers, and trade policies and practices that are unfair to developing nations.

Rising agricultural commodity prices have led to concerns about food insecurity and hunger. In an agricultural outlook report for 2010–2020, the Secretary-General of the Organisation for Economic Co-operation and Development states, “While higher prices are generally good news for farmers, the effect on the poor in developing countries who spend a high proportion of their income on food can be devastating. That is why we are calling on governments to improve information and transparency of both physical and financial markets, encourage investments that increase productivity in developing countries, remove production and trade distorting policies, and assist the vulnerable to better manage risk and uncertainty.”Organisation for Economic Co-operation and Development. “OECD-FAO Agricultural Outlook 2010–2020.” June 17, 2011. www.oecd.org/document/31/0,3746,en_21571361_44315115_48182047_1_1_1_1,00.html.

Who Bears the Cost?

The cost of our food is influenced by the policies and practices of farms, food and beverage companies, food wholesalers, food retailers, and food service companies. These costs include the energy required to produce and distribute food products from farm field to supermarket to table. Rising prices also reflect the marketing and advertising of food. All of these factors affect all participants in a food system, but some participants are more affected than others. A 2011 report by the Economic Research Service of the USDA shows the division of the consumer food dollar among various aspects of the American food system. A far greater amount of the money you spend to buy a product goes toward the marketing components than toward the actual farmer.US Department of Agriculture, Economic Research Service. “Overview.” Last updated November 19, 2012. http://www.ers.usda.gov/data-products/food-expenditures.aspx.

The Consumer Price Index

The Consumer Price Index (CPI) measures changes in the price level paid for goods and services. This economic indicator is based on the expenditures of the residents of urban areas, including working professionals, the self-employed, the poor, the unemployed, and retired workers, as well as urban wage earners and clerical workers. The CPI has subindices for many different types of products, including food and beverages. It is a closely-watched statistic that is used in a variety of ways, including measuring inflation and regulating prices.

Implications Around the World

Food prices and inflation disproportionately affect people at lower income levels. For the poorest people of the world, increasing prices can raise levels of hunger and starvation. In many developing countries where the cost for staple crops steadily rises, consumers have faced shortages or even the fear of shortages, which can result in hoarding and rioting. This happened in 2007 and 2008 during rice shortages in India and other parts of Asia. Rioters burned hundreds of food ration stores in the Indian region West Bengal. In the West African nation Burkina Faso, food rioters looted stores and burned government buildings as a result of rising prices for food and other necessities.Vivienne Walt, “The World’s Growing Food-Price Crisis,” *Time* Magazine, 27 February 2008.

www.time.com/time/world/article/0,8599,1717572-1,00.html. In some poor countries, protests also have been fueled by concerns over corruption, because officials earned fortunes from oil and minerals, while locals struggled to put food on their tables. Bringing down prices would quell protests, but could take a decade or more to accomplish.

The End of the Era of Cheap Food

Concerns about food shortages and rising prices reflect the end of the era of cheap food. Following World War II, grain prices fell steadily around the world for decades. As farms grew in scale, factory-farm practices, such as the use of synthetic and mined fertilizers and pesticides, increased. Agribusinesses also invested in massive planting and harvesting machines. These practices pushed crop yields up and crop prices down. Food became so inexpensive that we entered what came to be called the "era of cheap food."

However, by 2008, economic experts had declared that the era of cheap food was over. The rapid growth in farm output had slowed to the point that it failed to keep pace with population increases and rising affluence in once-developing nations. Consumption of four staples—wheat, rice, corn, and soybeans—outstripped production and resulted in dramatic stockpile decreases. The consequence of this imbalance has been huge spikes felt moderately in the West and to a much greater degree in the developing world. As a result, hunger has worsened for tens of millions of poor people around the world.Justin Gillis, "A Warming Planet Struggles to Feed Itself," *The New York Times*, 4 June 2011. http://www.nytimes.com/2011/06/05/science/earth/05harvest.html?_r=2&hp.

Two major trends played a part in this shift. First, prosperity in India and China led to increased food consumption in general, but more specifically to increased meat consumption. Increased meat consumption has led to an increased demand for livestock feed, which has contributed to an overall rise in prices. The second trend relates to biofuels, which are made from a wide variety of crops (such as corn and palm nuts), which increasingly are used to make fuel instead of to feed people.

The world population in 2010 was 6.9 billion.United Nations. "World Population Prospects, the 2010 Revision." http://esa.un.org/wpp/Analytical-Figures/htm/fig_1.htm. It is projected to grow to 9.4 billion by 2050.Food and Agricultural Organization of the United Nations. "Executive Summary." http://www.fao.org/docrep/004/y3557e/y3557e03.htm. The rate of increase is particularly high in the developing world, and the increased population, along with poverty and political instability, are helping to foster long-term food insecurity. In the coming decades, farmers will need to greatly increase their output to meet the rising demand, while adapting to any future trends.Christian Science Monitor. "Why the Era of Cheap Food Is Over." December 31, 2007. http://www.csmonitor.com/2007/1231/p13s01-wogi.html.

Key Takeaways

Food prices are rising in the United States and around the world, which has greatly affected both agricultural producers and consumers. A number of factors have contributed to rising costs, including population booms, natural disasters, and the production of biofuels, among others. Economic experts have declared that the era of cheap food, which began after World War II, has ended due to rising population rates and decreased agricultural production worldwide. As a result, hunger has worsened for tens of millions of poor people globally.

Discussion Starter

1. Examine the graphics from http://www.ers.usda.gov/data-products/food-dollar-series/documentation.aspx. What does each image indicate about agriculture and the American economy?

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16.5: Sustainability

Big Ideas

- Sustainability promotes nutrition today and protects natural resources for tomorrow.

As discussed in previous chapters, sustainability is a word that's often talked about in the realm of food and nutrition. The term relates to the goal of achieving a world that meets the needs of its present inhabitants while preserving resources for future generations. As awareness about sustainability has increased among the media and the public, both agricultural producers and consumers have made more of an effort to consider how the choices they make today will impact the planet tomorrow.



Figure 16.4.1: Raising free-range chickens that feed out in the open is one example of a sustainable agricultural practice. Free Range Hens The eggs these hens produce will be pretty tasty. from Adam Ward (via Wikipedia).

However, defining sustainability can be difficult because the term means different things to different groups. For most, sustainable agriculture can best be described as an umbrella term that encompasses food production and consumption practices that do not harm the environment, that do support agricultural communities, and that are healthy for the consumer.Sustainable Table. "Introduction to Sustainability." Accessed October 10, 2011. www.sustainabletable.org/intro/. From factory farms to smaller-scale ranches and granges, sustainable farming practices are being implemented more and more as the long-term viability of the current production system has been called into question.

Yet, the concept of sustainability is not new to agricultural science, practice, or even policy. It has evolved throughout modern history as a way to achieve self-reliance. It is also a vehicle for maintaining rural communities and supporting the concept of conservation and protection of the land.Ecological Agriculture Projects. "A History of Sustainable Agriculture." © 1990 Rod MacRae. http://eap.mcgill.ca/AASA_1.htm. In 1990, the US federal government defined sustainable agriculture in a piece of legislation known as the Farm Bill. The practice was described as an integrated system of plant and animal production that satisfies human needs for food, along with fiber for fabric and other uses. The Farm Bill further defines sustainable agriculture as a practice that enhances environmental quality and also the natural resource base upon which the agricultural economy depends. Sustainable agriculture also makes the most efficient use of nonrenewable resources, sustains the economic viability of farm operations, and supports the quality of life for farmers and society as a whole.Gold, M.V. "Sustainable Agriculture: Definitions and Terms." US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1.

In other words, the practice of sustainable agriculture strives to eschew conventional farming methods, including the cultivation of single crops and row crops continuously over many seasons, the dependency on agribusiness, and the rearing of livestock in concentrated, confined systems.Gold, M.V. "Sustainable Agriculture: Definitions and Terms." US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1. Instead, sustainability includes a focus on biodiversity among both crops and livestock; conservation and preservation to replenish the soil, air, and water; animal welfare; and fair treatment and wages for farm workers.Sustainable Table. "What Is Sustainable Agriculture?" Accessed October 10, 2011. www.sustainabletable.org/intro/whatis/. Sustainable agriculture also encourages the health of consumers by rejecting extensive use of pesticides and fertilizers and promoting the consumption of organic, locally produced food. Although many farmers and food companies work to implement these practices, some use the idea of sustainability to attract consumers without completely committing to the concept. "Greenwashing" is a derisive term (similar to "whitewashing") for a corporation or industry falsely utilizing a proenvironmental image or message to expand its market base.

Sustainability depends not only on agricultural producers, but also on consumers. The average person can do a number of things to consume a more sustainable diet, from eating less meat to purchasing fruits and vegetables grown on nearby farms. For example, produce sold in the Midwest typically travels an average of more than fifteen hundred miles from farm to supermarket. However, increasing the consumption of more locally-grown produce by 10 percent would save thousands of gallons in fossil fuel each year.Heller, M. C., G. A. Keoleian. "US Food System Factsheet." Center for Sustainable Systems, University of Michigan. *CSS Factsheets*, no. CSS01-06 (2001). http://www.css.snre.umich.edu/publication/css-factsheets-us-food-system.

You Decide

How will you adapt your lifestyle and dietary choices to help promote sustainable agricultural practices?

Some consumers are choosing to make smarter nutritional choices, eat healthier foods, and enjoy fresh, locally grown products. They read the labels on products in their local stores, make more home-cooked meals using whole-food ingredients, and pay attention to the decisions that legislators and other officials make regarding food production and consumption. Will you be one of them? How you can adjust your dietary selections to benefit not only your body and mind but also to help sustain the planet for future generations?



Video 16.4.1: *Green Careers: Sustainable Agriculture. This video focuses on the role of a farm manager on a small farm that follows sustainable agricultural practices (click to see video).*

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16.6: A Fresh Perspective- Sustainable Food Systems

Learning Objective

- Discuss some approaches to building a sustainable food system in your community.

The science of nutrition includes the study of how organisms obtain food from their environment. An ecosystem is defined as the biological and physical environments and their interactions with the community of organisms that inhabit those environments as well as the interactions among the organisms. Human nutrition and the health of the world's ecosystem are interdependent, meaning that what we eat and where we get it from affects the world. In turn, the health of the earth influences our health. The term sustainability is used to indicate the variety of approaches aimed at improving our way of life. Sustainability promotes the development of conditions under which people and nature can interact harmoniously. It is based on the principle that everything needed for human survival depends upon the natural environment.

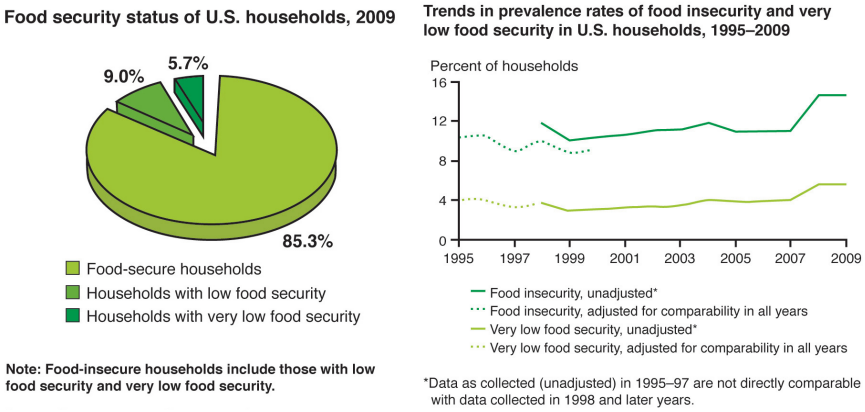


Figure 16.5.1: Food Security Status in the United States. Building a sustainable food system will help enforce measures to ensure that everyone on the planet has enough food to eat. Source: Calculated by ERS using data from the December 2009 Current Population Survey Food Security Supplement.

A major theme of sustainability is to ensure that the resources needed for human and environmental health will continue to exist. A healthy ecosystem, one that is maintained over time, is harmonious and allows for social and economic fulfillment for present and future generations. Nutritious foods come from our ecosystem and to ensure its availability for generations to come, it must be produced and distributed in a sustainable way. The American Public Health Association (APHA) defines a sustainable food system as "one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment."American Public Health Association. "Towards a Healthy, Sustainable Food System." *Policy Statement Database*. Policy no. 200712 (November 6, 2007). www.apha.org/advocacy/policy/policysearch/default.htm?id=1361 It also states that the attributes of a sustainable food system are:

- availability
- accessibility
- affordability to all
- humane
- just

A sustainable food system does not just include the food and those who consume the food, but also those that produce the food, like farmers and fishermen, and those who process, package, distribute, and regulate food. Unfortunately, we have a long way to go to build a sustainable food system.

The Challenges

The most prominent challenge to building a sustainable food system is to make food available and accessible to all. The Food and Agricultural Organization of the United Nations (FAO) states the right to food is a fundamental human right and its mission is to assist in building a food-secure world. Food security in America is defined as the "access by all people at all times to enough food for an active, healthy life."US Department of Agriculture, Economic Research Service. "Food Security in the United States: Key Statistics and Graphics." Last updated June 4, 2012. www.ers.usda.gov/Briefing/FoodSecurity/stats_graphs.htm#food_secure As of 2009, 14.9 percent of households, or 17.4 million people in the United States, had very low or low food security and these numbers have risen in recent years (Figure 1.7.2).Food and Agricultural Organization of the United Nations. "Food Security: Concepts and Measurement." In *Corporate Document Repository*, ID: 144369. 2003. http://www.fao.org/docrep/005/y4671e/y4671e06.htm

Food security is defined by the FAO as existing "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for an active and healthy life."Food and Agriculture Organization of the United Nations. "How Does International Price Volatility Affect Domestic Economies and Food Security? In *The State of Food Insecurity in the World*. 2011. http://www.fao.org/publications/sofi/en/ The FAO estimates that 925 million worldwide were undernourished in 2010. Although there was a recent decline in overall food insecurity (attributable mostly to a decline in undernourished people in Asia), the number of undernourished people worldwide is still higher than it was in 1970, despite many national and international goals to reduce it.

Another challenge to building a sustainable food system is to supply high-quality nutritious food. The typical American diet does not adhere to dietary guidelines and recommendations, is unhealthy, and thus costs this country billions of dollars in healthcare. The average American diet contains too many processed foods with added sugars and saturated fats and not enough fruits, vegetables, and whole grains. Moreover, the average American takes in more kilocalories each day than ever before. This shift of the population toward unhealthy, high-calorie diets has fueled the obesity and diet-related disease crisis in this nation. Overall the cost of food for the average American household has declined since the 1970s; however, there has been a growth of "food deserts." A food desert is a location that does not provide access to affordable, high-quality, nutritious food. One of the best examples of a "food desert" is in Detroit, Michigan. The lower socioeconomic status of the people who live in this city does not foster the building of grocery stores in the community. Therefore, the most accessible foods are the cheap, high-caloric ones sold in convenience stores. As a result, people who live in Detroit have some of the highest incidences of obesity, Type 2 diabetes, and cardiovascular disease in the country.

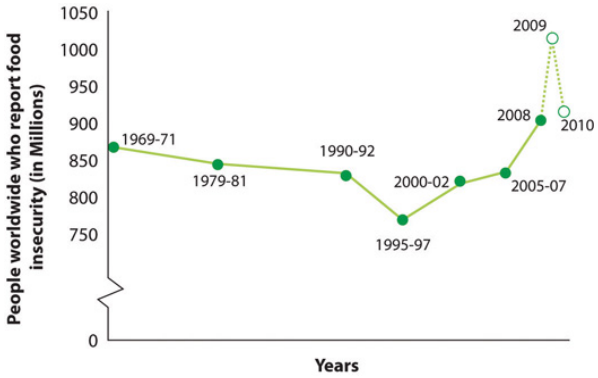


Figure 16.5.2: *Food Insecurity: A Global Perspective. Source: Calculated by ERS based on Current Population Survey Food Security Supplement data.*

A fourth challenge to building a sustainable food system is to change how we produce, process, and distribute food. Large agribusiness, complex industrial processing, and massive retail conglomerations distort the connection we have between the food on our plate and where it came from. More food is being produced in this nation than ever before, which might sound good at first. However, some factors that have contributed to higher food production include using genetically engineered plants, excessive use of herbicides and pesticides, and the selective promotion of only a few crops by the policy of crop-specific subsidies (money given to farmers by the federal government). The subsidies are given toward the support of only about eight crops, most notably corn and soybeans. This policy diminishes the variety of crops, decreases biodiversity among crops, and supports large agribusiness while disadvantaging small- and medium-sized farms. Additionally, the whole system of food production, processing, and distribution is lengthy, requiring a great deal of energy and fossil fuels, and promotes excessive use of chemicals to preserve foods during transportation and distribution. In fact, the current US food system uses approximately 22 percent of the energy in this country and is responsible for at least 20 percent of greenhouse gas emissions. Canning, P. et al. "Energy Use in the US Food System." US Department of Agriculture, *Economic Research Report, no. ERR-94* (March 2010).

Solutions to the Challenges

While these challenges are daunting there are many potential solutions that are gaining momentum in the United States. The APHA advocates expanding the infrastructure for locally grown food, improving access to healthy and local food for low-income Americans, providing education on food origin and production, building up the livelihoods of local farmers, and using sustainable farming methods. Detroit is currently a "food desert," but there is a fantastic example of how to positively impact the growth of a sustainable food system within the city. It is called the Eastern Market and it is a six-block inner city market with over 250 vendors marketing local produce, meat, seafood, plants, fresh-cut flowers and much, much more. Unlike many urban farmers' markets, it sells foods that are better quality and lower prices than grocery stores. Its forty-thousand visitors every Saturday demonstrate its success as a community-based way to foster good nutrition, good health, and social interaction.

Tools for Change

Ten Steps You Can Take to Help Build a Sustainable Food System in Your Community

1. Eat a "low-carbon diet." This is one where the foods that you eat require less energy and fuel to produce, process, and distribute than other foods.
2. Join a community-based farmers' market.
3. Have a garden at home and join a network of home gardeners. Find out how by visiting the USDA website on gardening: www.usda.gov/wps/portal/usda/usdahome?navid=GARDENING &parentnav=CONSUMER_CITIZEN&navtype=RT and the National Garden Association, http://www.garden.org/.
4. Compost your food and garden waste. Learn some of the essentials of composting by visiting "Composting at home," a fact sheet provided by Ohio State University (http://ohioline.osu.edu/hyg-fact/1000/1189.html).
5. Buy local food—make at least 10 percent of your food purchases local and share what you know about local food with friends and family.
6. Pool your resources with family and friends to purchase locally.
7. Drink tap water instead of bottled water.
8. When purchasing foods, choose the ones with less packaging.

9. Support state initiatives that support local farmers and build infrastructure to sell more healthy food.
10. When dining out, ask what nutrients are in the food and where the food labels are on the menu (to encourage the restaurants to label). Also, visit the restaurant's website as the information may be posted there with a space for comments.

These are some great steps to build a more sustainable food system for you and your family, friends, neighborhood, community, city, state, nation, and the world. For more solutions, watch Video 1.7.1. Throughout this book, we will highlight multiple steps you can take toward building a sustainable food system in the Tools for Change sections, so stay tuned.



Figure 16.5.3: You can do your part in building a sustainable environment by literally starting in your own backyard. © Shutterstock

Video 16.5.1: Sustainable Food Systems

This link brings you to an educational video on sustainable food systems.

Key Takeaways

- Sustainability promotes the ditions under which people and nature can interact harmoniously. It is based upon the principle that everything needed for huma upon the natural environment. A sustainable food system includes not only the food and those who consume the food, but also t ood (such as farmers and fishermen), and process, package, distribute, and regulate food.
- The challenges to building a stem are many, from providing affordable and accessible food, to supplying nutritious, high-quality, low-cost food regardless of socioeconomic status, to changing the ways foods are produced, processed, and distributed.
- There are many solutions to the challenges of building a sustainable food system. Some of the solutions are to: expand the infrastructure for locally grown food, improve access to healthy and local food for low-income Americans, provide education on food origin and production, build up the livelihoods of local farmers, and use sustainable farming methods.
- You can take action individually and locally to help build a sustainable food system.

Discussion Starters

1. Share with each other in the classroom some of the things you might have already done to help build a sustainable food system in your community.
2. Form debate teams in the classroom and have a formal debate on the topic of the regulation of food. One side must present the reasons it is beneficial for the government to regulate food. The other side will argue the reasons it is better for people to grow their food locally.

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16.7: Start Your Sustainable Future Today

Learning Objectives

- Discuss forms of activism in areas of food and nutrition.
- List steps individuals can take to support sustainable agriculture.

As we near the end of our journey in the world of health and nutrition, let's address how to adjust your lifestyle today to ensure better health and wellness tomorrow. Adopting sustainable practices can go a long way toward helping you achieve optimal health, while also helping to protect the health of our planet. Remember, that sustainability involves meeting present nutritional needs while preserving resources for the future. It includes agricultural practices and processes, along with the choices that consumers make when they shop for their food. Ideally, sustainable practices include methods that are healthy, conserve the environment, protect livestock, respect food industry workers, provide fair wages to farmers, and support farming communities. When a practice or a process is sustainable, it can be maintained for decades, or even centuries, to come.

Living a Sustainable Lifestyle

There are a number of steps you can take to live a more sustainable lifestyle. Utilizing an environmentally-friendly approach to good nutrition is a great way to remain and stay healthy. As an initial step, you might try to buy more whole foods rather than processed foods. You might also drink more water, rather than sodas and juices with added sugar. It is also a good idea to drink from a reusable water bottle to avoid adding more plastic to your local landfill, not to mention saving the fuel it takes to ship bottles of water. Here are some other suggestions to live a more sustainable lifestyle:

- **Learn more about food.** Learn about your local food system, what is native to the area, what is imported or shipped in, how food moves from farms to processors to retail in your area, and what practices are used. Read labels to see where food comes from and what the growing and processing practices are. You might also try taking a cooking class to learn more about food in general.
- **Eat a plant-based diet.** A plant-based diet is not necessarily vegetarian or vegan; it simply emphasizes whole grains, fruits, vegetables, and legumes over meat and poultry. Plant-based foods are good sources of carbohydrates, protein, fat, vitamins, and minerals. They also help to decrease your risk for cancer and other chronic conditions.
- **Support local farmers.** Purchase more locally grown food to promote sustainability. This could involve going to a farmer's market or a nearby farm. Locally grown food requires less fossil fuel because it does not have to travel great distances. Locally grown food also puts money back into your community and helps farmers in your area. Shopping at a farmer's market or a local farm may also provide an opportunity to talk to the farmer who grew the food to learn more about what you put on your plate.
- **Join a community garden.** You can't get more local than food that is grown in your own backyard. Consider growing your own food, or trying a community garden if you do not have the space at your home. Produce from a local garden will not only be fresher, it will often taste better. In addition, it will provide an opportunity to get to know like-minded individuals in your community.
- **Help spread the word.** Talk to friends and family members about food, nutrition, and living a sustainable lifestyle. Also, pay attention to food and nutrition policy at the federal, state, and local levels. Take a look at what foods are available in your community. Are there supermarkets or corner stores? What is available in the university dining hall? If healthy options are lacking, can you talk to someone to bring about changes?

Tools for Change

Another option to support local farmers is to sign up for a CSA (community-supported agriculture). Prior to a planting season, consumers who join a CSA purchase a produce share from a local farmer. When harvesting begins, farmers provide in-season, locally grown vegetables to shareholders at a local drop spot each week throughout the growing season. Some CSAs also include fruit, dairy products, meat, and more. CSA farmers often will allow you to visit the farm to learn more about the crops they grow or even volunteer to help with the harvest. Joining a CSA provides a direct connection between the local farming community and you.

Changing Your Behavior

Living a sustainable lifestyle and achieving optimal health is not easy. Taking steps to exercise more, eat healthier foods, and work harder to avoid food contamination may involve making major changes in your life. However, change is a process, and researchers

have long studied the various stages of that process, as well as what helps or hinders it. While creating and implementing change is not easy, the more conscious you are of the process, and the more you prepare, the greater the chances are for success. Learning about the different stages of behavioral change can help you take a proactive approach to living a sustainable lifestyle.

The Transtheoretical Model of Behavioral Change

The Transtheoretical Model of Behavioral Change identifies the five stages of change, along with things that can help people move through these different stages. It also includes strategies which help people make, create, and continue behavioral change. Learning about these different stages and techniques helps you decide how to best approach making healthy changes in your life.

The five stages of the Transtheoretical Model of Behavioral Change are (Figure 16.7.1):

1. **Precontemplation.** At this stage, an individual has no plans to make any changes and may not be aware that change is needed. For example, a person who has never thought of eating healthier or being more active is in the precontemplation stage. In this stage, a person often underestimates the pros of changing and underestimates the cons of maintaining the status quo.
2. **Contemplation.** An individual begins to see the importance of altering behavior and plans to do so within the next six months. Someone who has realized that they need to add more physical activity to their life, but hasn't made any concrete plans to start doing it, is in the contemplation stage. Although they may be more aware of the benefits of change, the individual may still exaggerate the negative aspects of change.
3. **Preparation.** At this stage, an individual becomes serious about making a change and plans to implement that change within thirty days. The person may have already started to alter behavior or told friends about any plans or intentions. For example, someone who wants to eat better and has started gathering healthier recipes is in the preparation stage.
4. **Action.** At this point, an individual is in the midst of change or has made a consistent change in behavior within the past six months. For example, someone in the action stage would have started eating better and exercising on a regular basis.
5. **Maintenance.** At this final stage, an individual has successfully changed their behavior for six months or more and intends to maintain it in the future.



Figure 16.6.1: *This is a graphic representation of the "Stages of Change" in the Transtheoretical Model of Behavior Change. from* Philciaccio (via Wikipedia).

Adopting a healthier lifestyle requires changes not only in behavior, but also in attitude and perception. The Transtheoretical Model calls them *decisional balance* and *self-efficacy*. Decisional balance means a person has realized that the benefits of making healthy changes outweigh any risks. Self-efficacy means a person has self-belief and the confidence to make and maintain positive changes. Both decisional balance and self-efficacy help people progress through the different stages of change. The Theoretical Model of Behavioral Change also includes ten techniques and strategies for bringing about change:

1. **Consciousness-raising.** Different methods that are used to raise awareness of healthier choices.
2. **Dramatic Relief.** The use of emotions through testimonials, role-playing, and the media to support change.
3. **Environmental Reevaluation.** Helping people become aware of how they affect others, and how a change on their part can also help those around them.
4. **Social Liberation.** Helping individuals realize that society may be more welcoming if they change their behavior.
5. **Self-Liberation.** Allowing people to believe in their ability to change, and make a commitment to it.
6. **Helping Relationships.** Providing connections between people seeking positive change with others who support their efforts.
7. **Counterconditioning.** Finding healthier substitutes for the unhealthy behavior.
8. **Reinforcement Management.** Increasing rewards for healthy behavior and reducing those for negative behavior.
9. **Stimulus Control.** Being aware of and eliminating cues for unhealthy behavior, and replacing them with cues for healthy choices.
10. **Self-reevaluation.** Changing your self-image to fit with a newer, healthier lifestyle.

Prochaska and colleagues state that their research related to the transtheoretical model shows that interventions to change behavior are more effective if they are "stage-matched," that is, "matched to each individual's stage of change (Figure 16.7.2).

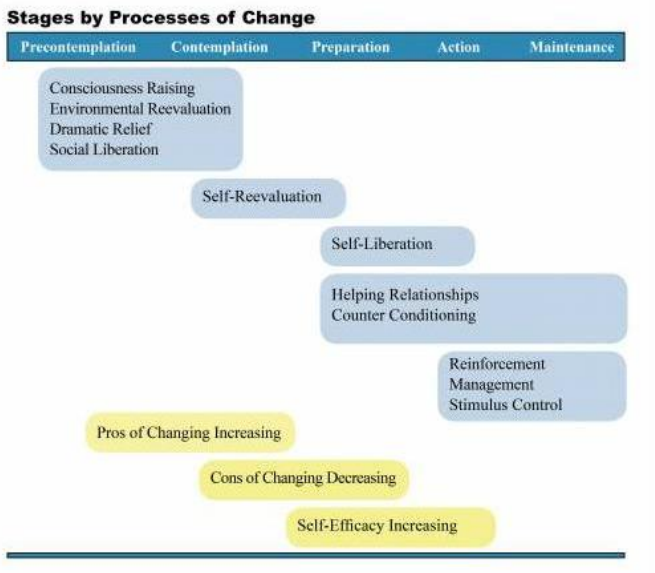


Figure 16.7.2: Processes of Change. from Wikipedia

Some of these processes of change are more effective at different points in the process. A person who is not even contemplating change could tune out emotional appeals or reinforcement management. However, combining knowledge of the change process with the effective use of strategies can help everyone turn their good intentions into healthier lifestyles.Center for Health Communications Research. “Transtheoretical Model (Stages of Change).” © 2009 The Regents of University of Michigan. Accessed December 21, 2011. chcr.umich.edu/how_we_do_it/health_theories/healththeories5/chcr_document_view.

Key Takeaways

Living a sustainable lifestyle can help you to work toward achieving optimal health. There are a number of steps you can take to promote sustainable practices, such as buying locally grown food, eating a plant-based diet, and becoming aware of food and nutrition issues in your community. The Transtheoretical Model of Behavioral Change outlines the different stages of the process of change, and provides tools and techniques to enable major changes.

Discussion Starter

1. Think of a change you might want to make in your life to become healthier, and discuss ways you can use the transtheoretical model to make this change.

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16.8: The Issue of Food Security

Learning Objectives

- Share an example of a food and nutrition program that seeks to mitigate hunger in the United States and/or Canada.

Physiologically, hunger relates to appetite and is the body's response to a need for nourishment. Through stomach discomfort or intestinal rumbling, the body alerts the brain that it requires food. This uneasy sensation is easily addressed with a snack or a full meal. However, the term "hunger" also relates to a weakened condition that is a consequence of a prolonged lack of food. People who suffer from this form of hunger typically experience malnourishment, along with poor growth and development.

Hunger

Adequate food intake that meets nutritional requirements is essential to achieve a healthy, productive lifestyle. However, millions of people in North America, not to mention globally, go hungry and are malnourished each year due to a recurring and involuntary lack of food. The economic crisis of 2008 caused a dramatic increase in hunger across the United States.World Hunger.org. "Hunger in America: 2011 United States Hunger and Poverty Facts." Accessed October 10, 2011. www.worldhunger.org/articles/Learn/us_hunger_facts.htm.

Key Hunger Statistics

In 2010, 925 million people around the world were classified as hungry. Although this was a decrease from a historic high of more than one billion people from the previous year, it is still an unbearable number. Every night, millions and millions of people go to sleep hungry due to a lack of the money or resources needed to acquire an adequate amount of food. This graph shows the division of hungry people around the globe.

Key Hunger Terms

A number of terms are used to categorize and classify hunger. Two key terms, food security and food insecurity, focus on status and affect hunger statistics. Another term, malnutrition, refers to the deficiencies that a hungry person experiences.

Food Security

Most American households are considered to be food secure, which means they have adequate access to food and consume enough nutrients to achieve a healthy lifestyle. However, a minority of US households experiences food insecurity at certain points during the year, which means their access to food is limited due to a lack of money or other resources. This graphic shows the percentage of food-secure and food-insecure households in the United States during the year 2010.

Food Insecurity

Food insecurity is defined as not having adequate access to food that meets nutritional needs. According to the USDA, about 48.8 million people live in food-insecure households and have reported multiple indications of food access problems. About sixteen million of those have "very low food security," which means one or more people in the household were hungry at some point over the course of a year due to the inability to afford enough food. The difference between low and very low food security is that members of low insecurity households have reported problems of food access, but have reported only a few instances of reduced food intake, if any.Coleman-Jensen, A. et al. "Household Food Security in the United States in 2010." US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011). African American and Hispanic households experience food insecurity at much higher rates than the national average.Coleman-Jensen, A. et al. "Household Food Security in the United States in 2010." US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

Households with limited resources employ a variety of methods to increase their access to adequate food. Some families purchase junk food and fast food—cheaper options that are also very unhealthy. Other families who struggle with food security supplement the groceries they purchase by participating in government assistance programs. They may also obtain food from emergency providers, such as food banks and soup kitchens in their communities.

Malnutrition

A person living in a food-insecure household may suffer from malnutrition, which results from a failure to meet nutrient requirements. This can occur as a result of consuming too little food or not enough key nutrients. There are two basic types of malnutrition. The first is macronutrient deficiency and relates to the lack of adequate protein, which is required for cell growth, maintenance, and repair. The second type of malnutrition is micronutrient deficiency and relates to inadequate vitamin and mineral intake.World Hunger. "2011 World Hunger and Poverty Facts and Statistics." Accessed October 10, 2011. http://www.worldhunger.org/articles/Learn/world%20hunger%20facts%202002.htm. Even people who are overweight or obese can suffer from this kind of malnutrition if they eat foods that do not meet all of their nutritional needs.

At-Risk Groups

Worldwide, three main groups are most at risk of hunger: the rural poor in developing nations who also lack access to electricity and safe drinking water, the urban poor who live in expanding cities and lack the means to buy food, and victims of earthquakes, hurricanes, and other natural and man-made catastrophes.Food and Agriculture Organization of the United Nations. "Hunger: Frequently Asked Questions." Accessed October 10, 2011. http://www.fao.org/hunger/en/ In the United States, there are additional subgroups that are at risk and are more likely than others to face hunger and malnutrion. They include low-income families and the working poor, who are employed but have incomes below the federal poverty level.

Senior citizens are also a major at-risk group. Many elderly people are frail and isolated, which affects their ability to meet their dietary requirements. In addition, many also have low incomes, limited resources, and difficulty purchasing or preparing food due to health issues or poor mobility. As a result, more than six million senior citizens in the United States face the threat of hunger.Meals on Wheels. "Our Vision and Mission." Accessed October 10, 2011. www.mowaa.org/page.aspx?pid=299

The Homeless

One of the groups that struggles with hunger are the millions of homeless people across North America. According to a recent study by the US Conference of Mayors, the majority of reporting cities saw an increase in the number of homeless families.The United States Conference of Mayors. "Hunger and Homelessness Survey: A Status Report on Hunger and Homelessness in America's Cities, a 27-City Survey." December 2009. usmayors.org/pressreleases/uploads/USCMHungercompleteWEB2009.pdf. Hunger and homelessness often go hand-in-hand as homeless families and adults turn to soup kitchens or food pantries or resort to begging for food.

Children

Rising hunger rates in the United States particularly affect children. Nearly one out of four children, or 21.6 percent of all American children, lives in a food-insecure household and spends at least part of the year hungry.Coleman-Jensen, A. et al. "Household Food Security in the United States in 2010." US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011). Hunger delays their growth and development and affects their educational progress because it is more difficult for hungry or malnourished students to concentrate in school. In addition, children who are undernourished are more susceptible to contracting diseases, such as measles and pneumonia.World Hunger. "2011 World Hunger and Poverty Facts and Statistics." Accessed October 10, 2011.

Video 16.7.1: Going Hungry in America

This video examines the effect of hunger on many American children. (click to see video)

Government Programs

The federal government has established a number of programs that work to alleviate hunger and ensure that many low-income families receive the nutrition they require to live a healthy life. A number of programs were strengthened by the passage of the Healthy, Hunger-Free Kids Act of 2010. This legislation authorized funding and set the policy for several key core programs that provide a safety net for food-insecure children across the United States.

The Federal Poverty Level

The federal poverty level (FPL) is used to determine eligibility for food-assistance programs. This monetary figure is the minimum amount that a family would need to acquire shelter, food, clothing, and other necessities. It is calculated based on family size and is adjusted for annual inflation. Although many people who fall below the FPL are unemployed, the working poor can qualify for

food programs and other forms of public assistance if their income is less than a certain percentage of the federal poverty level, along with other qualifications.

USDA Food Assistance Programs

Government food and nutrition assistance programs that are organized and operated by the USDA work to increase food security. They provide low-income households with access to food, the tools for consuming a healthy diet, and education about nutrition. The USDA monitors the extent and severity of food insecurity via an annual survey. This contributes to the efficiency of food assistance programs as well as the effectiveness of private charities and other initiatives aimed at reducing food insecurity.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

The Supplemental Nutrition Assistance Program

Formerly known as the Food Stamp Program, the Supplemental Nutrition Assistance Program (SNAP) provides monthly benefits for low-income households to purchase approved food items at authorized stores. Clients qualify for the program based on available household income, assets, and certain basic expenses. In an average month, SNAP provides benefits to more than forty million people in the United States.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

The program provides Electronic Benefit Transfers (EBT) which work similarly to a debit card. Clients receive a card with a certain allocation of money for each month that can be used only for food. In 2010, the average benefit was about $134 per person, per month and total federal expenditures for the program were $68.2 billion.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

The Special, Supplemental Program for Women, Infants, and Children

The Special, Supplemental Program for Women, Infants and Children (WIC) provides food packages to pregnant and breastfeeding women, as well as to infants and children up to age five, to promote adequate intake for healthy growth and development. Most state WIC programs provide vouchers that participants use to acquire supplemental packages at authorized stores. In 2010, WIC served approximately 9.2 million participants per month at an average monthly cost of about forty-two dollars per person.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

The National School Lunch Program

The National School Lunch Program (NSLP) and School Breakfast Program (SBP) ensure that children in elementary and middle schools receive at least one healthy meal each school day, or two if both the NSLP and SBP are provided. According to the USDA, these programs operate in over 101,000 public and nonprofit private schools and residential child-care institutions.US Department of Agriculture. “National School Lunch Program.” October 2011. www.fns.usda.gov/cnd/Lunch/AboutLunch/NSLPFactSheet.pdf. In 2010, the programs provided meals to an average of 31.6 million children each school day. Fifty-six percent of the lunches served were free, and an additional 10 percent were provided at reduced prices.

Other Food-Assistance Programs for Children

Other government programs provide meals for children after school hours and during summer breaks. The Child and Adult Care Food Program (CACFP) offers meals and snacks at child-care centers, daycare homes, and after-school programs. Through CACFP, more than 3.2 million children and 112,000 adults receive nutritious meals and snacks each day.US Department of Agriculture. “Child & Adult Care Food Program.” Last modified June 10, 2011. www.fns.usda.gov/cnd/care/. The Summer Food Service Program provides meals to children during summer break. Sponsors include day camps and other recreation programs where at least half of the attendees live in households with incomes below the federal poverty level.US Department of Agriculture. “Summer Food Service Program.” st.TER 14 2011r Congressbrary. Last modified July 20, 2011. http://www.summerfood.usda.gov/default.htm. These and other programs help to fill in the gaps during the typical day of a food-insecure child.

The Head Start Program

Head Start is a health and development program for children ages three to five, from low-income families. The philosophy behind the organization is that early intervention can help address the educational, social, and nutritional deficiencies that children from lower-income families often experience. Launched in 1965, it is one of the longest-running, poverty-related programs in the United States. Today, Head Start programs include education, meals, snacks, and access to other social services and health guidance.US Department of Health and Human Services. “About the Office of Head Start.” Last reviewed February 23, 2011. www.acf.hhs.gov/programs/ohs/about/index.html.

Other Forms of Assistance

Other forms of assistance include locally-operated charitable organizations, such as food banks and food pantries, which acquire food from local manufacturers, retailers, farmers, and community members to give to low-income families. Neighborhood soup kitchens provide meals to the homeless and other people in need. These and other organizations are run by nonprofit groups, as well as religious institutions, to provide an additional safety net for those in need of food.

Meals on Wheels

An organization known as Meals on Wheels delivers meals to elderly people who have difficulty buying or making their own food because of poor health or limited mobility. It is the oldest and largest program dedicated to addressing the nutritional needs of senior citizens. Each day, Meals on Wheels volunteers deliver more than one million meals across the United States. The first Meals on Wheels program began in Philadelphia in the 1950s. In the decades since, the organization has expanded into a vast network that serves the elderly in all fifty states and several US territories. Today, Meals on Wheels remains committed to ending hunger among the senior citizen community.Meals on Wheels. “The Meals on Wheels Association of America.” Accessed October 10, 2011. www.mowaa.org/page.aspx?pid=212.

Key Takeaways

Around the world, nearly one billion people suffer the effects of constant hunger. Key terms related to hunger include food security, which means having continual access to safe, sufficient, nutritious food, and food insecurity, which means not having continual access to safe, sufficient, nutritious food. There are two types of malnutrition. The first is macronutrient deficiency and relates to the lack of adequate protein, which is required for cell growth, maintenance, and repair. The second type of malnutrition is micronutrient deficiency and relates to inadequate vitamin and mineral intake. There are a number of groups at risk for hunger, including the unemployed and underemployed, poor families, the elderly, and the homeless. The United States has a number of federal and state programs, as well as local charities, which provide assistance and education for people who fall into the category of food insecurity.

Discussion Starter

1. Do you believe there are enough government programs currently in place to address the problem of hunger? Why or why not? If not, what additional solutions would you recommend?

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16.9: Diets around the World

Learning Objectives

- Give examples of how local taste preferences and availability influence food choices in different regions of the globe.
- Explain what is meant by Alice Waters' statement: "Food is precious."

In the past, people's culture and location determined the foods they ate and the manner in which they prepared their meals. For example, in the Middle East, wheat was a staple grain and was used to make flatbread and porridge, while halfway around the world in Mesoamerica, maize was the staple crop and was used to make tortillas and tamales. Today, most people have access to a wide variety of food and can prepare them any way they choose. However, customs and traditions still strongly influence diet and cuisine in most areas of the world.

Comparing Diets

There are a multitude of diets across the globe, in all regions and cultures. Each is influenced by the traditions of the past, along with the produce and livestock available. Local tastes, agricultural economics, and incomes still have a profound effect on what many people eat around the world. In this section, you will read a few examples of cuisines in different countries and regions, demonstrating differences in preferences. We will also compare common dietary choices in each region for a key meal—breakfast.

North America

The people of the United States and Canada consume a wide variety of food. Throughout both countries, people enjoy eating all kinds of cuisine from barbecue, pizza, peanut butter sandwiches, and pie to sushi, tacos, chow mein, and roti (an Indian flatbread). This is partly due to the influence of immigration. As people emmigrated to North America, they brought their dietary differences with them. In the 1800s, for example, Italian immigrants continued to cook spaghetti, pesto, and other cultural dishes after arriving in the United States. Today, Italian cuisine is enjoyed by many Americans from all backgrounds.

The variety of North American cuisine has also been impacted by regional variations. For example, fried chicken, cornbread, and sweet tea are popular in the southern states, while clam chowder, lobster rolls, and apple cider are enjoyed in New England. Also, as more people seek to support sustainable agriculture, locally grown crops and whole-food cooking practices often factor into what Americans eat and how they eat it.

Breakfast in North America

Meals can vary widely from one region of the world to another. Therefore, it can be interesting and informative to compare the choices made for a particular meal around the globe. Throughout this section, we will explore the kinds of foods that people consume as they begin their day. Breakfast is a vital meal in any part of the world because it breaks the long overnight fast. An adequate breakfast also provides fuel for the first part of the day and helps improve concentration and energy levels.

Let's begin with breakfast in North America. On weekdays, North Americans often eat breakfast in a hurry or on the go. Therefore, many people choose breakfast foods that are quick and easy to prepare or can be eaten during the trip to school or the office. As a result, breakfast cereals with milk are extremely popular, and also oatmeal, toast, or bagels. However, on the weekends, some people spend a longer time enjoying a hearty breakfast or going out for brunch. Typical choices emphasize hot foods and include egg dishes, such as omelettes and scrambled or fried eggs, along with pancakes, waffles, french toast, bacon or sausage, and orange juice, coffee, or tea to drink.

Central and South America

Both Central America and South America feature cuisines with rich Latin flavors. In addition, rice and corn are staples in both and form the basis for many dishes. Both regions are also affected by the mixture of influences from the native populations and the cultural traditions brought by Spanish and Portuguese immigrants during the 1600s and beyond.

South America has a diverse population, which is reflected in dietary choices across the continent. The northwestern region boasts some of the most exotic food in Latin America. In northeastern South America, many dishes feature a contrast of sweet and salty tastes, including raisins, prunes, capers, and olives. Also, rice grown in the area and seafood off the coast are key ingredients in South American-style paella. The north central part of the continent reflects a Spanish influence. Many of the dominant spices—

cumin, oregano, cinnamon, and anise—came from Spain, along with orange and lime juices, wine, and olive oil. The south is cattle country and the locals enjoy grass-fed beef cooked in the form of asados, which are large cuts roasted in a campfire. Another popular meat dish is parrilladas, which are thick steaks grilled over oak.Cooking Light. “South American Cuisine.” © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/south-american-cuisine -00400000001391/.

From Mexico in the North to Panama in the South, Central American cuisine features some of the world’s favorite foods, including rice, beans, corn, peppers, and tropical fruits. This area combines a variety of culinary traditions derived from the native Maya and Aztec populations, arrivals from Spain, and African and Latin-influenced neighbors along the Caribbean. In this region of the world, tamales are common. Spicy seasonings, including hot chili peppers, are also very popular.

Typical Southern and Central American Foods

Typical foods in South and Central America include quinoa, which is a grain-like crop that is cultivated for its edible seeds. Quinoa has a high protein and fiber content, is gluten-free, and is particulary tasty cooked in pilafs. Another popular grain product is the tortilla, which is a flatbread made from wheat or corn. Tortillas are used to make a number of dishes, including burritos, enchiladas, and tacos. Fruits and vegetables that are common in Mexico, Central America, and South America include corn, avocados, yucca, peppers, potatoes, mangoes, and papayas. Rice, beans, and a soft cheese known as queso fresco are common to the cuisine in this area of the world as well.



Figure 16.8.1: Tamales, which are popular in Mexico and parts of Central and South America, are made from a shell called a masa that is stuffed with meat or vegetables and steamed or boiled in a wrapper of dried corn leaves. The wrapping is discarded prior to eating. Salvadorean tamales shown above are made in banana or plantain leaves, and the masa (corn meal) is often seasoned with chicken stock. (Public Domain; Ll1324).

Breakfast in Central America

In this region, the first meal of the day commonly includes huevos rancheros (fried eggs served over a tortilla and topped with tomato sauce). Other popular breakfast dishes include pan dulce (a sweetened bread), along with fried plantains, and a spicy sausage called chorizo. The typical beverage is coffee, which is available in many forms, including café con leche (which is sweetened with lots of milk) and café de olla (with cinnamon and brown sugar). Hot chocolate is also popular and tends to be thick, rich, and flavored with spices such as cinnamon or achiote. In the Yucatan region, huevos motulenos are prepared by spreading refried beans onto fresh tortillas with fried eggs, peas, chopped ham, and cheese.

Europe

European cuisine is extremely diverse. The diet in Great Britain is different from what people typically consume in Germany, for example. However, across the continent, meat dishes are prominent, along with an emphasis on sauces. Potatoes, wheat, and dairy products are also staples of the European diet.

The nations along the Mediterranean Sea are particularly renowned for their flavorful food. This part of the world boasts a number of famous dishes associated with their countries of origin. They include Italy’s pasta, France’s coq au vin, and Spain’s paella.

Italy

Although Italy is a relatively small nation, the difference in cuisine from one region to another can be great. For example, the people of northern Italy tend to rely on dairy products such as butter, cream, and cheeses made from cow's milk, because the land is flatter and better suited to raising cattle. In southern Italy, there is greater reliance on olive oil than butter, and cheeses are more likely to be made from sheep's milk.Cooking Light. "Regional Italian Cuisine." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/regional-italian-cuisine -00400000001340/.

However, there are a number of common ingredients and dishes across the country. Italian cuisine includes a variety of pasta, such as spaghetti, linguine, penne, and ravioli. Other well-known dishes are pizza, risotto, and polenta. Italians are also known for cooking with certain spices, including garlic, oregano, and basil.

France

For centuries, the French have been famous for their rich, extravagant cuisine. Butter, olive oil, pork fat, goose fat, and duck fat are all key ingredients. Common French dishes include quiche, fondue, baguettes, and also creams and tarts. Frites, or French fries, are cut in different shapes and fried in different fats, depending on the region. Fresh-baked bread is also found across the nation from the skinny baguettes of Paris to the sourdough breads in other parts of the country.

Every region of France seems to have its version of coq au vin (braised chicken most often cooked with garlic, mushrooms, and pork fat in wine). For instance, in the northeast, the dish is prepared a la biere (in beer). In Normandy in the northwest, coq au vin is cooked au cidre (in apple cider).Cooking Light. "France's Regional Cuisine." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/frances-regional-cuisine -00400000001365/.

Spain

One of the most popular Spanish dishes is paella, a gumbo of rice, seafood, green vegetables, beans, and various meats. The ingredients can vary wildly from one region to another, but rice is always the staple of the dish. Spain is also renowned for its tapas, which are appetizers or snacks. In restaurants that specialize in preparing and serving tapas, diners often order a number of different dishes from a lengthy menu and combine them to make a full meal.

Cooks in Spain rely on a variety of olive oils known for their flavors, ranging from smooth and subtle to fruity and robust. Spanish cuisine combines Roman, Moorish, and New World flavors. Key ingredients include rice, paprika, saffron, chorizo, and citrus fruits.Cooking Light. "Spanish Flavor." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/specialties-spanish -00400000001203/.

Video 16.8.1: The Mediterranean Diet

This video shows the cultural history of the cuisine enjoyed by many people who live in the Mediterranean region of Europe.(click to see video)

Breakfast in Europe

In some countries, such as France, Italy, and Belgium, coffee and bread are common breakfast foods. However, the people of Great Britain and Ireland tend to enjoy a bigger breakfast with oatmeal or cold cereal, along with meats like bacon and sausage, plus eggs and toast. Tea is also popular in this area, not only for breakfast, but throughout the day. The continental-style breakfast is most commonly associated with France and includes fresh-baked croissants, toast, or a rich French pastry called brioche, along with a hot cup of tea, coffee, or café au lait.

Africa

The continent of Africa is home to many different countries and cultural groups. This diversity is reflected in the cuisine and dietary choices of the African people. Traditionally, various African cusines combine locally grown cereals and grains, with fruits and vegetables. In some regions, dairy products dominate, while in others meat and poultry form the basis of many dishes.

Ethiopia

Ethiopia, located along the Horn of Africa, is one of the few African countries never colonized by a foreign nation prior to the modern era. So, outside influences on the culture were limited. Religious influences from Jewish, Islamic, and Catholic traditions played a larger role on the shaping of Ethiopian cuisine, because of the need to adhere to different dietary restrictions. For example,

approximately half of Ethiopians are Muslim and must abstain from eating pork or using spices and nuts to flavor dishes. Ethiopia is also known for dishes that use local herbs and spices, including fenugreek, cumin, cardamom, coriander, saffron, and mustard. Many dishes also reflect a history of vegetarian cooking since meat was not always readily available.Cooking Light. “Ethiopian Tastes.” © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/vegetarian/ethiopian-tastes-00400000037116/.

In addition, Ethiopians use their hands to eat. First, diners tear off pieces of injera, a spongy, tangy flatbread made from teff flour. Then, they use the pieces as utensils to scoop up vegetables, legumes, and meats from a communal plate.Ethiopian Restaurant.com. “Injera.” © 2004–2012. http://www.ethiopianrestaurant.com/injera.html Teff is a grass that grows in the highlands of Ethiopia and is a staple of the diet.

Central and West Africa

Stretching from mountains in the north to the Congo River, Central Africa primarily features traditional cuisine. Meals are focused on certain staples, including cassava, which is a mashed root vegetable, and also plantains, peanuts, and chili peppers. In West Africa, which includes the Sahara Desert and Atlantic coast, the cuisine features dishes made from tomatoes, onions, chili peppers, and palm nut oil. Popular dishes in both regions include stews and porridges, such as ground nut stew made from peanuts, and also fufu, a paste made from cassava or maize.

Breakfast in Africa

African breakfast choices are strongly influenced by the colonial heritage of a region. The people of West Africa typically enjoy the French continental-style breakfast. However, in the eastern and southern parts of the continent, the traditional English breakfast is more common. In North Africa, breakfast is likely to include tea or coffee, with breads made from sorghum or millet. In East and West Africa, a common breakfast dish is uji, a thick porridge made from cassava, millet, rice, or corn. Kitoza is a delicacy made from dried strips of beef that are eaten with porridge in Madagascar. In Algeria, French bread, jam, and coffee is a typical breakfast. The people of Cameroon eat beignets, which is a doughnut eaten with beans or dipped in a sticky, sugary liquid called bouilli.

Asia

Asia is a massive continent that encompasses the countries of the Middle East, parts of Russia, and the island nations of the southeast. Due to this diversity, Asian cuisine can be broken down into several regional styles, including South Asia, which is represented for our purposes here by India, and East Asia which is represented for our purposes by China, Korea, and Japan. Even with this variety, the Asian nations have some dietary choices in common. For example, rice is a staple used in many dishes across the continent.

India

In India, there is much variety between the different provinces. The nation’s many kinds of regional cuisines can date back thousands of years and are influenced by geography, food availability, economics, and local customs. However, vegetarian diets are common across the nation for religious reasons, among others. As a result, Indian dishes are often based on rice, lentils, and vegetables, rather than meat or poultry. Indian cooking also features spicy seasonings, including curries, mustard oil, cumin, chili pepper, garlic, ginger, and garam masala, which is a blend of several spices.Curry Dishes.com. “Guide to Easy Indian Recipes, Curry Recipes and Curry Spices.” © 2009. www.currydishes.com/. India is also known for its breads, including the flatbreads roti and chapati. Dishes that are popular not only in India but around the world include samosa, a potato-stuffed pastry; shahi paneer, a creamy curry dish made out of soft cheese and tomato sauce; and chana masala, chickpeas in curry sauce.Food-India.com. “Your Guide to Indian Food.” © 2003–2011. http://www.food-india.com/.

China

China has the world’s most sizable population. As a result, there are many different culinary traditions across this vast country, which is usually divided into eight distinct cuisine regions. For example, Cantonese cuisine, which is also known as Guangdong, features light, mellow dishes that are often made with sauces, including sweet-and-sour sauce and oyster sauce. Cantonese-style cuisine has been popularized in Chinese restaurants around the world. Another cuisine is known as Zhejiang, which is often shortened to Zhe, and originates from a province in southern China. It features dishes made from seafood, freshwater fish, and bamboo shoots.eChinacities.com. “China’s Eight Cuisines Revealed and How to Identify Them.” ©2008–2011 www.echinacities.com/expat-corner/china-s-8-cuisines-revealed -and-how-to-indentify-them.html Key ingredients that are used in

several, but not all, of the different regions include rice, tofu, ginger, and garlic. Tea is also a popular choice in most parts of the country.

Chinese use chopsticks as utensils. These small tapered sticks can be made from a variety of materials, including wood, plastic, bamboo, metal, bone, and ivory. Both chopsticks are held in one hand, between the thumb and fingers, and are used to pick up food.

Korea

Korean cuisine is primarily centered around rice, vegetables, and meat. Commonly-used ingredients include sesame oil, soy sauce, bean paste, garlic, ginger, and red pepper. Most meals feature a number of side dishes, along with a bowl of steam-cooked, short grain rice. Kimchi, a fermented cabbage dish, is the most common side dish served in Korea and is consumed at almost every meal. Another signature dish, bibimbap, is a bowl of white rice topped with sautéed vegetables and chili pepper paste and can include egg or sliced meat. Bulgogi consists of marinated, barbecued beef.Korea Tourism Organization. “Food in Korea.” Accessed October 10, 2011. visitkorea.or.kr/enu/1051_Food.jsp.

Japan

As in other parts of Asia, rice is a staple in Japan, along with seafood, which is plentiful on this island nation. Other commonly-used ingredients include noodles, teriyaki sauce, dried seaweed, mushrooms and other vegetables, meat, and miso, which is soybean paste. Some favorite foods include the raw fish dishes sashimi and sushi, which are not only popular in Japan, but are also around the world. Typical beverages include green tea and also sake, which is a wine made of fermented rice.Web MD. “Diets of the World: The Japanese Diet.” © 2005–2011. http://www.webmd.com/diet/features/diets-of-world-japanese-diet.

The traditional table setting in Japan includes placing a bowl of rice on the left and a bowl of miso soup on the right side. Behind the rice and the soup are three flat plates which hold the accompanying side dishes. Similar to China, chopsticks are used in Japan and are generally placed at the front of the table setting. At school or work, many Japanese people eat out of a bento lunch box, which is a single-portion takeout or home-cooked meal. Bento boxes typically include rice, fish or meat, and cooked or pickled vegetables.

The Middle East

Middle Eastern cuisine encompasses a number of different cooking styles from Asian countries along the Mediterranean, as well as from North African nations, such as Egypt and Libya. In this part of the world, lamb is the most commonly consumed meat and is prepared in a number of ways, including as a shish kebab, in a stew, or spit-roasted. However, kosher beef, kosher poultry, and fish are eaten as well. Other staples include the fruits and vegetables that grow in the hills of many Middle Eastern countries, such as dates, olives, figs, apricots, cucumber, cabbage, potatoes, and eggplant. Common grains include couscous, millet, rice, and bulghur. Popular dishes include Syrian baba ganoush, which is pureed eggplant, and kibbeh, or lamb with bulghur wheat, from Lebanon.Saveur. “Middle Eastern Recipes.” Accessed December 5, 2011. www.saveur.com/solrSearchResults.jsp?fq=Cuisine:Middle\%20Eastern& sitesection=recipes. A flatbread called pita served with hummus, or pureed chickpeas, is another popular dish in this region of the world.

Most people who reside in the Arab countries of the Middle East are Muslim, which can affect their diet. Many Muslims do not consume alcohol or pork. They also observe certain diet-related religious traditions, such as a daytime fast during the month of Ramadan. Other residents of the Middle East include Jews and Christians, and their traditions also affect what foods they eat and how they prepare it. For example, many Jews in Israel keep kosher and follow a set of dietary laws that impact food choices, storage, and preparation.

Breakfast in Asia

To continue the comparison of breakfast around the world, let’s examine the first meal of the day in many parts of Asia. In India, the first meal of the day commonly includes eggs scrambled with spices, potatoes, and onions, as well as fresh fruit and yogurt. Breakfast in China often consists of rice complemented by vegetables, meat, or fish. In Korea, a traditional breakfast would include soup made of either beef ribs or pork intestines, a selection of bread and pastries, rice, and kimchi, which is believed to promote intestinal health. Breakfast in Japan does not greatly differ from any other meal. It typically consists of a bowl of steamed white rice, a small piece of fish, a bowl of miso soup with tofu, vegetables, green tea, and occasionally pickled plums called umeboshi. Hot bowls of noodles in broth topped with pork slices, scallions, and bamboo shoots are also common.



Figure 16.8.2: In the different regions of China, congee is prepared with various types of rice, which results in different consistencies. In Japan, Nanakusa-gayu (七草粥), seven-herb porridge. (CC BY-SA 3.0; Blue Lotus).

Congee is a common breakfast food across Asia. This dish is a porridge made of rice that is consumed in a number of Asian countries, including Vietnam, Thailand, Burma, and Bangladesh. Congee can be prepared both savory and sweet and contain a variety of ingredients, usually meats, vegetables, and herbs. It can be eaten alone or served as a side dish.

The Diversity of Palates and Habits

Around the globe, people enjoy different foods and different flavors. In some cultures, the main dishes are meat-based, while others focus on plant-based meals. You can also find different staples in different regions of the world, including rice, potatoes, pasta, corn, beans, root vegetables, and many kinds of grains. Different flavors are also popular on different parts of the planet, from sweet to salty to sour to spicy.

Food Availability

People tend to eat what grows or lives nearby. For example, people in coastal areas tend to consume more seafood, while those in inland areas tend to structure their diet around locally-grown crops, such as potatoes or wheat. In many developing countries, a large part of the diet is composed of cereal grains, starchy roots, and legumes. However, a number of common staples are consumed worldwide, including rice, corn, wheat, potatoes, cassava, and beans.

Income and Consumption

In addition to regional dissimilarities in diets, income also plays a major role in what foods people eat and how they prepare them. The average global calorie consumption has increased to record levels in recent years. This is a consequence of rising incomes, which have allowed consumers in many regions to expand both the variety and the quantity of food they eat. Among developing countries, the daily intake of calories per person rose by nearly 25 percent from the early 1970s to the mid-1990s.US Department of Agriculture, Foreign Agricultural Service. “Diets Around the World: How the Menu Varies.” Last modified October 14, 2004. www.fas.usda.gov/info/agexporter/2000/Apr/diets.htm.’ Centers for Disease Control and Prevention. “Caloric Consumption on the Rise in the United States, Particularly Among Women.” NCHS Press Room, February 5, 2004. http://www.cdc.gov/nchs/pressroom/04news/calorie.htm. People in the western world were able to increase their consumption of meat and poultry, fruits and vegetables, and fats and oils. However, those gains were minimal in the poorest countries, where many continue to struggle with hunger and a limited diet.US Department of Agriculture, Foreign Agricultural Service. “Diets Around the World: How the Menu Varies.” Last modified October 14, 2004. www.fas.usda.gov/info/agexporter/2000/Apr/diets.htm.

Different Ways of Eating

People from different parts of the world consume their food in different ways and what is common in one country may be considered impolite in another. For example, in some areas people eat with their fingers, while in others using a fork is much more acceptable. In some regions of the world, people slurp their soup, while in others they quietly sip it. In some places, diners eat off of individual plates, while in others people sit at a table with a large communal plate from which everyone eats.

No matter where you travel, you will find that food production, purchase, and preparation affect all facets of life, from health and economics to religion and culture. Therefore, it is vital for people from all walks of life to consider the choices they make regarding food, and how those decisions affect not only their bodies, but also their world. Alice Waters, an influential chef and founder of the nonprofit program Edible Schoolyard, as well as an advocate for sustainable production and consumption, has said, “Remember food is precious. Good food can only come from good ingredients. Its proper price includes the cost of preserving the environment and paying fairly for the labor of the people who produce it. Food should never be taken for granted.”Waters, A. “The Art of Eating.” PlanetGreen.com. March 31, 2009. http://planetgreen.discovery.com/feature/earth-day/alice-waters-eat-green.html.

Video 16.8.2: Alice Waters: Edible Education

In this video, Edible Schoolyard founder Alice Waters talks about the value of growing a garden and learning about food.(click to see video)

Key Takeaways

Many people around the world have access to a wide variety of food and can prepare it any way they choose. However, cuisine remains strongly influenced by location, culture, tradition, and economics. People from all cultures and all walks of life should consider the choices they make regarding food, and how those decisions affect not only their bodies, but also the world.

Discussion Starter

1. Compare and contrast breakfast in different parts of the world. What are common attitudes about the first meal of the day? How are the choices that people make the same? How are they different? Are there any breakfast dishes in common?

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16.10: Why Make Dietary Changes?

Big Idea

A groundbreaking study revealed the risk factors that can affect heart health.

The terms *risk factor*, *good cholesterol*, and *bad cholesterol* were not always on the tip of everyone's tongue when it came to cardiovascular disease. In fact, at one time doctors didn't even consider the concept of managing cholesterol levels to prevent heart disease. However, that was more than fifty years ago, before the Framingham Heart Study became one of the most important epidemiological studies in American health history. Conducted by what is now known as the National Heart, Lung, and Blood Institute in Massachusetts, the study changed the way healthcare professionals and consumers alike regard the prevention of heart disease.Framingham Heart Study. "History of the Framingham Heart Study." © 2011. www.framinghamheartstudy.org/about/history.html.



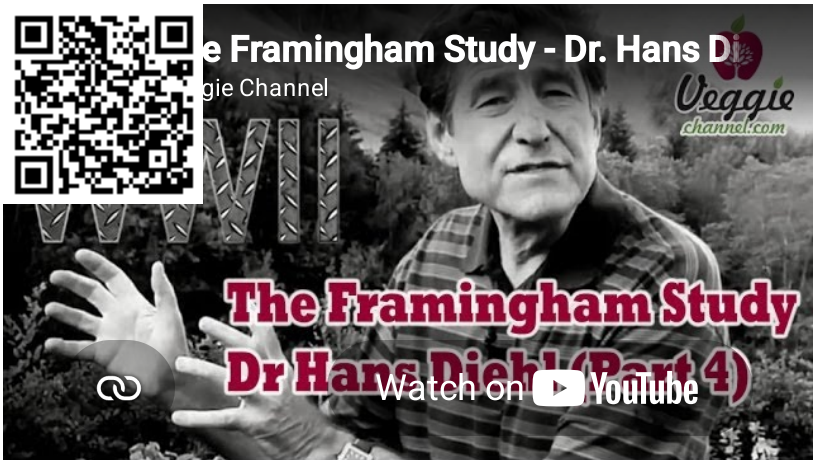
Figure 16.9.1: Scientific evidence continues to correlate the relationship between good dietary habits, adequate exercise, and a healthy body. Lance Corporal Anthony M. Madonia emerges from the water during the swimming portion of the triathlon. Marines and Sailors of Marine Security Company and the Naval Support Facility in Thurmont, Maryland, participated in the Catoctin Mountain Triathlon July 20, 2005. Image is Public Domain.

In the 1940s, little was known about the general causes of heart disease and stroke. Most doctors thought a hardening of the arteries was a natural part of aging, and that rising blood pressure with age was not a serious issue. Yet, the death rates for cardiovascular disease had been increasing steadily since the early 1900s and had become an American epidemic. Growing concern led the US Public Health Service to commission a study to determine which biologic and environmental factors were behind the growing problem. The objective was to follow the development of cardiovascular disease over a long period of time in a large group of participants who had not yet developed overt symptoms. Researchers believed this approach would enable them to identify common characteristics and factors.

In 1948, researchers enrolled more than five thousand participants between ages thirty and sixty-two from Framingham, Massachusetts. The participants returned to the study every two years for a detailed medical examination and laboratory tests. In 1971, the Framingham Heart Study enrolled a second generation—the original participants' adult children and their spouses. In 2002, a third generation—the grandchildren of the original group—joined the study. Recognizing the need to establish a new study reflecting a more diverse population, an additional group of participants was selected in 1994.Framingham Heart Study. "History of the Framingham Heart Study." © 2011. www.framinghamheartstudy.org/about/history.html.

The findings of these extensive, long-term studies have created a treasure trove of data for scientists that has revolutionized the way our nation looks at heart disease. The results revealed high blood pressure, diabetes, cholesterol, and LDL cholesterol in particular, as risk factors for heart disease. The study also identified lifestyle choices as factors which increased the risk of cardiovascular disease, including eating an unhealthy diet, remaining sedentary, and smoking. By utilizing new diagnostic technologies, the Framingham Study continues to make important strides in learning about heart disease. Framingham investigators also collaborate with leading researchers from around the world on projects related to osteoporosis, arthritis, and diabetes. In addition, they have

initiated the Framingham Nutrition Studies, which examine the connection between diet and nutrition to the risk and outcomes of cardiovascular disease. The discoveries of Framingham researchers can help discern opportunities for preventive nutrition intervention.Framingham Heart Study. “History of the Framingham Heart Study.” © 2011. www.framinghamheartstudy.org/about/history.html.



Video 16.9.1: *The Framingham Study. Dr. Hans Diehl discusses the driving forces behind the Framingham Heart Study. (click to see video)*

You Decide

Are you ready to make the necessary changes to achieve optimal health?

How will you benefit from the knowledge about nutrition that you have gained thus far? The link between good nutrition and good health is an undebatable scientific fact. Given the consequences of poor dietary choices and lifestyle habits, it is worthwhile to assess your current food and activity profile to determine areas for improvement. It is important to remember that there are no quick fixes, but with dedication, hard work, and persistence, much can be accomplished. Of course, giving up what we once found enjoyable may not be the easiest task. In fact, it can be very hard to develop new thinking patterns that will translate into better dietary and lifestyle choices. Are you willing to put forth the effort necessary to create change in your life? As you read this chapter, you will be presented with tools and concepts to help you with this task. After that, it will be up to you.

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16.11: Nutrition and Your Health

Learning Objectives

- Relate the research on home-cooked family meals to comprehensive health and wellness, taste, sustainability, and the strengthening of family bonds

The adage, “you are what you eat,” seems to be more true today than ever. In recent years, consumers have become more conscientious about the decisions they make in the supermarket. Organically grown food is the fastest growing segment of the food industry. Also, farmers’ markets and chains that are health-food-oriented are thriving in many parts of North America. Shoppers have begun to pay more attention to the effect of food on their health and well-being. That includes not only the kinds of foods that they purchase, but also the manner in which meals are cooked and consumed. The preparation of food can greatly affect its nutritional value. Also, studies have shown that eating at a table with family members or friends can promote both health and happiness.

Family Meals

In the past, families routinely sat down together to eat dinner. But in recent decades, that comfortable tradition has fallen by the wayside. In 1900, 2 percent of meals were eaten outside of the home. By 2010, that figure had risen to 50 percent. Mark Hyman, MD, “How Eating at Home Can Save Your Life,” Huffington Post.com, 9 January 2011. http://www.huffingtonpost.com/dr-mark-hyman/family-dinner-how _b_806114.html? Today, family members often go their own way at mealtimes and when they do sit down together, about three times a week, the meal often lasts less than twenty minutes and is spent eating a microwaved meal in front of a television.

However, recent studies have shown that home-cooked, family meals really matter. Family meals usually lead to the consumption of healthy food packed with nutrition, rather than an intake of empty calories. Other benefits include strengthening familial bonds, improving family communication, and helping young children learn table manners. Increased frequency of family meals has also been associated with certain developmental assets, such as support, boundaries and expectations, commitment to learning, positive values, and social competency.Rochford, M. “Do Family Meals Still Matter?” *Visions: Family and Community Health Sciences* (Rutgers University) 21, no. 3 (2009).

Home-prepared meals provide an opportunity for more balanced and better-portioned meals with fewer calories, sodium, and less saturated fat. When families prepare food together, parents or caregivers can also use the time to teach children about the ways their dietary selections can affect their health.

The Adolescent Diet

Teenagers’ dietary choices are influenced by their family’s economic status, the availability of food inside and outside the home, and established traditions. Studies have found links between the prevalence of family meals during adolescence and the establishment of healthy dietary behaviors by young adulthood. Yet, many of today’s teenagers make food selections on their own, which often means eating junk food or fast food on the go.

However, adolescents who regularly consume family meals or have done so in the past are more likely to eat breakfast and to eat more fruits and vegetables. Research has shown that adolescents who have regular meals with their parents are 42 percent less likely to drink alcohol, 50 percent less likely to smoke cigarettes, and 66 percent less likely to use marijuana. Regular family dinners also help protect teens from bulimia, anorexia, and diet pills. In addition, the frequency of family meals was inversely related to lower academic scores and incidents of depression or suicide.Mark Hyman, MD, “How Eating at Home Can Save Your Life,” Huffington Post.com, 9 January 2011. http://www.huffingtonpost.com/dr-mark-hyman/family-dinner-how _b_806114.html?

Sustainable Eating

As discussed at the beginning of this chapter, sustainable agricultural practices provide healthy, nutritious food for the consumers of today, while preserving natural resources for the consumers of tomorrow. Sustainability not only has economic and environmental benefits, but also personal benefits, including reduced exposure to pesticides, antibiotics, and growth hormones. Sustainable eaters do all of the following:

- **Consume less processed food.** People who eat sustainably focus on whole foods that are high in nutritive value, rather than heavily processed foods with lots of additives.
- **Eat more home-cooked meals.** Sustainable eaters go out to restaurants less often, and when they do, they dine at establishments that provide dishes made from whole-food ingredients.
- **Consume a plant-based diet.** Research has shown that a plant-based diet, focused on whole grains, vegetables, fruits, and legumes, greatly reduces the risk of heart disease.
- **Buy organic food products.** Organically produced foods have been cultivated or raised without synthetic pesticides, antibiotics, or genetic engineering. Certified organic foods can be identified by the USDA's stamp.
- **Buy locally grown foods.** Buying locally benefits the environment by reducing the fossil fuels needed to transport food from faraway places. Also, farmers keep eighty to ninety cents for every dollar spent at a farmer's market.

Disease Prevention and Management

Eating fresh, healthy foods not only stimulates your taste buds, but also can improve your quality of life and help you to live longer. As discussed, food fuels your body and helps you to maintain a healthy weight. Nutrition also contributes to longevity and plays an important role in preventing a number of diseases and disorders, from obesity to cardiovascular disease. Some dietary changes can also help to manage certain chronic conditions, including high blood pressure and diabetes. A doctor or a nutritionist can provide guidance to determine the dietary changes needed to ensure and maintain your health.

Heart Health

According to the WHO, cardiovascular disease is the leading cause of death on the planet.World Health Organization. "The Top 10 Causes of Death." Accessed http://www.who.int/mediacentre/factsheets/fs310/en/. However, a healthy diet can go a long way toward preventing a number of conditions that contribute to cardiovascular malfunction, including high levels of blood cholesterol and narrowed arteries. As discussed in this text, it is extremely helpful to reduce the intake of trans fat, saturated fat, and sodium. This can considerably lower the risk of cardiovascular disease, or manage further incidents and artery blockages in current heart patients. It is also beneficial to eat a diet high in fiber and to include more omega-3 fatty acids, such as the kind found in mackerel, salmon, and other oily fish.

High Blood Pressure

Blood pressure is the force of blood pumping through the arteries. When pressure levels become too high, it results in a condition known as hypertension, which is asymptomatic but can lead to a number of other problems, including heart attacks, heart failure, kidney failure, and strokes. For people with high blood pressure, it can be beneficial to follow the same recommendations as those for heart patients. First of all, it is crucial to reduce the intake of sodium to prevent pressure levels from continuing to rise. It can also be helpful to increase potassium intake. However, patients should check with a doctor or dietitian first, especially if there are kidney disease concerns.

Tools for Change

The Dietary Approaches to Stop Hypertension, or DASH diet, is highly recommended to lower blood pressure. This program promotes an increased intake of potassium and calcium by emphasizing fruits, vegetables, whole grains, low-fat dairy products, and limited amounts of lean meat. The DASH diet also decreases the intake of saturated fat and sugar. Studies have shown that blood-pressure patients on the DASH diet were able to reduce their diastolic pressure levels (the lower measurement, which is taken between beats when the heart is relaxed) by up to 5 mmHg regardless of age, gender, or ethnicity. You can learn more about the DASH diet at http://dashdiet.org/.

Diabetes

The rising rates of diabetes have triggered a health crisis in the United States and around the world. In diabetics, the levels of blood glucose, or blood sugar, are too high because of the body's inability to produce insulin or to use it effectively. There are two types of this disease. Although the causes of Type 1 diabetes are not completely understood, it is known that obesity and genetics are major factors for Type 2.

Nutrition plays a role in lowering the risk of Type 2 diabetes or managing either form of the disease. However, it is a myth that there is one diabetes diet that every patient should follow. Instead, diabetics should keep track of the foods they consume that contain carbohydrates to manage and control blood-glucose levels. Also, a dietitian can help patients create a specific meal plan that fits their preferences, lifestyle, and health goals.

The Crisis of Obesity

Excessive weight gain has become an epidemic. According to the National Institutes of Health, over two-thirds of American adults are overweight, and one in three is obese. Obesity in particular puts people at risk for a host of complications, including Type 2 diabetes, heart disease, high cholesterol, hypertension, osteoarthritis, and some forms of cancer. The more overweight a person is, the greater his or her risk of developing life-threatening complications. There is no single cause of obesity and no single way to treat it. However, a healthy, nutritious diet is generally the first step, including consuming more fruits and vegetables, whole grains, and lean meats and dairy products.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Overweight and Obesity Statistics." *NIH Publication No. 04-4158*. Updated February 2010. win.niddk.nih.gov/publications/PDFs/stat904z.pdf.

Kidney Disease

Chronic kidney failure is the gradual loss of kidney function and can cause dangerous levels of fluid and waste to build up in the body. Nutrition is very important in managing end-stage renal disease, and a patient with this condition should discuss a meal plan with a dietitian and physician. Certain macro- and micronutrients will need to be monitored closely, including protein, potassium, sodium, and phosphorus. Kidney patients must also keep track of their caloric intake and dietitians may recommend consuming more fast-releasing carbohydrates and low-saturated fats to boost the number of calories consumed each day.

Cancer

Certain cancers are linked to being overweight or obese. Additionally, some foods are related to either an increased or decreased risk for certain cancers. Foods linked to decreased cancer risk include whole grains, high-fiber foods, fruits, and vegetables. Foods linked to increased cancer risk include processed meats and excess alcohol.

Digestive Disorders

Digestive disorders can include constipation, heartburn or gastroesophageal reflux disease, inflammatory bowel disease, including Crohn's and ulcerative colitis, and irritable bowel syndrome. These disorders should be addressed with a physician. However, for many of them, diet can play an important role in prevention and management. For example, getting enough fiber and fluids in your diet and being active can help to alleviate constipation.

Key Takeaways

More and more consumers are weighing nutritional considerations as they choose which foods to purchase and prepare for their families. Studies have shown that family meals and home-cooked food not only benefit a person's health, but also their overall well-being. Family meals lead to the consumption of healthy food, tighter familial bonds, improved communication, and the teaching of table manners to young children. Diet plays a key role in the prevention and management of many chronic conditions or diseases, such as hypertension and diabetes.

Discussion Starter

1. What would you recommend to help people who are struggling with diabetes? What tips would you provide? What lifestyle changes might help? Use the dietary guidelines at the Mayo Clinic's website to help provide specific suggestions. http://www.mayoclinic.com/health/diabetes-diet/DA00027.

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16.12: Diet Trends and Health

Learning Objectives

- Identify and describe the nutritional pros and cons of diets and food trends.
- Discuss the role of dietary supplements and the importance of using food as your primary nutritional source.

In the past, health was regarded merely as the absence of illness. However, a growing understanding of the complexity and potential of the human condition has prompted a new way of thinking about health. Today, we focus on the idea of wellness, which involves a great deal more than just not being sick. Wellness is a state of optimal well-being that enables an individual to maximize their potential. This concept includes a host of dimensions—physical, mental, emotional, social, environmental, and spiritual—which affect one's quality of life.University of Illinois at Urbana-Champaign, McKinley Health Center. "What Is Wellness?" © 2011 The Board of Trustees of the University of Illinois at Urbana-Champaign. www.mckinley.illinois.edu/Units/Health_Ed/wellness.htm. Striving for wellness begins with an examination of dietary choices.

Dietary Food Trends

Hundreds of years ago, when food was less accessible and daily life required much more physical activity, people worried less about obesity and more about simply getting enough to eat. In today's industrialized nations, conveniences have solved some problems and introduced new ones, including the hand-in-hand obesity and diabetes epidemics. Fad diets gained popularity as more North Americans struggled with excess pounds. However, new evidence-based approaches that emphasize more holistic measures are on the rise. These new dietary trends encourage those seeking to lose weight to eat healthy, whole foods first, while adopting a more active lifestyle. These sound practices put dietary choices in the context of wellness and a healthier approach to life.

Functional Foods

Many people seek out foods that provide the greatest health benefits. This trend is giving rise to the idea of functional foods, which not only help meet basic nutritional needs but also are reported to fight illness and aging. According to the Academy of Nutrition and Dietetics (AND), formerly known as the The Academy of Nutrition and Dietetics, functional foods may reduce the risk of disease or promote optimal health. The AND recognizes four types of functional foods.The Academy of Nutrition and Dietetics. "Functional Foods." *J Am Diet Assoc* 109, no. 4 (April 2009): 735–46. www.eatright.org/About/Content.aspx?id=8354. They are: conventional foods, modified foods, medical foods, and special dietary use foods.

The first group, **conventional foods**, represents the simplest form of functional foods. They are whole foods that have not been modified. Examples include whole fruits and vegetables (which are abundant in phytochemicals and antioxidants), yogurt and kefir (which contain natural probiotic bacteria that can help maintain digestive system health), and dark chocolate (which contains antioxidants).

Modified foods have been fortified, enriched, or enhanced with additional nutrients or bioactive compounds. Foods are modified using biotechnology to improve their nutritional value and health attributes. Examples of modified foods include calcium-fortified orange juice, breads enriched with B vitamins, iodized salt, cereals fortified with vitamins and minerals, margarine enhanced with plant sterols, and energy drinks that have been enriched with herbs (ginseng or guarana) or amino acids (taurine). It is important to consider that the health claims of some modified foods may be debatable, or entirely fraudulent. Check with a health professional regarding the effects of modified foods on your health.

Medical foods are designed for enteric administration under the guidance of a medical professional. (During enteric administration, food is treated so that it goes through the stomach undigested. Instead, the food is broken down in the intestines only.) Medical foods are created to meet very specific nutritional requirements. Examples of medical foods include liquid formulas for people with kidney disease, liver disease, diabetes, or other health issues. Medical food is also given to comatose patients through a gastronomy tube because they cannot eat by mouth.

Special dietary use foods do not have to be administered under a doctor's care and can be found in a variety of stores. Similar to medical foods, they address special dietary needs and meet the nutritional requirements of certain health conditions. For example, a bottled oral supplement administered under medical supervision is a medical food, but it becomes a special dietary use food when it is sold to retail customers. Examples of special dietary use foods include gluten-free foods, lactose-free dairy products, and formulas and shakes that promote weight loss.

Popular Diets

The concept of functional foods represents initiatives aimed at addressing health problems. Certain diet plans take this concept one step further, by striving to prevent or treat specific conditions. For example, it is widely understood that people with diabetes need to follow a particular diet. Although some of these diet plans may be nutritionally sound, use caution because some diets may be fads or be so extreme that they actually *cause* health problems.Web MD. “Alternative Diet Programs: Topic Overview.” Last modified June 30, 2009. http://www.webmd.com/diet/tc/alternative-diet-programs-topic-overview. Before experimenting with a diet, discuss your plans with your doctor or a registered dietitian. Throughout this section, we will discuss some of the more popular diets. Some fall under the category of fad diets, while others are backed by scientific evidence. Those that fall into the latter category provide a good foundation to build a solid regimen for optimal health.

The DASH Diet

The Dietary Approaches to Stop Hypertension, or DASH diet, focuses on reducing sodium intake to either 2,300 milligrams per day (as recommended by the *Dietary Guidelines for Americans*) or 1,500 milligrams per day. The DASH diet is an evidence-based eating plan that can help reduce high blood pressure. This plan may also decrease the risk of heart attack, stroke, diabetes, osteoporosis, and certain cancers.DASH Diet Oregon. “DASH Diet Eating Plan.” © 2011 Nutrition Education Services/Oregon Dairy Council. http://www.dashdietoregon.org/. DASH tips to lower sodium include:

- Using spices instead of salt to add flavor
- Reading sodium content on processed or canned food labels, and choosing low-sodium options
- Removing some sodium from canned foods (such as beans) by rinsing the product before consumption
- Avoiding salt when cooking

DASH dieters eat lots of whole grains and high-fiber fruits and vegetables, and moderate amounts of low-fat dairy products, lean meats, and heart-healthy fish. In addition, DASH limits the use of saturated fats to less than 7 percent of total calories, and restricts the consumption of sweets and alcohol. The DASH diet also calls for consuming less added sugar and drinking fewer sugar-sweetened drinks. It replaces red meat with fish and legumes and calls for increased calcium, magnesium, potassium, and fiber. Also, even though some people on the DASH diet may find it lowers their HDL (good) cholesterol along with their LDL (bad) cholesterol, it still has a positive cumulative effect on heart health.DASH Diet Oregon. “DASH Diet Eating Plan.” © 2011 Nutrition Education Services/Oregon Dairy Council. http://www.dashdietoregon.org/.

The Gluten-Free Diet

The gluten-free diet helps people whose bodies cannot tolerate **gluten**, a protein found in wheat, barley, and rye. One of the most important ways to treat this condition is to avoid the problematic foods, which is not easy. Although following a gluten-free diet is challenging, it is prescribed for patients with gluten intolerance and celiac disease, an autoimmune disorder with a genetic link. People who have celiac disease cannot consume gluten products without damaging their intestinal lining. Eating a gluten-free diet means finding replacements for bread, cereal, pasta, and more. It also means emphasizing fresh fruits, vegetables, and other foods without gluten. However, it is important to note that the gluten-free trend has become something of a fad even for those without a gluten intolerance. Celiac disease is a relatively rare condition found in only 1 percent of the population. Therefore, a gluten-free diet should be followed only with a physician’s recommendation.

Low-Carb Diets

Low-carb diets, which include the Atkins Diet and the South Beach Diet, focus on limiting carbohydrates—such as grains, fruit, and starchy vegetables—to promote weight loss. The theory behind the low-carb diet is that insulin prevents the breakdown of fat by allowing sugar in the form of blood glucose to be used for energy. Proponents of this approach believe that because limiting carbs generally lowers insulin levels, it would then cause the body to burn stored fat instead. They believe this method not only brings about weight loss, but also reduces the risk factors for a number of conditions. However, some studies have shown that people who followed certain low-carb diet plans for two years lost an average of nearly 9 pounds, which is similar to the amount of weight lost on higher carbohydrate diets.The Mayo Clinic. “Low-Carb Diet: Can It Help You Lose Weight?” Accessed December 21, 2011. http://www.mayoclinic.com/health/low-carb-diet/NU00279.

The benefits of this kind of diet include an emphasis on whole, unprocessed foods and a de-emphasis of refined carbohydrates, such as white flour, white bread, and white sugar. However, there are a number of downsides. Typically, the first two weeks allow for only 20 grams of carbs per day, which can be dangerously low. In addition, dieters using the low-carb approach tend to consume twice as many saturated fats as people on a diet high in healthy carbohydrates. Low-carb diets are also associated with a

higher energy intake, and the notion that “calories don’t count,” which is prevalent in this kind of diet, is not supported by scientific evidence.Steele, V. “Health and Nutritional Effects of Popular Diets.” Kellogg Nutrition Symposium, The Team of Registered Dietitians & Nutrition Professionals at Kellogg Canada Inc. Insert to *Canadian Journal of Dietetic Practice and Research* 64, no. 3 (Fall 2003).

The Macrobiotic Diet

The macrobiotic diet is part of a health and wellness regimen based in Eastern philosophy. It combines certain tenets of Zen Buddhism with a vegetarian diet and supports a balance of the oppositional forces *yin* and *yang*. Foods are paired based on their so-called yin or yang characteristics. Yin foods are thought to be sweet, cold, and passive, while yang foods are considered to be salty, hot, and aggressive.

Whole grains make up about 50 percent of the calories consumed and are believed to have the best balance of yin and yang. Raw and cooked vegetables comprise about 30 percent of the diet and include kale, cabbage, collards, bok choy, and broccoli on a daily basis, along with mushrooms and celery a few times a week. Bean or vegetable-based soups and broths can make up 5 to 10 percent of daily caloric intake. Additionally, the diet allows small amounts of fish and seafood several times a week, along with a few servings of nuts. The macrobiotic diet prohibits certain foods, such as chocolate, tropical fruits, and animal products, because they are believed to fall on the far end of the yin-yang spectrum, which would make it difficult to achieve a Zen-like balance.

The macrobiotic diet focuses on foods that are low in saturated fats and high in fiber, which can help to lower the risk of cardiovascular disease. Proponents of this diet also believe that it may protect against cancer. However, many nutritionists and healthcare providers express concerns, particularly if the diet is followed strictly. Extreme macrobiotic eating can be low in protein, low in calories, and pose a risk for starvation. In addition, the diet is also very low in essential vitamins and minerals.Zelman, K.M. “Macrobiotic Diet.” Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/macrobiotic-diet.

The Mediterranean Diet

The traditional Mediterranean diet incorporates many elements of the dietary choices of people living in Greece and southern Italy. The Mediterranean diet focuses on small portions of nutritionally-sound food. This diet features food from plant sources, including vegetables, fruits, whole grains, beans, nuts, seeds, breads and potatoes, and olive oil. It also restricts the consumption of processed foods and recommends eating locally grown foods rich in micronutrients and antioxidants. Other aspects of this eating plan include consuming fish and poultry at least twice per week, eating red meat only a few times per month, having up to seven eggs per week, and drinking red wine in moderation and with meals. Unlike most diets, the Mediterranean diet does not cut fat consumption across the board. Instead, it incorporates low-fat cheese and dairy products, and it substitutes olive oil, canola oil, and other healthy oils for butter and margarine.

More than fifty years of nutritional and epidemiological research has shown that people who follow the Mediterranean diet have some of the lowest rates of chronic disease and the highest rates of longevity among the populations of the world. Studies have shown that the Mediterranean diet also helps to decrease excess body weight, blood pressure, blood fats, and blood sugar and insulin levels significantly.Kovacs, J. S. “Popular Diets of the World: The Mediterranean Diet.” Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/the-mediterranean-diet.

Tools for Change

For six years, researchers from the University of Bordeaux in France followed the dietary habits of more than seven thousand individuals age sixty-five and over. Participants who described greater consumption of extra-virgin olive oil reportedly lowered their risk of suffering a stroke by 41 percent. The study controlled for stroke risk factors, such as smoking, alcohol intake, high blood pressure, and a sedentary lifestyle. To increase the amount of olive oil in your diet, try spreading olive oil instead of butter on your toast, making your own salad dressing using olive oil, vinegar or lemon juice, and herbs, cooking with olive oil exclusively, or simply adding a dose of it to your favorite meal.Holohan, E. “More Olive Oil in Diet Could Cut Stroke Risk: Study.” HealthFinder.gov, US Department of Health and Human Services. © 2011 Health Day. healthfinder.gov/news/newsstory.aspx?docID=653917.

The Raw Food Diet

The raw food diet is followed by those who avoid cooking as much as possible in order to take advantage of the full nutrient content of foods. The principle behind **raw foodism** is that plant foods in their natural state are the most wholesome for the body. The raw food diet is not a weight-loss plan, it is a lifestyle choice. People who practice raw foodism eat only uncooked and

nonprocessed foods, emphasizing whole fruits and vegetables. Staples of the raw food diet include whole grains, beans, dried fruits, seeds and nuts, seaweed, sprouts, and unprocessed produce. As a result, food preparation mostly involves peeling, chopping, blending, straining, and dehydrating fruits and vegetables.

The positive aspects of this eating method include consuming foods that are high in fiber and nutrients, and low in calories and saturated fat. However, the raw food diet offers little in the way of protein, dairy, or fats, which can cause deficiencies of the vitamins A, D, E, and K. In addition, not all foods are healthier uncooked, such as spinach and tomatoes. Also, cooking eliminates potentially harmful microorganisms that can cause foodborne illnesses. Therefore, people who primarily eat raw foods should thoroughly clean all fruit and vegetables before eating them. Poultry and other meats should *always* be cooked before eating.Web MD. “Raw Food Diet.” Accessed December 21, 2011. www.webmd.com/diet/guide/raw-food-diet.

Vegetarian and Vegan Diets

Vegetarian and vegan diets have been followed for thousands of years for different reasons, including as part of a spiritual practice, to show respect for living things, for health reasons, or because of environmental concerns. For many people, being a vegetarian is a logical outgrowth of “thinking green.” When a food system is heavily focused on meat production there are deforestation issues, overgrazing of land and pasturage, and animal abuses. By avoiding animal flesh, vegetarians hope to look after their own health and that of the planet at the same time. Broadly speaking, vegetarians eat beans, grains, and fruits and vegetables, and do not eat red meat, poultry, seafood, or any other animal flesh. Some vegetarians, known as lactovegetarians, will eat dairy products. Others, known as lacto-ovo vegetarians, will eat dairy products and eggs. A vegan diet is the most restrictive vegetarian diet—vegans do not eat dairy, eggs, or other animal products, and some do not eat honey.

Vegetarian diets have a number of benefits. Well-balanced eating plans can lower the risk of a number of chronic conditions, including heart disease, diabetes, and obesity. They also help to promote sustainable agriculture. However, if a vegetarian does not vary his or her food choices, the diet may be insufficient in calcium, iron, omega-3 fatty acids, zinc, and vitamin B_{12}. Also, if people who follow these diets do not plan out their meals, they may gravitate toward foods high in fats.

Table 16.11.1: The Pros and Cons of Seven Popular Diets

Diet	Pros	Cons
DASH Diet	• Recommended by the National Heart, Lung, and Blood Institute, the American Heart Association, and many physicians • Helps to lower blood pressure and cholesterol • Reduces risk of heart disease and stroke • Reduces risk of certain cancers • Reduces diabetes risk	• There are very few negative factors associated with the DASH diet
Gluten-Free Diet	• Reduces the symptoms of gluten intolerance, such as chronic diarrhea, cramping, constipation, and bloating • Promotes healing of the small intestines for people with celiac disease, preventing malnutrition • May support weight loss • May be beneficial for other autoimmune diseases, such as Parkinson’s disease, rheumatoid arthritis, and multiple sclerosis • May be helpful for Types 1 and 2 diabetes and anemia	• Risk of folate and iron deficiencies • Special gluten-free products can be hard to find and expensive • Requires constant vigilance and careful food label reading, since gluten is found in many products

Diet	Pros	Cons
Low-Carb Diet	• Restricts refined carbohydrates, such as white flour and white sugar • May temporarily improve blood sugar or blood cholesterol levels	• Not entirely evidence-based • Results in higher fat and protein consumption
Macrobiotic Diet	• Low in saturated fats and high in fiber • Emphasizes whole foods and de-emphasizes processed foods • Rich in phytoestrogens, which may reduce the risk of estrogen-related cancers	• Not entirely evidence-based • Lacks certain vitamins and minerals; supplements are often required • Can result in a very low caloric intake • Lack of energy may result from inadequate protein
Mediterranean Diet	• A reduced risk of cardiovascular disease and mortality • A lower risk of cancer • De-emphasizes processed foods and emphasizes whole foods and healthy fats • Lower sodium intake, due to fewer processed foods • Emphasis on monosaturated fats leads to lower cholesterol • Highlighting fruits and vegetables raises consumption of antioxidants	• Does not specify daily serving amounts • Potential for high fat and high calorie intake as nuts and oils are calorie-dense foods • Drinking one to two glasses of wine per day may not be healthy for those with certain conditions
Raw Food Diet	• Emphasizes whole foods • Focuses on nutritionally-rich foods • High in fiber	• Not entirely evidence-based • Very restrictive and limits protein and healthy fat intake • Could encourage the development of foodborne illness • Extremely difficult to follow • Can cause deficiencies in essential vitamins
Vegetarianism and Veganism	• May reduce cancer risk • May reduce heart disease risk • May reduce obesity risk • May help prevent Type 2 diabetes • Helps with weight reduction and weight maintenance	• Guidelines regarding fat and nutrient consumption must be followed • Requires vigilance to watch out for hidden animal products • Requires negotiating meals and holidays with meat-eating friends and family

Food Supplements and Food Replacements

Current trends also include the use of supplementation to promote health and wellness. Vitamins, minerals, herbal remedies, and supplements of all kinds constitute big business and many of their advertising claims suggest that optimal health and eternal youth are just a pill away. The main types of dietary supplements are macronutrients (amino acids, proteins, essential fatty acids), micronutrients (vitamins and minerals that promote healthy body functions), probiotics (beneficial bacteria such as the kind found in the intestines), and herbal supplements, which often target a specific body part, such as bones.



Figure 16.11.1: Multivitamins contain multiple micronutrients, such as vitamins and dietary minerals. Are dietary supplements really necessary to achieve optimal health? from Rageross (via Wikipedia)

Some public health officials recommend a daily multivitamin due to the poor diet of most North Americans. The US Preventive Task Force also recommends a level of folate intake which can be easier to achieve with a supplement. In addition, the following people may benefit from taking daily vitamin and mineral supplements:

- women who are pregnant or breast-feeding
- premenopausal women who may need extra calcium and iron
- older adults
- people with health issues that affect their ability to eat
- vegetarians, vegans, and others avoiding certain food groupsWatson, S. “How to Evaluate Vitamins and Supplements.” Web MD. Accessed December 21, 2011. http://www.webmd.com/vitamins-and-supplements/lifestyle-guide -11/how-to-evaluate-vitamins-supplements.

However, before you begin using dietary supplementation, consider that the word *supplement* denotes something added. Vitamins, minerals, and other assorted remedies should be considered as extras. They are add-ons—not replacements—for a healthy diet. As food naturally contains nutrients in its proper package, remember that food should always be your primary source of nutrients. When considering taking supplements, it is important to recognize possible drawbacks that are specific to each kind:

Micronutrient Supplements. Some vitamins and minerals are toxic at high doses. Therefore, it is vital to adhere to the Tolerable Upper Intake Levels (UL) so as not to consume too much of any vitamin. For example, too much vitamin A is toxic to the liver. Symptoms of vitamin A toxicity can include tinnitus (ringing in the ears), blurred vision, hair loss, and skin rash. Too much niacin can cause a peptic ulcer, hyperglycemia, dizziness, and gout.

Herbal Supplements. Some herbs cause side effects, such as heart palpitations and high blood pressure, and must be taken very carefully. Also, some herbs have contraindications with certain medicines. For example, Valerian and St. John’s Wort negatively interact with certain prescription medications, most notably antidepressants. Additionally, there is a real risk of overdosing on herbs because they do not come with warning labels or package inserts.

Amino Acid Supplements. Certain amino acid supplements, which are taken by bodybuilders among others, can increase the risk of consuming too much protein. An occasional amino acid drink in the place of a meal is not a problem. However, problems may arise if you add the supplement to your existing diet. Most Americans receive two to three times the amount of protein required on a daily basis from their existing diets—taking amino acid supplements just adds to the excess.Web MD. “Choosing a Vitamin and Mineral Supplement—Topic Overview.” Last revised May 4, 2011. http://www.webmd.com/food-recipes/tc/choosing-a-vitamin -and-mineral-supplement-topic-overview.

Supplement Claims and Restrictions

The Food and Drug Administration (FDA) regulates supplements, but it treats them like food rather than pharmaceuticals. Dietary supplements must meet the FDA’s Good Manufacturing Standards, but are not required to meet the standards for drugs, although some companies do so voluntarily. Also, although supplement manufacturers are allowed to say a particular ingredient may reduce the risk of a disease or disorder, or that it might specifically target certain body systems, these claims are not approved by the FDA. This is why labels that make structural and functional claims are required to carry a disclaimer saying the product is not intended “to diagnose, treat, cure, or prevent any disease.” In addition, in the United States, supplements are taken off the market only after

the FDA has proven that they are hazardous.Watson, S. “How to Evaluate Vitamins and Supplements.” Web MD. Accessed December 21, 2011. http://www.webmd.com/vitamins-and-supplements/lifestyle-guide -11/how-to-evaluate-vitamins-supplements.

Before Taking Supplements

The phrase *caveat emptor* means “buyer beware,” and it is important to keep the term in mind when considering supplementation. Just because a product is “natural” that does not mean it can’t be harmful or dangerous, particularly if used inappropriately. The following are helpful questions to explore before deciding to take a supplement:

- Does the scientific community understand how this supplement works and are all its effects well known?
- Is there proof that the supplement actually performs in the manner that it claims?
- Does this supplement interact with food or medication?
- Is taking this supplement necessary for my health?
- Is the supplement affordable?
- Is the supplement safe and free from contaminants?

Lastly, please remember that a supplement is only as good as the diet that accompanies it. We cannot overstate the importance of eating a healthy, well-balanced diet designed to provide all of the necessary nutrients. Food contains many more beneficial substances, such as phytochemicals and fiber, that promote good health and cannot be duplicated with a pill or a regimen of supplements. Therefore, vitamins and other dietary supplements should never be a substitute for food. Nutrients should always be derived from food first.

Key Takeaways

Attitudes toward food change over time, so it is important to ground dietary choices in fact, not fashion. Popular, evidence-based diets, such as the Mediterranean diet, the DASH diet, vegetarianism, and the gluten-free diet offer different approaches to promoting health, and each has its own benefits and risks. It is important to weigh the pros and cons of dietary supplementation. There are risks of overdosing and risks of contraindications with certain medications. Although supplements can be helpful, it is important to remember—food first!

Discussion Starter

1. Discuss the Mediterranean diet. What foods do you already consume that are recommended by this diet? What changes could you make to follow the diet more closely? How can you modify any concerns so that this diet will work for you?

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16.13: Threats to Health

Learning Objectives

- Discuss the roles of nutrition and lifestyle choices in the prevention and management of chronic disease.

Chronic Diseases

Chronic diseases are ongoing, life-threatening, and life-altering health challenges. They are the leading cause of death worldwide. Chronic conditions are increasing in frequency. They cause significant physical and emotional suffering and are an impediment to economic growth and vitality. It is important, now more than ever, to understand the different risk factors for chronic disease and to learn how to prevent their development.



Figure 16.12.1*: Obesity is a risk factor for a number of conditions, including arthritis and certain cancers. A "super obese" male with a BMI of 53 kg/m^2: weight 182 kg (400 lb), height 185 cm (6 ft 1 in). Image is public domain.*

The Risk Factors of Chronic Disease

A **risk factor** is a signal that your chances for acquiring a chronic disease may be increased. You might liken a risk factor to the flags that lifeguards sometimes set up at beaches. When you see these flags, you know immediately that swimming within the marked areas could be hazardous, and that if you choose to swim within these parameters anyway, you are doing so at your own risk. But, if you heed the warnings, you are taking the necessary step to protect your safety and health. Similarly, risk factors are warning signs that coincide with the development and progression of disease. However, risk factors are not a 100-percent guarantee that a person will develop a chronic disease, only that the conditions are right. For example, if a person gets sick with the flu, we can say with certainty that the illness was caused by a virus. However, we cannot say that a sedentary lifestyle caused the onset of cardiovascular disease in a patient, because a risk factor indicates a correlation, not a causation.

Chronic disease usually develops alongside a combination of the following risk factors: genetics, a prior disease such as obesity or hypertension, dietary and lifestyle choices, and environmental problems. Risk factors such as genetics and age cannot be changed. However, some risk factors can be altered to promote health and wellness (such as diet). For example, a person who continuously eats a diet high in sugars, saturated fats, and red meat is at risk for becoming obese and developing Type 2 diabetes, cardiovascular disease, or several other conditions. Making more healthy dietary choices can greatly reduce that risk. Being a woman over age sixty-five is a risk factor for developing osteoporosis, but that cannot be changed. Also, people without a genetic predisposition for a particular chronic illness can still develop it. Not having a genetic predipostion for a chronic disease is not a guarantee of immunity.

Identifying Your Risk Factors

To estimate your own risk factors for developing certain chronic diseases, search through your family's medical history. What diseases do you note showing up among close blood relatives? This may be of concern to you. At your next physical, pay attention to your blood tests and ask the doctor if any results are out of normal range. It is also helpful to note your vital signs, particularly your blood pressure and resting heart rate. In addition, you may wish to keep a food diary to make a note of the dietary choices that you make on a regular basis and be aware of foods that are high in saturated fat, among other unhealthy options. As a general rule, it is important to look for risk factors that you can modify.to promote your health. For example, if you discover that your grandmother, aunt, and uncle all suffered from high blood pressure, then you may decide to avoid a high sodium diet. Identifying your risk factors can arm you with the information you need to help ward off disease.

Cardiovascular Disease

Throughout the remainder of this section, we will examine some of the more prevalent chronic diseases, their risk factors, and the choices that can help to discourage their development or progression. Let's begin with cardiovascular disease. According to the Centers for Disease Control and Prevention (CDC), heart disease is the leading cause of death in the United States.Centers for Disease Control and Prevention. "Leading Causes of Death." Last updated September 6, 2011. http://www.cdc.gov/nchs/fastats/lcod.htm. The disease generally starts with atherosclerosis, or a hardening of the arteries, a chronic condition so common that most people show signs of it by the time they turn thirty. Arteries start to narrow and harden when fats accumulate along their inner walls and form plaques. A plaque is made of fat, cholesterol, calcium, and other substances found in blood.

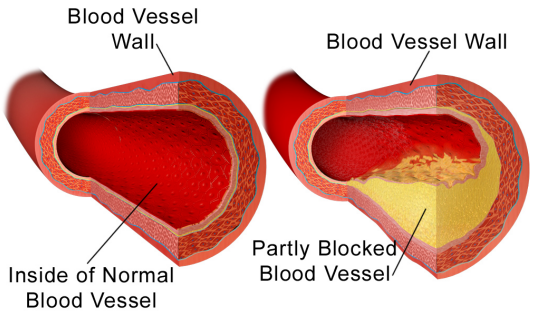


Figure 16.12.2: Illustration comparing a normal blood vessel and partially blocked vessel due to atherosclerotic plaque build-up. Plaque formation along arterial walls impedes blood flow and can create a thrombus, or stationary blood clot. from BruceBlaus (via Wikipedia). For a video of the process click here.

Plaque formation causes arteries to narrow and harden, which elevates blood pressure because the vessels can't expand effectively to accommodate blood pulses. Higher blood pressure strains the heart and causes more damage. Arterial walls can become so weakened due to high blood pressure that they balloon and form what is known as an aneurysm. If the aneurysm bursts, it becomes a life-threatening event. The plaques themselves can also rupture due to a spike in blood pressure or a tremor along an arterial wall, and the body responds to this perceived injury by forming blood clots. These clots are serious health threats, whether they are stationary (a thrombus) or moving (an embolus). A stable clot can slowly kill off surrounding tissue, or grow so big that it blocks blood circulation and causes thrombosis. When a moving clot becomes stuck in an artery too small for its passage, it cuts off blood flow and causes cell death. This is referred to as an embolism. Blood clots in heart and brain arteries can cause heart attacks or strokes.

Table 16.12.1: The Risk Factors for Cardiovascular Disease

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases for men at forty-five, and for women at fifty-five. • **Sex.** Men have a higher risk than women, though the risk for women steeply rises after menopause. • **Family history.** The more family members who have heart disease, the greater the risk.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of atherosclerosis. • **Obesity.** Excess weight worsens other risk factors. • **Diabetes.** This condition is associated with an increased risk of heart disease. Both types have certain risk factors in common, including obesity and high blood pressure. • **Physical inactivity.** Lack of exercise is associated with heart disease. • **Cholesterol levels.** High levels of blood cholesterol can increase the risk. A high level of low-density lipoprotein (LDL), or the "bad" cholesterol, is a common contributing factor. However, a low level of high-density lipoprotein (HDL), or "good" cholesterol, can also promote atherosclerosis.

Steps to Reducing the Risk of Cardiovascular Disease

Diet and nutrition can play a significant role in reducing the risk of cardiovascular disease. It is helpful to lower sodium intake, increase consumption of dietary fiber, and limit consumption of saturated fat, which promotes plaque formation. In addition, it is important to replace refined starches and added sugar, which can boost triglycerides, with whole grains, fruits, and vegetables. Eating foods rich in omega-3 fatty acids, especially fish, using alcohol in moderation, and opting for low or no-fat dairy products can all help reduce your cardiovascular disease risk. Emphasizing vegetable-based sources of protein, such as beans and legumes, can be beneficial, as well as consuming more soy products. It is also important to maintain a healthy weight, manage cholesterol levels, and avoid smoking or chewing tobacco.

Hypertension

Chronic high blood pressure, also known as hypertension, is a significant health hazard affecting one out of three adults in the United States.Centers for Disease Control and Prevention. “High Blood Pressure Facts.” Last updated March 21, 2011. www.cdc.gov/bloodpressure/facts.htm. This chronic condition is a major cause of heart attacks and strokes, yet it has no symptoms until blood pressure reaches very high levels, which is why it is known as “the silent killer.” The only way to find out if you have high blood pressure is to get an accurate reading of your resting blood pressure rate, which is best done by a medical professional and should be monitored regularly.

High blood pressure is such an important factor in cardiovascular disease, that keeping it within a healthy range is vitally important. As explained previosuly, blood pressure readings consist of two numbers. The top number measures **systolic** pressure (when the heart contracts) and the bottom number measures **diastolic** pressure (when the heart is at rest). The key blood pressure numbers to keep in mind are:

- **Ideal.** 120 over 80 or below
- **Prehypertension.** Higher than 120 over 80 and lower than 139 over 89
- **Hypertension.** Greater than 139 over 89

Table 16.12.2: The Risk Factors for Hypertension

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** After fifty-five, the risk of developing high blood pressure is 90 percent. • **Race.** African-Americans are more likely to develop hypertension, manifest it at a younger age, and have higher blood pressure readings. • **Family history.** There is a strong genetic component to high blood pressure, and an individual’s risk goes up along with the number of family members who have hypertension.	• **Weight.** Roughly 60 percent of people with hypertension are obese. • **Sodium consumption.** The more salt in a person’s diet, the more likely they are to have high blood pressure. • **Alcohol.** Drinking more than two drinks per day for men and one drink for women increases the likelihood of hypertension. • **Diet.** In addition to salt and alcohol consumption, other dietary factors increase chances of developing hypertension.

Steps to Reducing the Risk of High Blood Pressure

Although it is not possible to change one’s age or genetics, there are actions that people can take to decrease their risk of hypertension. Techniques to reduce blood pressure include becoming physically active, maintaining a healthy weight, reducing sodium intake below 2,400 milligrams per day (or below 1,500 milligrams if you are in a high-risk group or already have been diagnosed with hypertension), using alcohol moderately, and following the DASH diet, which was outlined in Section 15.1. Additionally, vitamin C, calcium, and potassium have all been shown to promote healthy blood pressure. It is also vital to monitor your blood pressure levels on a regular basis. Prompt intervention when readings rise above the ideal level (120 over 80) can save lives, which is why everyone should know the status of their blood pressure.

Cancer

More than one hundred diseases are classified as different forms of cancer, all of them characterized by the uncontrolled growth of abnormal cells. Cancer is triggered by mutations in a cell’s genetic material. The cause of these changes may be inherited, or it may result from exposure to carcinogens, which are agents that can cause cancer. Carcinogens include chemicals, viruses, certain medical treatments such as radiation, pollution, or other substances and exposures that are known or suspected to cause cancer.American Cancer Society. “Known and Probable Human Carcinogens.” Last medical review June 29, 2011. http://www.cancer.org/Cancer/CancerCauses/OtherCarcinogens/GeneralInformationaboutCarcinogens/known-and-probable -

human-carcinogens. The National Institutes of Health has classified fifty-four different compounds as known cancer-causing agents in humans.Brett Israel, “How Many Cancers Are Caused by the Environment?” *Scientific American*, 21 May 2010. http://www.scientificamerican.com/article.cfm?id=how-many -cancers-are-caused-by-the-environment.

Under normal conditions, a healthy cell will either repair any damage that has been done or self destruct so that no future cells will be affected. Cells become cancerous when their DNA is damaged, but they do not self-destruct or stop reproducing as normal cells would. As these abnormal cells continue their rapid growth, in most cancers they coalesce in a mass called a tumor. Cancer cells can overwhelm healthy cells and interfere with the healthy functioning of the body. They can also invade other organs and spread throughout the body in a process known as metastasis. Scientists and the medical community are giving considerable attention to the early stages of cancer, from the moment a healthy cell is exposed to a carcinogen to the point where cells with damaged DNA are replicating out of control. Intervention at any of these early stages could prove to be quite beneficial, because it is thought that most cancers are the result of lifestyle choices and environmental exposure.

The risk factors for different cancers can vary. For example, exposure to ultraviolet radiation from the sun and from tanning beds is a risk factor for skin cancer, while exposure to asbestos is a risk factor for mesothelioma cancer. Table 15.4.3 shows some common risk factors for a number of different types of cancer.

Table 16.12.3: The Risk Factors for Cancer

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Most cancers occur in people over the age of sixty-five. However, people of all ages, including children, can get cancer. • **Family history.** Certain types of cancer have a genetic link. However, environmental factors may also play a part.	• **Tobacco.** Smoking or chewing tobacco greatly increases the risk for certain cancers, including cancer of the lungs, bladder, cervix, kidneys, mouth, and pancreas. • **Alcohol.** Drinking alcohol is linked to cancers of the mouth, throat, esophagus, and breast, as well as to cancers of the neck and head. • **Obesity.** Linked to cancers of the colon, uterus, pancreas, esophagus, kidney, and breast. • **Cooking techniques.** Grilling, smoking, and preparing meat at high temperatures forms carcinogens. • **Red meat.** The risk of colon cancer seems to increase with the consumption of red meat and processed meat. • **Cured meats.** According to a recent study, there is a mild risk of pancreatic cancer with the consumption of cured meats, such as sausage, pepperoni, bacon, ham, smoked turkey, salami, and hot dogs. • **Physical inactivity.** Linked to colon, breast, and other cancers. • **Exposure to chemicals.** People who have jobs that expose them to chemicals on a regular basis, such as construction workers and painters, have an increased risk of cancer. • **Viruses or bacteria.** Certain viruses or bacteria may increase the risk of developing cancer. For example, human papillomaviruses, which are sexually transmitted, are the primary cause of cervical cancer.

Steps to Reducing the Risk of Cancer

According to the American Cancer Society, half of all American men and one-third of American women will be diagnosed with some form of cancer in their lifetime.American Cancer Society. “What Is Cancer?” Last medical review March 19, 2010. http://www.cancer.org/Cancer/CancerBasics/what-is-cancer. Although cancer is one of the leading causes of death worldwide, ongoing research and innovations in treatment have improved the outlook for cancer patients to the point where millions now survive or live with cancer, making it a chronic disease.

The American Institute for Cancer Research (AICR) has published guidelines for preventing cancer and staying healthy. They include several dietary and lifestyle choices, such as participating in physical activity for thirty minutes per day or more, and maintaining a healthy weight. In addition, AICR recommends consuming a plant-based diet.American Institute for Cancer

Research. “Guidelines for Cancer Prevention.” No. E93-GL. © November 2007. http://preventcancer.aicr.org/site/DocServer/Guidelines_Brochure.pdf?docID=3561. Several epidemiological studies have found a link between eating plenty of fruits and vegetables and a low incidence of certain cancers. Fruits and vegetables containing a wide variety of nutrients and phytochemicals may either prevent or reduce the oxidative damage to cell structures. Cruciferous vegetables, such as cauliflower, broccoli, and Brussels sprouts, may also reduce the risk of certain cancers, such as endometrial, esophageal, and others. Also, studies have shown that the more fiber you have in your diet, the lower your risk of colon cancer.

Supplementation may also be helpful to a limited degree. Vitamin D and antioxidants have been linked to lowering the risk of some cancers (however taking an iron supplement may promote others). But, obtaining vital nutrients from food first is the best way to help prevent or manage cancer. In addition, regular and vigorous exercise can lower the risk of breast and colon cancers, among others. Also, wear sunblock, stay in the shade, and avoid the midday sun to protect yourself from skin cancer, which is one of the most common kinds of cancer.Mayo Clinic. “Cancer Prevention: 7 Steps to Reduce Your Risk.” September 21, 2010. Accessed December 21, 2011. http://www.mayoclinic.com/health/cancer -prevention/CA00024.

Diabetes

The World Health Organization reports that more than 346 million people around the world have diabetes and they predict that deaths due to the consquences of diabetes will double from 2005 to 2030.World Health Organization. “Diabetes.” *Fact Sheet*, no. 312. August 2011. http://www.who.int/mediacentre/factsheets/fs312/en/. **Diabetes mellitus** is a metabolic disorder that results when the pancreas does not produce enough insulin to meet its needs or the body does not effectively utilize the insulin that it does produce. Insulin is the hormone that regulates blood glucose levels. The most common complication is hyperglycemia (elevated blood sugar), which gradually leads to damage in many of the body’s systems, most notably the eyes, kidneys, nerves, and heart and blood vessels.

There are three kinds of diabetes: Type 1, Type 2, and gestational. Formerly known as juvenile or childhood-onset diabetes, Type 1 diabetes is an autoimmune condition in which the pancreas does not produce insulin. Type 1 diabetes is not preventable, and it’s cause is unknown. Symptoms include excessive urination, thirst, persistant hunger, weight loss, vision problems, and fatigue.

Formerly known as adult-onset diabetes, Type 2 diabetes results when the pancreas produces enough insulin initially, but the body is unable to use the hormone properly (insulin resistance). Until recently, this disease was only found in adults. However, it is now found among children, too. More than 90 percent of diabetics have Type 2.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. “Diabetes Overview.” *NIH Publication No. 09–3873* (November 2008). diabetes.niddk.nih.gov/dm/pubs/overview/. Major contributing factors to the development of Type 2 diabetes include excessive body weight and physical inactivity. The symptoms for Type 2 diabetes are similar to Type 1, but are much less noticeable. As a result, Type 2 diabetes may remain undiagnosed for several years after the onset, generally after complications have already manifested.

About 3 to 8 percent of pregnant women develop gestational diabetes during the latter stages of pregnancy. This condition is caused by a shortage of insulin or by pregnancy hormones. Gestational diabetes has symptoms similar to Type 2 diabetes, and some women may not experience any symptoms at all. In general, gestational diabetes fades away after the birth of the baby. However, women who have had gestational diabetes are at a greater risk of developing Type 2 diabetes within five to ten years. Also, infants born of mothers who suffer from this condition are at an increased risk of developing Type 2 diabetes as they grow older.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. “Diabetes Overview.” *NIH Publication No. 09–3873* (November 2008). diabetes.niddk.nih.gov/dm/pubs/overview/.

Table 16.12.4: The Risk Factors for Diabetes

Unmodifiable Risk Factors	Modifiable Risk Factors

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases after age forty-five • **Medical history.** Diabetes during a previous pregnancy or recently giving birth to an infant who weighs more than 9 pounds. • **Family history.** A history of diabetes among one or more close relatives. • **Race and ethnicity.** Individuals from specific ethnic groups may have an increased risk for developing diabetes, including African Americans, Hispanic Americans, Asian Americans, and Native Americans. • **Viruses.** Exposure to: Epstein-Barr, Coxsackie, mumps, or cytomegalo viruses may trigger Type 1 diabetes.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of Type 2 diabetes. • **Obesity.** Excess body weight, especially around the waist, is a major contributing factor to Type 2 diabetes. • **Physical inactivity.** Lack of exercise is strongly associated with diabetes. • **High blood pressure.** Greater than or equal to 140/90 mmHg. • **Cholesterol levels.** HDL cholesterol under 35 mg/dL. • **Blood sugar.** Impaired glucose tolerance. • **Blood fats.** Elevated triglycerides (250 mg/dL or more).

Steps to Reducing the Risk of Diabetes

Unfortunately, Type 1 diabetes is almost impossible to prevent, although some clinical research suggests that breastfeeding an infant for at least three months may decrease the child's risk of developing this condition. However, people who are at risk for Type 2 or gestational diabetes can take steps to avoid the disease. For example, it is crucial to achieve and maintain a healthy body weight through regular physical activity. If you are at risk, strive for at least thirty minutes of moderate to intense exercise at least three times per week. Proper nutrition is also vital, and it is important to restrict sugary snacks, beverages, and desserts, and to limit the intake of trans fats and saturated fats. In addition, those who are at risk should consume whole grains, legumes, fruits, and vegetables, along with two servings of nonfried fish per week.

For people over age forty-five, it is important to have a glucose test every three years. Regular testing should begin at a younger age, and be performed frequently if you have any risk factors for developing Type 2 diabetes. In order to assess your health status, the following is recommended:

- Early diagnosis through blood testing
- Blood pressure measurement
- Blood lipid measurement

Food: The Best Medicine

As mentioned in Chapter 1, poor dietary choices and a sedentary lifestyle account for about 300–600 thousand deaths every year according to the US Department of Health and Human Services. That number is thirteen times higher than the deaths due to gun violence.Nutrition Policy, Center for Science in the Public Interest. "Why Good Nutrition Is Important." Accessed December 21, 2011. http://www.cspinet.org/nutritionpolicy/nutrition_policy.html. The typical North American diet is too high in saturated fat, sodium, and sugar, and too low in fiber in the form of whole fruits, vegetables, and whole grains to keep people healthy. With so many threats to optimal health it is vital to address those factors that are under your control, namely dietary and lifestyle choices. A diet that supplies your body with the needed energy and nutrients daily will result in efficient body functioning and in protection from disease. Making sound nutritional choices can also provide support for individuals undergoing treatment for short-term or chronic conditions. Finding a balance between nutritional needs with concerns about drug interactions can hasten recovery, improve quality of life, and minimize the side effects from treatment protocols.

Key Takeaways

Chronic diseases such as cardiovascular disease, high blood pressure, cancer, and diabetes are major public health threats, and major causes of mortality. Knowing the modifiable risk factors (such as diet, level of physical activity, and cigarette smoking) for certain diseases can help you to adapt your lifestyle to protect them. By following a healthy diet, becoming active, and making other sound lifestyle choices, individuals can reduce their risk of developing chronic diseases, or better manage their condition to prevent further complications.

Discussion Starter

1. Assess your risk for developing one of the four chronic diseases discussed in this section. Which risk factors can be modified? Which risk factors can't be modified? What can you do to lessen the chance that you will develop the disease?

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16.14: Careers in Nutrition

Learning Objectives

- List some of the jobs available to students who are interested in a career in food and nutrition.

If you are considering a career in nutrition, it is important to understand the opportunities that may be available to you. Both dietitians and nutritionists provide nutrion-related services to people in the private and public sectors. A dietitian is a healthcare professional who has registered credentials and can provide nutritional care in the areas of health and wellness for both individuals and groups. A nutritionist is an unregistered professional who may have the credentials of a dietitian, or may have acquired the knowledge via other avenues. People in both professions work to apply nutritional science, using evidence-based best practices, to help people nourish their bodies and improve their lives.

Becoming a registered dietitian requires a Bachelor's or Master's degree in dietetics, including courses in biology, chemistry, biochemistry, microbiology, anatomy and physiology, nutrition, and food-service management. Other suggested courses include economics, business, statistics, computer science, psychology, and sociology. In addition, people who pursue this path must complete a dietetic internship and pass a national exam. Also, some states have licensure that requires additional forms and documentation. To become a registered dietetic technician you must complete a dietetic technician program that involves supervised practice. Forty-seven states have licensure requirements for registered dietitians and nutritionists. A few remaining states do not have laws that regulate this profession.Bureau of Labor Statistics. "Dietitians and Nutritionists." *Occupational Outlook Handbook, 2010-11 Edition.* Last modified April 7, 2010. www.bls.gov/oco/ocos077.htm. Go to www.cdrnet.org/certifications/licensure/index.cfm to learn more.

Working in Nutrition

Dietitians and nutritionists plan food and nutrition programs, promote healthy eating habits, and recommend dietary modifications. For example, a dietitian might teach a patient with hypertension how to follow the DASH diet and reduce their sodium intake. Nutrition-related careers can be extremely varied. Some individuals work in the government, while others are solely in the private sector. Some jobs in nutrition focus on working with athletes, while others provide guidance to patients with long-term, life-threatening diseases. But no matter the circumstance or the clientele, working in the field of diet and nutrition focuses on helping people improve their dietary habits by translating nutritional science into food choices.

In the public sector, careers in nutrition span from government work to community outreach. Nutritionists and dietitians who work for the government may become involved with federal food programs, federal agencies, communication campaigns, or creating and analyzing public policy. On the local level, clinical careers include working in hospitals and nursing-care facilities. This requires creating meal plans and providing nutritional guidance to help patients restore their health or manage chronic conditions. Clinical dietitians also confer with doctors and other health-care professionals to coordinate dietary recommendations with medical needs. Nutrition jobs in the community often involve working in public health clinics, cooperative extension offices, and HMOs to prevent disease and promote the health of the local community. Nutrition jobs in the nonprofit world involve antihunger organizations, public health organizations, and activist groups.

Nutritionists and dietitians can also find work in the private sector. Increased public awareness of food, diet, and nutrition has led to employment opportunities in advertising, marketing, and food manufacturing. Dietitians working in these areas analyze foods, prepare marketing materials, or report on issues such as the impact of vitamins and herbal supplements. Consultant careers can include working in wellness programs, supermarkets, physicians' offices, gyms, and weight-loss clinics. Consultants in private practice perform nutrition screenings for clients and use their findings to provide guidance on diet-related issues, such as weight reduction. Nutrition careers in the corporate world include designing wellness strategies and nutrition components for companies, working as representatives for food or supplement companies, designing marketing and educational campaigns, and becoming lobbyists. Others in the private sector work in food-service management at health-care facilities or at company and school cafeterias. Sustainable agricultural practices are also providing interesting private sector careers on farms and in food systems. There are employment opportunities in farm management, marketing and sales, compliance, finance, and land surveying and appraisal.

Working toward Tomorrow

Whether you pursue nutrition as a career or simply work to improve your own dietary choices, what you have learned in this course can provide a solid foundation for the future. Remember, your ability to wake up, to think clearly, communicate, hope, dream, go to school, gain knowledge, and earn a living are totally dependent upon one factor—your health. Good health allows you to function normally and work hard to pursue your goals. Yet, achieving optimal health cannot be underestimated. It is a complex process, involving multiple dimensions of wellness, along with your physical or medical reality. The knowledge you have now acquired is also key. However, it is not enough to pass this nutrition class with good grades. Nutrition knowledge must be applied to make a difference in your life, throughout your life.

Throughout this textbook, we have focused on the different aspects of nutritional science, which helps to optimize health and prevent disease. Scientific evidence provides the basis for dietary guidelines and recommendations. In addition, researchers in the field of nutrition work to advance our knowledge of food production and distribution. Nutritional science also examines the ill effects of malnutrition and food insecurity. The findings that are uncovered today will influence not only what we eat, but how we grow it, distribute it, prepare it, and even enjoy it tomorrow.



Video 16.18.1: *Farms of the Future. This video examines the philosophy and science behind vertical farming. Could it provide our nutrients in the future (click to see video)?*

Summary and Key Takeaway

There are many paths that one can take to become a professional in the field of nutrition, including working as a nutritionist or becoming a registered dietitian. Some confuse the terms "dietitian" and "nutritionist," and this tends to be erroneous. A nutritionist is a person who advises on matters of food and nutrition impacts on health. In contrast, A dietitian is an expert in the relationship between human nutrition and the regulation of diet; a dietitian alters their patient's nutrition based upon their medical condition and individual needs.

Discussion Starter

1. Compare and contrast nutrition-related careers in the public and private sectors. Discuss which area would most interest you and the reasons why.

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CHAPTER OVERVIEW

Back Matter

Index

Index

Glossary

Detailed Licensing

Index

A

alactic anaerobic
15.4: Anaerobic Exercise

B

bone
9.2: Bone Structure and Function
bone anatomy
9.2: Bone Structure and Function
bone structure
9.2: Bone Structure and Function

C

carcinogenesis
7.2: Carcinogenesis

G

gastrointestinal tract
2: Gastrointestinal Tract

H

Harris Benedict Equation
6.5: Balancing Energy Input with Energy Output

L

lactic anaerobic
15.4: Anaerobic Exercise

M

minerals
6.4: Minerals Important for Metabolism and for Blood Function and Renewal

O

obesogenic
6.1: Chapter Introduction
osmosis
10.2: Overview of Fluid and Electrolyte Balance
osteocytes
9.2: Bone Structure and Function

R

resting metabolic rate
15.7: Fitness and Health

Index

A

alactic anaerobic
15.4: Anaerobic Exercise

B

bone
9.2: Bone Structure and Function

bone anatomy
9.2: Bone Structure and Function

bone structure
9.2: Bone Structure and Function

C

carcinogenesis
7.2: Carcinogenesis

G

gastrointestinal tract
2: Gastrointestinal Tract

H

Harris Benedict Equation
6.5: Balancing Energy Input with Energy Output

L

lactic anaerobic
15.4: Anaerobic Exercise

M

minerals
6.4: Minerals Important for Metabolism and for Blood Function and Renewal

O

obesogenic
6.1: Chapter Introduction

osmosis
10.2: Overview of Fluid and Electrolyte Balance

osteocytes
9.2: Bone Structure and Function

R

resting metabolic rate
15.7: Fitness and Health

Glossary

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    - Licensing - *Undeclared*
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    - 1.2: Defining Nutrition, Health, and Disease - *CC BY-NC-SA 4.0*
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    - 1.4: Historical Perspectives on Food - *CC BY-NC-SA 4.0*
    - 1.5: The Broad Role of Nutritional Science - *CC BY-NC-SA 4.0*
    - 1.6: Health Factors and Their Impact - *CC BY-NC-SA 4.0*
    - 1.7: Nutrition and the Media - *CC BY-NC-SA 4.0*
    - 1.8: Assessing Personal Health - *CC BY-NC-SA 4.0*
    - 1.9: Dietary Toolkit - *CC BY-NC-SA 4.0*
    - 1.10: A Healthy Philosophy toward Food - *CC BY-NC-SA 4.0*
    - 1.11: Understanding the Bigger Picture of Dietary Guidelines - *CC BY-NC-SA 4.0*
    - 1.12: What Is Nutritional Balance and Moderation? - *CC BY-NC-SA 4.0*
    - 1.13: National Goals for Nutrition and Health-Healthy People 2020 - *CC BY-NC-SA 4.0*
    - 1.14: Recommendations for Optimal Health - *CC BY-NC-SA 4.0*
    - 1.15: Understanding Dietary Reference Intakes - *CC BY-NC-SA 4.0*
    - 1.16: Discovering Nutrition Facts - *CC BY-NC-SA 4.0*
    - 1.17: When Enough is Enough - *CC BY-NC-SA 4.0*
    - 1.18: Foodborne Illness and Food Safety - *CC BY-NC-SA 4.0*
    - 1.E: Nutrition and You (Exercises) - *CC BY-NC-SA 4.0*
  - 2: Gastrointestinal Tract - *CC BY-NC-SA 4.0*
    - 2.1: Chapter Introduction - *CC BY-NC-SA 4.0*
    - 2.2: The Basic Structural and Functional Unit of Life-The Cell - *CC BY-NC-SA 4.0*
    - 2.3: Digestion and Absorption - *CC BY-NC-SA 4.0*
    - 2.4: Nutrients Are Essential for Organ Function - *CC BY-NC-SA 4.0*
    - 2.5: Energy and Calories - *CC BY-NC-SA 4.0*
    - 2.6: Gastrointestinal Tract and Your Health - *CC BY-NC-SA 4.0*
    - 2.E: Exercises - *CC BY-NC-SA 4.0*
  - 3: Carbohydrates - *CC BY-NC-SA 4.0*
    - 3.1: Introduction to Carbohydrates - *CC BY-NC-SA 4.0*
    - 3.2: A Closer Look at Carbohydrates - *CC BY-NC-SA 4.0*
    - 3.3: Digestion and Absorption of Carbohydrates - *CC BY-NC-SA 4.0*
    - 3.4: The Functions of Carbohydrates in the Body - *CC BY-NC-SA 4.0*
    - 3.5: Looking Closely at Diabetes - *CC BY-NC-SA 4.0*
    - 3.6: Health Consequences and Benefits of High-Carbohydrate Diets - *CC BY-NC-SA 4.0*
    - 3.7: Carbohydrates and Personal Diet Choices - *CC BY-NC-SA 4.0*
    - 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes - *CC BY-NC-SA 4.0*
    - 3.E: Exercises - *CC BY-NC-SA 4.0*
  - 4: Lipids - *CC BY-NC-SA 4.0*
    - 4.1: Chapter Introduction - *CC BY-NC-SA 4.0*
    - 4.2: What Are Lipids? - *CC BY-NC-SA 4.0*
    - 4.3: How Lipids Work - *CC BY-NC-SA 4.0*
    - 4.4: Digestion and Absorption of Lipids - *CC BY-NC-SA 4.0*

- 4.5: Understanding Blood Cholesterol - *CC BY-NC-SA 4.0*
- 4.6: Balancing Your Diet with Lipids - *CC BY-NC-SA 4.0*
- 4.7: Lipids and the Food Industry - *CC BY-NC-SA 4.0*
- 4.8: Lipids and Disease - *CC BY-NC-SA 4.0*
- 4.9: A Personal Choice about Lipids - *CC BY-NC-SA 4.0*
- 4.E: Exercises - *CC BY-NC-SA 4.0*

5: Proteins - *CC BY-NC-SA 4.0*

- 5.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 5.2: Defining Protein - *CC BY-NC-SA 4.0*
- 5.3: The Role of Proteins in Foods- Cooking and Denaturation - *CC BY-NC-SA 4.0*
- 5.4: Protein Digestion, Absorption and Metabolism - *CC BY-NC-SA 4.0*
- 5.5: Protein's Functions in the Body - *CC BY-NC-SA 4.0*
- 5.6: Diseases Involving Proteins - *CC BY-NC-SA 4.0*
- 5.7: Proteins, Diet, and Personal Choices - *CC BY-NC-SA 4.0*
- 5.E: Proteins (Exercises) - *CC BY-NC-SA 4.0*

6: Energy Metabolism - *CC BY-NC-SA 4.0*

- 6.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 6.2: Metabolism Overview - *CC BY-NC-SA 4.0*
- 6.3: Vitamins Important for Metabolism - *CC BY-NC-SA 4.0*
- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal - *CC BY-NC-SA 4.0*
- 6.5: Balancing Energy Input with Energy Output - *CC BY-NC-SA 4.0*
- 6.6: Too Little or Too Much Weight? - *CC BY-NC-SA 4.0*
- 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution - *CC BY-NC-SA 4.0*
- 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management - *CC BY-NC-SA 4.0*
- 6.E: Exercises - *CC BY-NC-SA 4.0*

7: Nutrition and Cancer - *CC BY-NC-SA 4.0*

- 7.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 7.2: Carcinogenesis - *CC BY-NC-SA 4.0*
- 7.3: Diet and Cancer - *CC BY-NC-SA 4.0*

8: Antioxidant Nutrients - *CC BY-NC-SA 4.0*

- 8.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 8.2: Generation of Free Radicals in the Body - *CC BY-NC-SA 4.0*
- 8.3: Antioxidant Micronutrients - *CC BY-NC-SA 4.0*
- 8.4: The Whole Nutrient Package versus Disease - *CC BY-NC-SA 4.0*
- 8.E: Exercises - *CC BY-NC-SA 4.0*

9: Nutrients and Bone Metabolism - *CC BY-NC-SA 4.0*

- 9.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 9.2: Bone Structure and Function - *CC BY-NC-SA 4.0*
- 9.3: Bone Mineral Density is an Indicator of Bone Health - *CC BY-NC-SA 4.0*
- 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D - *CC BY-NC-SA 4.0*
- 9.5: Other Essential Micronutrients for Bone Health - *CC BY-NC-SA 4.0*
- 9.6: Osteoporosis - *CC BY-NC-SA 4.0*
- 9.7: Risk Factors for Osteoporosis - *CC BY-NC-SA 4.0*
- 9.8: Osteoporosis Prevention and Treatment - *CC BY-NC-SA 4.0*
- 9.9: Deficiency, Supplementation, and Choices - *CC BY-NC-SA 4.0*
- 9.E: Nutrients Important for Bone Health (Exercises) - *CC BY-NC-SA 4.0*

10: Water, Electrolytes, Acid-Base Balance - *CC BY-NC-SA 4.0*

- 10.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 10.2: Overview of Fluid and Electrolyte Balance - *CC BY-NC-SA 4.0*
- 10.3: Water's Importance to Vitality - *CC BY-NC-SA 4.0*
- 10.4: Regulation of Water Balance - *CC BY-NC-SA 4.0*
- 10.5: Electrolytes Important for Fluid Balance - *CC BY-NC-SA 4.0*
- 10.6: Consequences of Deficiency or Excess - *CC BY-NC-SA 4.0*
- 10.7: Water Concerns - *CC BY-NC-SA 4.0*
- 10.E: Water, Electrolytes, Acid-Base Balance (Exercises) - *CC BY-NC-SA 4.0*

11: Nutrients Involved in Hematopoietic System - *CC BY-NC-SA 4.0*

- 11.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 11.2: Blood's Function in the Body and in Metabolism Support - *CC BY-NC-SA 4.0*
- 11.3: Vitamins Important for Metabolism and for Blood Function and Renewal - *CC BY-NC-SA 4.0*
- 11.4: Minerals Important for Blood Function and Renewal - *CC BY-NC-SA 4.0*
- 11.5: Iron-Deficiency Anemia - *CC BY-NC-SA 4.0*
- 11.E: Exercises - *CC BY-NC-SA 4.0*

12: Maternal, Infant, Childhood, and Adolescent Nutrition - *CC BY-NC-SA 4.0*

- 12.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 12.2: The Human Life Cycle - *CC BY-NC-SA 4.0*
- 12.3: Pregnancy and Nutrition - *CC BY-NC-SA 4.0*

- 12.4: Infancy and Nutrition - *CC BY-NC-SA 4.0*
- 12.5: Nutrition in the Toddler Years - *CC BY-NC-SA 4.0*
- 12.6: Childhood and Nutrition - *CC BY-NC-SA 4.0*
- 12.7: Puberty and Nutrition - *CC BY-NC-SA 4.0*
- 12.8: Older Adolescence and Nutrition - *CC BY-NC-SA 4.0*
- 12.E: Exercises - *CC BY-NC-SA 4.0*

13: Nutrition From Adulthood to the Elderly Years - *CC BY-NC-SA 4.0*

- 13.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 13.2: The Human Life Cycle Continues - *CC BY-NC-SA 4.0*
- 13.3: Young Adulthood and Nutrition - *CC BY-NC-SA 4.0*
- 13.4: Middle Age and Nutrition - *CC BY-NC-SA 4.0*
- 13.5: Old Age and Nutrition - *CC BY-NC-SA 4.0*
- 13.E: Exercises - *CC BY-NC-SA 4.0*

14: Alcohol - *CC BY-NC-SA 4.0*

- 14.1: Introduction to Alcohol - *CC BY-NC-SA 4.0*
- 14.2: Alcohol Absorption and Metabolism - *CC BY-NC-SA 4.0*
- 14.3: Pros and Cons of Drinking Alcohol - *CC BY-NC-SA 4.0*
- 14.4: How Much to Drink? - *CC BY-NC-SA 4.0*

15: Nutrition and Exercise - *CC BY-NC-SA 4.0*

- 15.1: Chapter Introduction - *CC BY-NC-SA 4.0*
- 15.2: Introduction to Nutrition and Physical Fitness - *CC BY-NC-SA 4.0*
- 15.3: Aerobic Exercise - *CC BY-NC-SA 4.0*
- 15.4: Anaerobic Exercise - *CC BY-NC-SA 4.0*
- 15.5: Nutrients that are critical to athletes - *CC BY-NC-SA 4.0*
- 15.6: Fitness Supplements and Steroids - *CC BY-NC-SA 4.0*
- 15.7: Fitness and Health - *CC BY-NC-SA 4.0*
- 15.8: Supplemental- Creating your own fitness plan - *CC BY-NC-SA 4.0*

16: Additional Reading - *CC BY-NC-SA 4.0*

- 16.1: Food Politics and Perspectives - *CC BY-NC-SA 4.0*
- 16.2: The Politics of Food - *CC BY-NC-SA 4.0*
- 16.3: The Food Industry - *CC BY-NC-SA 4.0*
- 16.4: Food Cost and Inflation - *CC BY-NC-SA 4.0*
- 16.5: Sustainability - *CC BY-NC-SA 4.0*
- 16.6: A Fresh Perspective- Sustainable Food Systems - *CC BY-NC-SA 4.0*
- 16.7: Start Your Sustainable Future Today - *CC BY-NC-SA 4.0*
- 16.8: The Issue of Food Security - *CC BY-NC-SA 4.0*
- 16.9: Diets around the World - *CC BY-NC-SA 4.0*
- 16.10: Why Make Dietary Changes? - *CC BY-NC-SA 4.0*
- 16.11: Nutrition and Your Health - *CC BY-NC-SA 4.0*
- 16.12: Diet Trends and Health - *CC BY-NC-SA 4.0*
- 16.13: Threats to Health - *CC BY-NC-SA 4.0*
- 16.14: Careers in Nutrition - *CC BY-NC-SA 4.0*

Back Matter - *CC BY-NC-SA 4.0*

- Index - *CC BY-NC-SA 4.0*
- Index - *CC BY-NC-SA 4.0*
- Glossary - *CC BY-NC-SA 4.0*
- Detailed Licensing - *Undeclared*

CHAPTER OVERVIEW

Front Matter

TitlePage
InfoPage
Table of Contents
Licensing

APUS: An Introduction to Nutrition

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TABLE OF CONTENTS

Licensing

1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet

- 1.1: Chapter Introduction
- 1.2: Defining Nutrition, Health, and Disease
- 1.3: What Are Nutrients?
- 1.4: Historical Perspectives on Food
- 1.5: The Broad Role of Nutritional Science
- 1.6: Health Factors and Their Impact
- 1.7: Nutrition and the Media
- 1.8: Assessing Personal Health
- 1.9: Dietary Toolkit
- 1.10: A Healthy Philosophy Toward Food
- 1.11: Understanding the Bigger Picture of Dietary Guidelines
- 1.12: What Is Nutritional Balance and Moderation?
- 1.13: National Goals for Nutrition and Health- Healthy People 2030
- 1.14: Recommendations for Optimal Health
- 1.15: Understanding Dietary Reference Intakes
- 1.16: Discovering Nutrition Facts
- 1.17: When Enough is Enough
- 1.E: Nutrition and You (Exercises)

2: Gastrointestinal Tract

- 2.1: Chapter Introduction
- 2.2: The Basic Structural and Functional Unit of Life- The Cell
- 2.3: Digestion and Absorption
- 2.4: Nutrients Are Essential for Organ Function
- 2.5: Energy and Calories
- 2.6: Gastrointestinal Tract and Your Health
- 2.E: Exercises

3: Carbohydrates

- 3.1: Introduction to Carbohydrates
- 3.2: A Closer Look at Carbohydrates
- 3.3: Digestion and Absorption of Carbohydrates
- 3.4: The Functions of Carbohydrates in the Body
- 3.5: Looking Closely at Diabetes
- 3.6: Health Consequences and Benefits of High-Carbohydrate Diets
- 3.7: Carbohydrates and Personal Diet Choices
- 3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
- 3.E: Exercises

4: Lipids

- 4.1: Chapter Introduction
- 4.2: What Are Lipids?
- 4.3: How Lipids Work

- 4.4: Digestion and Absorption of Lipids
- 4.5: Understanding Blood Cholesterol
- 4.6: Balancing Your Diet with Lipids
- 4.7: Lipids and the Food Industry
- 4.8: Lipids and Disease
- 4.9: A Personal Choice about Lipids
- 4.E: Exercises

5: Proteins

- 5.1: Chapter Introduction
- 5.2: Defining Protein
- 5.3: The Role of Proteins in Foods- Cooking and Denaturation
- 5.4: Protein Digestion, Absorption and Metabolism
- 5.5: Protein's Functions in the Body
- 5.6: Diseases Involving Proteins
- 5.7: Proteins, Diet, and Personal Choices
- 5.E: Proteins (Exercises)

6: Energy Metabolism

- 6.1: Chapter Introduction
- 6.2: Metabolism Overview
- 6.3: Vitamins Important for Metabolism
- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
- 6.5: Balancing Energy Input with Energy Output
- 6.6: Too Little or Too Much Weight?
- 6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
- 6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
- 6.E: Exercises

7: Food Drivers That Impact Your Nutrition

- 7.1: Foodborne Illness and Food Safety
- 7.2: The Politics of Food
- 7.3: The Food Industry
- 7.4: Food Cost and Inflation
- 7.5: Sustainability
- 7.6: A Fresh Perspective- Sustainable Food Systems
- 7.7: Start Your Sustainable Future Today
- 7.8: The Issue of Food Security
- 7.9: Diets around the World
- 7.10: Why Make Dietary Changes?
- 7.11: Nutrition and Your Health
- 7.12: Diet Trends and Health
- 7.13: Threats to Health
- 7.14: Careers in Nutrition

8: Antioxidant Nutrients

- 8.1: Chapter Introduction
- 8.2: Generation of Free Radicals in the Body
- 8.3: Antioxidant Micronutrients
- 8.4: The Whole Nutrient Package versus Disease

- 8.E: Exercises

9: Nutrients and Bone Metabolism

- 9.1: Chapter Introduction
- 9.2: Bone Structure and Function
- 9.3: Bone Mineral Density is an Indicator of Bone Health
- 9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D
- 9.5: Other Essential Micronutrients for Bone Health
- 9.6: Osteoporosis
- 9.7: Risk Factors for Osteoporosis
- 9.8: Osteoporosis Prevention and Treatment
- 9.9: Deficiency, Supplementation, and Choices
- 9.E: Nutrients Important for Bone Health (Exercises)

10: Nutrients Involved in Hematopoietic System

- 10.1: Chapter Introduction
- 10.2: Blood's Function in the Body and in Metabolism Support
- 10.3: Vitamins Important for Metabolism and for Blood Function and Renewal
- 10.4: Minerals Important for Blood Function and Renewal
- 10.5: Iron-Deficiency Anemia
- 10.E: Exercises

11: Water, Electrolytes, Acid-Base Balance

- 11.1: Chapter Introduction
- 11.2: Overview of Fluid and Electrolyte Balance
- 11.3: Water's Importance to Vitality
- 11.4: Regulation of Water Balance
- 11.5: Electrolytes Important for Fluid Balance
- 11.6: Consequences of Deficiency or Excess
- 11.7: Water Concerns
- 11.E: Water, Electrolytes, Acid-Base Balance (Exercises)

12: Maternal, Infant, Childhood, and Adolescent Nutrition

- 12.1: Chapter Introduction
- 12.2: The Human Life Cycle
- 12.3: Pregnancy and Nutrition
- 12.4: Infancy and Nutrition
- 12.5: Nutrition in the Toddler Years
- 12.6: Childhood and Nutrition
- 12.7: Puberty and Nutrition
- 12.8: Older Adolescence and Nutrition
- 12.E: Exercises

13: Nutrition From Adulthood to the Elderly Years

- 13.1: Chapter Introduction
- 13.2: The Human Life Cycle Continues
- 13.3: Young Adulthood and Nutrition
- 13.4: Middle Age and Nutrition
- 13.5: Old Age and Nutrition
- 13.E: Exercises

14: Alcohol

- 14.1: Introduction to Alcohol
- 14.2: Alcohol Absorption and Metabolism
- 14.3: Pros and Cons of Drinking Alcohol
- 14.4: How Much to Drink?

15: Nutrition and Exercise

- 15.1: Chapter Introduction
- 15.2: Introduction to Nutrition and Physical Fitness
- 15.3: Aerobic Exercise
- 15.4: Anaerobic Exercise
- 15.5: Nutrients that are critical to athletes
- 15.6: Fitness Supplements and Steroids
- 15.7: Fitness and Health
- 15.8: Supplemental- Creating your own fitness plan

Index

Index

Glossary

Detailed Licensing

Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

1: Nutrition and You- An Introduction and How to Achieve a Healthy Diet

This Chapter provides an overview of nutrition as an evidence-based science and explores the concepts of health, wellness, and disease. We also introduce nutrients, health factors, personal health assessment, and the concept of sustainable food systems.

1.1: Chapter Introduction
1.2: Defining Nutrition, Health, and Disease
1.3: What Are Nutrients?
1.4: Historical Perspectives on Food
1.5: The Broad Role of Nutritional Science
1.6: Health Factors and Their Impact
1.7: Nutrition and the Media
1.8: Assessing Personal Health
1.9: Dietary Toolkit
1.10: A Healthy Philosophy Toward Food
1.11: Understanding the Bigger Picture of Dietary Guidelines
1.12: What Is Nutritional Balance and Moderation?
1.13: National Goals for Nutrition and Health- Healthy People 2030
1.14: Recommendations for Optimal Health
1.15: Understanding Dietary Reference Intakes
1.16: Discovering Nutrition Facts
1.17: When Enough is Enough
1.E: Nutrition and You (Exercises)

Template:HideTOC

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1.1: Chapter Introduction

Nutrition is an evidence-based science. Nutritional scientists continuously advance our knowledge of nutrition by building on prior research.

Video Link 1.1.1

Nutrition Quiz: Listen to what Americans think 100 Calories looks like.



As we begin our journey into health and nutrition, our first focus will be to demonstrate that nutritional science is an evolving field of study, continually being updated and supported by research, studies, and trials. Once we establish this, your confidence will be strengthened in nutritional science to help guide your eating habits. Let's begin with the story of hurry, curry, and worry: the story of *Helicobacter (H.) pylori*.

Peptic ulcers are painful sores in the gastrointestinal tract and can cause symptoms of abdominal pain, nausea, loss of appetite, and weight loss. The cure for this ailment took some time for scientists to figure out. If your grandfather complained to his doctor about symptoms of peptic ulcer, he was probably told to avoid spicy foods, alcohol, and coffee and to manage his stress. In the early twentieth century, the medical community thought peptic ulcers were caused by what you ate and drank and by stress. In 1915, Dr. Bertram W. Sippy devised the "Sippy diet" for treating peptic ulcers. Dr. Sippy advised patients to drink small amounts of cream and milk every hour to neutralize stomach acid. Then, gradually, introduce soft, bland foods with frequent meal times. This diet sometimes worked for a while, fooling doctors and patients. However, the disappearance of peptic ulcer symptoms was likely the result of having a full stomach all the time, as the symptoms more often occur when the stomach is empty. Ultimately, the Sippy diet did not cure peptic ulcers. In the latter 1960s, scientists discovered the diet was associated with a significant increase in heart disease due to its high saturated fat content.

In the 1980s, Australian physicians, Barry Marshall and Robin Warren Currey, proposed a radical hypothesis—that the cause of ulcers was bacteria that could survive in the acidic environment of the stomach and small intestine. They faced significant opposition to their hypothesis but persisted with their research. Their research led to an understanding that the spiral shape of the bacterium *H. pylori* allows it to penetrate the stomach's mucous lining, where it secretes an enzyme that generates substances to neutralize the stomach's acidity. This process weakens the stomach's protective mucus, making the tissue more susceptible to the damaging effects of acid and developing sores and ulcers. *H. pylori* also prompts the stomach to produce even more acid, further damaging the lining. Marshall drank a dish of *H. pylori*, hoping to give himself an ulcer to prove his point. A few days later, he was vomiting and had inflamed tissue in his stomach. The presence of H. pylori was confirmed. He then took an antibiotic, and the symptoms of *H. pylori* infection dissipated. Experimental success? It still took years for the medical community to be entirely convinced of the link between peptic ulcers and *H. pylori*.

Video Link 1.1.2

YouTube Video about the discovery of H. *pylori*.



In 1994, the National Institutes of Health held a conference on the cause of peptic ulcers. There was scientific consensus that H. pylori causes most peptic ulcers and that patients should be treated with antibiotics. In 1996, the Food and Drug Administration (FDA) approved the first antibiotic that could be used to treat patients with peptic ulcers. Nevertheless, the link between H. pylori and peptic ulcers was not sufficiently communicated to health-care providers. In fact, 75 percent of patients with peptic ulcers in the late 1990s were still being prescribed antacid medications and advised to change their diet and reduce their stress. In 1997, the Centers for Disease Control and Prevention (CDC) and other public health organizations began an intensive educational campaign to convince the public and healthcare providers that peptic ulcers are a curable condition requiring antibiotic treatment. Today, if you go to your primary physician, you will be given the choice to take an antibiotic to eradicate *H. pylori* from your gut. Scientists have progressed even further and mapped the entire genome of H. pylori, hopefully aiding in discovering even better drugs to treat peptic ulcers.

The *H. pylori* discovery was made recently, overturning a theory applied in our own time. Demystifying disease requires the continuous march of science, overturning old, traditional theories and discovering new, more effective ways to treat disease and promote health. In 2005, Marshall and Warren were awarded the prestigious Nobel Prize in medicine for discovering that many stomach ulcers are caused by H. pylori—not by hurry, curry, and worry.

> *Commit to empowering yourself with scientific evidence as a strategy for achieving a healthier diet.*



A primary goal of this text is to provide you with information backed by nutritional science and various resources that use scientific evidence to optimize health and prevent disease. In this chapter, you will see many conditions and deadly diseases that can be prevented by good nutrition. You will also discover many other determinants of health and disease, how the powerful tool of scientific investigation is used to design dietary guidelines, and recommendations that will promote health and prevent disease.

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1.2: Defining Nutrition, Health, and Disease

Learning Objective

- Explain the terms nutrition, health, health promotion, and disease prevention.

Your View of Food

Food is any nutritious substance that people or animals eat or drink, or that plants absorb, in order to maintain life and growth. Americans are bombarded with television programs that show where to find the best dinners, pizzas, and cakes, and the restaurants that serve the biggest and juiciest burgers. Other programs feature chefs battling to prepare meals, and the top places to burst your belly from consuming atomic chicken wings and deli sandwiches longer than a foot. There are also shows that feature bizarre foods from cultures around the world. How do you use the information from popular network food shows to build a nutritious meal? You don't—these shows are for entertainment. The construction of a nutritious meal requires learning about which foods are healthy and which foods are not, how foods and nutrients function in your body, and how to use scientific resources. This text is designed to provide you with the information necessary to make sound nutritional choices that will optimize health and help prevent disease.



Figure 1.2.1: The Nutrition Facts panel provides information to help you select foods so you can fill your plate wisely. © Shutterstock

How do you fill your plate?

The word nutrition first appeared in 1551 and comes from the Latin word *nutrire*, meaning "to nourish." Today, we define Nutritional science as the investigation of how an organism is nourished and incorporates the study of how nourishment affects personal health, population health, and planetary health. Nutritional science covers a wide spectrum of disciplines. As a result, nutritional scientists can specialize in particular aspects of nutrition such as biology, physiology, immunology, biochemistry, education, psychology, sustainability, and sociology.

Without adequate nutrition, the human body does not function optimally, and severe nutritional inadequacy can lead to disease and even death. The typical American diet is lacking in many ways, from not containing the proper amounts of essential nutrients, to being too speedily consumed, to being only meagerly satisfying. Dietitians are nutrition professionals who integrate their knowledge of nutritional science into helping people achieve a healthy diet and develop good dietary habits. The Academy of Nutrition and Dietetics (AND) is the largest organization of nutrition professionals worldwide and dietitians registered with the AND are committed to helping Americans eat well and live healthier lives. To learn more from the AND's nutritional advice, visit EatRight.Org

Your ability to wake up, to think clearly, to communicate, to hope, to dream, to go to school, to gain knowledge, to go to work, to earn a living, and to do all of the things that you like to do are dependent upon one factor—your health. Good health means you are able to function normally and work hard to achieve your goals in life. For the next few minutes, take some time to view snapshots of the insides of the refrigerators of American mechanics, doctors, school teachers, hunters, short-order cooks, college students, vegans, and more. Visit Mark Menjivar's portrait exhibition, "You Are What You Eat". Menjivar hopes these images will invoke new thoughts about, "How we care for our bodies. How we care for others. And how we care for the land." As you look at these

images think about your personal health, the health of your family and friends, and the health of this planet. These hopes encompass the inspirations for this book.

Interactive 1.2.1

Mark Menjivar has traveled around the United States taking photographs of the contents of refrigerators of numerous types of people. The portraits are available for viewing on his website under “You Are What You Eat.” Then click on "Refrigerators" on the left.

Nutrition and Health and Disease

In 1946, the World Health Organization (WHO) defined health as “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.”World Health Organization. The preamble to the *Constitution of the World Health Organization* as adopted by the International Health Conference, New York, June 19–July 22, 1946. http://www.who.int/suggestions/faq/en/ This definition was adopted into the WHO constitution in 1948 and has not been amended since. A triangle is often used to depict the equal influences of physical, mental, and social well-being on health (Figure 1.1). Disease is defined as any abnormal condition affecting the health of an organism and is characterized by specific signs and symptoms. Signs refer to identifying characteristics of a disease such as swelling, weight loss, or fever. Symptoms are the features of a disease recognized by a patient and/or their doctor. Symptoms can include nausea, fatigue, irritability, and pain. Diseases are broadly categorized as resulting from pathogens (i.e., bacteria, viruses, fungi, and parasites), deficiencies, genetics, and physiological dysfunction. Diseases that primarily affect physical health are those that impair body structure (as is the case with osteoporosis), or functioning (as is the case with cardiovascular disease). Mental illnesses primarily affect mental and social well-being.

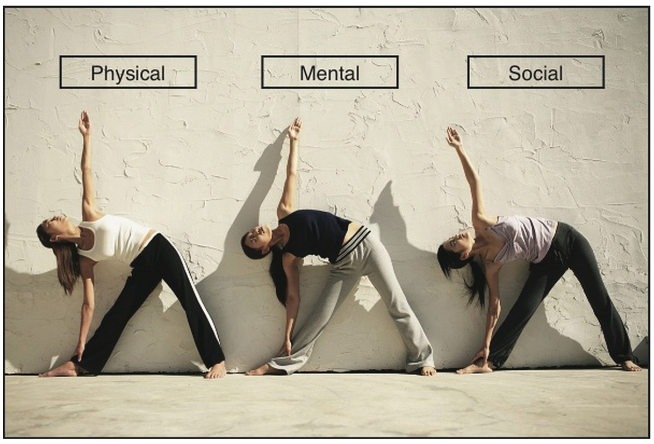


Figure 1.2.2: The Health Triangle. © Thinkstock

The foods we eat affect all three aspects of our health. For example, a teen with Type 2 diabetes (a disease brought on by poor diet) is first diagnosed by physical signs and symptoms such as increased urination, thirstiness, and unexplained weight loss. But research has also found that teens with Type 2 diabetes have impaired thinking and do not interact well with others in school, thereby affecting mental and social well-being. Type 2 diabetes is just one example of a physiological disease that affects all aspects of health—physical, mental, and social.

Public Health and Disease Prevention

In 1894, the first congressional funds were appropriated to the US Department of Agriculture (USDA) for the study of the relationship between nutrition and human health. Dr. Wilbur Olin Atwater was appointed as the Chief of Nutrition Investigations and is regarded as the “Father of Nutrition Science” in America. Under his guidance, the USDA released the first bulletin to the American public that contained information on the amounts of fat, carbohydrates, proteins, and food energy in various foods. Nutritional science advanced considerably in these early years, but it took until 1980 for the USDA and the US Department of Health and Human Services (HHS) to jointly release the first edition of *Nutrition and Your Health: Dietary Guidelines for Americans*.

Although the wide distribution of dietary guidelines did not come about until the 1980s, many historical events that demonstrated the importance of diet to health preceded their release. Assessments of the American diet in the 1930s led President Franklin D. Roosevelt to declare in his inaugural address on January 20, 1937, “I see one-third of our nation is ill-housed, ill-clad, and ill-nourished.” From the time of Atwater until the onset of the Great Depression, nutrition scientists had discovered many of the vitamins and minerals that are essential for the functioning of the human body. Their work and the acknowledgment by President FDR of the nutritional inadequacy of the American diet evoked a united response from scientists and the government, leading to the enrichment of flour, the development of school lunch programs, and advancements in nutritional education in this country.

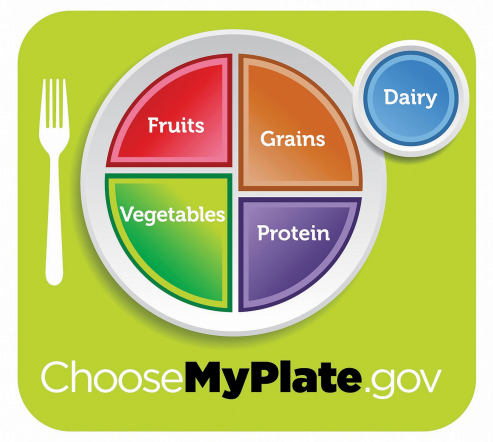


Figure 1.2.3: The Federal Government’s New and Improved Tool of Nutritional Communication

In the latter part of the twentieth century, nutrition scientists, public health organizations, and the American public increasingly recognized that eating too much of certain foods is linked to chronic diseases. We now know that diet-related conditions and diseases include: hypertension (high blood pressure), obesity, Type 2 diabetes, cardiovascular disease, some cancers, and osteoporosis. These diet-related conditions and diseases are some of the biggest killers of Americans, with heart disease being the number one killer. The United States Department of Health and Human Services (HHS) reports that unhealthy diets and inactivity cause between 310,000 and 580,000 deaths every single year. According to the United States Department of Agriculture (USDA), eating healthier could save Americans over $70 billion per year, and this does not include the cost of obesity, which is estimated to cost a further $117 billion per year. Unfortunately, despite the fact that healthier diets and increased physical activity can decrease the prevalence of these diseases, the Center for Disease Control (CDC) reports that the federal government spends one thousand times more to treat disease than to prevent it ($1,390 versus $1.21 per person each year). In 2015, the Dietary Guidelines for Americans identified obesity as the number one nutritional-related health problem in the United States and established strategies to combat its incidence and health consequences in the American population. A 2008 study in the journal *Obesity* reported that if current trends are not changed, 100 percent of Americans will be overweight or obese in 2048! Wang Y, et al. “Will All Americans Become Overweight or Obese? Estimating the Progression and Cost of the US Obesity Epidemic.” *Obesity* 10, no. 16 (October 2008): 2323–30. http://www.nature.com/oby/journal/v16/n10/full/oby2008351a.html In 2011, the US federal government released a new multimedia tool that aims to help Americans choose healthier foods from the five food groups (grains, vegetables, fruits, dairy, and proteins). The tool, called “Choose MyPlate,” is available at choosemyplate.gov.

Key Takeaways

- Health is defined as “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.” World Health Organization.
- Disease is defined as any abnormal condition that affects the health of an organism and is characterized by specific signs and symptoms.
- Nutrition is defined as the science of how we take in food and that food is utilized by our body.
- Disease affects all three aspects of the health triangle.
- Good nutrition provides a mechanism to promote health and prevent disease.
- Diet-related conditions and diseases include obesity, Type 2 diabetes, cardiovascular disease, some cancers, and osteoporosis.
- It took until the 1980s for the US federal government to develop a diet-related public policy designed to equip Americans with the tools to change to a healthier diet.

Discussion Starters

1. How might the way we nourish our bodies affect planetary health?
2. Debate your classmates: Should the federal government be concerned with what Americans eat?

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1.3: What Are Nutrients?

Learning Objective

- Define the word “nutrient” and identify the six classes of nutrients essential for health.
- List the three energy-yielding nutrients and their energy contribution.

What is in Food?

The foods we eat contain nutrients. Those nutrients that contain carbon are called organic while those that do not contain carbon are called inorganic. Nutrients are substances required by the body to perform its basic functions. Since the human body does not synthesize nutrients, they must be obtained from the diet, making them essential. Eating inadequate amounts can cause poor health.

Nutrients are used to produce energy, detect and respond to environmental surroundings, move, excrete wastes, respire (breathe), grow, and reproduce. There are six classes of nutrients required for the body to function and maintain overall health. These are carbohydrates, lipids, proteins, water, vitamins, and minerals. Foods also contain nonnutrients that may be harmful (such as cholesterol, dyes, and preservatives) or beneficial (such as phytochemicals like antioxidants and zoochemicals like omega-3 fatty acids).

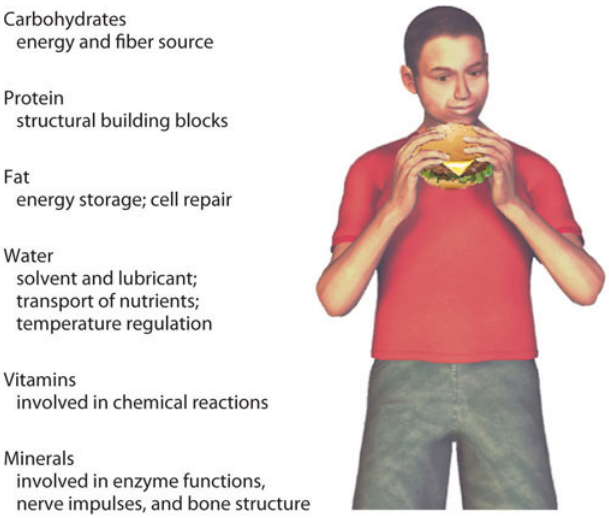


Figure 1.3.1: The Six Classes of Nutrients. Source: www.chemistry.wustl.edu/~edudev/LabTutorials/Vitamins/vitamins.html.

Macronutrients

Nutrients that are needed in large amounts (grams) are called macronutrients. There are three classes of macronutrients: carbohydrates, lipids, and proteins. These can be metabolically processed into cellular energy. The energy from macronutrients comes from their chemical bonds. This chemical energy is converted into cellular energy that is then utilized to perform work, allowing our bodies to conduct their basic functions. A unit of measurement of food energy is the calorie. On nutrition food labels the amount given for “calories” is actually equivalent to each calorie multiplied by one thousand. A kilocalorie (one thousand calories, denoted with a small “c”) is synonymous with the “Calorie” (with a capital “C”) on nutrition food labels. Water is also a macronutrient in the sense that you require a large amount of it, but unlike the other macronutrients it does not yield calories.

Carbohydrates

Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. The major food sources of carbohydrates are grains, milk, fruits, and vegetables, including starchy vegetables like potatoes. Nonstarchy vegetables also contain carbohydrates but in lesser quantities. Carbohydrates are broadly classified into two forms based on their chemical structure: fast-releasing carbohydrates often called simple sugars, and complex or slow-releasing carbohydrates also called polysacchrides.

Fast-releasing carbohydrates consist of one or two basic units. Examples of simple sugars include sucrose, the type of sugar you would have in a bowl on the breakfast table, and glucose, the type of sugar that circulates in your blood.

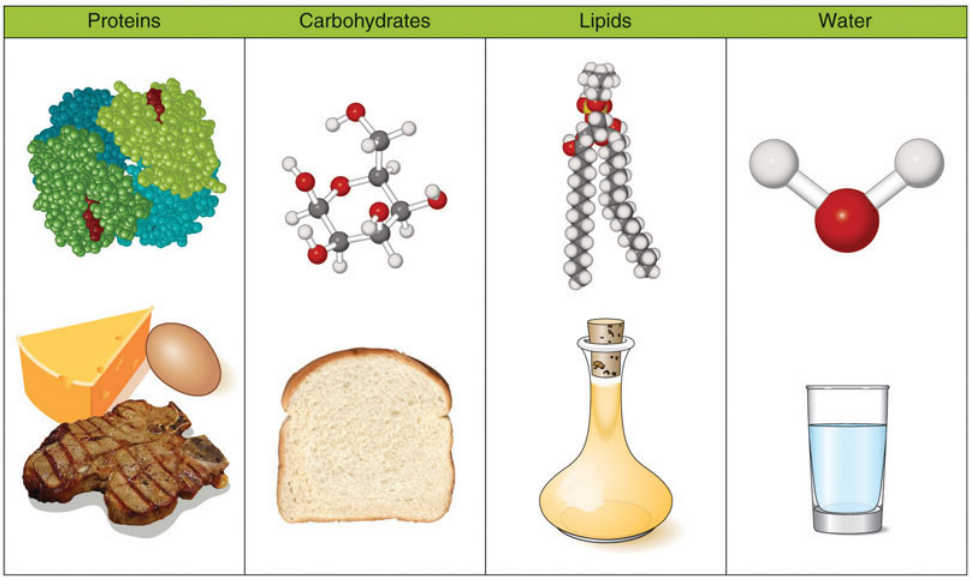


Figure 1.3.2: The Macronutrients: Carbohydrates, Lipids, Protein, and Water

Slow-releasing or complex carbohydrates are long chains of simple sugars that can be branched or unbranched. Starch is an example of a slow-releasing carbohydrate. During digestion, the small intestine breaks down all slow-releasing carbohydrates to simple sugars, mostly glucose. Glucose is then absorbed and transported to all our cells where it is stored in the form of glycogen, used to make energy, or used to build macromolecules. Fiber is also a slow-releasing carbohydrate, but it cannot be broken down in the human body and passes through the digestive tract undigested unless the bacteria that inhabit the gut break it down.

One gram of carbohydrates yields four kilocalories of energy for the cells in the body to perform work. In addition to providing energy and serving as building blocks for bigger macromolecules, carbohydrates are essential for proper functioning of the nervous system, heart, and kidneys. As mentioned, glucose can be stored in the body for future use. In humans, the storage molecule of carbohydrates is called glycogen and in plants, it is known as starches. Glycogen and starches are slow-releasing carbohydrates.

Lipids

Lipids are also a family of molecules composed of carbon, hydrogen, and oxygen, but unlike carbohydrates, they are insoluble in water. This class of molecules may be visible (for example vegetable oil) or invisible (for example, cream) in the food you eat. Lipids are found predominately in butter, oils, meats, dairy products, nuts, and seeds, and in many processed foods. The three main types of lipids are triglycerides (also called triacylglycerols), phospholipids, and sterols. The main job of lipids is to store energy. Lipids provide more energy per gram than carbohydrates (nine kilocalories per gram of lipids versus four kilocalories per gram of carbohydrates). In addition to energy storage, lipids serve as cell membranes, surround and protect organs, aid in temperature regulation, and regulate many other functions in the body. The main job of lipids is to store energy. Lipids provide more energy per gram than carbohydrates (nine kilocalories per gram of lipids versus four kilocalories per gram of carbohydrates). In addition to energy storage, lipids serve as cell membranes, surround and protect organs, aid in temperature regulation, and regulate many other functions in the body.

- ## Proteins

  Proteins are macromolecules composed of chains of subunits called amino acids which are called the building blocks of protein. Amino acids are simple subunits composed of carbon, oxygen, hydrogen, and nitrogen. The food sources of protein come from animals such as meats, dairy products, seafood, and a variety of different plant-based foods, for example, soy, beans, and nuts. The word protein comes from a Greek word meaning “of primary importance,” which is an apt description of these macronutrients; they are also known colloquially as the “workhorses” of life. Proteins provide four kilocalories of energy per gram; however, providing energy is not protein’s most important function. Proteins provide structure to bones, muscles, and skin, and play a role in conducting most of the chemical reactions that take place in the body. Scientists estimate that greater than one hundred thousand different proteins exist within the human body.

Water

There is one other nutrient that we must have in large quantities: water. Water does not contain carbon, but is composed of two hydrogens and one oxygen per molecule of water. More than 60 percent of your total body weight is water. Without it, nothing could be transported in or out of the body, chemical reactions would not occur (acts as a solvent), organs would not be cushioned, joints would not be lubricated, and body temperature would fluctuate widely. On average, an adult consumes just over two liters of water per day from food and drink. According to the "rule of threes," a generalization supported by survival experts, a person can survive three minutes without oxygen, three days without water, and three weeks without food. Since water is so critical for life's basic processes, the amount of water input and output is supremely important, a topic we will explore in detail in Chapter 7.

- ## Micronutrients

Micronutrients are nutrients required by the body in lesser amounts but are still essential for carrying out bodily functions. Micronutrients include all the essential minerals and vitamins. There are thirteen vitamins and sixteen essential minerals (See Table 1.3.1 and Table 1.3.2 for a complete list and their major functions). In contrast to carbohydrates, lipids, and proteins, micronutrients are not directly used for making energy, but they assist in the process as being part of enzymes (i.e., coenzymes). Enzymes are proteins that catalyze chemical reactions in the body and are involved in all aspects of body functions from producing energy to digesting nutrients to building macromolecules. Micronutrients play many roles in the body.

Vitamins

The thirteen vitamins are organic compounds (carbon-based) categorized as either water-soluble or fat-soluble. The water-soluble vitamins are vitamin C and all the B vitamins, which include thiamine, riboflavin, niacin, pantothenic acid, pyroxidine, biotin, folate, and cobalamin. The fat-soluble vitamins are A, D, E, and K. Vitamins are required to perform many functions in the body (regulatory and metabolic capacity) such as making red blood cells, synthesizing bone tissue, and playing a role in normal vision, nervous system function, and immune system function. Some function in chemical reactions involved in the release of energy from carbohydrates, fat, protein, and alcohol while others are involved in regulating body processes. Vitamins do not supply energy directly and are not structural; they enable chemical reactions to occur.

Table 1.03.1: Vitamins and Their Major Functions

Vitamins	Major Functions
Water-soluble	
B_1 (thiamine)	Coenzyme, energy metabolism assistance
B_2 (riboflavin)	Coenzyme, energy metabolism assistance
B_3 (niacin)	Coenzyme, energy metabolism assistance
B_5 (pantothenic acid)	Coenzyme, energy metabolism assistance
B_6 (pyroxidine)	Coenzyme, amino acid synthesis assistance
Biotin	Coenzyme
Folate	Coenzyme, essential for growth
B_{12} (cobalamin)	Coenzyme, red blood cell synthesis
C	Collagen synthesis, antioxidant
Fat-soluble	
A	Vision, reproduction, immune system function
D	Bone and teeth health maintenance, immune system function
E	Antioxidant, cell membrane protection
K	Bone and teeth health maintenance, blood clotting

Vitamin deficiencies can cause severe health problems. For example, a deficiency in niacin causes a disease called pellagra, which was common in the early twentieth century in some parts of America. The common signs and symptoms of pellagra are known as the "4D's—diarrhea, dermatitis, dementia, and death." Until scientists found out that better diets relieved the signs and symptoms of pellagra, many people with the disease ended up in insane asylums awaiting death (Video 1.3.1). Other vitamins were also found to prevent certain disorders and diseases such as scurvy (vitamin C), night blindness (vitamin A), and rickets (vitamin D).

Minerals

Minerals are solid inorganic substances that form crystals and are classified depending on how much of them we need. Trace minerals, such as molybdenum, selenium, zinc, iron, and iodine, are only required in a few milligrams or less and macrominerals, such as calcium, magnesium, potassium, sodium, and phosphorus, are required in hundreds of milligrams. Minerals function in structural, regulatory, and metabolic capacities. Building bone and teeth are an example of a structural function; while maintaining fluid balance, building bone tissue, synthesizing hormones, transmitting nerve impulses, contracting and relaxing muscles, and protecting against harmful free radicals are examples of regulatory and metabolic processes. Minerals do not supply energy directly.

Table 1.3.2: Minerals and Their Major Functions

Minerals	Major Functions
Macro or Major Minerals (>100 mg/day)	
Sodium	Fluid balance, nerve transmission, muscle contraction
Chloride	Fluid balance, stomach acid production
Potassium	Fluid balance, nerve transmission, muscle contraction
Calcium	Bone and teeth health maintenance, nerve transmission, muscle contraction, blood clotting
Phosphorus	Bone and teeth health maintenance, acid-base balance
Magnesium	Protein production, nerve transmission, muscle contraction
Sulfur	Protein production
Microminerals or Trace (<100 mg/day)	
Iron	Carries oxygen, assists in energy production
Zinc	Protein and DNA production, wound healing, growth, immune system function
Iodine	Thyroid hormone production, growth, metabolism
Selenium	Antioxidant
Copper	Coenzyme, iron metabolism
Manganese	Coenzyme
Fluoride	Bone and teeth health maintenance, tooth decay prevention
Chromium	Assists insulin in glucose metabolism
Molybdenum	Coenzyme
	Ultra Trace Minerals
Nickel	Coenzyme
Aluminum	Exact biological function unknown

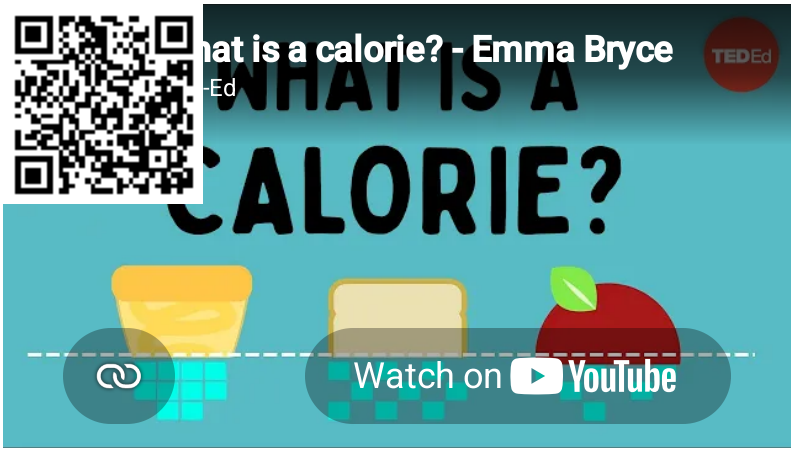
Minerals	Major Functions
Silicon	promotes bone and connective tissue health; exact biological function unknown
Vanadium	similar to phosphate; exact biological function unknown
Arsenic	Exact biological function unknown; may play a role in converting methionine to its active metabolites
Boron	Exact biological function unknown; may play a role in cell membrane characteristics and transmembrane signaling



***Video 1.3.1**: This video provides a brief history of Dr. Joseph Goldberger's discovery that pellagra was a diet-related disease.*

Food Energy and Food Quality

Though this is only Chapter 1, you have already seen the words "Calories" and "Energy" used several times. In everyday life, you have probably heard people talk about how many Calories they burned on the treadmill or how many Calories are listed on a bag of chips. Calories are a measure of energy. It takes quite a lot of Calories (energy) to keep us alive. Even if a person is in a coma, they still burn approximately 1000 Calories of energy in order for their heart to beat, their blood to circulate, their lungs to breathe, etc... We burn even more calories when we exercise. The carbohydrates, fats, and proteins we eat and drink provide calories for us (and alcohol as well if we choose to consume it). Sometimes people refer to these nutrients as "energy yielding". As you read above, carbohydrates provide 4 Calories for every gram we consume; proteins provide 4 Calories for every gram we consume; fats provide 9 Calories for every gram we consume and alcohol provides 7 Calories of energy for every gram we consume. Vitamins, minerals, and water do not provide any calories, even though they are still essential nutrients. Please watch the following Ted Ed video called "What is a Calorie" which will describe in more detail what a Calorie is and why you may want to know how many Calories you are consuming compared to how many you are burning each day.



***Video 1.03.2**: This video describes a calorie. We hear about calories all the time: How many calories are in this cookie? How many are burned by doing 100 jumping jacks, or long-distance running, or fidgeting? But what is a calorie, really? And how many of them do we actually need? Emma Bryce explains how a few different factors should go into determining the recommended amount for each person.*

One measurement of food quality is the amount of nutrients it contains relative to the amount of energy (Calories) it provides. High-quality foods are nutrient dense, meaning they contain lots of the nutrients relative to the amount of Calories they provide. Nutrient-dense foods are the opposite of "empty-calorie" foods such as carbonated sugary soft drinks, which provide many calories and very little, if any, other nutrients. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it. The quantity of nutrients present in foods can be influenced by farming conditions, ripeness of plants when harvested, cooking processes, and length of time it is stored.

Food: A Better Source of Nutrients

It is better to get all your micronutrients from the foods you eat as opposed to from supplements. Supplements contain only what is listed on the label, but foods contain many more macronutrients, micronutrients, and other chemicals, like antioxidants that benefit health. While vitamins, multivitamins, and supplements are a $20 billion industry in this country and more than 50 percent of Americans purchase and use them daily, there is no consistent evidence that they are better than food in promoting health and preventing disease. Dr. Marian Neuhouser, associate of the Fred Hutchinson Cancer Research Center in Seattle, says that "…scientific data are lacking on the long-term health benefits of supplements. To our surprise, we found that multivitamins did not lower the risk of the most common cancers and also had no impact on heart disease."Woodward, K. "Multivitamins Each Day Will Not Keep Common Cancers Away; Largest Study of Its Kind Provides Definitive Evidence that Multivitamins Will Not Reduce Risk of Cancer or Heart Disease in Postmenopausal Women." Fred Hutchinson Cancer Research Center. *Center News* 16 (February 2009). http://www.fhcrc.org/about/pubs/center_news/online/2009/02/multivitamin_study.html

Key Takeaways

- Foods contain nutrients that are essential for our bodies to function.
- Four of the nutrient classes required for bodily function are needed in large amounts. They are carbohydrates, lipids, proteins, and water, and are referred to as macronutrients.
- Two of the classes of nutrients are needed in lesser amounts but are still essential for bodily function. They are vitamins and minerals.
- One measurement of food quality is the amount of essential nutrients a food contains relative to the amount of energy it has (nutrient density).

Discussion Starters

1. Make a list of some of your favorite foods and visit the "What's In the Foods You Eat?" search tool provided by the USDA. What are some of the nutrients found in your favorite foods?

   http://www.ars.usda.gov/Services/docs.htm?docid=17032

2. Have a discussion in class on the "progression of science" and its significance to human health as depicted in the video on pellagra (Video 1.3.1).

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1.4: Historical Perspectives on Food

Learning Objectives

- Contrast ancient perspectives on food and nutrition with more modern explanatory systems

Throughout history, our relationship with food has been influenced by changing practices and perspectives. From the invention of agriculture to the birth of refrigeration, technological advances have also affected what we eat and how we feel about our food. Therefore, it can be helpful to examine theories and customs related to diet and nutrition across different civilizations and time periods.

Civilizations and Time Periods

Diet and cuisine have undergone enormous changes from ancient times to today. The basic diet of the ancient era consisted of cereals, legumes, oil, and wine. These staples were supplemented by vegetables and meat or fish, along with other items, such as honey and salt. During the Middle Ages, poor people consumed meager diets that consisted of small game supplemented with either barley, oat, or rye, while the wealthy had regular access to meat and fish, along with wheat.Our Food Recipes. “European Medieval Food.” © 2011–2012. www.our-food-recipes.com/medieval-food.html. During the Industrial Revolution, diets became more varied, partly because of the development of refrigeration and other forms of food preservation. In the contemporary era, many people have access to a wide variety of food that is grown locally or shipped from far-off places.



Picture 1.4.1 Flatbread made from barley or wheat was a staple in the traditional diet during the ancient era. (CC -BY-SA 3.0; Jonathunder).

Hunters and Gatherers

Human beings lived as hunters and gatherers until the invention of agriculture. Following a nomadic lifestyle, early people hunted, fished, and gathered fruit and wild berries, depending on their location and the availability of wild plants and wild game. To aid their constant quest for food, humans developed weapons and tools, including spears, nets, traps, fishing tackle, and the bow and arrow.Our Food Recipes. “Pre Historic Food.” © 2011–2012. www.our-food-recipes.com/pre-historic-food.html.

The Beginning of Agriculture

About ten thousand years ago, people began to cultivate crops and domesticate livestock in Mesopotamia, an area of the world that is known today as the Middle East. Agriculture flourished in this region due to the fertile floodplain between the Euphrates and Tigris Rivers, and early crops included wheat, barley, and dates. The development of agriculture not only enriched the diet of these early people, it also led to the birth of civilization as farmers began to settle into sizable, stable communities.Bioworld. “History of Agriculture.” Accessed October 10, 2011. www.bioworldusa.com/agriculture/history-agriculture.

One of the most fertile regions of the ancient world was located along the Nile River Valley in ancient Egypt. The rich soil yielded several harvests per year. Common crops were barley, wheat, lentils, peas, and cabbage, along with grapes, which were used to make wine. Even poor Egyptians ate a reasonably healthy diet that included fish, vegetables, and fruit. However, meat was primarily a privilege of the rich. Popular seasonings of this era included salt, pepper, cumin, coriander, sesame, fennel, and dill.Experience Ancient Egypt. “Ancient Egyptian Food: The Pharaonic Diet.” © 2009–2011. http://www.experience-ancient-egypt.com/ancient-egyptian-food.html.

The “Three Sisters”

Thousands of years ago, across an area that encompasses Mexico and Central America today,Foundation for the Advancement of Mesoamerican Studies. “Mesoamerica.” Accessed October 10, 2011. http://www.famsi.org/. Mesoamerican farmers cultivated three major plants—squash, beans, and maize (also known as corn). Known as the “three sisters,” these crops proved to be both complementary and sustainable. Corn provides a pole for bean vines to climb. The roots of bean vines provide nitrogen that helps corn grow. These vines also stabilize corn stalks by making them less vulnerable to the wind. Shallow-rooted squash vines prevent the evaporation of soil moisture, while their spiny plants discourage predators. Both of these attributes aid the cultivation of all three crops.Renee’s Garden. “Celebrate the Three Sisters,” During the post-Columbian era, Native American groups adopted the practice of interplanting squash, beans, and maize, and now thousands of years later, many small farmers continue to cultivate the “three sisters.”

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Meals Determined Social Status

In ancient Rome, differences in social standing affected the diet. For people of all socioeconomic classes, breakfast and lunch were typically light meals that were often consumed in taverns and cafes. However, dinners were eaten at home and were taken much more seriously. Wealthy senators and landowners ate meals with multiple courses, including appetizers, entrees, and desserts. Rich Romans also held extravagant dinner parties, where guests dined on exotic foods, such as roasted ostrich or pheasant. In contrast, people of the lower classes ate mostly bread and cereals.PBS. “Home Life.” *The Roman Empire in the First Century*. © 2006 Devillier Donegan Enterprises. http://www.pbs.org/empires/romans/empire/home.html. The average person ate out of clay dishes, while wealthy people used bronze, gold, or silver.

Social status determined the kinds of food that people consumed in many other parts of the world as well. In ancient China, emperors used their wealth and power to hire the best chefs and acquire delicacies, such as honey, to sweeten food. Dishes of the ancient era included steamed Mandarin fish, rice and wheat noodles, and fried prawns. Imperial cuisine also included improved versions of dishes that were consumed by the common people, such as soups and cereals.China.org. “The History of Chinese Imperial Cuisines.” © China Information Center. Accessed December 5, 2011. http://www.china.org.cn/english/imperial/25995.htm.

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The Medieval Era

The eating habits of most people during the Medieval Era depended mainly on location and financial status. In the feudal system of Europe, the majority of the population could not afford to flavor their food with extravagant spices or sugar. In addition, transporting food was either outrageously expensive or out of the question due to the inability to preserve food for a long period of time. As a result, the common diet consisted of either wheat, meat, or fish, depending on location. The typical diet of the lower classes was based on cereals and grains, porridge, and gruel. These staples were supplemented with seasonal fruits, vegetables, and herbs. Wine, beer, and cider were also common, and were often safer to drink than the unsanitized, untreated water.

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The Crusades

During the Medieval Era, soldiers from Europe waged war over religion in the Middle East in military campaigns that came to be known as the Crusades. Upon their return, the crusaders brought back new foods and spices, exposing Europeans of the Middle Ages to unusual flavors. Cooking with exotic spices, such as black pepper, saffron, and ginger, became associated with wealth because they were expensive and had to be imported.

-

Food Preservation in the Past

During the Medieval and Renaissance eras, most meals consisted of locally grown crops because it was extremely difficult to transport food over long distances. This was mostly due to an inability to preserve food for long periods. At that time, food preservation consisted mostly of drying, salting, and smoking. Pickling, which is also known as brining or corning, was another common practice and involved the use of fermentation to preserve food.

The Modern Era

The modern era began in North America and Europe with the dawn of the Industrial Age. Before that period, people predominantly lived in agrarian communities. Farming played an important role in the development of the United States and Canada. Almost all areas of the country had agrarian economies dictated by the harvesting seasons.

People noticed that certain foods were needed for health. For example, British sailors in the 1700's observed that limes could prevent scurvy. In the late 1700 and into the 1900s, physicians and scientists began to look at the relationship between food deficiencies and the development of disease more closely by looking at physical signs during the absence of specific foods.

In the 1800s, society began to change as new machines made it easier to cultivate crops and to package, ship, and store food. The invention of the seed drill, the steel plow, and the reaper helped to speed up planting and harvesting. Also, food could be transported more economically as a result of developments in rail and refrigeration. These and other changes ushered in the modern era and affected the production and consumption of food.

Food Preservation in Modern Times

Technological innovations during the 1800s and 1900s also changed the way we cultivate, prepare, and think about food. The invention and refinement of the refrigerator and freezer made it possible for people to store food for much longer periods. This, in turn, allowed for the transportation of food over greater distances. For example, oranges grown in Florida would still be fresh when they arrived in Seattle.

Prior to refrigeration, people relied on a number of different methods to store and preserve food, such as pickling. Other preservation techniques included using sugar or honey, canning, and preparing a confit, which is one of the oldest ways to preserve food and involves salting meat and cooking it in its own fat. To store foods for long periods, people used iceboxes or kept vegetables, such as potatoes, onions, and winter squash, in cellars during the winter months.

During the early 1900s, scientists began to identify nutrients. In 1922, McCollum showed vitamin D deficiency caused rickets in children.

The Great Depression

During the Great Depression of the 1930s, the United States faced incredible food shortages and many people went hungry. This was partly because extreme droughts turned parts of the Midwest into a Dust Bowl, where farmers struggled to raise crops. Millions of Americans were unemployed or underemployed and were forced to wait in long bread lines for free food. This was also a period of incredible reforms, as the government worked to provide for and protect the people. Some important changes included subsidies and support for suffering farmers.

World War II

Food shortages also occurred during World War II in the 1940s. At that time, people voluntarily made due with less to ensure that soldiers training and fighting overseas had the supplies they needed. To focus on saving at home, government programs included rationing food (particularly meat, butter, and sugar), while the media encouraged families to plant their own fruits and vegetables in “victory” (backyard) gardens.

In the 1950s, several vitamins and essential minerals were discovered and research focused on nutrient deficiencies.

Contemporary Life

Today, agriculture remains a large part of the economy in many developing nations. In fact, nearly 50 percent of the world's labor is employed in agriculture.Bioworld. "History of Agriculture." Accessed October 10, 2011. www.bioworldusa.com/agriculture/history-agriculture. In the United States however, less than 2 percent of Americans produce food for the rest of the population.Gold, M.V. "Sustainable Agriculture: Definitions and Terms." US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1. Also, most farms are no longer small-scale or family-owned. Large-scale agribusiness is typical for both crop cultivation and livestock rearing, including concentrated animal feeding operations. Conventional farming practices can include abuses to animals and the land. Therefore, more and more consumers have begun to seek out organic and locally grown foods from smaller-scale farms that are less harmful to the environment.

Other changes also affect food production and consumption in the modern era. The invention of the microwave in the 1950s spurred the growth of frozen foods and TV dinners. Appliances such as blenders and food processors, toasters, coffee and espresso machines, deep fryers, and indoor grills have all contributed to the convenience of food preparation and the kinds of meals that people enjoy cooking and eating.

Nutrition scientists expanded their research to include optimal nutrition, nutritional pharmacology, nutrient excesses, disease patterns, and food security.

-

Diet Trends Over Time

Today, consumers can choose from a huge variety of dietary choices that were not available in the past. For example, strawberries can be purchased in New York City in wintertime, because they are quickly and easily transported from places where the crop is in season, such as California, Mexico, or South America. In the western world, especially in North America, food products are also relatively cheap. As a result, there is much less disparity between the diets of the lower and upper classes than in the past. It would not be unusual to find the same kind of meat or poultry served for dinner in a wealthy neighborhood as in a poorer community.

Key Takeaways

Perspectives and practices related to food and nutrition have greatly changed from the ancient era to today. In the ancient world, location and economic status had a profound effect on what people ate. Also, societies often were based on crop cultivation and livestock rearing, which influenced how people ate, worked, and lived. During the Medieval Era, people became more exposed to food from other parts of the world because of the growing ability to ship goods and because of the Crusades, among other factors. Technological advances, such as refrigeration and the microwave, have had huge effects on the way food is produced and consumed.

Discussion Starter

1. Compare and contrast the diet of a civilization from the ancient world or the Medieval Era to the food choices of today. In what ways has our diet changed? In what ways has it remained the same?

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1.5: The Broad Role of Nutritional Science

Learning Objective

- Provide an example of how the scientific method works to promote health and prevent disease.

How to Determine the Health Effects of Food and Nutrients

Similar to the method by which a police detective finally charges a criminal with a crime, nutritional scientists discover the health effects of food and its nutrients by following a process known as scientific method. The scientific method involves five steps: 1) ask a question or make an observation; 2) investigate the current and past literature to determine what is known about that observation or question; 3) construct a hypothesis; 4) test that hypothesis using experimental procedure; and 5) analyze the results and draw conclusions.

Below is an illustration of the scientific method at work—in this case, to prove that iodine is a nutrient. Zimmerman, M.B. "Research on Iodine Deficiency and Goiter in the 19th and Early 20th Centuries." *J Nutr* 138, no. 11 (November 2008): 2060–63. Carpenter, K.J. "David Marine and the Problem of Goiter." *J Nutr* 135, no.4 (April 2005): 675–80. In 1811, French chemist Bernard Courtois was isolating saltpeter for producing gunpowder to be used by Napoleon's army. To carry out this isolation he burned some seaweed and in the process observed an intense violet vapor that crystallized when he exposed it to a cold surface. He sent the violet crystals to an expert on gases, Joseph Gay-Lussac, who identified the crystal as a new element. It was named iodine, the Greek word for violet. The following scientific record is some of what took place in order to conclude that iodine is a nutrient.

Observation. Eating seaweed is a cure for goiter, a gross enlargement of the thyroid gland in the neck.

- **Hypothesis.** In 1813, Swiss physician Jean-Francois Coindet hypothesized that the seaweed contained iodine and he could use just iodine instead of seaweed to treat his patients.
- **Experimental test.** Coindet administered iodine tincture orally to his patients with goiter.
- **Interpret results.** Coindet's iodine treatment was successful.
- **Gathering more evidence.** Many other physicians contributed to the research on iodine deficiency and goiter.

Hypothesis. French chemist Chatin proposed that the low iodine content in food and water of certain areas far away from the ocean were the primary cause of goiter and renounced the theory that goiter was the result of poor hygiene.

- **Experimental test.** In the late 1860s the program, "The stamping-out of goiter," started with people in several villages in France being given iodine tablets.
- **Results.** The program was effective and 80 percent of goitrous children were cured.

Hypothesis. In 1918, Swiss doctor Bayard proposed iodizing salt as a good way to treat areas endemic with goiter.

- **Experimental test.** Iodized salt was transported by mules to a small village at the base of the Matterhorn where more than 75 percent of school children were goitrous. It was given to families to use for six months.
- **Results.** The iodized salt was beneficial in treating goiter in this remote population.
- **Experimental test.** Physician David Marine conducted the first experiment of treating goiter with iodized salt in America in Akron, Ohio.
- **Results.** This study conducted on over four-thousand school children found that iodized salt prevented goiter.

Conclusions. Seven other studies similar to Marine's were conducted in Italy and Switzerland that also demonstrated the effectiveness of iodized salt in treating goiter. In 1924, US public health officials initiated the program of iodizing salt and started eliminating the scourge of goiterism. Today more than 70 percent of American households use iodized salt and many other countries have followed the same public health strategy to reduce the health consequences of iodine deficiency.

Evidence-Based Approach to Nutrition

It took more than one hundred years from iodine's discovery as an effective treatment for goiter until public health programs recognized it as such. Although a lengthy process, the scientific method is a productive way to define essential nutrients and determine their ability to promote health and prevent disease. The scientific method is part of the overall evidence-based approach to designing nutritional guidelines. An evidence-based approach to nutrition includes:Briss, P.A., et al. "Developing an Evidence-Based Guide to Community Preventive Services—Methods." *Am J Prev Med* 18, no. 1S (2000): 35–43.' Myers, E. "Systems for Evaluating Nutrition Research for Nutrition Care Guidelines: Do They Apply to Population Dietary Guidelines?" *J Am Diet Assoc* 103, no. 12, supplement 2 (December 2003): 34–41.

- Defining the problem or uncertainty (e.g., the rate of colon cancer is higher in people who eat red meat)
- Formulating it as a question (e.g., Does eating red meat contribute to colon cancer?)
- Setting criteria for quality evidence
- Evaluating the body of evidence
- Summarizing the body of evidence and making decisions
- Specifying the strength of the supporting evidence required to make decisions
- Disseminating the findings

The Food and Nutrition Board of the Institute of Medicine, a nonprofit, nongovernmental organization, constructs its nutrient recommendations (i.e., Dietary Reference Intakes, or DRI) using an evidence-based approach to nutrition. The entire procedure for setting the DRI is documented and made available to the public. The same approach is used by the USDA and HHS, which are departments of the US federal government. The USDA and HHS websites are great tools for discovering ways to optimize health; however, it is important to gather nutrition information from multiple resources as there are often differences in opinion among various scientists and public health organizations. Here is an example. While the 2010 *Dietary Guidelines* were well-received by some, there were nongovernmental public health organizations that are convinced that some pieces of the guidelines may be influenced by lobbying groups and/or the food industry. For example, the Harvard School of Public Health (HSPH) felt the government fell short by being "too lax on refined grains." (The Harvard School of Public Health. "New US Dietary Guidelines: Progress, Not Perfection." © 2010 The President and Fellows of Harvard College.) Although the guidelines recommend getting at least *half* of grains from whole grains—according to HSPH this still leaves too much consumption of refined grains. This recommendation continues today with the 2020-2025 *Dietary Guidelines*.

For a list of reliable sources that advocate good nutrition to promote health and prevent disease using evidence-based science see Table 1.5.1. In this Chapter, we will further discuss distinguishing criteria that will enable you to wade through misleading nutrition information and instead gather your information from reputable, credible websites and organizations.

Table 1.5.1: Web Resources for Nutrition and Health

Organization	Website
Governmental	
US Department of Agriculture	http://www.usda.gov/wps/portal/usda/usdahome
USDA Center for Nutrition Policy and Promotion	www.cnpp.usda.gov/
US Department of Health and Human Services	http://www.hhs.gov/
Centers for Disease Control and Prevention	http://www.cdc.gov/
Food and Drug Administration	http://www.fda.gov/
Healthy People	http://www.healthypeople.gov/2020/default.aspx
Office of Disease Prevention and Health Promotion	odphp.osophs.dhhs.gov/
Health Canada	http://www.hc-sc.gc.ca/
International	
World Health Organization	http://www.who.int/en/
Food and Agricultural Organization of the United Nations	www.fao.org/
Nongovernmental	
Harvard School of Public Health	www.hsph.harvard.edu/nutritionsource/index.html
Mayo Clinic	http://www.mayoclinic.com/
Linus Pauling Institute	http://lpi.oregonstate.edu/
American Society for Nutrition	http://www.nutrition.org/
American Medical Association	http://www.ama-assn.org/
American Diabetes Association	http://www.diabetes.org/
The Academy of Nutrition and Dietetics	http://www.eatright.org/
Institute of Medicine: Food and Nutrition	www.iom.edu/Global/Topics/Food-Nutrition.aspx
Dietitians of Canada	http://www.dietitians.ca/

Types of Scientific Studies

There are many types of scientific studies that can be used to provide supporting evidence for a particular hypothesis. The various types of studies include epidemiological studies, interventional clinical trials, and randomized clinical interventional trials.

Epidemiological studies are observational studies that look for health patterns and are often the front-line studies for public health. The CDC defines epidemiological studies as scientific investigations that define the frequency, distribution, and patterns of health events in a population. Thus, these studies describe the occurrence and patterns of health events over time. The goal of an epidemiological study is to find factors associated with an increased risk for a health event, though these sometimes remain elusive. An example of an epidemiological study is the Framingham Heart Study, a project of the National Heart, Lung and Blood Institute and Boston University that has been ongoing since 1948. This study first examined the

physical health and lifestyles of 5,209 men and women from the city of Framingham, Massachusetts, and has now incorporated data from the children and grandchildren of the original participants. One of the seminal findings of this ambitious study was that higher cholesterol levels in the blood are a risk factor for heart disease. The Framingham Heart Study is a project of the National Heart, Lung, and Blood Institute and Boston University. “History of the Framingham Heart Study.” Epidemiological studies are a cornerstone for examining and evaluating public health and some of their advantages are that they can lead to the discovery of disease patterns and risk factors for diseases, and they can be used to predict future healthcare needs and provide information for the design of disease prevention strategies for entire populations. Some shortcomings of epidemiological studies are that investigators cannot control environments and lifestyles, a specific group of people studied may not be an accurate depiction of an entire population, and these types of scientific studies cannot directly determine if one variable causes another. Scientists regard epidemiological studies as a starting place for ideas about what types of lifestyle choices MAY contribute to disease. They can show a correlation between two things happening but not whether one factor CAUSED the other. My favorite example of this is a thought experiment where a make-believe scientist observes (through epidemiological studies) that gray hair often goes along with Alzheimer's Disease. Wouldn't it be silly for that scientist to predict that gray hair CAUSES Alzheimer's Disease? Could that scientist easily test that silly prediction? Suppose that scientists dyed a group of people's hair gray to see if the color gray truly increased their risk of Alzheimer's Disease. The whole thing is silly but I think you get the point. Epidemiological studies may give us ideas but those ideas need clinical trials to figure out what the patterns mean.

There are many different types of study designs including randomized controlled trials, cohort studies (prospective observational studies), case-control studies, cross-sectional studies, and case reports. Each has its strengths and weaknesses and the selection of the study type depends on the hypothesis being tested and the resources available.

A cohort study (prospective observational study) is a clinical study in which a group of people with a particular condition or treatment, for example, lung cancer or patients taking an antihypertensive, is followed over time. In addition, a second cohort of people that does not have that condition or treatment is followed and compared to the first group with the condition. Here is an example of a cohort study: Zacche MM, Giarenis I, Thiagamoorthy G, Robinson D, Cardozo L. Is there an association between aspects of the metabolic syndrome and overactive bladder? A prospective cohort study in women with lower urinary tract symptoms. Eur J Obstet Gynecol Reprod Biol. 2017 Aug 2;217:1-5. https://www.ncbi.nlm.nih.gov/pubmed/28826038

A case-control study does not follow people over time and pre-selects individuals with a particular result (the cases), for example, people with osteoporosis (outcome), and then interviews that group or checks their records to determine what specific experience they had. From this information, an odds ratio is calculated to determine the odds of having an experience with the outcome of having the experience without the outcome. Here is an example of a cohort study: Alvarado-Esquivel C, Maldonado-Soto E, Sanchez-Anguiano LF, Hernandez-Tinoco J, Ramos-Nevarez A, Cerrillo-Soto SM, Sandoval-Carrilo AA, Salas-Pacheco JM, Antuna-Salcido EI, Estrada-Martinez S, Guido-Arreola CA. Lack of Serological and Molecular Association between Toxoplasma Gondii Exposure and Obesity: A Case-Control Study. Int J Biomed Sci. 2017 Jun;13(2):74-78.

Cross-sectional studies look at a single point in time or time interval in a particular population. Exposure and outcome are determined simultaneously. Here is an example of a cohort study: Nygaard L, Skallerup A, Olesen SS, Køhler M, Vinter-Jensen L, Kruse C, Vestergaard P, Rasmussen HH. Osteoporosis in patients with intestinal insufficiency and intestinal failure: Prevalence and clinical risk factors. Clin Nutr. 2017 Aug 5. pii: S0261-5614(17)30259-5. doi:10.1016/j.clnu.2017.07.018. [Epub ahead of print]

Case reports involve cases with a particular outcome. No control group is involved. The report may include one subject or several subjects. Here is an example of a cohort study: Meade RD, D'Souza AW, Krishen L, Kenny GP. The physiological strain incurred during electrical utilities work over consecutive work shifts in hot environments: A case report. J Occup Environ Hyg. 2017 Aug 21:0. doi: 10.1080/15459624.2017.1365151. [Epub ahead of print]

Some studies may involve the use of a placebo which is a harmless medicine, procedure or task that has no therapeutic effect. Instead, it may have a powerful psychological benefit.

Interventional clinical trial studies are scientific investigations in which a variable is changed between groups of people. When well done, this type of study allows one to determine causal relationships. An example of an interventional clinical trial study is the Dietary Approaches to Stop Hypertension (DASH) trial published in the April 1997 issue of *The New England Journal of Medicine*. Appel, L. J., et al. “A Clinical Trial of the Effects of Dietary Patterns on Blood Pressure.,” *N Engl J Med* 336 (April 1997): 1117–24. In this study, 459 people were randomly assigned to three different groups; one was put on an average American control diet, a second was put on a diet rich in fruits and vegetables, and the third was put on a combination diet rich in fruits, vegetables, and low-fat dairy products with reduced saturated and total fat intake. The groups remained on the diets for eight weeks. Blood pressures were measured before starting the diets and after eight weeks. Results of the study showed that the group on the combination diet had significantly lower blood pressure at the end of eight weeks than those who consumed the control diet. The authors concluded that the combination diet is an effective nutritional approach to treat high blood pressure. The attributes of high-quality clinical interventional trial studies are:

- those that include a control group, which does not receive the intervention, to which you can compare the people who receive the intervention being tested;
- those in which the subjects are randomized into the group or intervention group, meaning a given subject has an equal chance of ending up in either the control group or the intervention group. This is done to ensure that any possible confounding variables are likely to be evenly distributed between the control and the intervention groups;
- those studies that include a sufficient number of participants.

What are confounding variables? These are factors other than the one being tested that could influence the results of the study. For instance, in the study, we just considered, if one group of adults did less physical activity than the other, then it could be the amount of physical activity rather than the diet being tested that caused the differences in blood pressure among the groups.

The limitations of these types of scientific studies are that they are difficult to carry on for long periods of time, are costly, and require that participants remain compliant with the intervention. Furthermore, it is unethical to study certain interventions. (An example of an unethical intervention would be to advise one group of pregnant mothers to drink alcohol to determine the effects of alcohol intake on pregnancy outcome because we know that alcohol consumption during pregnancy damages the developing fetus.)

Randomized clinical interventional trial studies are powerful tools to provide supporting evidence for a particular relationship and are considered the "gold standard" of scientific studies. A randomized clinical interventional trial is a study in which participants are assigned by chance to separate groups that compare different treatments. Neither the researchers nor the participants can choose which group a participant is assigned. However, from their limitations, it is clear that epidemiological studies complement interventional clinical trial studies and both are necessary to construct strong foundations of scientific evidence for health promotion and disease prevention.

Other scientific studies used to provide supporting evidence for a hypothesis include laboratory studies conducted on animals or cells. An advantage of this type of study is that they typically do not cost as much as human studies and they require less time to conduct. Other advantages are that researchers have more control over the environment and a number of confounding variables can be significantly reduced. Moreover, animal and cell studies provide a way to study relationships at the molecular level and are also helpful in determining the exact mechanism by which a specific nutrient causes a change in health. An animal model can closely mimic the exact disease in humans. The disadvantage of these types of studies is that researchers are not working with whole humans and thus the results may not be relevant. Nevertheless, well-conducted animal and cell studies that can be repeated by multiple researchers and obtain the same conclusion are definitely helpful in building the evidence to support a scientific hypothesis.

Evolving Science

Science is always moving forward, albeit sometimes slowly. One study is not enough to make a guideline or a recommendation or cure a disease. Science is a stepwise process that builds on past evidence and finally culminates in a well-accepted conclusion. Unfortunately, not all scientific conclusions are developed in the interest of human health and it is important to know where a scientific study was conducted and who provided the money. Indeed, just as an air quality study paid for by a tobacco company diminishes its value in the minds of readers, so does one on red meat performed at a laboratory funded by a national beef association.

Science can also be contentious even amongst experts that don't have any conflicting financial interests. To see scientists debating over the nutritional guidelines, watch Video 1.5.1. Contentious science is actually a good thing as it forces researchers to be of high integrity, well-educated, well-trained, and dedicated. It also instigates public health policymakers to seek out multiple sources of evidence in order to support a new policy. An agreement involving many experts across multiple scientific disciplines is necessary for recommending dietary changes to improve health and prevent disease. Although a somewhat slow process, it is better for our health to allow the evidence to accumulate before incorporating some change in our diet.

http://www.youtube.com/embed/KBryEJXSaLk

Video 1.5.1: *Debate" This we 29, 2011, demonstrates how science is always evolving and how debate among nutrition science experts influences policy deci rd School of Public Health, in collaboration with Reuters.*

Nutritional Science Evc

One of the newest areas in th al science is the scientific discipline of nutritional genetics, also called nutrigenomics. Genes are part of DNA and contain the genetic information that makes up all our traits. Genes are codes for proteins and when they are turned "on" or "off," they change how the body works. While we know that health is defined as more than just the absence of disease, there are currently very few accurate genetic markers of good health. Rather, there are many more genetic markers for disease. However, science is evolving and nutritional genetics aims to identify what nutrients to eat to "turn on" healthy genes and "turn off" genes that cause disease. Eventually, this field will progress so that a person's diet can be tailored to their genetics. Thus, your DNA will determine your optimal diet.

www.youtube.com/v/-K7w59tHFMI

Video 1.5.2: *Nutrigenomics: A the new scientific discipline of nutrigenomics and its potential impact on diet and health.*

Using Science and Tec nge the Future

As science evolves, so does t n be used to create a healthy diet, optimize health, and prevent disease. Picture yourself not too far into the future: you are wear y watch" that painlessly samples your blood, and downloads the information to your cell phone, which has an app that evaluates the nutrient profile of your blood and then recommends a snack or dinner menu to assure you maintain adequate nutrient levels. What else is not far off? How about another app that provides a shopping list that adheres to all dietary guidelines and is emailed to the central server at your local grocer who then delivers the food to your home? The food is then stored in your smart fridge which documents your daily diet at home and delivers your weekly dietary assessment to your home computer. On your computer, you can compare your diet with other

diets aimed at weight loss, optimal strength training, reduction in risk for specific diseases, or any other health goals you may have. You may also delve into the field of nutritional genetics and download your gene expression profiles to a database that analyzes yours against millions of others.



Figure 1.5.1: *The "Smart Fridge". Source: http://www.yankodesign.com/2010/05/28/smart-fridge-is-your-new-recipe-card/.*

Key Takeaways

- The scientific method is an organized process of inquiry used in nutritional science to determine if the food suspect fits the claim.
- The scientific method is part of the overall evidence-based approach to designing nutritional guidelines that are based on facts.
- There are different types of scientific studies—epidemiological studies, randomized clinical interventional trial studies, and laboratory animal and cell studies—which all provide different, complementary lines of evidence.
- It takes time to build scientific evidence that culminates as a commonly accepted conclusion.
- Agreement of experts across multiple scientific disciplines is a necessity for recommending dietary changes to improve health and help to prevent disease.
- Science is always evolving as more and more information is collected.

Discussion Starters

1. What are some of the ways in which you think like a scientist and use the scientific method in your everyday life? Any decision-making process uses at least pieces of the scientific method. Think about some of the major decisions you have made in your life and the research you conducted that supported your decision. For example, what computer brand do you own? Where is your money invested? What college do you attend?
2. Do you use technology, appliances, and/or apps that help you to optimize your health?

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1.6: Health Factors and Their Impact

Learning Objective

- Explain the role that genetics, environment, life cycle, and lifestyle play in health status.
- Describe economic, social, cultural, and emotional determinants that affect personal choices of foods.

In addition to nutrition, health is affected by genetics, the environment, life cycle, and lifestyle. These factors are referred to as "determinants" of health and they all interact with each other. For example, family income influences the food choices available and the quantity and quality of food that can be purchased, which of course affects nutrition. Except for nutrition and lifestyle, these factors can be difficult or impossible to change.

Genetics

Everyone starts out in life with the genes handed down to them from the families of their mother and father. Genes are responsible for your many traits as an individual and are defined as the sequences of DNA that code for all the proteins in your body. The expression of different genes can determine the color of your hair, skin, and eyes, and even if you are more likely to be fat or thin and if you have an increased risk for a certain disease. The sequence of DNA that makes up your genes determines your genetic makeup, also called your genome, which is inherited from your mother and father. In 2003, the Human Genome Project was completed and now the entire sequence of DNA in humans is known. It consists of about three billion individual units and contains between twenty-five and thirty thousand genes. The human genome that was sequenced was taken from a small population of donors and is used as a reference DNA sequence for the entire population. Each of us has a similar but unique DNA sequence. Only identical twins and cloned animals have the exact same DNA sequence.



Figure 1.6.1: Identical twins are the only individuals in the world that have identical DNA, sharing the same genotype. However, their phenotype is different, meaning that their identical DNA is expressed differently. Marian and Vivian Brown, identical twins, photographed by Christopher Michel.

Now that we understand the map of the human genome, let's enter the fields of nutrigenomics and epigenetics. Recall that nutrigenomics is an emerging scientific discipline aimed at defining healthy genes and not-so-healthy genes and how nutrients affect them. Currently, scientists cannot change a person's DNA sequence. But they have discovered that chemical reactions in the body can turn genes "on" and "off," causing changes in the amounts and types of proteins expressed. Epigenetics is another rapidly advancing scientific field in which researchers study how chemical reactions turn genes "on" and "off" and the factors that influence the chemical reactions. Some of these factors are now known to be nutrients. Researchers at the Genetic Science Learning Center at the University of Utah conducted an experiment in which some pregnant mice were fed a diet containing folate, choline, vitamin B_{12}, and betaine, and other pregnant mice were fed a diet that did not contain these nutrients and chemicals. Both groups of pregnant mice were also fed bisphenol A, a chemical in plastic, which alters DNA by inhibiting a specific chemical reaction. The mice born from the mother fed the supplemented diet were brown, thin, and healthy. The mice born from the mother fed the unsupplemented diet were yellow, fat, and unhealthy. This is a dramatic example of how nutrients change not the sequence of DNA, but which genes are expressed. These two mice look different but have identical DNA sequences. Thus, not only do the things you eat determine your health but so do the things your mother ate during pregnancy. Moreover, other studies have

demonstrated what your dad ate—and what your grandmother ate while she was pregnant with your mother!—also can affect your gene expression and, consequently, your health. Does this make it OK for you to blame your mother and father for all of your shortcomings? No. Genetics are important in determining your health, but they are certainly not the only determinant.

? Interactive 1.6.1

This is a good animation of the central foundation of modern biology. Turn "on" a gene, make messenger RNA, and make protein. Spin the dial all the way to the left to turn off the expression, and then slowly move it to the right.

http://learn.genetics.utah.edu/content/epigenetics/control/

Source: Genetic Science Learning Center at the University of Utah.



***Video 1.6.1**: Diet during Pregnancy. Watch as Jen discovers how what you eat during pregnancy affects the health of your baby.*

The Life Cycle

The life cycle of human beings originates from a fertilized egg, which develops into a fetus that is eventually born as a baby. A baby develops into a child, transitions through the wonderful phase of adolescent to an adult, and then into old age and eventually death (Figure 1.6.1). The current average life expectancy in America is approaching eighty. To see how this compares with other countries, see Interactive 1.06.2.

? Interactive 1.6.2: The World Bank

Visit this public database from the World Bank to learn how the life expectancy in America differs from those in other countries.

http://www.google.com/publicdata?ds=wb-wdi&met_y=sp_dyn_le00_in&idim=country:USA&dl=en&hl=en&q=america+average+life+expectancy

A person's stage of life influences their health and nutritional requirements. For example, when you are an adolescent, your bones grow quickly. More calcium, a bone-building nutrient, is required in the diet during this life stage than at other ages. As you get older, the aging process affects how your body functions. One effect of aging, apparently earlier in women than in men, is the deterioration of bone tissue. As a result, women over age fifty-one need more calcium in their diet than younger adult women. Another life-cycle stage, pregnancy, requires several adjustments to nutrition compared to nonpregnant women. It is recommended that a pregnant woman consumes more protein than a nonpregnant woman to support growth and development, and to consume more of some vitamins, such as folate, to prevent certain birth defects. The USDA provides information on healthy diets for many different stages of the life cycle on their website. Healthy aging requires eating a diet that matches one's life stages to support the body's specific physiological requirements. What else is known to help a person age slowly and gracefully? Diets high in vegetables and fruits are associated with increased longevity and a decreased risk of many diseases.



***Figure 1.6.2**: The Life Cycle: The Forward March to Old Age and Ultimately Death. © Shutterstock*

Environment

Your environment has a large influence on your health, genetics, life cycle, and lifestyle. Scientists say that the majority of your expressed traits are a product of your genes and environment, of which nutrition is a component. An example of this interaction can be observed in people who have the rare genetic disorder, phenylketonuria (PKU). The clinical signs of PKU are mental retardation, brain damage, and seizures and are caused by the build-up of the amino acid phenylalanine and its metabolites (breakdown products produced during metabolism) in the body. The high level of phenylalanine in a person who has PKU is the result of a change in the gene that encodes for an enzyme that converts phenylalanine into the amino acid tyrosine. This genetic change, called a mutation, causes the enzyme to not function properly.

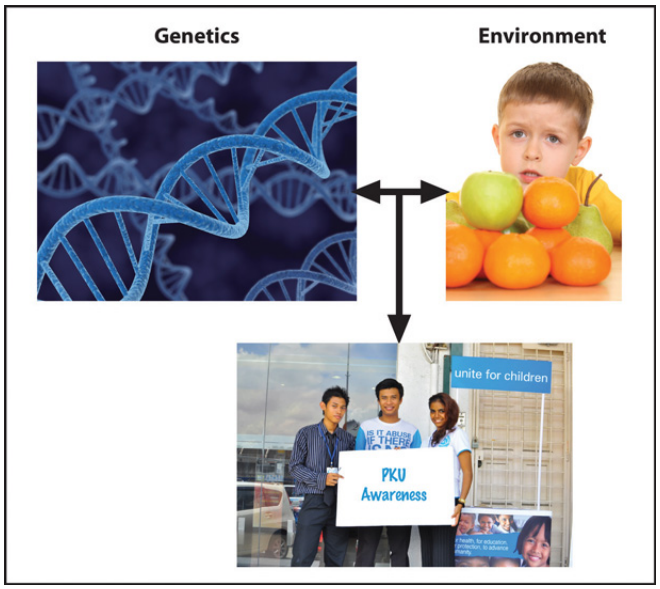


Figure 1.6.3: The interplay of genetics and environment can determine the consequences of disease. Sources: http://topnews.co.uk/214471-rare-disorder-known-phenylketonuria and www.georgiapku.org/AboutUs.html. © Shutterstock

In this country and many others, all newborn babies are screened for PKU in order to diagnose and treat the disease before the development of mental retardation and brain damage. Once diagnosed, PKU is treated by strict adherence to a diet low in phenylalanine, consisting mostly of fruits, vegetables, and grains. Adhering to this diet for life allows an individual with PKU to lead a normal life without suffering the consequences of brain damage, mental retardation, or seizures. In the example of PKU, the consequences of a genetic mutation are modified by diet. Thus, a person's genes can make them more susceptible to a particular disease, or cause a disease, and their environment can decrease or increase the progression and severity of the condition.

Socioeconomic Status

Multiple aspects of a person's environment can affect nutrition, which in turn affects health. One of the best environmental predictors of a population's health is socioeconomic status. Socioeconomic status is a measurement made up of three variables: income, occupation, and education. Socioeconomic status affects nutrition by influencing what foods you can afford and

consequently, food choice and food quality. Nutrition and health are generally better in populations that have higher incomes, better jobs, and more education. On the other hand, the burden of disease is highest in the most disadvantaged populations. A commentary in the *Journal of the American Medical Association* reports that the lower life expectancy of populations of lower socioeconomic status is largely attributable to increased death from heart disease.Fiscella, K. and D. Tancredi. "Socioeconomic Status and Coronary Heart Disease Risk Prediction." *JAMA* 300, no. 22 (2008): 2666–68. The American Heart Association states that having a healthy diet is one of the best weapons to fight heart disease and it is therefore essential that all socioeconomic status groups have access to high-quality, nutrient-dense foods. The disparities in nutrition and health in America are directly related to the disparity in socioeconomic status. Other dimensions that affect health disparity are race, ethnic group, sex, sexual identity, age, disability, and geographic location. The issue of inequitable health among Americans is recognized by the federal government and one of the overarching goals of Healthy People 2020, a large program managed by the HHS, is to "Achieve health equity, eliminate disparities, and improve the health of all groups." To work toward this monumental goal, the HHS is actively tracking disease patterns, chronic conditions, and death rates among the many different types of people that live in the United States. This will be further discussed in Chapter 2.

? Interactive 1.06.3

To see the differences in causes of death for different sexes, races, and age groups, visit the website of Healthy People and compare the top ten causes of death for different populations.

http://www.healthypeople.gov/2020/default.aspx

Lifestyle

One facet of lifestyle is your dietary habits. Recall that we discussed briefly how nutrition affects health. A greater discussion of this will follow in subsequent chapters in this book as there is an enormous amount of information regarding this aspect of lifestyle. Dietary habits include what a person eats, how much a person eats during a meal, how frequently meals are consumed, and how often a person eats out at restaurants. Other aspects of lifestyle include physical activity level, recreational drug use, and sleeping patterns, all of which play a role in health and impact nutrition. Following a healthy lifestyle improves your overall health.

In 2008, the HHS released the *Physical Activity Guidelines for Americans*. The HHS states that "Being physically active is one of the most important steps that Americans of all ages can take to improve their health. The *2008 Physical Activity Guidelines for Americans* provides science-based guidance to help Americans aged six and older improve their health through appropriate physical activity." The guidelines recommend exercise programs for people in many different stages of their lifecycle and for pregnant women and adults and children who have disabilities. The HHS reports that there is strong evidence that increased physical activity decreases the risk of early death, heart disease, stroke, Type 2 diabetes, high blood pressure, and certain cancers; prevents weight gain and falls; and improves cognitive function in the elderly. Also unveiled recently are the *Canadian Physical Activity Guidelines*, which are available at the website of The Canadian Society for Exercise Physiology.

? 2008 Physical Activity Guidelines for Americans.

http://www.health.gov/PAGuidelines/default.aspx

Recreational Drug Use

Recreational drug use, which includes tobacco-smoking and alcohol consumption along with narcotic and other illegal drug use, has a large impact on health. Smoking cigarettes causes lung cancer, eleven other types of cancer, heart disease, and several other disorders or diseases that markedly decrease quality of life and increase mortality. In the United States, smoking causes more than four hundred thousand deaths every single year, which is far more than deaths associated with any other lifestyle component. Centers for Disease Control and Prevention. "Smoking and Tobacco Use." Last updated March 21, 2011. Also, according to the CDC, excessive alcohol intake causes an estimated seventy-five thousand deaths per year. Centers for Disease Control and Prevention. "Alcohol and Drug Use." Last updated June 7, 2012. http://www.cdc.gov/healthyyouth/alcoholdrug/ Staying away from excessive alcohol intake lowers blood pressure, the risk from injury, heart disease, stroke, liver problems, and some types of cancer. Abstaining from alcohol also aids in weight loss and increases the money in your wallet. While heavy drinking of alcoholic beverages is associated with several bad health effects, consuming alcohol in moderation has been found to promote health such as reducing the risk for heart disease and Type 2 diabetes in some people. The HHS defines drinking in moderation as no more than one drink a day for women and two drinks a day for men.

Illicit and prescription drug abuse are associated with decreased health and is a prominent problem in the United States. The health effects of drug abuse can be far-reaching including increased risk for stroke, heart disease, cancer, lung disease, and liver disease.

Sleeping Patterns

Inadequate amounts of sleep, or not sleeping well, can also have remarkable effects on a person's health. In fact, sleeping can affect your health just as much as diet or exercise. At least 10 percent of Americans have chronic insomnia.National Sleep Foundation. "Can't Sleep? What to Know about Insomnia." Accessed February 12, 2012. Scientific studies have shown that insufficient sleep increases the risk for heart disease, Type 2 diabetes, obesity, and depression. Abnormal breathing during sleep, a condition called sleep apnea, is also linked to an increased risk for chronic disease.

? Exercise 1.6.5

Go to the HHS website and discover the many tools at your fingertips to live a healthier lifestyle.

www.healthfinder.gov/prevention/

Nutrition, Genetics, Environment, and Lifestyle Interact to Affect Health

The Pima Indians who inhabit parts of southern Arizona and the Pima Indians that live across the border in Mexico are genetically and culturally similar, but there are vast differences in the health of these two populations. In America, the Pima Indians have the highest rate of obesity and Type 2 diabetes compared to any other ethnic group. However, the Pima Indians who live in Mexico do not share these same health problems because of a complex interplay between nutrition, genetics, environment, and lifestyle. Over one hundred years ago, the Pima Indians were farmers, hunters, and gatherers and their diets consisted of about 70 percent carbohydrate, 15 percent protein, and 10 to 15 percent fat. Typical of the lives of farmers, hunters, and gatherers a century ago, they lived through times of feast and times of famine. The geneticist James Neel proposed in 1962 that the Pima Indians carried a "thrifty gene" that makes them very efficient at storing fat during times of plenty so they do not starve when food is scarce.

After World War II, the Pima Indians in America either went back to reservations in southern Arizona or moved to the cities for work. They rapidly adopted the American diet and lifestyle and consumed high-fat, processed foods and refined grains and were more sedentary than their counterparts in Mexico, who retained their more traditional diet and lifestyle. Today, the typical American Pima Indian diet obtains more than 40 percent of calories from fat. The "thrifty gene" in the American Pima Indian population increased their susceptibility to the consequences of the high-fat American diet and sedentary lifestyle because they were genetically better at storing fat than others. The story of the Pima Indians and the difference between the health of their populations in America and Mexico demonstrates the interactions between nutrition, genetics, environment, and lifestyle. Indeed, preliminary studies suggest that when American Pima Indians switch back to the diets of their ancestors and consume beans, corn, grains, and greens and other low-fat, high-fiber plant foods, the benefits are weight loss and reduced risk of chronic disease. The health status of American Pima Indians is considered "a canary in the coal mine, " meaning they provide a warning to the American people.

Although the health consequences of the American diet and lifestyle in Pima Indians appeared rapidly in their population, all Americans that partake in the current trends of American diet and lifestyle are at risk. On the lighter side (literally!), the new studies that show changing back to more traditional diets markedly improved the health of the American Pima Indians suggest that all Americans can reduce their risk for diet-related diseases even when their genetic susceptibility for these diseases is high.

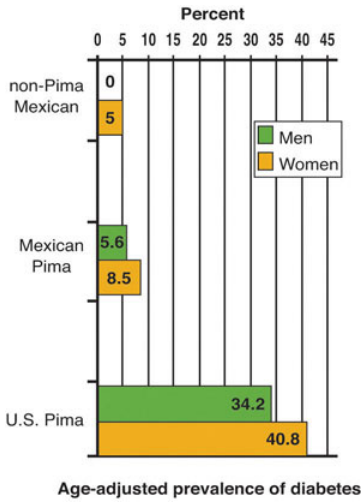


Figure 1.6.4: The Interplay of nutrition, genetics, environment, and lifestyle affects health. Pima Indians living in America are genetically similar to those who live in Mexico, but differences in their nutrition, environment, and lifestyle changes their health. Source: paleobioticslab.com/general-interest-articles/so-go-the-pimas-so-go-the-rest-of-us/.

Tools for Change

Heed the warning of the Pima Indians and seek out ways to establish a more traditional dietary pattern. The American diet in the nineteenth century consisted of less meat, less processed food, and more home-grown fruits, vegetables, and whole grains. Think of ways to include these types of foods in your diet or partake in some of the traditional foods of a particular ethnic group in your community. Visit the following websites to find out the unique foods of some traditional diets.

- Traditional Mediterranean diet: www.oldwayspt.org/mediterraneandiet
- Native Tech: http://www.nativetech.org/recipes/index.php
- Traditional foods, with recipes, by country: http://www.foodbycountry.com/index.html

Personal Choice: The Challenge of Choosing Foods

From visiting websites about traditional foods of different cultures and ethnic groups, you may have noticed that a few more things besides environment and lifestyle that influence the foods you choose to eat. Different foods affect energy level, mood, how much is eaten, how long before you eat again, and if cravings are satisfied. We have talked about some of the physical effects of food on your body, but there are other effects too. Food regulates your appetite and how you feel. Multiple studies have demonstrated that some high-fiber foods and high-protein foods decrease appetite by slowing the digestive process and prolonging the feeling of being full. The effects of individual foods and nutrients on mood are not backed by consistent scientific evidence, but in general most studies support that healthier diets are associated with a decrease in depression and improved well-being. To date, science has not been able to track the exact path in the brain that occurs in response to eating a particular food, but it is quite clear that foods, in general, stimulate emotional responses in people.

Food also has psychological, cultural, and religious significance, so your personal choices of food affect your body, mind, and soul. The social implications of food have a great deal to do with what people eat, as well as how and when. Special events in individual lives—from birthdays to funerals—are commemorated with equally special foods. Being aware of these forces can help people make healthier food choices—and still honor the traditions and ties they hold dear. Typically, eating kosher food means a person is Jewish; eating fish on Fridays during Lent means a person is Catholic; fasting during the ninth month of the Islamic calendar means a person is Muslim. On New Year's Day, people from New England like to combine pork and sauerkraut as a way to eat their way to luck. Several hundred miles away in the southern United States, people eat Hoppin' John, a favorite local dish made with black-eyed peas and pork, while fish is the "lucky" food of choice for Japanese Americans. National food traditions are carried to other countries when people immigrate. American cuisine would not be what it is today without the contributions of Italian, Chinese, Mexican, and other immigrants.

Factors that Drive Food Choices

Along with these influences, a number of other factors affect the dietary choices individuals make, including:

- **Taste, texture, and appearance.** Individuals have a wide range of tastes which influence their food choices, leading some to dislike milk and others to hate raw vegetables. Some foods that are very healthy, such as tofu, may be unappealing at first to many people. However, creative cooks can adapt healthy foods to meet most peoples' taste.
- **Economics.** Access to fresh fruits and vegetables may be scant, particularly for those who live in economically disadvantaged or remote areas, where cheaper food options are limited to convenience stores and fast food.
- **Early food experiences.** People who were not exposed to different foods as children, or who were forced to swallow every last bite of overcooked vegetables, may make limited food choices as adults.
- **Habits.** It's common to establish eating routines, which can work both for and against optimal health. Habitually grabbing a fast food sandwich for breakfast can seem convenient, but might not offer substantial nutrition. Yet getting in the habit of drinking an ample amount of water each day can yield multiple benefits.
- **Culture.** The culture in which one grows up affects how one sees food in daily life and on special occasions.
- **Geography.** Where a person lives influences food choices. For instance, people who live in Midwestern US states have less access to seafood than those living along the coasts.
- **Advertising.** The media greatly influences food choice by persuading consumers to eat certain foods.
- **Social factors.** Any school lunchroom observer can testify to the impact of peer pressure on eating habits, and this influence lasts through adulthood. People make food choices based on how they see others and want others to see them. For example, individuals can purchase cheap and fast pizzas or opt for high-end versions at fancy restaurants.
- **Health concerns.** Some people have significant food allergies, to lactose or peanuts for example, and need to avoid those foods. Others may have developed health issues, which require them to follow a low-salt diet. In addition, people who have never worried about their weight have a very different approach to eating than those who have long struggled with excess pounds.
- **Emotions.** There is a wide range in how emotional issues affect eating habits. When faced with a great deal of stress, some people tend to overeat, while others find it hard to eat at all.
- **Green food/Sustainability choices.** Based on a growing understanding of diet as a public and personal issue, more and more people are starting to make food choices based on their environmental impact. Realizing that their food choices help shape the world, many individuals are opting for a vegetarian diet, or, if they do eat animal products, striving to find the most "cruelty-free" options possible. Purchasing local and organic food products and items grown through sustainable products also helps shrink the size of one's dietary footprint.

Key Takeaways

In this section, you discovered that there are many determinants that affect your health status. You can change some of them and others you cannot. All the determinants of health interact together in influencing your health.

- The expression of genes determines all of your traits including your risk for certain diseases. Nutrients can change the way genes are turned "on" and "off," consequently affecting health.
- Certain stages of life require changes in nutrition to maintain bodily functions, such as growing.
- The traits that a person has are largely a product of their genes and environment. One aspect of a person's environment is socioeconomic status, which is dependent on income, occupation, and education. Socioeconomic status is one of the best environmental predictors of a population's health.
- Besides dietary habits, other components of lifestyle which affect health are physical activity level, recreational drug use, and sleeping patterns.
- Nutrition, genetics, environment, and lifestyle interplay on health.
- Cultural and religious tradition, along with social values can affect food choices. The foods you choose to eat affect your appetite and feelings. Numerous factors other than nutrition drive food choices.

Discussion Starters

1. What types of diseases and/or conditions are present in your family?
2. Discuss the different cultures and religions that are represented by the people in your classroom and learn the different foods that they choose to eat.

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1.7: Nutrition and the Media

Learning Objectives

- List at least four sources of reliable and accurate nutrition information.

A motivational speaker once said, “A smart person believes half of what they read. An *intelligent* person knows which half to believe.” In this age of information where instant Internet access is just a click away, it is easy to be misled if you do not know where to go for reliable nutrition information. There are a few websites that can be consistently relied upon for accurate material that is updated regularly.



Figure 1.7.1: Right information or wrong information? How can you know? © Shutterstock

Using Eyes of Discernment

“New study shows that margarine contributes to arterial plaque.” “Asian study reveals that two cups of coffee per day can have detrimental effects on the nervous system.” How do you react when you read news of this nature? Do you boycott margarine and coffee? When reading nutrition-related claims, articles, websites, or advertisements always remember that one study does not substantiate a fact. One study neither proves nor disproves anything. Readers who may be looking for complex answers to nutritional dilemmas can quickly misconstrue such statements and be led down a path of misinformation. Listed below are ways that you can develop discerning eyes when reading nutritional news.

1. The scientific study under discussion should be published in a peer-reviewed journal, such as the *Journal of the International Society of Sports Nutrition*. Question studies that come from less trustworthy sources (such as non peer-reviewed journals or websites) or that are not published.
2. The report should disclose the methods used by the researcher(s). Did the study last for three or thirty weeks? Were there ten or one hundred participants? What did the participants actually do? Did the researcher(s) observe the results themselves or did they rely on self reports from program participants?
3. Who were the subjects of this study? Humans or animals? If human, are any traits/characteristics noted? You may realize you have more in common with certain program participants and can use that as a basis to gauge if the study applies to you.
4. Credible reports often disseminate new findings in the context of previous research. A single study on its own gives you very limited information, but if a body of literature supports a finding, it gives you more confidence in it.
5. Peer-reviewed articles deliver a broad perspective and are inclusive of findings of many studies on the exact same subject.
6. When reading such news, ask yourself, “Is this making sense?” Even if coffee does adversely affect the nervous system, do you drink enough of it to see any negative effects? Remember, if a headline professes a new remedy for a nutrition-related topic, it may well be a research-supported piece of news, but more often than not it is a sensational story designed to catch the attention of an unsuspecting consumer. Track down the original journal article to see if it really supports the conclusions being drawn in the news report.

When reading information on websites, remember the following criteria for discerning if the site is valid:

1. Who sponsors the website?
2. Are names and credentials disclosed?

3. Is an editorial board identified?
4. Does the site contain links to other credible informational websites? Even better, does it reference peer-reviewed journal articles? If so, do those journal articles actually back up the claims being made on the website?
5. How often is the website updated?
6. Are you being sold something at this website?
7. Does the website charge a fee?

Trustworthy Sources

Now let's consider some reputable organizations and websites from which you can obtain valid nutrition information.

1. **Centers for Disease Control and Prevention (CDC):** The Centers for Disease Control and Prevention (http://www.cdc.gov) distributes an online newsletter called *CDC Vital Signs*. This newsletter is a valid and credible source for up-to-date public health information and data regarding food, nutrition, cholesterol, high blood pressure, obesity, teenage drinking, and tobacco usage.
2. **The Academy of Nutrition and Dietetics (AND):** The AND promotes scientific evidenced-based, research-supported food and nutrition related information on its website, http://www.eatright.org. It is focused on informing the public about recent scientific discoveries and studies, weight-loss concerns, food safety topics, nutrition issues, and disease prevention.
3. **US Department of Agriculture (USDA):** The USDA site fnic.nal.usda.gov has more than twenty-five hundred links to dietary, nutrition, diet and disease, weight and obesity, food-safety and food-labeling, packaging, dietary supplement and consumer questions sites. Using this interactive site, you can find tips and resources on how to eat a healthy diet, my Foodapedia, and a food planner, among other sections.
4. **US Department of Health and Human Services (HHS):** The HHS website, HealthFinder.gov, provides credible information about healthful lifestyles and the latest in health news. A variety of online tools are available to assist with food-planning, weight maintenance, physical activity, and dietary goals. You can also find healthful tips for all age groups, tips for preventing disease, and on daily health issues in general.
5. **Dietitians of Canada:** Dietitians of Canada, http://www.dietitians.ca/, is the national professional association for dietitians. It provides trusted nutrition information to Canadians and health professionals.
6. **Health Canada:** Health Canada, http://www.hc-sc.gc.ca/index-eng.php, is the Federal department that helps Canadians improve their health. Its website also provides information about health-related legislation.

Key Takeaways

- Reliable nutritional news will be based upon solid scientific evidence, supported by multiple studies, and published in peer-reviewed journals. Be sure the website you use for information comes from a credible and trustworthy source, such as the USDA Food and Nutrition Center, the HHS, and the CDC.

Discussion Starter

1. Discuss why it is important to get information from proper and credible sources and not to rely upon single study findings.

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1.8: Assessing Personal Health

Learning Objectives

- Discuss ways of assessing your personal health status and your diet.
- Set a goal to adopt, maintain, or improve a nutrition-related practice.
- Formulate an effective, long-term, personal health and nutrition plan.

You may remember that when you were younger your mother or grandmother made you swallow that teaspoonful of cod liver oil because she said it was good for you. You don't have to have a PhD to know some of the basic ways you can adapt your life to be healthier. However, the mainstream media inundates the American population with health cures and tips, making it confusing to develop the best plan for your health. This section will equip you with tools to assess and improve your health. To find some other reliable sources on health see video below.

? Exercise 1.8.1: Quackwatch!

With all of the false Nutrition information out there, we need to be able to figure out which websites are reliable and which ones are simply quackery (false nutrition information)! Here is a website which will help you figure out who is trying their best to give you good information on nutrition and health and who is lying!

https://quackwatch.org/04ConsumerEdu...nonrecorg.html

Nutritional Status

The food you eat every day influences your health. For your body to function optimally, you need to eat the appropriate amount of nutrients daily to supports routine chemical processes. If you deviate from the "optimal" amount and consume too much or too little of a nutrient, you could become under- or over-nourished. This imbalance is called malnutrition and is your nutritional status.



Video 1.8.1 *What is malnutrition? Both over and under nutrition.*

Undernutrition occurs when someone does not eat enough calories, water, or other essential nutrients to meet their needs for cellular activities. You can be deficient in one nutrient or several nutrients simultaneously. Signs of undernutrition don't show immediately but is usually a slow process. Many different factors can play a role in its development including but not limited to decreased dietary intake, excessive losses, or increased requirements. These result in a depletion of tissue stores that lead to biochemical changes resulting in clinical signs or symptoms.

Overnutrition occurs when an excess consumption of calories, water, and/ or a nutrient(s) occur. For example, today, many people are overweight or obese because they consume too many calories. This state can be accompanied by an unobservable deficiency in other nutrients or undernutrition in other nutrients. It is possible to experience both over and undernutrition at the same time. Americans are at a greater risk of developing overnutrition.

You can also have an imbalance in nutrients, for example, zinc and copper that will cause a poor nutritional status.

Next, we will discuss ways you can assess your personal health to check your nutritional status.

Personal Health Assessment

One of the easiest places to begin a personal health assessment is by examining the results from your last physical. Often a person will leave the doctor's office without these results. Remember that the results belong to you and having this information on hand provides you with much of what you need to keep track of your health. Many of the results in that assessment are related to nutritional status.

During a physical, the nurse will obtain anthropometric values such as weight, height, length (babies), circumference (waist for adults and head for babies) skinfold thickness, etc. Then the nurse typically examines blood pressure. Blood pressure is a measurement of the forces in the arteries that occur during each heart beat. It is a principle vital sign and an indicator of cardiovascular health. A desirable blood pressure is 120 over 80 mmHg. After the nurse, generally, the doctor will also conduct a clinical examination which includes a medical history and physical exam.

In most circumstances, a physical includes biochemical indices such as blood, urine, feces, sweat and hair tests. These tests measure many health indicators, and you have to request the results. Once you have the results in hand, it is good practice to file them in a binder so you can compare them from year to year. This way you can track your blood-cholesterol levels and other blood lipid levels and blood glucose levels. These are some of the more general measurements taken, but in many instances, blood tests also examine liver and kidney function, vitamin and mineral levels, hormone levels, and disease markers. Your doctor uses all of these numbers to assess your health and you can use them to play a more active role in keeping track of your health.



Figure 1.8.1: Don't forget to get the results of your physical the next time you visit your doctor. They will help you keep track of your health. (National Cancer Institute, an agency part of the National Institutes of Health; Linda Bartlett (Photographer)).

Hearing and vision are additionally part of a general health assessment. If you wear glasses, contacts, or a hearing aid you already are aware of how important it is to know the results of these exams. If you have not experienced vision or hearing problems yet your likelihood of experiencing them markedly increases over the age of forty. Another component of overall health is oral health. The health of your teeth, gums, and everything else in your mouth are an integral component of your overall health. This becomes apparent when a person experiences a tooth infection, which if left untreated significantly impairs physical, mental, and social well-being.

Other indicators of health that you can measure yourself are body mass index (BMI) and fitness. BMI is simply a ratio of an individual's weight and height. More specifically BMI is calculated using an individual's body weight (in kilograms, or kg) divided by the square of their height (in meters) and the unit of measurement is kg/m^2. You can calculate this yourself or use one of the many BMI calculators on the web (see Interactive). BMI is a standardized measurement that indicates if a person is underweight, of normal weight, overweight, or obese and is based on data from the average population. It has some limitations. One limitation is that it does not take into account how much of your weight is made up of muscle mass, which weighs more than fat tissue. BMI and other measurements of body composition and fitness are more fully discussed elsewhere.

? Interactive 1.8.1

One of the better websites for assessing your health is available at the Institute for Good Medicine from the Pennsylvania Medical Society. Note: to convert your weight in pounds into kilograms simply divide by divide your weight in pounds by 2.2. For example: 160 pounds divided by 2.2 = 72.7 kilograms.

www.myfamilywellness.org/MainMenuCategories/YouYourPhysician/YourHealthToolkit

This personal health assessment has focused primarily on physical health, but remember that mental and social well-being also affect health. During a physical, a doctor will ask how you are feeling, if you are depressed, and if you are experiencing behavioral problems. Be prepared to answer these questions truthfully, so that your doctor can develop a proper treatment plan to manage these aspects of health. Interactive 1.8 provides some tools to assess your mental and social well-being.

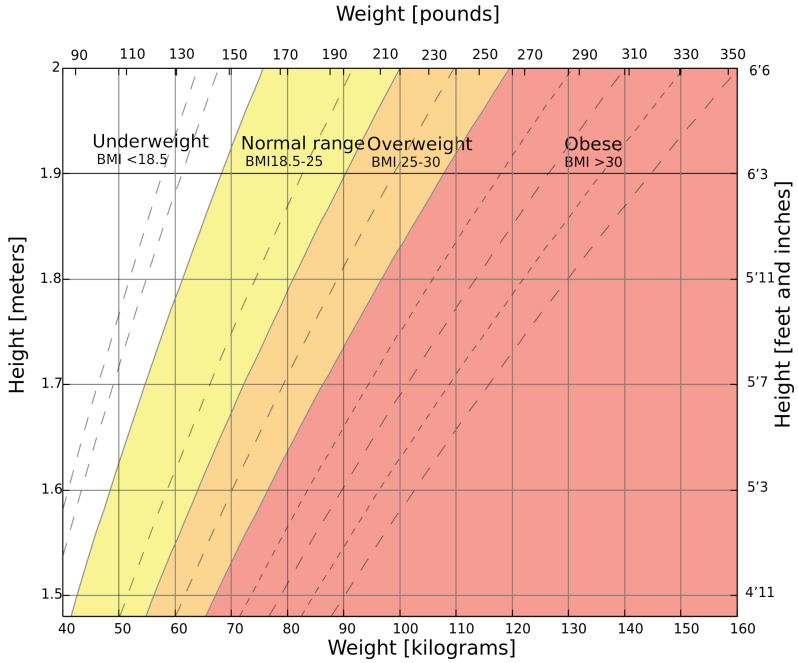


Figure 1.8.2: A graph of body mass index is shown above. By lining up weight and height you can find out in which range an adult person falls. Left of normal range means too thin, to the right of normal means too fat. Dashed lines give a rough idea of how much too thin or how much too fat a person is. (Public Domain).

Taking charge of your health will pay off and equip you with the knowledge to better take advantage of your doctor's advice during your next physical. Health calculators, such as those that calculate BMI, ideal weight, target heart rate among many others, and personal health assessments will help you to take charge of your health, but they should not take the place of visiting your doctor.

Dietary Assessment

The first step in assessing your diet is to find out if the foods you eat are good for your health and provide you with all the nutrients you need. Begin by recording in a journal what you eat every day, including snacks and beverages. Then visit the USDA website, www.choosemyplate.gov/myplate/index.aspx, which has various tools to help you assess your diet. You can track calories over time, diet quality, and find many other tools to evaluate your daily food consumption. The questions these tools can help answer include: How much food do you have to eat to match your level of activity? How many calories should you eat? What are the best types of food to get the most nutrients? What nutrients are contained in different foods? How do you plan a menu that contains all the nutrients you need? Make the first step and assess your diet. This book will provide you with interactive resources, videos, and audio files to empower you to create a diet that improves your health.

Nutrition scientists use a variety of different dietary assessment tools to determine the nutrients intake of individuals or groups. Dietitians may use these same tools with their clients. The 24-hour recall, as the name implies, asks the person to remember what they ate the last 24 hours. Dietary records cover a longer period; usually, 3 - 7 days and the person writes down what they ate at the time it is eaten. A trained person then checks the record for accuracy. The diet history method asks an individual what they usually eat. The information is collected in a historical perspective. Finally, the food frequency questionnaire asks the respondent to recall how often and how much they eat a particular food. Each of these methods has pros and cons and which one is used depends on the strength and weakness of that tool to quantitate what a person is or has eaten.

Family Medical History

Because genetics play a large role in defining your health it is a good idea to take the time to learn some of the diseases and conditions that may affect you. To do this, you need to record your family's medical history. Start by simply drawing a chart that details your immediate family and relatives. Many families have this and you may have a good start already. The next time you attend a family event start filling in the blanks. What did people die from? What country did Grandpa come from? While this may be a more interesting project historically, it can also provide you with a practical tool to determine what diseases you might be more susceptible to. This will allow you to make better dietary and lifestyle changes early on to help prevent a disease from being handed down from your family to you. It is good to compile your information from multiple relatives.

Lifestyle Assessment

A lifestyle assessment includes evaluating your personal habits, level of fitness, emotional health, sleep patterns, and work-life balance. Many diseases are preventable by simply staying away from certain lifestyles. Don't smoke, don't drink excessively, and don't do recreational drugs. Instead, make sure you exercise. Find out how much to exercise by reading the *2008 Physical Activity Guidelines for Americans*. There is a wealth of scientific evidence that increased physical activity promotes health, prevents disease, and is a mood enhancer. Emotional health is often hard to talk about; however a person's quality of life is highly affected by emotional stability. Harvard's Women's Health Watch notes six reasons to get enough sleep: Sleep promotes healthy brain function, while lack of sleep can cause weight gain and increase appetite, decrease safety (falling asleep while driving), make a person moody and irritable, decrease health of the cardiovascular system and prevent the immune system from functioning well.Harvard Health Publications. "Importance of Sleep: Six Reasons Not to Scrimp on Sleep." *Harvard's Women's Health Watch* (January 2006). © 2000–2012 Harvard University. http://www.health.harvard.edu/press_releases/importance_of_sleep_and _health Finding balance between work and life is a difficult and continuous process involving keeping track of your time, taking advantage of job flexibility options, saying no, and finding support when you need it. Work-life balance can influence what you eat too.

Key Takeaways

This section equips you with some tools to assess your lifestyle and make changes towards a healthier one.

- **Step 1.** Take charge of tracking your personal health.
- **Step 2.** Assess your diet and identify where it can be changed to promote health and prevent disease.
- **Step 3.** Start finding out the medical history of your family and identify the diseases you may be more susceptible to getting.
- **Step 4.** Assess your lifestyle by evaluating your personal habits, emotional health, sleep patterns, and work-life balance.
- **Step 5.** Start living a healthier life.

Discussion Starters

1. What websites in Interactive 1.8 did you find to be the most helpful in the assessment of your health?
2. Share your comments on these tools with your classmates and get their opinions, too.

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1.9: Dietary Toolkit

The dietary toolkit contains numerous ideas to help you achieve a healthy diet.

Let's talk about a toolkit for a healthy diet. The first thing in it would be the Recommended Daily Allowances (RDAs). Then we could add the Dietary Reference Intakes (DRIs), the Estimated Average Requirements (EARs), and the Tolerable Upper Limits (ULs). All of these tools are values for important nutrients, calculated to meet the health needs of different age groups. But long before the dietary toolkit full of acronyms such as DRI, RDA, EAR, and UL, daily standards were created with the single goal of keeping workers alive and toiling in the factories and workhouses of the early Industrial Revolution. In the late nineteenth-century powerhouse tycoons operated without fear of legal consequences and paid their workers as little as possible in order to maximize their own profits. Workers could barely afford housing and depended on their bosses to fed them at the workhouses to fend off starvation.



Figure 1.9.1: Without programs like food stamps, workers and military personnel often had to accept whatever meager rations were given to them by their employers. People eating at a soup kitchen. Montreal, Canada. Public domain image.

Living conditions in those days show that the term "starvation wages" was not just a figure of speech. Here's a typical day's menu:

- **Breakfast.** 1-pint porridge, one 6-ounce piece of bread.
- **Lunch.** Beef broth one day, boiled pork and potatoes the next.
- **Dinner.** 1-pint porridge, one 6-ounce piece of bread.

As public awareness about these working conditions grew, so did public indignation. Experts were eventually called in to create the first dietary guidelines, which were designed only to provide a typical individuals with what they needed to survive each day and no more. It wasn't until World War I that the British Royal Society first made recommendations about the nutrients people needed to be healthy, as opposed to merely surviving. They included ideas we now take for granted, such as making fruits and vegetables part of the diet and giving milk to children. Since then, most governments have established their own dietary standards. Food is a precious commodity, like energy, and controlling the way it is distributed confers power. Sometimes this power is used to influence other countries, as when the United States withholds food aid from countries with regimes of which it disapproves. Governments can also use their power over food to support their most fragile citizens with food relief programs, such as the Supplemental Nutrition Assistance Program (SNAP) and the Women, Infants, and Children Supplemental Food Program (WIC).

The US government has also established dietary standards to help citizens follow a healthy diet. The first of these were the Recommended Daily Allowances (RDAs), published in 1943 because of the widespread food shortages caused by World War II. During the war, the government rationed sugar, butter, milk, cheese, eggs, coffee, and canned goods. Limited transportation made it hard to distribute fruits and vegetables. To solve this problem, the government encouraged citizens to plant "victory gardens" to produce their own fruits and vegetables. More than twenty million people began planting gardens in backyards, empty lots, and on rooftops. Neighbors pooled their resources and formed cooperatives, planting in the name of patriotism.

Today in the United States, various measures are used to maintain access to nutritious, safe, and sufficient food for the citizenry. Many of these dietary guidelines are provided by the government and are found on the USDA's website, MyPlate.gov. We call this collection of guidelines the "dietary toolkit."

Note

How will you use the dietary toolkit?

The government works to provide citizens with information, guidance, and access to healthy foods. How will you decide which information to follow? What are the elements of a healthy diet, and how do you figure out ways to incorporate them into your personal diet plan? The dietary toolkit can be likened to a mechanics toolkit, with every tool designed for a specific task(s). Likewise, there are many tools in the dietary toolkit that can help you build, fix, or maintain your diet for good health. In this chapter, you will learn about many of the tools available to you.

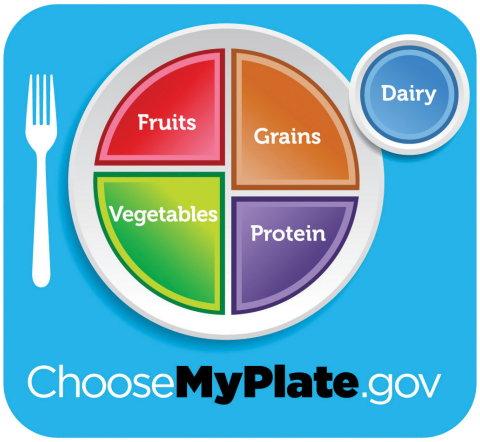


Figure 1.9.2: Today, the US government sets dietary guidelines that provide evidence-based nutrition information designed to improve the health of the population. Source: US Department of Agriculture.

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1.10: A Healthy Philosophy Toward Food

Learning Objectives

- Explain why nutrition is important to health.

"Tell me what you eat, and I will tell you what you are" wrote the French lawyer and politician, Antheime Brillat-Savarin in his book, *Physiologie du Gout, ou Meditations de Gastronomie Transcendante*, in 1826. Almost one hundred years later, nutritionist Victor Lindlahr wrote in an ad in 1923, "Ninety percent of the diseases known to man are caused by cheap foodstuffs. You are what you eat." Today, we know this phrase simply as, "You are what you eat."

Good nutrition equates to receiving enough (but not too much) of the macronutrients (proteins, carbohydrates, fats, and water) and micronutrients (vitamins and minerals) so that the body can stay healthy, grow properly, and work effectively. The phrase "you are what you eat" refers to the fact that your body will respond to the food it receives, either good or bad. Processed, sugary, high-fat, and excessively salted foods leave the body tired and unable to perform effectively. By contrast, eating fresh, natural whole foods fuels the body by providing what it needs to produce energy, promote metabolic activity, prevent micronutrient deficiencies, ward off chronic disease, and to promote a sense of overall health and well-being.

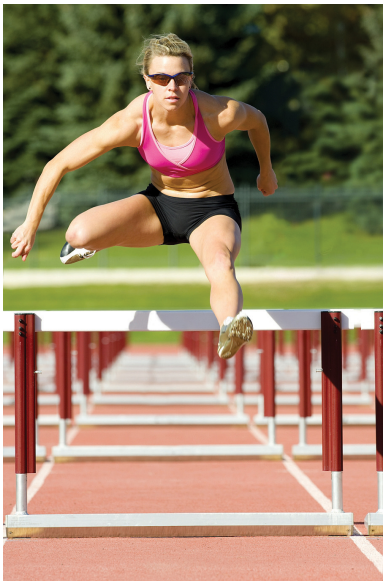


Figure Runaway argument for \eatSpaces?: .1: Nutrition provides the body with the nutrients it needs to perform all activities, from taking a breath to strenuous athletic activity. © Dreamstime

Table 1.10.1: Why Nutrition Is Important to Health

Protein	Necessary for tissue formation, cell reparation, and hormone and enzyme production. It is essential for building strong muscles and a healthy immune system.
Carbohydrates	Provide a ready source of energy for the body and provide structural constituents for the formation of cells.
Fat	Provides stored energy for the body, functions as structural components of cells and also as signaling molecules for proper cellular communication. It provides insulation to vital organs and works to maintain body temperature.
Vitamins	Regulate body processes and promote normal body-system functions.
Minerals	Regulate body processes, are necessary for proper cellular function, and comprise body tissue.

Water	Transports essential nutrients to all body parts, transports waste products for disposal, and aids with body temperature maintenance.

Undernutrition, Overnutrition, and Malnutrition

For many, the word “malnutrition” produces an image of a child in a third-world country with a bloated belly, and skinny arms and legs. However, this image alone is not an accurate representation of the state of malnutrition. For example, someone who is 150 pounds overweight can also be malnourished. Malnutrition refers to one not receiving proper nutrition and does not distinguish between the consequences of too many nutrients or the lack of nutrients, both of which impair overall health. Undernutrition is characterized by a lack of nutrients and insufficient energy supply, whereas overnutrition is characterized by excessive nutrient and energy intake. Overnutrition can result in obesity, a growing global health threat. Obesity is defined as a metabolic disorder that leads to an over accumulation of fat tissue. A person can be over nourished in one nutrient and undernourished in other nutrients.

Although not as prevalent in America as it is in developing countries, undernutrition is not uncommon and affects many subpopulations, including the elderly, those with certain diseases, and those in poverty. Many people who live with diseases either have no appetite or may not be able to digest food properly. Some medical causes of malnutrition include cancer, inflammatory bowel syndrome, AIDS, Alzheimer’s disease, illnesses or conditions that cause chronic pain, psychiatric illnesses, such as anorexia nervosa, or as a result of side effects from medications. Overnutrition is an epidemic in the United States and is known to be a risk factor for many diseases, including Type 2 diabetes, cardiovascular disease, inflammatory disorders (such as rheumatoid arthritis), and cancer.

Growth and Development

From birth to adulthood, nutrients fuel proper growth and function of all body cells, tissue, and systems. Without proper amounts of nutrients, growth and development are stunted. Some nutrient deficiencies manifest right away, but sometimes the effects of undernutrition aren’t seen until later in life. For example, if children do not consume proper amounts of calcium and vitamin D, peak bone mass will be reduced compared to what it would be had adequate amounts of these nutrients been consumed. When adults enter old age without adequate bone mass, they are more susceptible to osteoporosis, putting them at risk for bone fractures. Therefore, it is vital to build bone strength through proper nutrition during youth because it cannot be done in later life.MedicineNet.com. “Nutrients for the Growing Years.” Last reviewed August 13, 2003. http://www.medicinenet.com/script/main/art.asp?articlekey=10054.

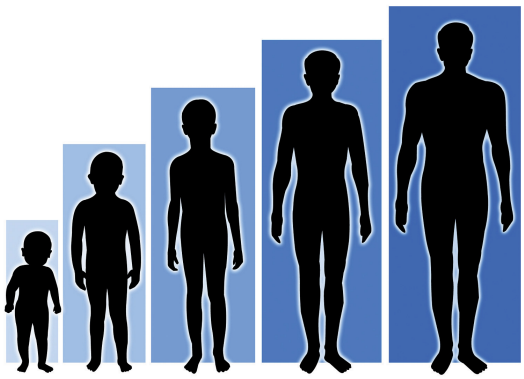


Figure Runaway argument for \eatSpaces?: .2: Proper growth throughout the life stages depends upon proper nutrition. © Dreamstime

The Healing Process

With all wounds, from a paper cut to major surgery, the body must heal itself. Healing is facilitated through proper nutrition,MacKay, D., ND, and A. L. Miller, ND. “Nutritional Support for Wound Healing.” *Alternative Medicine Review* 8, no. 4 (2003): 359–77. while malnutrition inhibits and complicates this vital process. The following nutrients are important for proper healing:



Figure Runaway argument for \eatSpaces?: .3: Healing, a critical function of a healthy body, is facilitated by adequate nutrition.

- **Vitamin A.** Helps to enable the epithelial tissue (the thin outer layer of the body and the lining that protects your organs) and bone cells form.
- **Vitamin C.** Helps form collagen, an important protein in many body tissues.
- **Protein.** Facilitates tissue formation.
- **Fats.** Play a key role in the formation and function of cell membranes.
- **Carbohydrates.** Fuel cellular activity, supplying needed energy to support the inflammatory response that promotes healing.

Now that we have discussed the importance of proper nutrition for your body to perform normal tissue growth, repair, and maintenance, we will discuss ways of achieving a healthy diet.

Key Takeaways

- Nutrition promotes vitality and an overall sense of health and well-being by providing the body with energy and nutrients that fuel growth, healing, and all body systems and functions. Good nutrition will also help to ward off the development of chronic disease.
- A person is malnourished by being either undernourished or overnourished. Malnutrition results when the body does not receive the required amounts of calories, fats, proteins, carbohydrates, vitamins, and minerals necessary to keep the body and its systems in good functioning order.

Discussion Starter

1. Describe what the phrase, “You are what you eat” means. Do you notice how you feel after eating certain types of foods? How might this relate to your overall health?

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1.11: Understanding the Bigger Picture of Dietary Guidelines

Learning Objectives

- Describe the major themes of the *2020-2025 US Dietary Guidelines for Americans*.

The first US dietary recommendations were set by the National Academy of Sciences in 1941. The recommended dietary allowances (RDA) were first established out of concern that America's overseas World War II troops were not consuming enough daily nutrients to maintain good health. The first Food and Nutrition Board was created in 1941, and in the same year set recommendations for the adequate intake of caloric energy and eight essential nutrients. These were disseminated to officials responsible for food relief for armed forces and civilians supporting the war effort. Since 1980, the dietary guidelines have been reevaluated and updated every five years by the advisory committees of the US Department of Agriculture (USDA) and the US Department of Health and Human Services (USDHHS). The guidelines are continually revised to keep up with new scientific evidence-based conclusions on the importance of nutritional adequacy and physical activity to overall health. While dietary recommendations set prior to 1980 focused only on preventing nutrient inadequacy, the current dietary guidelines have the additional goals of promoting health, reducing chronic disease, and decreasing the prevalence of overweight and obesity. The guidelines are also used to provide a scientific basis for the USDA school food lunch program and the Food Stamp program.

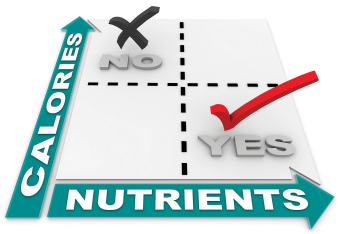


Figure Runaway argument for \eatSpaces?: .1: Dietary guidelines help people to stay on a healthful track by drawing attention to the overall scope of their diet and lifestyle. © Dreamstime

Why Are Guidelines Needed?

Instituting nationwide standard policies provides consistency across organizations and allows healthcare workers, nutrition educators, school boards, and elder-care facilities to improve nutrition and, subsequently, the health of their respective populations. At the same time, the goal of the *2020-2025 Dietary Guidelines (*https://www.dietaryguidelines.gov/) is to provide informative guidelines that will help any interested person in obtaining optimal nutritional balance and health. The ninth edition of the *Dietary Guidelines* was released in 2020 and focuses on making every bite count. This edition marks the first time the guidelines have provided recommendations by life stage, from birth through older adulthood. The *Dietary Guidelines* are formulated by the Food and Nutrition Board of the Institute of Medicine (IOM) from the review of thousands of scientific journal articles by a consensus panel consisting of many nutrition experts with the overall mission of improving the nation's health.



Figure Runaway argument for \eatSpaces?: .2: The major theme of the *2015 Dietary Guidelines for Americans* is a healthy eating pattern combined with regular physical activity.

Major Themes of the *2020-2025 Dietary Guidelines*

The *2020-2025 Dietary Guidelines* consist of four guidelines to help the American public improve their eating habits. Each guideline has specific recommendations. Here are the four guidelines:

1. Follow a healthy dietary pattern at every life stage.
2. Customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations
3. Focus on meeting food group needs with nutrient-dense foods and beverages, and stay within calorie limits.
4. Limit foods and beverages higher in added sugars, saturated fat, and sodium, and limit alcoholic beverages.

Here is more detailed guidance from the *Dietary Guidelines* for Americans on how to make every bite count:

1. *Follow a healthy dietary pattern at every life stage.* At every life stage—infancy, toddlerhood, childhood, adolescence, adulthood, pregnancy, lactation, and older adulthood—it is never too early or too late to eat healthfully.
   - For about the first 6 months of life, exclusively feed infants human milk. Continue to feed infants human milk through at least the first year of life, and longer if desired. Feed infants iron-fortified infant formula during the first year of life when human milk is unavailable. Provide infants with supplemental vitamin D beginning soon after birth.
   - At about 6 months, introduce infants to nutrient-dense complementary foods. Introduce infants to potentially allergenic foods along with other complementary foods. Encourage infants and toddlers to consume a variety of foods from all food groups. Include foods rich in iron and zinc, particularly for infants fed human milk.
   - From 12 months through older adulthood, follow a healthy dietary pattern across the lifespan to meet nutrient needs, help achieve a healthy body weight, and reduce the risk of chronic disease.
2. Customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations. A healthy dietary pattern can benefit all individuals regardless of age, race, or ethnicity, or current health status. The Dietary Guidelines provide a framework intended to be customized to individual needs and preferences, as well as the foodways of the diverse cultures in the United States.
3. Focus on meeting food group needs with nutrient-dense foods and beverages, and stay within calorie limits. An underlying premise of the Dietary Guidelines is that nutritional needs should be met primarily from foods and beverages—specifically, nutrient-dense foods and beverages. Nutrient-dense foods provide vitamins, minerals, and other health-promoting components and have no or little added sugars, saturated fat, and sodium. A healthy dietary pattern consists of nutrient-dense forms of foods and beverages across all food groups, in recommended amounts, and within calorie limits.
   1. The core elements that make up a healthy dietary pattern include:

      • Vegetables of all types—dark green; red and orange; beans, peas, and lentils; starchy; and other vegetables

      • Fruits, especially whole fruit

      • Grains, at least half of which are whole grain

      • Dairy, including fat-free or low-fat milk, yogurt, and cheese, and/or lactose-free versions and fortified soy beverages and yogurt as alternatives

      • Protein foods, including lean meats, poultry, and eggs; seafood; beans, peas, and lentils; and nuts, seeds, and soy products

      • Oils, including vegetable oils and oils in food, such as seafood and nuts
4. Limit foods and beverages higher in added sugars, saturated fat, and sodium, and limit alcoholic beverages. At every life stage, meeting food group recommendations—even with nutrient-dense choices—requires most of a person's daily calorie needs and sodium limits. A healthy dietary pattern doesn't have much room for extra added sugars, saturated fat, or sodium—or for alcoholic beverages. A small amount of added sugars, saturated fat, or sodium can be added to nutrient-dense foods and beverages to help meet food group recommendations, but foods and beverages high in these components should be limited. Limits are:

- Added sugars—Less than 10 percent of calories per day starting at age 2. Avoid foods and beverages with added sugars for those younger than age 2.
- Saturated fat—Less than 10 percent of calories per day starting at age 2.
- Sodium—Less than 2,300 milligrams per day—and even less for children younger than age 14.

- Alcoholic beverages—Adults of legal drinking age can choose not to drink, or to drink in moderation by limiting intake to 2 drinks or less in a day for men and 1 drink or less in a day for women, when alcohol is consumed. Drinking less is better for health than drinking more. There are some adults who should not drink alcohol, such as women who are pregnant.

Finally, all Americans, regardless of age, should meet the *Physical Activity Guidelines for Americans* (https://health.gov/our-work/nutrition-physical-activity/physical-activity-guidelines/current-guidelines/scientific-report).

Foods and Food Components to Reduce

High consumption of certain foods, such as those high in saturated and trans fat, sodium, and added sugars may contribute to the increased incidence of chronic disease. Additionally, excessive consumption of these foods replaces the intake of more nutrient-dense foods.

Table 1.11.1: A Little Less of These, Please

Dietary Constituent	Health Implications	Recommendations
Excess sodium	High blood pressure	Limit intake to 2,300 mg daily
SoFAS (solid fats and added sugars)	Obesity, Type 2 diabetes, CVD, cancer	Avoid if possible
Too much alcohol	Impaired liver function, impaired motor function	No more than one drink per day for women; No more than two drinks per day for men
Too much saturated fat	Cardiovascular disease	Limit intake to < 10 percent of total calories
Trans fats	Cardiovascular disease	Minimal, if any consumption
Cholesterol	Cardiovascular disease	Minimal, if any consumption
Caffeine		Drink in moderation (no more than three to five 8 oz cups/day)

The average person consumes 3,400 milligrams of sodium per day, mainly in the form of table salt. The *2020 Dietary Guidelines* recommend that Americans reduce their daily sodium intake to less than 2,300 milligrams. If you are over the age of fifty-one, are African American, or have cardiovascular risk factors, such as high blood pressure or diabetes, sodium intake should be reduced even further to 1,500 milligrams. The *Dietary Guidelines* also recommend that less than 10 percent of calories come from saturated fat, and those fat calories should be obtained by eating foods high in unsaturated fatty acids. Cholesterol and trans fatty acid intake should be as low as possible without compromising the diet's nutrition adequacy. The *Dietary Guidelines* stress the importance of limiting the consumption of foods with refined grains and added sugars. Added sugars should make up less than 10% of one's total daily caloric intake. If alcohol is consumed, it should be consumed in moderation, which is not more than one drink per day for women and not more than two drinks per day for men. The macronutrients protein, carbohydrates, and fats contribute considerably to total caloric intake. The IOM has made recommendations for different age groups on the percentage of total calories that should be obtained from each macronutrient class (Table 1.11.2).

Table 1.11.2: Recommendations for Macronutrient Intake As Percentage of Total Calories

Age Group	Protein (%)	Carbohydrates (%)	Fat (%)
Children (1–3)	5–20	45–65	30–40
Children and Adolescents (4–18)	10–30	45–65	25–35
Adults (>19)	10–35	45–65	20–35

Source: *2020 Dietary Guidelines*.

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1.12: What Is Nutritional Balance and Moderation?

Learning Objectives

- Define the components of a healthful diet.

Achieving a Healthy Diet

Achieving a healthy diet is a matter of balancing the quality and quantity of food that is eaten. There are five key factors that make up a healthful diet:

- A diet must be adequate, by providing sufficient amounts of each essential nutrient, as well as fiber and calories.
- A balanced diet results when you do not consume one nutrient at the expense of another, but rather get appropriate amounts of all nutrients.
- Calorie control is necessary so that the amount of energy you get from the nutrients you consume equals the amount of energy you expend during your day's activities.
- Moderation means not eating to the extremes, neither too much nor too little.
- Variety refers to consuming different foods from within each of the food groups on a regular basis.

A healthy diet is one that favors whole foods. As an alternative to modern processed foods, a healthy diet focuses on "real" fresh whole foods that have been sustaining people throughout the millenniums. Whole foods supply the needed vitamins, minerals, protein, carbohydrates, fats, and fiber that are essential to good health. Commercially prepared and fast foods are often lacking nutrients and often contain inordinate amounts of sugar, salt, saturated and trans fats, all of which are associated with the development of diseases such as atherosclerosis, heart disease, stroke, cancer, obesity, high cholesterol, diabetes, and other illnesses. A balanced diet is a mix of food from the different food groups (vegetables, legumes, fruits, grains, protein foods, and dairy).

Adequacy

An adequate diet is one that favors nutrient-dense foods. Nutrient-dense foods are defined as foods that contain many essential nutrients per calorie. Nutrient-dense foods are the opposite of "empty-calorie" foods, such as sugary carbonated beverages, which are also called "nutrient-poor." Nutrient-dense foods include fruits and vegetables, lean meats, poultry, fish, low-fat dairy products, and whole grains. Choosing more nutrient-dense foods will facilitate weight loss, while simultaneously providing all necessary nutrients.

Tools for Change

Does your diet contain nutrient-dense foods? Record your eating habits for one week. Note the sugary, fatty, and calorie-heavy foods you most often consume. Look at Table 2.2 to decide what you can substitute those foods with.

Table 1.12.1: The Smart Choice: Nutrient-Dense Food Alternatives

Instead of…	Replace with…
Sweetened fruit yogurt	Plain fat-free yogurt with fresh fruit
Whole milk	Low-fat or fat-free milk
Cheese	Low-fat or reduced-fat cheese
Bacon or sausage	Canadian bacon or lean ham
Sweetened cereals	Minimally sweetened cereals with fresh fruit
Apple or berry pie	Fresh apple or berries
Deep-fried French fries	Oven-baked French fries or sweet potato baked fries
Fried vegetables	Steamed or roasted vegetables
Sugary sweetened soft drinks	Seltzer mixed with 100 percent fruit juice

Instead of…	Replace with…
Recipes that call for sugar	Experiment with reducing amount of sugar and adding spices (cinnamon, nutmeg, etc…)
Source: US Department of Agriculture. “Food Groups.” www.choosemyplate.gov/food-groups/.	

Balance

Balance the foods in your diet. Achieving balance in your diet entails not consuming one nutrient at the expense of another. For example, calcium is essential for healthy teeth and bones, but too much calcium will interfere with iron absorption. Most foods that are good sources of iron are poor sources of calcium, so in order to get the necessary amounts of calcium and iron from your diet, a proper balance between food choices is critical. Another example is that while sodium is a vital nutrient, an overabundance of it can contribute to congestive heart failure and chronic kidney disease. Remember, everything must be consumed in the proper amounts.



Figure Runaway argument for \eatSpaces?: .1: With careful planning, a balanced diet providing optimal nutrition can be achieved and maintained. © Shutterstock

Moderation

Eat in moderation. Moderation is crucial for optimal health and survival. Burgers, French fries, cake, and ice cream each night for dinner will lead to health complications. But as part of an otherwise healthful diet and consumed only on a weekly basis, this should not have too much of an impact on overall health. If this is done once per month, it will have even less of an impact upon overall health. It’s important to remember that eating is, in part, about enjoyment and indulging with a spirit of moderation. This fits within a healthy diet.

-

Calorie Control

Monitor food portions. For optimum weight maintenance, it is important to ensure that energy consumed from foods meets the energy expenditures required for body functions and activity. If not, the excess energy contributes to gradual, steady weight gain. In order to lose weight, you need to ensure that more calories are burned than consumed. Likewise, in order to gain weight, calories must be eaten in excess of what is expended daily.

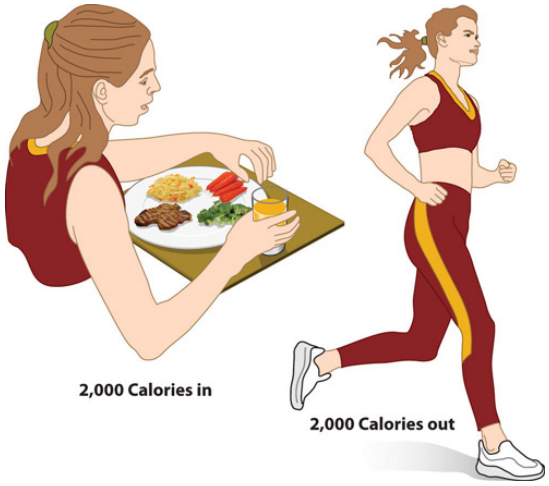


Figure Runaway argument for \eatSpaces?: .2: The number of calories consumed should always match the number of calories being expended by the body to maintain a healthy weight.© Networkgraphics

Variety

Variety involves eating different foods from all the food groups. Eating a varied diet helps to ensure that you receive all the nutrients necessary for a healthy diet. One of the major drawbacks of a monotonous diet is the risk of consuming too much of some nutrients and not enough of others. Trying new foods can also be a source of pleasure—you never know what foods you might like until you try them.

Table 1.12.2: Food Choices for a Healthful Diet

Grain	Vegetable	Fruit	Dairy	Protein
Whole-grain products, brown rice, quinoa, barley, buckwheat, millet, wild rice, oats, rye berries, sorghum, bulgur, kasha, farrow, wheat berries, corn, amaranth, spelt, Teff	**Dark green:** broccoli, collards, kale, romaine lettuce, spinach, turnip greens, watercress	apples, apricots, bananas	all fluid milk (fat free, low-fat, reduced-fat, whole milk, lactose-free), fortified soy milk, yogurt	**Meats:** beef, ham, lamb, pork, veal
	Red and orange: Acorn squash, butternut squash, carrots, pumpkin, red peppers, sweet potatoes	**Berries:** strawberries, blueberries, raspberries, cherries, grapefruit, kiwi fruit, lemons, limes, mangoes	**Hard natural cheeses:** cheddar, mozzarella, Swiss, parmesan	**Poultry:** chicken, goose, turkey, duck
	Beans and peas: Black beans, black-eyed peas, chickpeas, kidney beans, lentils, navy beans, pinto beans, soybeans, split peas, white beans	**Melons:** cantaloupe, honey dew, watermelon	**Soft cheeses:** ricotta, cottage	**Eggs**
	Starchy: Cassava, green bananas, green peas, green lima beans, plantains, potatoes, taro, water chestnuts	**Other fruits:** nectarines, oranges, peaches, pears, papaya, pineapple, plums, prunes		**Beans and peas:** (see vegetable column)

Grain	Vegetable	Fruit	Dairy	Protein
	Other vegetables: Asparagus, avocado, bean sprouts, beets, Brussels sprouts, cabbage, cauliflower, celery, eggplant, green beans, green peppers, mushrooms, okra, onions, parsnips			**Nuts and seeds:** almonds, cashews, hazelnuts, peanuts, pecans, pistachios, pumpkin seeds, sesame seeds, sunflower seeds, walnuts
				Seafood: catfish, cod, flounder, haddock, halibut, herring, mackerel, pollock, porgy, salmon, sea bass, snapper, swordfish, trout, tuna
				Shellfish: scallops, muscles, crab, lobster

Source: Adapted from www.choosemyplate.gov/food-groups/protein-foods.html.

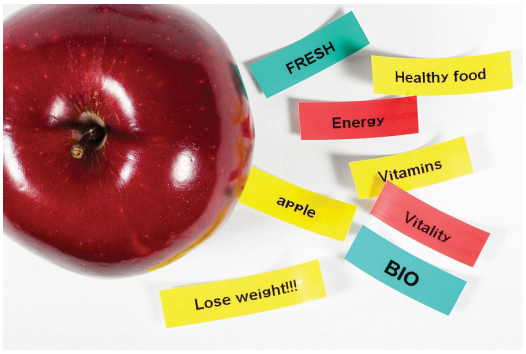


Figure Runaway argument for \eatSpaces?: .3: Scientific evidence confirms that a diet full of fresh whole foods reduces the risks for developing chronic disease and helps maintain a healthy weight. © Dreamstime

Video Link 1.12.1:

Different Types of Grains: In this video, a registered dietitian discusses the benefits of eating whole grains. http://www.ehow.com/video_4983984_different-types-grains.html

Developing a healthful diet can be rewarding, but be mindful that all of the principles presented must be followed to derive maximal health benefits. For instance, introducing variety in your diet can still result in the consumption of too many high-calorie, nutrient-poor foods and inadequate nutrient intake if you do not also employ moderation and calorie control. Using all of these principles together will afford you lasting health benefits.



Figure Runaway argument for \eatSpaces?: .4: Widening your food palate will increase your intake of vital nutrients. © Dreamstime

Key Takeaways

- A healthful diet is adequate in providing proper amounts of nutrient-dense foods, is balanced in relation to food types so that one nutrient is not consumed at the expense of another, practices calorie control by supplying food energy to match energy output, is moderate in unwanted constituents, and draws from a variety of nutritious foods.
- Nutrient-dense foods contribute to daily nutritional requirements while limiting caloric intake, thus allowing people to either lose weight safely or to maintain a healthy weight.

Discussion Starters

1. Discuss the principles of a healthy diet. How can you employ these principles in your diet, if you are not already?
2. Review the list of grains in Table 1.12.23. Pick one that you have not tried before. Make a dish using this grain. Discuss with your classmates your experience eating this new food.

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1.13: National Goals for Nutrition and Health- Healthy People 2030

Learning Objectives

- State the Healthy People 2030 nutrition- and weight-status goals.
- List three related objectives for the Healthy People 2030 program.

The Healthy People 2030 program, launched in 2020, is a ten-year national program instituted by the US government with objectives to improve the health of all Americans. The vision of Healthy People 2030 is “A society in which all people can achieve their full potential for health and well-being across the lifespan.” The mission is “to promote, strengthen, and evaluate the nation’s efforts to improve the health and well-being of all people.” This means that the understanding of what makes and keeps people healthy is consistently refined. The determinants of health approach reflects the evidence from outside factors that greatly affect the health of individuals.(US Department of Health and Human Services. “Healthy People 2030.”. https://health.gov/healthypeople. It takes into consideration the circumstances in which people are born, live, work, and age. It also reflects the conditions that shape their circumstances, such as money, power, and resources at the local, national, and global levels. Social determinants of health are primarily accountable for the lack of fair health opportunities and the unjust differences in health status that exist within and between countries. World Health Organization. “Social Determinants of Health.” © 2017. http://www.who.int/social_determinants/en/.

Video 1.13.1: Preparing for the Next Decade



Video 1.13.1: *2030 Healthy People 2030 (click to see video)*

Helping People Make Healthy Choices

It is not just ourselves, the food industry, and the federal government that shapes our choices of food and physical activity, but also our sex, genetics, disabilities, income, religion, culture, education, lifestyle, age, and environment. All of these factors must be addressed by organizations and individuals that seek to make changes in dietary habits. The socioeconomic model incorporates all of these factors and is used by health-promoting organizations, such as the United States Department of Agriculture (USDA) and Health and Human Services (HHS) to determine multiple avenues through which to promote healthy eating patterns, to increase levels of physical activity, and to reduce the risk of chronic disease for all Americans.



Figure Runaway argument for \eatSpaces?: .1: The socioeconomic model helps organizations and the government to plan and promote effective healthy-eating programs tailored to specific populations. © Networkgraphics

Lower economic prosperity influences diet specifically by lowering food quality, decreasing food choices, and decreasing access to enough food. Food insecurity is the inability to meet one's food needs all the time. We think of this in developing countries, but it also occurs in the United States and other developing countries. For children, food insecurity is associated with impaired physical and mental health. As a result of the recent financial crisis in America in 2008, the number of people who struggle to have enough to eat is rising and approaching fifty million (15% of the population). In response to these recent numbers, USDA Secretary Tom Vilsack said, “These numbers are a wake-up call…for us to get very serious about food security and hunger, about nutrition and food safety in this country.”Amy Goldstein, “Hunger a Growing Problem in America, USDA Reports,” *Washington Post*, 17 November 2009. www.washingtonpost.com/wp-dyn/content/article/2009/11/16/AR2009111601598.html. The Federal government has several programs to help. These include Food Stamps, WIC (Woman, Infant, and Children) program, school food lunch program, and SNAP (Supplemental Nutrition Assistance Program). Most programs are administered by the USDA>



Video 1.13.2: *Determinants of Health Approach in Healthy People 2020 (click to see video)*

Goals for Nutrition and Weight Status

While Healthy People 2030 has many goals and objectives, we are going to focus on the two goals for nutrition and weight status. They are to promote health and reduce the risk of developing chronic diseases by encouraging Americans to consume healthful diets and to achieve and maintain healthy body weights. Nutrition criteria are reflective of a solid scientific foundation for health and weight management. Emphasis is on modifying individual behavior patterns and habits, and having policies and environments that will support these behaviors in various settings, such as schools and local community-based organizations.



Figure Runaway argument for \eatSpaces?: .2: One of the ways that Healthy People 2030 strives to promote good health and nutrition is by bringing together multiple agencies and groups dedicated to achieving the Healthy People 2030 nationwide objectives. © Shutterstock

Healthy People 2030 is going to follow these foundational principles to guide its decisions about Healthy People 2030:

- The health and well-being of all people and communities is essential to a thriving, equitable society.
- Promoting health and well-being and preventing disease are linked efforts that encompass physical, mental, and social health dimensions.
- Investing to achieve the full potential for health and well-being for all provides valuable benefits to society.
- Achieving health and well-being requires eliminating health disparities, achieving health equity, and attaining health literacy.
- Healthy physical, social, and economic environments strengthen the potential to achieve health and well-being.
- Promoting and achieving health and well-being nationwide is a shared responsibility that is distributed across the national, state, tribal, and community levels, including the public, private, and not-for-profit sectors.
- Working to attain the full potential for health and well-being of the population is a component of decision-making and policy formulation across all sectors.

Achieving these broad and ambitious goals requires setting, working toward, and achieving a wide variety of much more specific goals. Healthy People 2030's overarching goals are to:

- Attain healthy, thriving lives and well-being free of preventable disease, disability, injury, and premature death.
- Eliminate health disparities, achieve health equity, and attain health literacy to improve the health and well-being of all.
- Create social, physical, and economic environments that promote attaining the full potential for health and well-being for all.
- Promote healthy development, healthy behaviors, and well-being across all life stages.
- Engage leadership, key constituents, and the public across multiple sectors to take action and design policies that improve the health and well-being of all.

Healthy People 2030 has set 68 nutrition objectives. Here are a few highlights:

- Increase the proportion of health care visits by adults with obesity that include counseling on weight loss, nutrition, or physical activity
- Increase the proportion of worksites that offer an employee nutrition program
- Increase vegetable consumption by people aged 2 years and over
- Increase fruit consumption by people aged 2 and over
- Increase calcium consumption by people aged 2 years and over



Figure Runaway argument for \eatSpaces?: .3: Consuming nutrient-dense foods and limiting portion sizes of food will contribute to weight management. Avoiding excessive amounts of anything allows room for many food types in the diet. © Dreamstime

Benefits of Following the Healthy People 2030 Goals

Nutrition and weight status are important to children's growth and development. In addition, healthy eating habits will decrease the risk of developing chronic health conditions such as obesity, malnutrition, anemia, cardiovascular disease, high blood pressure, dyslipidemia (poor lipid profiles), Type 2 diabetes, osteoporosis, dental disease, constipation, diverticular disease, and certain types of cancer. National Digestive Disease Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Am I at Risk for Type 2 Diabetes?" *NIH Publication No. 09-4805* (November 2008). Last updated December 6, 2011. diabetes.niddk.nih.gov/dm/pubs/riskfortype2/.

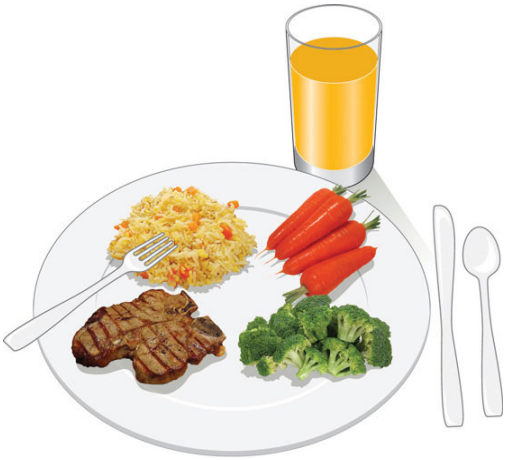


Figure Runaway argument for \eatSpaces?: .4: Following the *2020 Dietary Guidelines* will promote nutrition, weight loss, and weight maintenance as well as the reduction of chronic disease. © Networkgraphics

Video 1.13.3: Active versus Sedentary Lifestyles



Video 1.13.3: *This video provides a short overview of leading an active life versus a sedentary life.*



Figure Runaway argument for \eatSpaces?: .5: Healthy children will lead to a healthy adult population with less disease, lower healthcare costs, and increased longevity. © Shutterstock

For more information on Healthy People 2030 and its related objectives for nutrition and weight status, please visit the website https://health.gov/healthypeople.

Key Takeaways

- Healthy People 2030 is a health initiative with a ten-year objective of helping Americans improve health and well-being, and to live long, healthy lives. Among its many objectives are to promote health and reduce the risk of developing chronic diseases by encouraging Americans to consume healthful diets and to achieve and maintain healthy body weights.
- The goals of Healthy People 2030 are founded upon a determinants of health approach, which means they are reflective of the circumstances in which people are born, live, and work, as well as the conditions that shape their circumstances such as money, power, and resources at the local, national, and global levels. Diet patterns are influenced by genetics, environment, and cultural values. All of these things must be considered to provide the optimal approach to improving the health of the American population.
- Decreasing caloric intake and increasing physical activity are important strategies for achieving the goals of the Healthy People 2030 program.

Discussion Starters

1. Think of fun ways to increase physical activity in your life. Watch the video below for ideas.

   How to Avoid a Sedentary Lifestyle (click to see video)

2. Review some of the Healthy People 2030 nutrition and physical activity program objectives. What objectives would you like to see enacted in your community? Why is this important to you? http://www.healthypeople.gov/2020

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1.14: Recommendations for Optimal Health

Learning Objectives

- Design a quality diet plan using MyPlate Daily Food Plan.
- State recommendation(s) for fruit and vegetable consumption and list the potential benefits of this eating program.

For many years, the US government has been encouraging Americans to develop healthful dietary habits. In 1992 the food pyramid was introduced, and in 2005 it was updated. This was the symbol of healthy eating patterns for all Americans. However, some felt it was difficult to understand, so in 2011, the pyramid was replaced with MyPlate.

The MyPlate program uses a tailored approach to give people the needed information to help design a healthy diet. The plate is divided according to the amount of food and nutrients you should consume for each meal. Each food group is identified with a different color, showing the food variety that all plates must have. Aside from educating people about the type of food that is best to support optimal health, the new food plan offers the advice that it is okay to enjoy food, just eat less of it.US Department of Agriculture. Accessed August 22, 2017. http://www.choosemyplate.gov/.

Video 1.14.1: Introducing the New Food Icon: MyPlate



Video 1.14.1: *This video provides an introduction to the new MyPlate food guide.*

- ## Building a Healthy Plate: Choose Nutrient-Rich Foods

  Planning a healthy diet using the MyPlate approach is not difficult. According to the icon, half of your plate should have fruits and vegetables, one-quarter should have whole grains, and one-quarter should have protein. Dairy products should be low-fat or non-fat. The ideal diet gives you the most nutrients within the fewest calories. This means choosing nutrient-rich foods.

  Fill half of your plate with red, orange, and dark green vegetables and fruits, such as kale, collard greens, tomatoes, sweet potatoes, broccoli, apples, oranges, grapes, bananas, blueberries, and strawberries in main and side dishes. Vary your choices to get the benefit of as many different vegetables and fruits as you can. You may choose to drink fruit juice as a replacement for eating fruit. (As long as the juice is 100 percent fruit juice and only half your fruit intake is replaced with juice, this is an acceptable exchange.) For snacks, eat fruits, vegetables, or unsalted nuts.

  Fill a quarter of your plate with whole grains such as 100 percent whole-grain cereals, breads, crackers, rice, and pasta. Half of your daily grain intake should be whole grains. Read the ingredients list on food labels carefully to determine if a food is comprised of whole grains.

  Video 1.14.2: Tools for Change

  Consider the information in this video:



Video 1.14.2: *Buying Local: The Importance of Locally Produced and Organically Grown Foods to Local Economy. (click to see video)*

Identify which vegetables and fruits are in season and local to your area. By consuming in-season, local foods you cut down on transportation costs (emission and financial) and you are likely to get fresher produce. You also support your local farms by purchasing their produce.



Figure Runaway argument for \eatSpaces?: .1: Make sure at least half of your daily grain intake comes from whole-grain foods. © Shutterstock

Select a variety of protein foods to improve nutrient intake and promote health benefits. Each week, be sure to include a nice array of protein sources in your diet, such as nuts, seeds, beans, legumes, poultry, soy, and seafood. The recommended consumption amount for seafood for adults is two 4-ounce servings per week. When choosing meat, select lean cuts. Be conscious to prepare meats using little or no added saturated fat, such as butter.



Figure Runaway argument for \eatSpaces?: .2: Remember to vary your selections of protein. Lentils contain good amounts of protein and make great meals. Try using lentils or beans as a meat substitute each week. © Thinkstock

If you enjoy drinking milk or eating milk products, such as cheese and yogurt, choose low-fat or nonfat products. Low-fat and nonfat products contain the same amount of calcium and other essential nutrients as whole-milk products, but with much less fat and calories. Calcium, an important mineral for your body, is also available in lactose-free and fortified soy beverage and rice beverage products. You can also get calcium in vegetables and other fortified foods and beverages.

Oils are essential for your diet as they contain valuable essential fatty acids, but the type you choose and the amount you consume is important. Be sure the oil is plant-based rather than based on animal fat. You can also get oils from many types of fish, as well as avocados, and unsalted nuts and seeds. Although oils are essential for health they do contain about 120 calories per tablespoon. It is vital to balance oil consumption with total caloric intake. The Nutrition Facts label provides the information to help you make healthful decisions.

In short, substituting vegetables and fruit in place of unhealthy foods is a good way to make a nutrient-poor diet healthy again. Vegetables are full of nutrients and antioxidants that help promote good health and reduce the risk for developing chronic diseases such as stroke, heart disease, high blood pressure, Type 2 diabetes, and certain types of cancer. Regularly eating fresh fruits and vegetables will boost your overall health profile.

Discretionary Calories

When following a balanced, healthful diet with many nutrient-dense foods, you may consume enough of your daily nutrients before you reach your daily calorie limit. The remaining calories are discretionary (to be used according to your best judgment). To find out your discretionary calorie allowance, add up all the calories you consumed to achieve the recommended nutrient intake and then subtract this number from your recommended daily caloric allowance. For example, someone who has a recommended 2,000-calorie per day diet may eat enough nutrient-dense foods to meet requirements after consuming only 1,814 calories. The remaining 186 calories are discretionary. These calories may be obtained from eating an additional piece of fruit, adding another teaspoon of olive oil on a salad or butter on a piece of bread, adding sugar or honey to cereal, or consuming an alcoholic beverage. US Department of Agriculture. “MyPyramid Education Framework.” Accessed July 22, 2012. http://www.choosemyplate.gov

The amount of discretionary calories increases with physical activity level and decreases with age. For most physically active adults, the discretionary calorie allowance is, at most, 15 percent of the recommended caloric intake. By consuming nutrient-dense foods, you afford yourself a discretionary calorie allowance.

Table 1.14.1: Sample Menu Plan Containing 2,000 Calories

Meal	Calories	Total Meal/Snack Calories
Breakfast		
1 scrambled egg	92	
with sliced mushrooms and spinach	7	
½ whole-wheat muffin	67	
1 tsp. margarine-like spread	15	

Meal	Calories	Total Meal/Snack Calories
1 orange	65	
8 oz. low-sodium tomato juice	53	299
Snack		
6 oz. fat-free flavored yogurt	100	
with ½ c. raspberries	32	132
Lunch		
1 sandwich on pumpernickel bread	160	
with smoked turkey deli meat,	30	
4 slices tomato	14	
2 lettuce leaves	3	
1 tsp. mustard	3	
1 oz. baked potato chips	110	
½ c. blueberries, with 1 tsp. sugar	57	
8 oz. fat-free milk	90	467
Snack		
1 banana	105	
7 reduced-fat high-fiber crackers	120	225
Dinner		
1 c. Greek salad (tomatoes, cucumbers, feta)	150	
with 5 Greek olives,	45	
with 1.5 tsp. olive oil	60	
3 oz. grilled chicken breast	150	
½ c. steamed asparagus	20	
with 1 tsp. olive oil,	40	
with 1 tsp. sesame seeds	18	
½ c. cooked wild rice	83	
with ½ c. chopped kale	18	
1 whole-wheat dinner roll	4	
with 1 tsp. almond butter	33	691
(Total calories from all meals and snacks = 1,814)		
Discretionary calorie allowance: 186		

Healthy Eating Index

To assess whether the American diet is conforming to the *2010 Dietary Guidelines*, the Center for Nutrition Policy and Promotion (CNPP), a division of the USDA, uses a standardized tool called the Healthy Eating Index (HEI). US Department of

Agriculture. “Healthy Eating Index.” Last modified March 14, 2012. www.cnpp.usda.gov/healthyeatingindex.htm. The first HEI was developed in 1995 and revised in 2015. This tool is a simple scoring system of dietary components. The data for scoring diets is taken from national surveys of particular population subgroups, such as children from low-income families or Americans over the age of sixty-five. Diets are broken down into several food categories including milk, whole fruits, dark green and orange vegetables, whole grains, and saturated fat, and then a score is given based on the amount consumed. For example, a score of ten is given if a 2,000-kilocalorie diet includes greater than 2.6 cups of milk per day. If less than 10 percent of total calories in a diet are from saturated fat, a score of eight is given. All of the scores are added up for the different food categories and the diets are given an HEI score. Using this standardized diet-assessment tool at different times, every ten years, for instance, the CNPP can determine if the eating habits of certain groups of the American population are getting better or worse. The HEI tool provides the federal government with information to make policy changes to better the diets of American people. For more information on the HEI, visit this website: www.cnpp.usda.gov/healthyeatingindex.htm.

Key Takeaways

- The Food Pyramid has been replaced by MyPlate, a system that was designed to be easier to implement. The new MyPlate encourages all plates to be filled with fruits and vegetables (50 percent), protein (25 percent), and grains (25 percent). Half of daily grain intake should be from whole-grain sources. Dairy choices should be switched to low-fat or non-fat sources.
- A diet rich in fresh fruits and vegetables will help you lose and/or maintain weight, will lower your risk for stroke, heart disease, high blood pressure, Type 2 diabetes, and certain types of cancer, and will boost your overall health profile.
- By choosing nutrient-dense foods, you may have discretionary calories to “spend” at the end of the day.

Discussion Starter

1. As you analyze the new MyPlate, how do your regular dietary habits compare to this new format? What changes, if any, will you have to make to your breakfast? Lunch? Dinner?

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1.15: Understanding Dietary Reference Intakes

Learning Objectives

- Use the Dietary Reference Intakes to determine daily nutrient recommendations.

Dietary Reference Intakes (DRI) are the recommended levels for specific nutrients and consist of a number of different types of recommendations. This DRI system is used in both the United States and Canada.

Dietary Reference Intakes: A Brief Overview

The most recent recommendations from the Food and Nutrition Board are the "Dietary Reference Intakes" (DRI). The DRI include 4 sets of standards:

- Recommended Dietary Allowances (RDA): average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%-98%), healthy people.
- Adequate Intakes (AI): established when evidence is insufficient to develop an RDA and is set at a level assumed to ensure nutritional adequacy.
- Tolerable Upper Intake Levels (UL): maximum daily intake unlikely to cause adverse health effects.
- Estimated Average Requirements (EARs): expected to satisfy the needs of 50% of the people in that age group based on a review of the scientific literature.

The DRIs are not minimum or maximum nutritional requirements and are not intended to fit everybody. They are to be used as guides only for the majority of the healthy population. https://ods.od.nih.gov/Health_Information/Dietary_Reference_Intakes.aspx

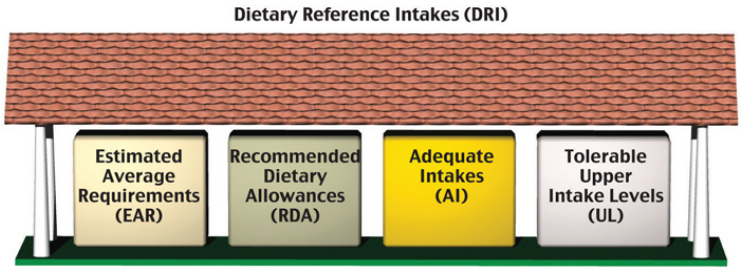


Figure Runaway argument for \eatSpaces?: .1: The DRIs are inclusive of all four reference values. © Networkgraphics

DRIs are important not only to help the average person determine whether their intake of a particular nutrient is adequate, they are also used by health-care professionals and policy makers to determine nutritional recommendations for special groups of people who may need help reaching nutritional goals. This includes people who are participating in programs such as the Special Supplemental Food Program for Women, Infants, and Children. The DRI is not appropriate for people who are ill or malnourished, even if they were healthy previously.

Determining Dietary Reference Intakes

Each DRI value is derived in a different way. See below for an explanation of how each is determined:

1. **Estimated Average Requirements (EAR).** The EAR for a nutrient is determined by a committee of nutrition experts who review the scientific literature to determine a value that meets the requirements of 50 percent of people in their target group within a given life stage and for a particular sex. The requirements of half of the group will fall below the EAR and the other half will be above it. It is important to note that, for each nutrient, a specific bodily function is chosen as the criterion on which to base the EAR. For example, the EAR for calcium is set using a criterion of maximizing bone health. Thus, the EAR for calcium is set at a point that will meet the needs, with respect to bone health, of half of the population. EAR values become the scientific foundation upon which RDA values are set.
2. **Recommended Daily Allowances (RDA).** Once the EAR of a nutrient has been established, the RDA can be mathematically determined. While the EAR is set at a point that meets the needs of half the population, RDA values are set to meet the needs of the vast majority (97 to 98 percent) of the target healthy population. It is important to note that RDAs are not the same thing as individual nutritional requirements. The actual nutrient needs of a given individual will be different than the RDA. However, since we know that 97 to 98 percent of the population's needs are met by the RDA, we can assume that if a person is consuming

the RDA of a given nutrient, they are most likely meeting their nutritional need for that nutrient. The important thing to remember is that the RDA is meant as a *recommendation* and meeting the RDA means it is very likely that you are meeting your actual *requirement* for that nutrient.

The RDA was established by the Food and Nutrition Board of the National Academy of Sciences. It was first published in 1941 in the "interest of national defense." During World War II, many potential soldiers did not qualify for military duty because they were malnourished. Also, in many places during the war and after the war, food had to be rationed. It was important that everyone received the nutrients they needed. Now, the criteria for establishing the RDA is based on the EAR for healthy individuals. That requirement is increased by 30-50% to cover the need of most people (all but 3% of the population).

The "R" in RDA does not mean required but is for recommended. The RDA is designed to satisfy the nutrient requirement for most healthy individuals and thus, exceeds the nutrient need for most people. The "D" does not mean daily, but dietary. A person does not need to meet the RDA every day but is the average intake needed every 3-7 days.

The RDA is categorized by age, sex, lactation, and pregnancy. Only nineteen nutrients of the approximately 45 essential nutrients have an RDA. We need to eat a variety of foods to get all our nutrients and the RDA is built on that assumption.

For what do we use the RDA? It is best used for populations or large groups of people, for example, school lunch programs. It is not useful for individuals although it is often used to assess an individual's diet.

Understanding the Difference

There is a distinct difference between a requirement and a recommendation. For instance, the DRI for vitamin D is a *recommended* 600 international units each day. However, in order to find out your true personal *requirements* for vitamin D, a blood test is necessary. The blood test will provide an accurate reading from which a medical professional can gauge your required daily vitamin D amounts. This may be considerably more or less than the DRI, depending on what your level actually is.

1. **Adequate Intake (AI).** AIs are created for nutrients when there is insufficient consistent scientific evidence to set an EAR for the entire population. As with RDAs, AIs can be used as nutrient intake goals for a given nutrient. For example, there has not been sufficient scientific research into the particular nutritional requirements of infants. Consequently, all of the DRI values for infants are AIs derived from nutrient values in human breast milk. For older babies and children, AI values are derived from human milk coupled with data on adults. The AI is meant for a healthy target group and is not meant to be sufficient for certain at-risk groups, such as premature infants.
2. **Tolerable Upper Intake Levels (UL).** The UL was established to help distinguish healthful and harmful nutrient intakes. Developed in part as a response to the growing usage of dietary supplements, ULs indicate the highest level of continuous intake of a particular nutrient that may be taken without causing health problems. When a nutrient does not have any known issue if taken in excessive doses, it is not assigned a UL. However, even when a nutrient does not have a UL it is not necessarily safe to consume in large amounts.

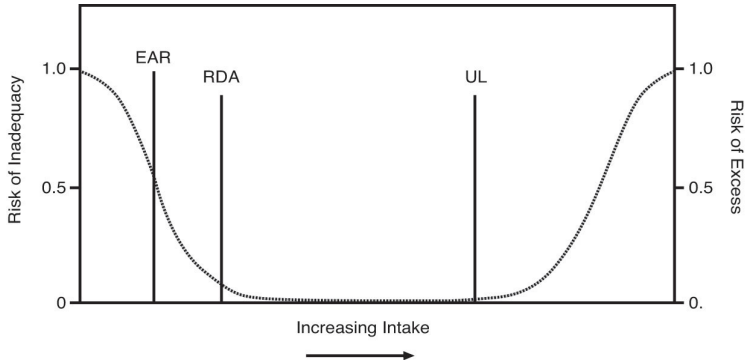


Figure 1.15.15: .2: DRI Graph. This graph illustrates the risks of nutrient inadequacy and nutrient excess as we move from a low intake of a nutrient to a high intake. Starting on the left side of the graph, you can see that when you have a very low intake of a nutrient, your risk of nutrient deficiency is high. As your nutrient intake increases, the chances that you will be deficient in that nutrient decrease. The point at which 50 percent of the population meets their nutrient need is the EAR, and the point at which 97 to 98 percent of the population meets their needs is the RDA. The UL is the highest level at which you can consume a nutrient without it being too much—as nutrient intake increases beyond the UL, the risk of health problems resulting from that nutrient increases. Source: Institute of Medicine. © 2012 National Academy of Sciences. All Rights Reserved. www.iom.edu.

3. **Acceptable Macronutrient Distribution Ranges (AMDR).** The Acceptable Macronutrient Distribution Range (AMDR) is the calculated range of how much energy from carbohydrates, fats, and protein is recommended for a healthy diet. People who do not reach the AMDRs for their target group increase their risk of developing health complications.

Table 1.15.1: AMDR Values for Adults

Nutrient	Value (percentage of Calories)
Fat	20.0–35.0
Carbohydrate	45.0–65.0
Protein	10.0–35.0
Polyunsaturated fatty acids	5.0–10.0
alpha - Linolenic acid	0.6–1.2

Source: Food and Nutrition Board of the Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. (Washington, DC: National Academies Press, 2002).

Tips for Using the Dietary Reference Intakes to Plan Your Diet

You can use the DRIs to help assess and plan your diet. Keep in mind when evaluating your nutritional intake that the values established have been devised with an ample safety margin and should be used as guidance for optimal intakes. Also, the values are meant to assess and plan average intake over time; that is, you don't need to meet these recommendations every single day—meeting them on average over several days is sufficient.

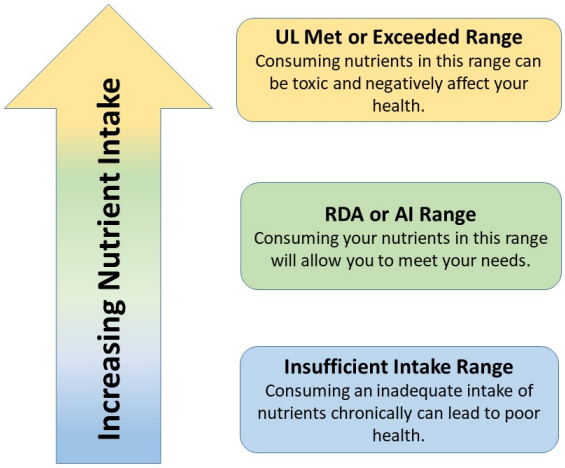


Figure Runaway argument for \eatSpaces?: .2: Relationship among insufficient intake, RDA, and UL.

Estimated Energy Requirements (EER)

Energy is not a nutrient but is required in the body for metabolic processes, physiological functions, muscular activity, heat production, growth and synthesis of new tissues. It is released from food components by oxidation. The main sources of energy are carbohydrates, proteins, fats and, to a lesser degree, alcohol. Energy requirements vary with age, gender, body size and activity, recommendations are needed for each age and gender group.

Two separate terms can, therefore, be used to express and determine Estimated Energy Requirements (EER). The Estimated Energy Requirement for Maintenance (EERM or actual energy requirement) is the dietary energy intake that is predicted to maintain energy balance (plus extra needs for pregnancy, lactation, and growth) in healthy individuals or groups of individuals at current levels of body size and level of physical activity. The Desirable Estimated Energy Requirement (DEER, or energy reference value) is the dietary energy intake that is predicted to maintain energy balance (plus extra needs for pregnancy, lactation and growth) in healthy individuals or groups of individuals of a defined gender, age, weight, height and level of physical activity consistent with good health and/or development.

Key Takeaways

- Nutrient-intake recommendations set for healthy people living in the United States and Canada are known as Dietary Reference Intakes.

- The DRIs includes the AI, EAR, RDA, and UL for micronutrients and the AMDR ranges for energy-yielding macronutrients. The DRI provides a set of standards for researchers and government policy-makers and specifies nutrient consumption guidelines for individuals.

Discussion Starter

1. Why do you think it is important for the government to set the DRI standards? How will you use this information for your personal dietary choices?

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1.16: Discovering Nutrition Facts

Learning Objectives

- Use the Nutrition Facts panel to discover the nutritional information of food.

The Labels on Your Food

Understanding the significance of dietary guidelines and how to use DRIs in planning your nutrient intakes can make you better equipped to select the right foods the next time you visit the supermarket.

In the United States, the Nutrition Labeling and Education Act was passed in 1990 and became effective in 1994. In Canada, mandatory labeling came into effect in 2005. As a result, all packaged foods sold in the United States and Canada must have nutrition labels that accurately reflect the contents of the food products. There are several mandated nutrients and some optional ones that manufacturers or packagers include. The FDA oversees mandatory labeling of foods. Table 1.16.1 lists the mandatory and optional inclusions. The FDA regulates these.

Table 1.16.1: Mandatory and Optional Inclusions on Nutrition Labels

Mandatory Inclusion	Optional Inclusion
Total Calories	Polyunsaturated fat
Total fat	Monounsaturated fat
Saturated fat	Insoluble fiber
Trans fat	Soluble fiber
Cholesterol	Sugar alcohol
Total carbohydrates	Other carbohydrates
Dietary fiber	Other essential vitamins and minerals
Total sugars	
Added sugar	
Protein	
Vitamin D	
Calcium	
Iron	
Potassium	

Source: US Food and Drug Administration. “Food Labeling Guide.” Last updated August 3, 2016. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm

Other types of information are required by law to appear somewhere on the consumer packaging. They include:

The Nutrition Facts panel provides a wealth of information about the product's nutritional content. The information also allows shoppers to compare products. Because the serving sizes are included on the label, you can see how much of each nutrient is in each serving to make the comparisons. Knowing how to read the label is important because of the way some foods are presented. For example, a bag of peanuts at the grocery store may seem like a healthy snack to eat on the way to class. But have a look at that label. Does it contain one serving or multiple servings? Unless you are buying the individual serving packages, chances are the bag you picked up is at least eight servings, if not more.

- Name and address of the manufacturer, packager, or distributor
- Statement of identity, what the product actually is
- Net contents of the package: weight, volume, measure, or numerical count

- Ingredients, listed in descending order by weight
- Nutrient information of serving size and % daily values

According to the 2010 health and diet survey released by the FDA, 54 percent of first-time buyers of a product will check the food label and will use this information to evaluate fat, calorie, vitamin, and sodium content. US Food and Drug Administration. "Survey Shows Gain in Food-Label Use, Health/Diet Awareness." March 2, 2010. www.fda.gov/ForConsumers/ConsumerUpdates/ucm202611.htm#FoodLabelHighlights. The survey also notes that more Americans are using food labels and are showing an increased awareness of the connection between diet and health. Having reliable food labels is a top priority of the FDA, which has a new initiative to prepare guidelines for the food industry to construct "front of package" labeling that will make it even easier for Americans to choose healthy foods. Stay tuned for the newest on food labeling by visiting the FDA website: www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm.

Interactive Link 1.16.1: The Food Label and You.

The FDA has prepared a new video about nutrition labeling that is packed with helpful information. You can watch the full-length video or individual segments. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm275409.htm#fullvideo

Reading the Label

On May 20, 2016, the FDA announced the new Nutrition Facts Panel. The figure below shows the original label and the new format label. Now, all packages must carry the new nutrition facts panel.

Both Nutrition Facts panels give you information on the serving size and how many servings are in the container. The new format has expanded the size of this area. For example, a label on a box of crackers might tell you that twenty crackers equal one serving and that the whole box contains 10 servings. All other values listed after that, from the calories to the dietary fiber, are based on this one serving. On the panel, the serving size is followed by the number of calories and then a list of selected nutrients.

Both Nutrition Facts panels give you information on the serving size and how many servings are in the container. The new format has expanded the size of this area. For example, a label on a box of crackers might tell you that twenty crackers equal one serving and that the whole box contains 10 servings. All other values listed thereafter, from the calories to the dietary fiber, are based on this one serving. On the panel, the serving size is followed by the number of calories and then a list of selected nutrients.

You will also see "Percent Daily Value" on the far right-hand side. The Daily Value (DV) has been updated with the new label, so the values on the original label do not match the new label even though the calories, serving size, and servings per package are the same. The % DV helps you determine if the food is or is not a good source of a particular nutrient. The DV represents the recommended amount of a given nutrient based on the Reference Daily Intake (RDI) and DRI of that nutrient in a 2,000-kilocalorie diet. Daily reference values (DRV) are set for all nutrients. The percentage of DV represents the proportion of the total daily recommended amount you will get from one serving of the food. The DV is not age-specific or gender specific. For example, on the food label in Figure 1.16.1, the percent DV of calcium for one serving is 20 percent, which means that one serving provides 20 percent of the daily recommended calcium intake.

Several nutrients have been dropped from the label - vitamins A and C because these are no longer low in the American diet. Added to the new label is "added sugar." This number reflects the amount of sugar or sugar-like substances the manufacturer added to the package.

Here is a website with more explanation: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm

Original Label

Nutrition Facts

Serving Size 2/3 cup (55g)
Servings Per Container About 8

Amount Per Serving

Calories 230	Calories from Fat 72
	% Daily Value*
Total Fat 8g	**12%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**12%**
Dietary Fiber 4g	**16%**
Sugars 1g	
Protein 3g	
Vitamin A	10%
Vitamin C	8%
Calcium	20%
Iron	45%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs.

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

New Format Label

Nutrition Facts

8 servings per container
Serving size **2/3 cup (55g)**

Amount per serving
Calories **230**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Generally, a DV percentage of 5 is considered low, and a DV percentage of 20 is considered high. As a general rule, for fat, saturated fat, trans fat, cholesterol, or sodium, look for foods with a low percent DV. Alternatively, consider a high percent DV when concentrating on essential mineral or vitamin intake. To figure out your fat allowance remaining for the day after consuming one serving, look at the percent DV for fat, which is 18 percent, and subtract it from 100 percent. To know this amount in grams of fat, read the footnote of the food label to find that the recommended maximum amount of fat grams to consume per day for a 2,000 kilocalories diet is 65 grams. Eighteen percent of sixty-five equals about 12 grams. This means that 53 grams of fat are remaining in your fat allowance. Remember, to have a healthy diet, the recommendation is to eat less than this amount of fat grams per day, especially if you want to lose weight.

Table 1.16.2: DVs Based on a Caloric Intake of 2,000 Calories (For Adults and Children Four or More Years of Age)

Nutrient	Current DV
Added sugars	50g
Total fat	78 g
Saturated fat	20 g
Cholesterol	300 mg
Sodium	2,300 mg
Potassium	4,700 mg
Total carbohydrate	275 g
Dietary fiber	28 g
Protein	50 g
Added Sugar	50 g
Calcium	1,300 mg

Nutrient	Current DV
Iron	18 mg
Vitamin D	20 mcg

Source: FDA, https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm

Of course, this is a lot of information to put on a label, and some products are too small to accommodate it all. For small packages, such as small containers of yogurt, candy, or fruit bars, permission has been granted to use an abbreviated version of the Nutrition Facts panel. To learn additional details about all of the information contained within the Nutrition Facts panel, see the following website: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm

Video Link 1.16.2: How to Read Food Labels.

Pay attention to the fine print when grocery shopping. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm275409.htm#fullvideo

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- ## Claims on Labels

In addition to mandating nutrients and ingredients that must appear on food labels, any nutrient-content claims must meet certain requirements. For example, a manufacturer cannot claim that a food is fat-free or low-fat if it is not, in reality, fat-free or low-fat. Low fat indicates that the product has three or fewer grams of fat; low salt indicates fewer than 140 milligrams of sodium; low- cholesterol indicates fewer than 20 milligrams of cholesterol and two grams of saturated fat. See Table 1.16.3 for some examples. US Food and Drug Administration. “Additional Requirements for Nutrient Content Claims.” Appendix B in *Food Labeling Guide* (August 2016). https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm

Table 1.16.3: Common Label Terms Defined

Nutrient Content Claim	What the Claim Means Per Serving
High (rich in, excellent source)	20% or more of the Daily Value
Good	10% to 19% of the Daily Value
More	Contains at least 10% more of the Daily Value for vitamins, minerals, protein, dietary fiber, or potassium.*
Light	Has at least ⅓ fewer calories or 50% less fat.* If more than half the calories are from fat, fat content must be reduced by 50% or more.
Less or fewer	Has 25% less of a nutrient or of calories
Calorie Claims	
Calorie free	Less than 5 calories
Low calorie	40 calories or less
Reduced calories	At least 25% fewer calories*
Sugar Claims	
Sugar-free	Less than 0.5 gram sugars

Nutrient Content Claim	What the Claim Means Per Serving
Reduced sugar	At least 25% less sugar*
Fiber Claims (If food is not low in total fat, the label must state total fat in conjunction with the fiber claims.)	
High fiber	5 grams or more
Good source of fiber	2.5 grams to 4.9 grams
More or added fiber	At least 2.5 grams more*
Sodium Claims	
Sodium free or salt-free	Less than 5 milligrams sodium
Very low sodium	35 milligrams of sodium or less
Low sodium	140 milligrams of sodium or less
Reduced sodium	At least 25% less sodium*
Light in sodium	At least 50% less sodium
Salt-free	Less than 5 milligrams sodium
Fat Claims	
Fat-free	Less than 0.5 gram fat
Low fat	3 grams or less total fat
Reduced fat	At least 25% less fat than the regular version
Saturated Fat Claims	
Saturated fat-free	Less than 0.5 gram saturated fat and less than 0.5 gram trans fatty acids
Low in saturated fat	1 gram or less saturated fat & no more than 15% calories from saturated fat
Reduced saturated fat	At least 25% less saturated fat* and reduced by more than 1 gram fat
Note: Trans-fat has no FDA-defined nutrient content claims.	
Cholesterol Claims	
Cholesterol free	Less than 2 milligrams cholesterol and 2 grams or less saturated fat
Low cholesterol	20 milligrams or less cholesterol and 2 grams or less saturated fat
Reduced cholesterol	At least 25% less cholesterol and 2 grams or less saturated fat*
Lean Claims	
Lean	Contains less than 10 grams total fat, 4.5 grams or less saturated fat, and less than 95 milligrams cholesterol
Extra lean	Contains less than 5 grams total fat, less than 2 grams saturated fat, and less than 95 milligrams cholesterol
*compared to the reference, or regular, food this would replace	

Source: US Food and Drug Administration. “Food Labeling Guide.” Last updated August 2016. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm and http://www.clemson.edu/extension/hgic/food/nutrition/nutrition/dietary_guide/hgic4061.html

Health Claims

Often, we hear news of a particular nutrient or food product that contributes to our health or may prevent disease. A health claim is a statement that links a particular food with a reduced risk of developing a disease. As such, the FDA must evaluate health claims such as “reduces heart disease” before they appear on packaging. Prior to the passage of the NLEA, products that made such claims were categorized as drugs and not food. All health claims must be substantiated by scientific evidence in order for them to be approved and put on a food label. Laws also regulate how health claims are presented on food packaging to prevent companies from making false claims. In addition to the claim being backed up by scientific evidence, it may never claim to cure or treat the disease. For a detailed list of approved health claims, visit: https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/default.htm

- ### Qualified Health Claims

While health claims must be backed up by *hard* scientific evidence, qualified health claims have *supportive* evidence, which is not as definitive as health claims. The evidence may suggest that the food or nutrient is beneficial. Wording for this type of claim may look like this: “Supportive but not conclusive research shows that consumption of EPA and DHA omega-3 fatty acids may reduce the risk of coronary artery disease. One serving of [name of food] provides [X] grams of EPA and DHA omega-3 fatty acids. [See nutrition information for total fat, saturated fat, and cholesterol content.] US Food and Drug Administration. “FDA Announces Qualified Health Claims for Omega-3 Fatty Acids.” December 14, 2014. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm073992.htm

Structure/Function Claims

Despite no scientific evidence, some companies claim that certain foods and nutrients benefit health. In these cases, food labels are permitted to claim that you may benefit from the food because it may boost your immune system, for example. There may not be claims of diagnosis, cures, treatment, or disease prevention, and there must be a disclaimer that the FDA has not evaluated the claim. US Food and Drug Administration. “Claims That Can Be Made for Conventional Foods and Dietary Supplements.” April 2016. www.fda.gov/food/ingredientspackaginglabeling/labelingnutrition/ucm111447.htm.

Allergy Warnings

The FDA requires food manufacturers to list on their packages if the product contains any of the eight most common ingredients that cause food allergies. These eight common allergens are as follows: milk, eggs, peanuts, tree nuts, fish, shellfish, soy, and wheat. (More information on these allergens will be discussed elsewhere). The FDA does not require warnings that cross-contamination may occur during packaging; however, most manufacturers include this advisory as a courtesy. For instance, you may notice a label that states, “This product is manufactured in a factory that also processes peanuts.” If you have food allergies, avoiding products that may have been contaminated with the allergen is best.

Key Takeaways

Discussion Starter

- The Nutrition Labeling and Education Act made it a law that foods sold in the United States have a food label that provides the accurate contents of nutrients within them. Canada has a similar law.
- The Nutrition Labeling and Education Act made it a law that foods sold in the United States have a food label that provides the accurate contents of nutrients within them. Canada has a similar law.
- The percent DV is the percentage of the amount of the food's nutrient in relation to its recommended intake. It is a guide to help you determine if a food is a good or poor source of nutrients.
- To keep companies from making false claims, the FDA regulates food manufacturers' labels on packages that promote health. Allergens must also be listed on food labels. Sometimes, cross-contamination occurs during packaging. Most food manufacturers voluntarily list this information. If you have a food allergy, it is best to avoid any product that has even had the possibility of coming in contact with a known allergen.

1. Recall the food you buy from the supermarket on a regular basis. How many of the food products you purchase regularly are nutrient-dense? How many are nutrient-poor? What foods can you substitute in place of the nutrient-poor food choices?

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1.17: When Enough is Enough

Learning Objectives

- Judge food portion sizes for adequacy.

Estimating Portion Size

Have you ever heard the expression, “Your eyes were bigger than your stomach?” This means that you thought you wanted a lot more food than you could actually eat. Amounts of food can be deceiving to the eye, especially if you have nothing to compare them to. It is very easy to heap a pile of mashed potatoes on your plate, particularly if it is a big plate, and not realize that you have just helped yourself to three portions instead of one.

The food industry makes following the *2020 Dietary Guidelines* a challenge. In many restaurants and eating establishments, portion sizes have increased, the use of solid fats and added sugar (SoFAS) has increased, and consequently, the typical meal contains more calories than it used to. In addition, our sedentary lives make it difficult to expend enough calories during normal daily activities. In fact, more than one-third of adults are not physically active at all.

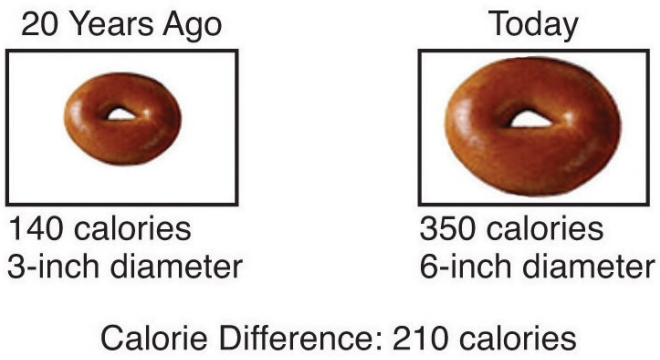


Figure Runaway argument for \eatSpaces?: .1: As food sizes and servings increase it is important to limit the portions of food consumed on a regular basis.

Dietitians have come up with some good hints to help people tell how large a portion of food they really have. Some suggest using common items such as a deck of cards while others advocate using your hand as a measuring rule. See Table 1.17.1 for some examples.American Cancer Society. “Controlling Portion Sizes.” Last revised June 30, 2014. http://www.cancer.org/Healthy/EatHealthyGetActive/TakeControlofYourWeight/controlling-portion-sizes.

Table 1.17.1: Determining Food Portions

Food Product	Amount	Object Comparison	Hand Comparison
Pasta, rice	½ c.	Tennis ball	Cupped hand
Fresh vegetables	1 c.	Baseball	
Cooked vegetables	½ c.	Cupped hand	
Meat, poultry, fish	3 oz.	Deck of cards	Palm of your hand
Milk or other beverages	1 c.	Fist	
Salad dressing	1 Tbsp.	Thumb	
Oil	1 tsp.	Thumb tip	

Video 1.17.1: Managing a Healthy Diet: Judging Healthy Portion Sizes



Video 1.17.1: *A dietitian shows how to compare food sizes with hands and other objects.(click to see video)*

MyPlate Planner

Estimating portions can be done using the MyPlate Planner. Recall that the MyPlate symbol is divided according to how much of each food group should be included with each meal. Note the MyPlate Planner Methods of Use:

- Fill half of your plate with vegetables such as carrots, broccoli, salad, and fruit.
- Fill one-quarter of your plate with lean meat, chicken, or fish (about 3 ounces)
- Fill one-quarter of your plate with a whole grain such as ⅓ cup rice
- Choose one serving of dairy
- Add margarine or oil for preparation or addition at the table

Table 1.17.2: Meal Planning Guidelines

Carbohydrates	Meats/Proteins	Fats	Free Foods
Choose three servings with each meal.	Choose one to three servings with each meal.	Choose one to two servings with each meal.	Use as desired.
Examples of *one* serving:	Examples of *one* serving:	Examples of *one* serving:	Examples
Breads and Starches • 1 slice bread or small roll • ⅓ c. rice or pasta • ½ c. of cooked cereal or potatoes • ¾ c. dry cereal • ½ c. corn	• 1 oz. lean meat, poultry, or fish • 1 egg • 1 oz. cheese • ¾ c. low-fat cottage cheese	• 1 tsp. margarine, oil, or mayonnaise • 1 Tbsp. salad dressing or cream cheese	**Foods with less than 20 calories per serving.*** • Most vegetables • Sugar-free soda • Black coffee or plain tea
Fruits • 1 piece, such as a small pear • 1 c. fresh fruit • ½ c. canned fruit • ½ c. fruit juice			
Milk • 1 c. skim or low fat • 1 c. unsweetened low-fat yogurt			

Key Takeaways

- Judging portion sizes can be done using your hand or household objects in comparison. It can also be done using the MyPlate guide to determine how much food is a portion for that meal.

Discussion Starter

1. Why is it important to judge portion sizes properly? Explain why it can be tricky to read food labels and figure out the caloric content for one serving.

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1.E: Nutrition and You (Exercises)

It's Your Turn

1. You are writing a short article for the *Daily News*. Explain how health means much more than a mere absence of disease.
2. Create a table that summarizes the six classes of nutrients and their major functions.
3. List five ideas on how to change the nutrition of Americans to protect their health and the health of the planet.
4. Draw a diagram that shows the role that nutrition plays in human health.
5. Write three ways in which cultural, religious, and social values affect dietary eating patterns.
6. Compare and contrast the Nutrition Facts label on two of your favorite foods. Make a smart choice for eating the most nutrient-dense food option. Which food did you select and why?

Apply It

1. Explore the nutritional and health information provided by the USDA, the HSS, and the IOM. Make a pros and cons list on how helpful the information from each of these sources was to you.
2. Revisit the photographs of the inner contents of refrigerators by Mark Menjivar. Describe how factors associated with a person's environment, lifestyle, and culture may affect the personal food choices in at least six different refrigerators.
3. Write a paragraph on your opinion of the role of the federal government in promoting health and preventing disease in Americans.
4. You have been hired to write a two-page article for a weekly magazine about why nutrition is important to health. Using simple terms and a good supply of photographs, create your article. Be prepared to share your project with the class.
5. Record a food diary this week. At the end of the week, circle the foods that contain SoFAS. Next, to each food, write a substitute food to replace it. Record a food diary next week. Be sure to eat the substitute foods you have selected to replace the foods that contained the SoFAS.
6. Search the Internet for sites that claim to give you nutritional advice. Check to see who sponsors the sites and if the site is trying to sell you a product or service. Compare the information found on the sites to those recommended in this text. What similarities do you notice? What differences do you notice?

Expand Your Knowledge

1. Conduct an assessment of your diet. Begin by recording what you eat every day, including snacks and beverages, in a journal. Then visit the website, www.choosemyplate.gov/myplate/index.aspx, which has tools to help you assess your diet. Calculate your average daily calorie consumption.
2. Conduct an informal survey of five of your friends and family members. Create a questionnaire with ten to fifteen questions pertaining to their perception of food, their favorite food shows, what restaurants they frequent, what they purchase from the grocery store each week, etc. Ask questions about their general eating habits and record the answers. Next, get a camera and take pictures of the insides of their refrigerators. What have you learned about their eating habits? What advice would you give them? Review all the material and put it together in a report. Be prepared to share your findings.
3. Define eight steps your community can take to build a more sustainable food system. Visit the websites of Toronto's and California's plans to help provide you with some good ideas to accomplish the challenge.
    - Toronto's plan for a sustainable food system: wx.toronto.ca/inter/health/food.nsf/Resources/340ACEEDBF1B2D6085257738000B22F2/$file/Cultivating%20Food%20Connections%20report.pdf
    - California's plan for a sustainable food system: www.vividpicture.net/

1. You have just been hired at the local Boys and Girls club in an inner city neighborhood that happens to have a large high school drop-out rate. You have been put in charge of creating physical and nutritional opportunities for the community. Your goal for the first quarter is to enroll one hundred students in an exercise/nutrition program. You must develop two programs.
    - Define each program and state its objectives
    - Describe the ways in which the program will benefit participants
    - List ways in which you will encourage enrollment
    - Create a marketing flyer for each program

2. You are planning a big meal for a surprise graduation party for your friend. You expect fifty guests to attend. Using the information you have learned regarding healthy eating and food portions, plan a healthful meal. Determine how much protein, vegetables, fruits, and starch you will need to purchase to feed everyone comfortably. Write down a detailed list so that you can shop and prepare your budget accordingly. Share your results with the class.
3. You are a Registered Dietitian who has been asked to help a vegan patient adjust their eating habits to get more nutrients from their diet and halt unwanted weight loss. Develop a week's worth of meals to help this person have balance in their diet.

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CHAPTER OVERVIEW

2: Gastrointestinal Tract

Because we know that you may not have a background in biology, we start with a tour through the human body, from the single cell to the full organism, we set up for a discussion about the processes of digestion and absorption, followed by explorations of the other organ systems. After that, we discuss the concept of energy and calories. We also discuss some disorders and diseases related to nutritional health.

2.1: Chapter Introduction
2.2: The Basic Structural and Functional Unit of Life- The Cell
2.3: Digestion and Absorption
2.4: Nutrients Are Essential for Organ Function
2.5: Energy and Calories
2.6: Gastrointestinal Tract and Your Health
2.E: Exercises

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2.1: Chapter Introduction

Big take away

- Eat your way to health.

"Let food be thy medicine and medicine be thy food." These words, espoused by the Greek physician Hippocrates over two thousand years ago, bear much relevance on our food choices and their connection to our health. Today, the scientific community echoes Hippocrates' statement as it recognizes some foods as *functional foods*. The Academy of Nutrition and Dietetics defines functional foods as "whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels."



Figure 2.1.1: Do you understand the relationship between food and health? © Thinkstock

In the latter nineteenth century, a Russian doctor of immunology, Elie Metchnikoff, was intrigued by the healthy life spans of people who lived in the tribes of the northern Caucasus Mountains. What contributed to their long life span and their resistance to life-threatening diseases? A possible factor lay wrapped up in a leather satchel used to hold fermented milk. One legend recounts that Mohammed, the great prophet of Islam, revealed this recipe to members of the Orthodox faith on the condition that they would not tell anyone outside of the faith how to create such a good-feeling beverage. The tribes, under Mohammed's direction, combined a tiny amount of small grains that resembled white broccoli with milk in a leather satchel. This bag was hung from a doorway in a house, so that all who passed would hit the bag, mixing up the contents. The result was a refreshing, slightly carbonated, creamy beverage with tangy overtones.

Observing the connection between the beverage and longevity, Dr. Elie Metchnikoff began his research on beneficial bacteria and the longevity of life that led to his book, *The Prolongation of Life*. He studied the biological effects and chemical properties of the kefir elixir whose name came from the Turkish word "kef" or "pleasure." Intrigued, the Russian Society of Physicians went on a quest to locate the recipe in order to prescribe this drink to their patients. However, just as instructed, no one would share the recipe. As a result, the mission of obtaining this highly guarded recipe was placed on the Blandov brothers, who owned the Moscow Dairy and some holdings in the Caucasus Mountains.

The Blandov brothers had a beautiful employee, Irina Sakharova, whom they sent to the courts of the Caucasus tribe of Prince Bek-Mirza Barchorov in order to charm the recipe out of him. The prince immediately fell in love with Irina. As time went on, Irina asked the prince for some kefir grains. He refused, explaining that he was forbidden from sharing this secret and feared the consequences of violating religious law. Irina returned home when she realized that she would never pry the recipe from the prince. However, on orders from the heartbroken prince, Irina was kidnapped and brought back to marry him. She was taken aback and

refused this proposal. Her refusal was rejected and the marriage was arranged. The Blandov brothers courageously stole into the tribe the night before the marriage and managed to free Irina. Insulted and still seeing a way to retrieve the kefir grains, Irina brought her case before the Russian Czar, charging the prince with kidnapping. Upon review of the evidence, it was ruled in her favor and Irina won her case. As part of her grievance repayment, Irina requested some kefir grains. Bound by law, the prince had to comply. Irina gave the grains to the Blandov brothers who mass-produced kefir from these kernels. To this day, kefir is one of the most widely enjoyed beverages in Russia.

Kefir has since found its way into America, where it is marketed in several flavors and can be found at your local grocery store. It is one product of the billion-dollar functional food industry marketed with all sorts of health claims from improving digestion to preventing cancer. What is the scientific evidence that kefir is a functional food? Expert nutritionists agree that probiotics, such as kefir, reduce the symptoms of lactose intolerance and can ward off virally caused diarrhea. While some health claims remain unsubstantiated, scientific studies are ongoing to determine the validity of other health benefits of probiotics.

You Decide

Will you eat your way to health with probiotic foods?

Knowing how to maintain the balance of friendly bacteria in your intestines through proper diet can promote overall health. Recent scientific studies have shown that probiotic supplements positively affect intestinal microbial flora, which in turn positively affect immune system function. As good nutrition is known to influence immunity, there is great interest in using probiotic foods and other immune-system-friendly foods as a way to prevent illness. In this chapter, we will explore not only immune system function but also all other organ systems in the human body. We will learn the process of nutrient digestion and absorption, which further reiterates the importance of developing a healthy diet to maintain a healthier you. The evidence abounds that food can indeed be “thy medicine.”

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2.2: The Basic Structural and Functional Unit of Life- The Cell

Learning Objectives

- Diagram the components of a cell.
- Describe the organization of the human body.

What distinguishes a living organism from an inanimate object? A living organism conducts self-sustaining biological processes. A cell is the smallest and most basic form of life. Robert Hooke, one of the first scientists to use a light microscope, discovered the cell in 1665. In all life forms, including bacteria, plants, animals, and humans, the cell was defined as the most basic structural and functional unit. Based on scientific observations over the next 150 years, scientists formulated the cell theory, which is used for all living organisms no matter how simple or complex. The cell theory incorporates three principles:

- Cells are the most basic building units of life.
- All living things are composed of cells.
- New cells are made from preexisting cells, which divide into two.

Who you are has been determined because of two cells that came together inside your mother's womb. The two cells containing all of your genetic information (DNA) united to begin making new life. Cells divided and differentiated into other cells with specific roles that led to the formation of the body's numerous body organs, systems, blood, blood vessels, bone, tissue, and skin. As an adult, you are comprised of trillions of cells. Each of your individual cells is a compact and efficient form of life—self-sufficient, yet interdependent upon the other cells within your body to supply its needs.

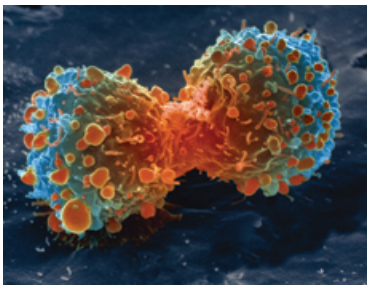


Figure 2.2.1: One cell divides into two, which begins the creation of millions of more cells that ultimately become you. (Public Domain; National Institutes of Health).

Independent single-celled organisms must conduct all the basic processes of life: it must take in nutrients (energy capture), excrete wastes, detect and respond to its environment, move, breathe, grow, and reproduce. Even a one-celled organism must be organized to perform these essential processes. All cells are organized from the atomic level to all its larger forms. Oxygen and hydrogen atoms combine to make the molecule water (H_2O). Molecules bond together to make bigger macromolecules. The carbon atom is often referred to as the backbone of life because it can readily bond with four other elements to form long chains and more complex macromolecules. Four macromolecules—carbohydrates, lipids, proteins, and nucleic acids—make up all of the structural and functional units of cells.

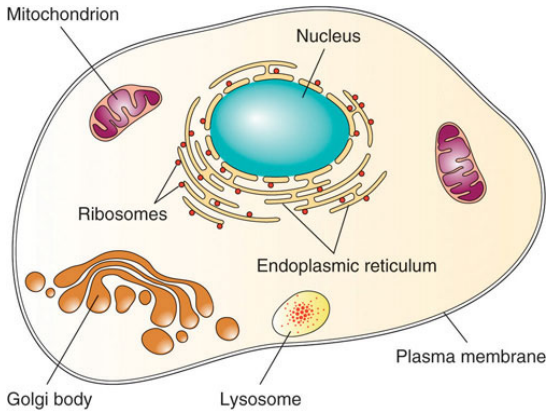


Figure 2.2.2: The cell is structurally and functionally complex.

Although we defined the cell as the “most basic” unit of life, it is structurally and functionally complex (Figure 2.2.1). A cell can be thought of as a mini-organism consisting of tiny organs called organelles. The organelles are structural and functional units constructed from several macromolecules bonded together. A typical animal cell contains the following organelles: the nucleus (which houses the genetic material DNA), mitochondria (which generate energy), ribosomes (which produce protein), the endoplasmic reticulum (which is a packaging and transport facility), and the Golgi apparatus (which distributes macromolecules). In addition, animal cells contain little digestive pouches, called lysosomes and peroxisomes, which break down macromolecules and destroy foreign invaders. All of the organelles are anchored in the cell’s cytoplasm via a cytoskeleton. The cell’s organelles are isolated from the surrounding environment by a plasma membrane.

Video 2.2.1: Discovery Video: Cells

This video describes the importance of cells in the human body.



Tissues, Organs, Organ Systems, and Organisms

Unicellular (single-celled) organisms can function independently, but the cells of multicellular organisms are dependent upon each other and are organized into five different levels in order to coordinate their specific functions and carry out all of life’s biological processes.

- **Cells.** Cells are the basic structural and functional unit of all life. Examples include red blood cells and nerve cells.
- **Tissues.** Tissues are groups of cells that share a common structure and function and work together. There are four types of human tissues: connective, which connects tissues; epithelial, which lines and protects organs; muscle, which contracts for movement and support; and nerve, which responds and reacts to signals in the environment.
- **Organs.** Organs are a group of tissues arranged in a specific manner to support a common physiological function. Examples include the brain, liver, and heart.
- **Organ systems.** Organ systems are two or more organs that support a specific physiological function. Examples include the digestive system and central nervous system. There are eleven organ systems in the human body (Table 3.2.1).
- **Organism.** An organism is the complete living system capable of conducting all of life’s biological processes.

Table 2.2.1: The Eleven Organ Systems in the Human Body and Their Major Functions

Organ System	Organ Components	Major Function
Circulatory	heart, blood/lymph vessels, blood, lymph	Transport nutrients and waste products
Digestive	mouth, esophagus, stomach, intestines	Digestion and absorption
Endocrine	all glands (thyroid, ovaries, pancreas)	Produce and release hormones
Immune	white blood cells, lymphatic tissue, marrow	Defend against foreign invaders
Integumentary	skin, nails, hair, sweat glands	Protective, body temperature regulation
Muscular	skeletal, smooth, and cardiac muscle	Body movement

Organ System	Organ Components	Major Function
Nervous	brain, spinal cord, nerves	Interprets and responds to stimuli
Reproductive	gonads, genitals	Reproduction and sexual characteristics
Respiratory	lungs, nose, mouth, throat, trachea	Gas exchange
Skeletal	bones, tendons, ligaments, joints	Structure and support
Urinary	kidneys, bladder, ureters	Waste excretion, water balance

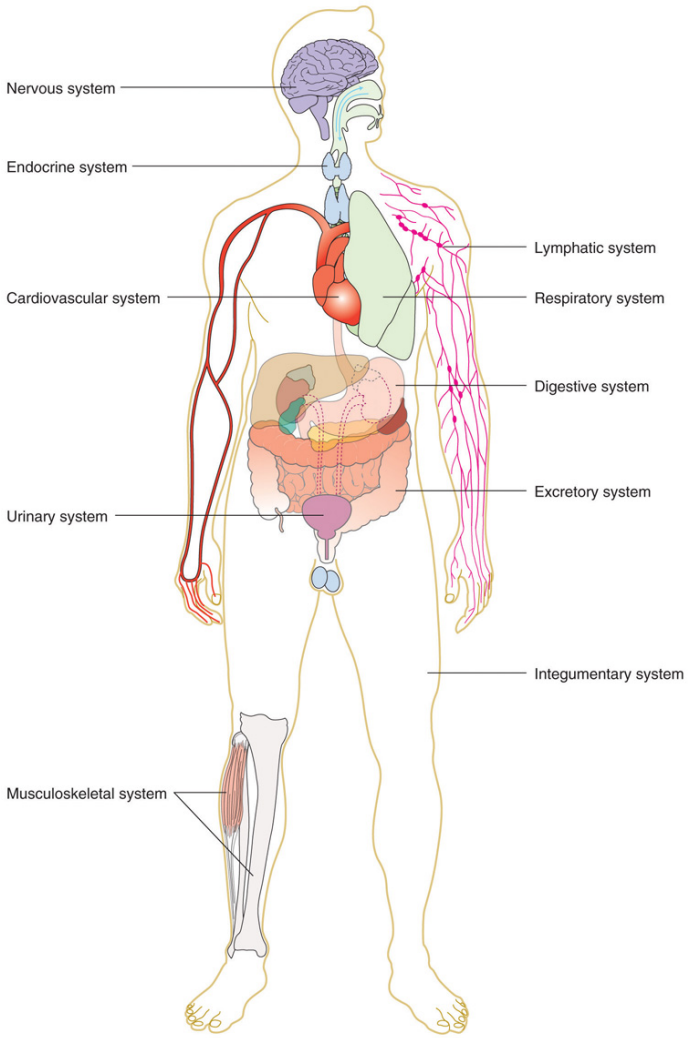


Figure 2.2.3: Organ Systems in the Human Body © Networkgraphics

An Organism Requires Energy and Nutrient Input

Energy is required in order to build molecules into larger macromolecules, and to turn macromolecules into organelles and cells, and then turn those into tissues, organs, and organ systems, and finally into an organism. Proper nutrition provides the necessary nutrients to make the energy that supports life's processes. Your body builds new macromolecules from the nutrients in food.

Nutrient and Energy Flow

Energy is stored in a nutrient's chemical bonds. Energy comes from sunlight, which plants then capture and, via photosynthesis, use it to transform carbon dioxide in the air into the molecule, glucose. When the glucose bonds are broken, energy is released. Bacteria, plants, and animals (including humans) harvest the energy in glucose via a biological process called cellular respiration.

In this process the chemical energy of glucose is transformed into cellular energy in the form of the molecule, adenosine triphosphate (ATP). Cellular respiration requires oxygen (aerobic) and it is provided as a waste product of photosynthesis. The waste products of cellular respiration are carbon dioxide (CO_2) and water, which plants use to conduct photosynthesis again. Thus, energy is constantly cycling between plants and animals. As energy is consumed nutrients are recycled within it.

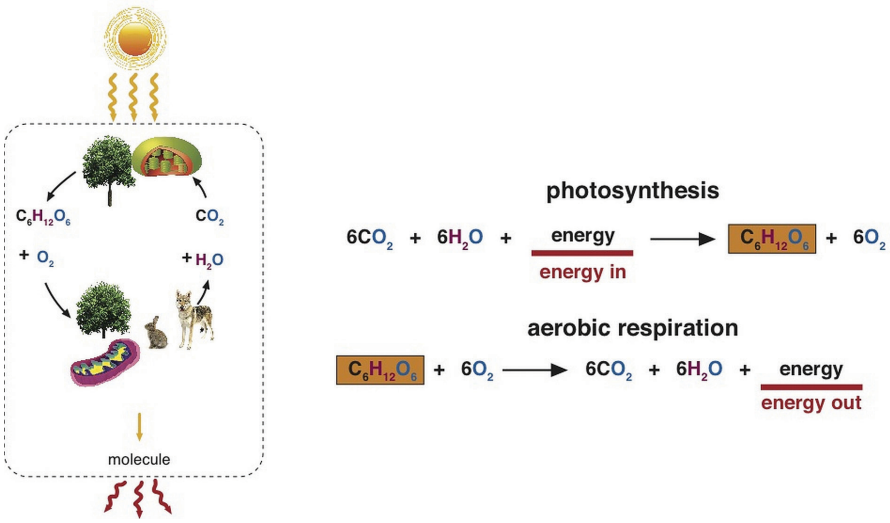


Figure 2.2.4: Plants harvest energy from the sun and capture it in the molecule, glucose. Humans harvest the energy in glucose and capture it into the molecule, ATP.

In this section, we have learned that all life is composed of cells capable of transforming small organic molecules into energy. How do complex organisms such as humans convert the large macromolecules in the foods that we eat into molecules that can be used by cells to make cellular energy? In the next section, we will discuss the physiological process of digestion to answer this question.

Key Takeaways

- The cell is the basic structural and functional unit of life. Cells are independent, single-celled organisms that take in nutrients, excrete wastes, detect and respond to their environment, move, breathe, grow, and reproduce. The macromolecules carbohydrates, proteins, lipids, and nucleic acids make up all of the structural and functional units of cells.
- In complex organisms, cells are organized into five levels so that an organism can conduct all basic processes associated with life.
- There are eleven organ systems in the human body that work together to support life, all of which require nutrient input.
- Energy is constantly cycling between plants and animals. As energy is consumed nutrients are recycled within it.

Discussion Starter

1. Discuss the importance of organization in the human body. If the body becomes disorganized by a disease or disorder what happens to its function? Can you think of a good example (what about leg fracture and movement)?

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2.3: Digestion and Absorption

Learning Objectives

- Sketch and label the major organs of the digestive system and state their functions.

Digestion begins even before you put food into your mouth. When you feel hungry, your body sends a message to your brain that it is time to eat. Sights and smells influence your body's preparedness for food. Smelling food sends a message to your brain. Your brain then tells the mouth to get ready, and you start to salivate in preparation for a delicious meal.

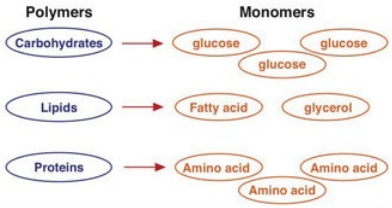


Figure 2.3.1: The Digestion Process. Digestion converts the food we eat into smaller particles, which will be processed into energy or used as building blocks.

Once you have eaten, your digestive system (Figure 2.3.1) breaks down the food into smaller components. Another word for the breakdown of complex molecules into smaller, simpler molecules is "catabolism". To do this, catabolism functions on two levels, mechanical and chemical. Once the smaller particles have been broken down, they will be absorbed into the blood and delivered to cells throughout the body for energy or for building blocks needed for cells to function. The digestive system is one of the eleven organ systems of the human body and it is composed of several hollow tube-shaped organs including the mouth, pharynx, esophagus, stomach, small intestine, large intestine (or colon), rectum, and anus. It is lined with mucosal tissue that secretes digestive juices (which aid in the breakdown of food) and mucus (which facilitates the propulsion of food through the tract). Smooth muscle tissue surrounds the digestive tract and its contraction produces waves, known as peristalsis, that propel food down the tract. Nutrients as well as some non-nutrients are absorbed. Substances such as fiber get left behind and are appropriately excreted.

From the Mouth to the Stomach

There are four steps in the digestion process (Figure 2.3.2). The first step is ingestion, which is the collection of food into the digestive tract. It may seem a simple process, but ingestion involves smelling food, thinking about food, and the involuntary release of saliva, in the mouth to prepare for food entry. In the mouth, where the second step of digestion occurs, the mechanical and chemical breakdown of food begins. The chemical breakdown of food involves enzymes, which break apart the components in food. In the mouth, the enzyme amylase is secreted to begin breaking down complex carbohydrate. Mechanical breakdown starts with mastication (chewing) in the mouth. Teeth crush and grind large food particles, while saliva initiates the chemical breakdown of food and enables its movement downward. The slippery mass of partially broken-down food is called bolus, which moves down the digestive tract as you swallow. Swallowing may seem voluntary at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins.

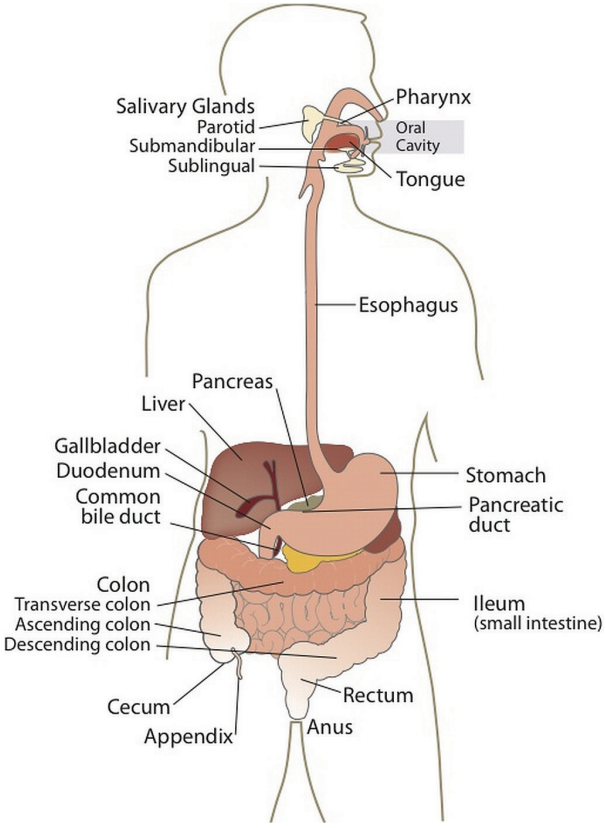


Figure 2.3.2: The Human Digestive System : © Networkgraphics

As you swallow, the bolus is pushed from the mouth through the pharynx and into a muscular tube called the esophagus. As it travels through the pharynx, a small flap called the epiglottis closes, to prevent choking by keeping food from going into the trachea. Peristaltic contractions in the esophagus propel the food down to the stomach. At the junction between the esophagus and stomach, there is a sphincter muscle that remains closed until the food bolus approaches. The pressure of the food bolus stimulates the lower esophageal sphincter to relax and open and food then moves from the esophagus into the stomach. The mechanical breakdown of food is accentuated by the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal. Solid food takes between four and eight seconds to travel down the esophagus, and liquids take about one second.

From the Stomach to the Small Intestine

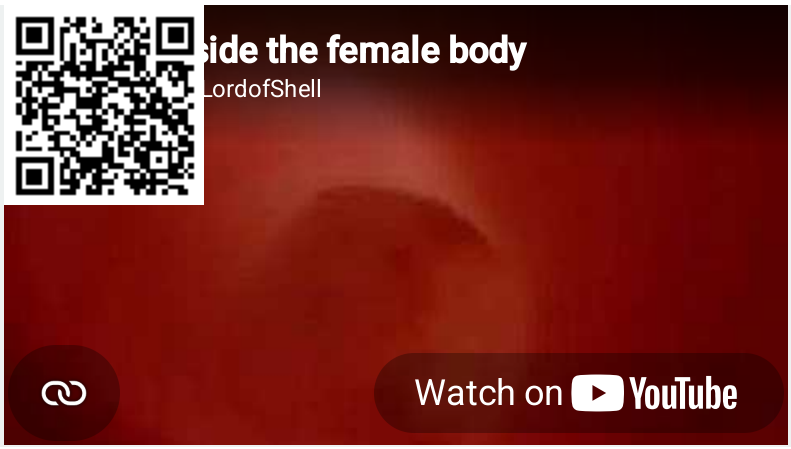
When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. Chyme is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. Cells in the stomach also secrete hydrochloric acid and the enzyme pepsin, that chemically breaks down protein into smaller molecules. A thick mucus coat lines the stomach to protect it from digesting itself. The stomach has three basic tasks:

1. To store food
2. To mechanically and chemically break down food
3. To empty partially broken-down food into the small intestine

The length of time food spends in the stomach varies by the macronutrient composition of the meal. A high-fat or high-protein meal takes longer to break down than one rich in carbohydrates. It usually takes a few hours after a meal to empty the stomach contents completely. The sphincter that allows chyme to pass into the small intestine is known as the pyloric sphincter.

Video 2.3.1: Digestion Video

This video shows the mechanical and chemical breakdown of food into chyme.



The small intestine is divided into three structural parts: the duodenum, the jejunum, and the ileum. Once the chyme enters the duodenum (the first segment of the small intestine), three accessory (or helper) organs: liver, pancreas, and gallbladder are stimulated to release juices that aid in digestion. The pancreas secretes up to 1.5 liters of pancreatic juice through a duct into the duodenum per day. This fluid consists mostly of water, but it also contains bicarbonate ions that neutralize the acidity of the stomach-derived chyme and enzymes that further break down proteins, carbohydrates, and lipids. The gallbladder secretes a much smaller amount of bile to help digest fats, also through a duct that leads to the duodenum. Bile is made in the liver and stored in the gallbladder. Bile's components act like detergents by surrounding fats similar to the way dish soap removes grease from a frying pan. This allows for the movement of fats in the watery environment of the small intestine. Two different types of muscular contractions, called peristalsis and segmentation, move and mix the food in various stages of digestion through the small intestine. Similar to what occurs in the esophagus and stomach, peristalsis is circular waves of smooth muscle contraction that propel food forward. Segmentation sloshes food back and forth in both directions promoting further mixing of the chyme. Almost all the components of food are completely broken down to their simplest unit within the first 25 centimeters of the small intestine. Instead of proteins, carbohydrates, and lipids, the chyme now consists of amino acids, monosaccharides, and emulsified fatty acids.

The next step of digestion (nutrient absorption) takes place in the remaining length of the small intestine, or ileum (> 5 meters).

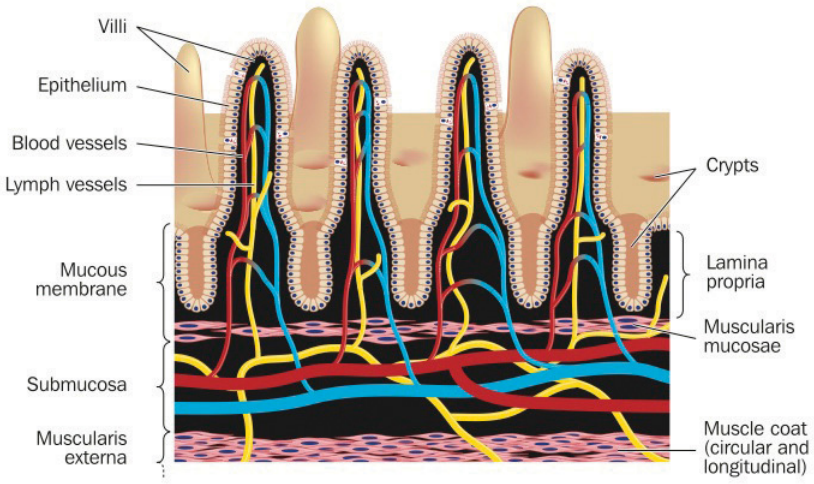


Figure 2.3.3: The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvilli. © Shutterstock

The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The surface area of the small intestine increases by multiple levels of folding. The internal tissue of the small intestine is covered in villi, which are tiny finger-like projections that are covered with even smaller projections, called microvilli (Figure 2.3.3). The digested nutrients pass through the absorptive cells of the intestine via diffusion or special transport proteins. Amino acids, minerals, alcohol, water soluble vitamins, and monosaccharides (sugars like glucose) are

transported from the intestinal cells into capillaries, but the much larger emulsified fatty acids, fat-soluble vitamins, and other lipids are transported first through lymphatic vessels, which soon meet up with blood vessels.

From the Small Intestine to the Large Intestine

The process of digestion is fairly efficient. Any food that is still incompletely broken down (usually less than ten percent of food consumed) and the food's indigestible fiber content moves from the small intestine to the large intestine (colon) through a connecting valve, ileoceceal sphincter. The main task of the large intestine is to reabsorb water. Remember, water is present not only in solid foods but also the stomach releases a few hundred milliliters of gastric juice and the pancreas adds approximately another 500 milliliters during the digestion of the meal. For the body to conserve water, it is important that the water is reabsorbed. In the large intestine, no further chemical or mechanical breakdown of food takes place, unless it is accomplished by the bacteria that inhabit this portion of the digestive tract. The number of bacteria residing in the large intestine is estimated to be greater than $10^{(14)}$, which is more than the total number of cells in the human body ($10^{(13)}$). This may seem rather unpleasant, but the great majority of bacteria in the large intestine are harmless and some are even beneficial. The bacteria synthesize the essential nutrient, vitamin K, short chain fatty acids, which are essential for our health, from the undigested fiber. Also, minerals, such as sodium and potassium, are absorbed.

Kefir

There has been significant talk about pre- and probiotic foods in the mainstream media. The World Health Organization defines probiotics as live bacteria that confer beneficial health effects on their host. They are sometimes called "friendly bacteria." The most common bacteria labeled as probiotic is lactic acid bacteria (lactobacilli). They are added as live cultures to certain fermented foods such as yogurt. Prebiotics are indigestible foods, primarily soluble fibers, that stimulate the growth of certain strains of bacteria in the large intestine and provide health benefits to the host. Examples of prebiotics would be inulin, soluble fiber and resistant starch. A review article in the June 2008 issue of the *Journal of Nutrition* concludes that there is a scientific consensus that probiotics ward off viral-induced diarrhea and reduce the symptoms of lactose intolerance.Farnworth, E. R. "The Evidence to Support Health Claims for Probiotics." *J Nutr* 138, no. 6 (2008): 1250S–4S. http://jn.nutrition.org/content/138/6/1250S.long. Expert nutritionists agree that more health benefits of pre- and probiotics will likely reach a scientific consensus. As the fields of pre- and probiotic manufacturing and their clinical study progress, more information on proper dosing and what exact strains of bacteria are potentially "friendly" will become available.



Figure 2.3.4: Kefir, a dairy product fermented with probiotic bacteria, can make a pleasant tasting milkshake. (CC BY-SA 3.0; Quijote)

You may be interested in trying some of these foods in your diet. A simple food to try is kefir. Several websites provide good recipes, including www.kefir.net/recipes.htm.

From the Large Intestine to the Anus

After a few hours in the stomach, plus three to six hours in the small intestine, and about sixteen hours in the large intestine, the digestion process enters step four, which is the elimination of indigestible food as feces. Feces contain indigestible food and gut bacteria (almost 50 percent of content). It is stored in the rectum until it is expelled through the anus via defecation.

Video 2.3.2: The Stages of Digestion

This video reviews the sequence of events during food digestion.



Processes of Digestion

Digestion involves two processes - physical and chemical. During the physical process, the food is mixed and moved throughout the gastrointestinal tract. This process is also referred to as motility and the partially digested food is propelled by the wave-like action called peristalsis. Ring-like muscular valves called sphincters prevent the back flow of partially digested food and digestive juices. There are sphincters between the esophagus and stomach (esophageal sphincter), between the stomach and small intestine (pyloric sphincter) and small intestine and colon (ileocecal sphincter).

The chemical process of digestion involves the release of water, acid, bicarbonate and enzymes to be mixed with the food to further break it down into smaller subunits. Chemical breakdown starts in the mouth where enzymes break down complex carbohydrate. In the stomach, water and acid are released to begin the breakdown of protein. A mucus lining protects the stomach from the corrosive acid. The mixture, also known as chyme, enters the small intestine where bicarbonate is introduced to neutralize the acid and enzymes are added to break chemical bonds. Most small intestine digestive enzymes are produced in the pancreas and small intestine.

Regulation of Digestion

Our nervous system and hormones control digestion. The nervous system consists of the central nervous system, and the peripheral nervous system. Our brain and spinal cord make up the central nervous system while the peripheral system lies outside the skull and vertebral column. There are two components to the peripheral system: the somatic system that supplies the skin and muscle, and the autonomic system which supplies smooth muscle, cardiac muscle, and glands. The autonomic system has two divisions: the parasympathetic (PSNS or PNS) and sympathetic system (SNS). The PSNS supplies signals to maintain normal function and conserve body processes. The SNS provides signals to accelerate the process. Our gastrointestinal tract receives signals from the central and autonomic systems as well as sends signals to these systems.

https://www.youtube.com/watch?v=hWks2wS56Qs

Hormones are also involved in regulating digestion. Your digestive tract secretes hormones to control the release of digestive enzymes and juices. Here is a table of some hormones.

Table 2.3.1: Hormones involved in digestion.

Hormone	Origin	Stimulus	Action
Gastrin	Stomach	Food, especially proteins, caffeine, spices, alcohol	Stimulates stomach acids and enzymes
Cholecystokinin (CCK)	Small Intestine	Fat and protein	Stimulates pancreas and liver secretions (enzymes and bile) for protein and fat digestion

Hormone	Origin	Stimulus	Action
Secretin	Small Intestine	Acid (from stomach) in small intestine	Secretes bicarbonate to neutralize acid
Gastric inhibitory protein (GIP)	Small Intestine	Fat and protein	Inhibits gastric motility and secretion of gastric juices

Our appetite and hunger are controlled by a complex process that involves many signals. Here is a brief overview of that process.

https://www.youtube.com/watch?v=bQT17Mifh94

Key Takeaways

- The breakdown of complex macromolecules in foods to simple absorbable components is accomplished by the digestive system. These components are processed by cells throughout the body into energy or are used as building blocks.
- The digestive system is composed of the mouth, pharynx, esophagus, stomach, small intestine, large intestine (or colon), rectum, and anus. There are four steps in the digestion process: ingestion, the mechanical and chemical breakdown of food, nutrient absorption, and elimination of indigestible food.
- The mechanical breakdown of food occurs via muscular contractions called peristalsis and segmentation. Enzymes secreted by the salivary glands, stomach, pancreas, and small intestine accomplishes the chemical breakdown of food. Additionally, bile emulsifies fats.

Discussion Starter

1. Decide whether you want to consume pre- and probiotic foods to benefit your health. Visit the websites below to help in your decision-making process. Defend your decision scientifically.

   http://www.health.harvard.edu/fhg/updates/update0905c.shtml

   nccam.nih.gov/research/results/spotlight/110508.htm

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2.4: Nutrients Are Essential for Organ Function

Learning Objectives

- Generalize how the body distributes nutrients to the rest of the body.
- Summarize the importance of adequate nutrition on other organ systems.

When the digestive system has broken down food to its nutrient components the body eagerly awaits delivery. The first stop of most absorbed nutrients is the liver. One of the liver's primary functions is to regulate metabolic homeostasis. Metabolic homeostasis may be defined as when the nutrients consumed and absorbed matches the energy required to carry out life's biological processes. Simply put, nutrient energy intake equals energy output. Through the body's network of blood vessels and veins, glucose and amino acids are directly transported from the small intestine to the liver. Lipids are transported to the liver by a more circuitous route involving the lymphatic system, which contains vessels similar to the circulatory system that transport white blood cells called lymph.

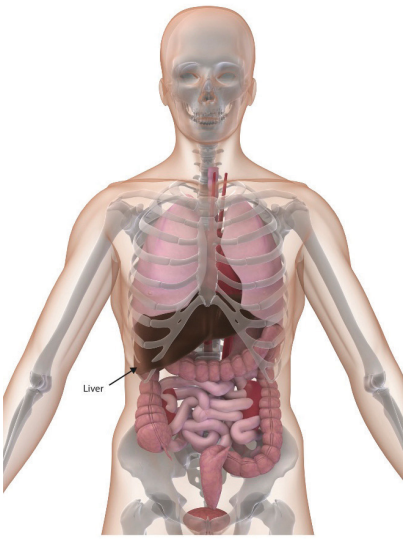


Figure 2.4.1: The liver is the checkpoint for metabolic activity. © Shutterstock

Maintaining the body's energy status quo is crucial because when metabolic homeostasis is disturbed by an eating disorder or disease, bodily function suffers. This will be discussed in more depth in the last section of this chapter. The liver is the only organ in the human body that is capable of exporting nutrients for energy production to other tissues. Therefore, when a person is in between meals (fasted state) the liver exports nutrients and when a person has just eaten (fed state) the liver stores nutrients within itself. Nutrient levels and the hormones that respond to their levels in the blood provide the input so that the liver can distinguish between the fasted and fed states and distribute nutrients appropriately.

All eleven organ systems in the human body require nutrient input to perform their specific biological functions. No energy in means no work output. Overall health and the ability to carry out all of life's basic processes are fueled by nutrients. Without them organ systems would fail, humans would not reproduce, and the race would disappear. In this section, we will discuss some of the critical nutrients that support specific organ system functions.

The Circulatory System (also known as part of the Cardiovascular System)

The circulatory system, which is part of the "cardiovascular" system, is one of the eleven organ systems of the human body. Its main function is to transport nutrients to cells and wastes from cells (Figure 3.4.1). This system consists of the heart, blood, and blood vessels. The heart pumps the blood, and the blood is the transportation fluid. The transportation route to all tissues is a highly intricate blood-vessel network, comprised of arteries, veins, and capillaries. Nutrients absorbed in the small intestine travel mainly to the liver through the hepatic portal vein. From the liver, nutrients travel upward through the inferior vena cava blood vessel to the heart. The heart forcefully pumps the nutrient-rich blood first to the lungs to pick up some oxygen and then to all other cells in the body. Arteries become smaller and smaller on their way to cells so that by the time blood reaches a cell, the artery's diameter is

extremely small and the vessel is now called a capillary. The reduced diameter of the blood vessel substantially slows the speed of blood flow. This dramatic reduction in blood flow gives cells time to harvest the nutrients in blood and exchange metabolic wastes.

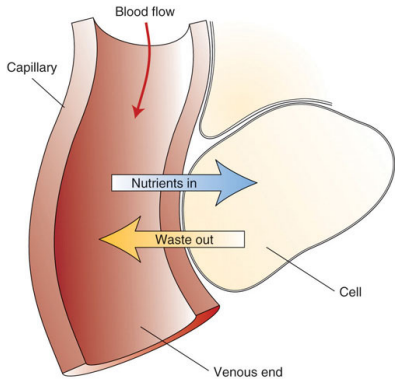


Figure 2.4.2: The Circulatory System: The circulatory system transports nutrients to all cells and carries wastes out.

The Central Nervous System

The human brain (which weighs only about 3 pounds, or 1,361 grams) is estimated to contain over one hundred billion neurons. Neurons form the core of the central nervous system, which consists of the brain, spinal cord, and other nerve bundles in the body. The main function of the central nervous system is to sense changes in the external environment and create a reaction to them. For instance, if your finger comes into contact with a thorn on a rose bush, a sensory neuron transmits a signal from your finger up through the spinal cord and into the brain. Another neuron in the brain sends a signal that travels back to the muscles in your hand and stimulates muscles to contract and you jerk your finger away. All of this happens within a tenth of a second. All nerve impulses travel by the movement of charged sodium, potassium, calcium, and chloride atoms. These are some of the essential minerals in our diets—essential because they are absolutely required for central nervous system function. Nerves communicate with each other via chemicals built from amino acids called neurotransmitters. Eating adequate protein from a variety of sources will ensure the body gets all of the different amino acids that are so important for central nervous system function.

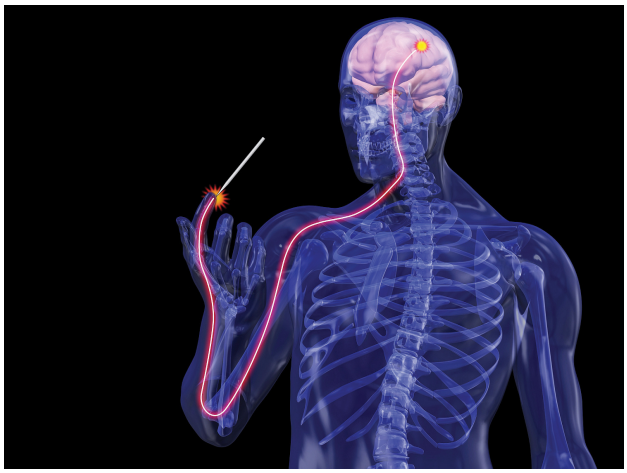


Figure 2.4.3: The brain has been compared to a central computer that controls all body functions. It relays messages to and from various body parts at lightning speed within a vast communication network of cells. © Shutterstock

Every day the brain uses over 20 percent of the energy obtained from nutrients. Its main fuel is glucose and only in extreme starvation will it use anything else (ketones). For acute mental alertness and clear thinking, glucose must be systematically delivered to your brain. This does not mean that sucking down a can of sugary soda before your next exam is a good thing. Just as too much glucose is bad for other organs, such as the kidneys and pancreas, it also produces negative effects upon the brain. Excessive glucose levels in the blood can cause a loss of cognitive function and chronically high blood-glucose levels can damage brain cells. The brain's cognitive functions include language processing, learning, perceiving, and thinking. Recent scientific studies demonstrate that having continuously high blood-glucose levels substantially elevates the risk of developing Alzheimer's disease, which is the greatest cause of age-related cognitive decline.

The good news is that much research is directed toward determining the best diets and foods that slow cognitive decline and maximize brain health. A study in the June 2010 issue of the *Archives of Neurology* reports that people over age sixty-five who adhered to diets that consisted of higher intakes of nuts, fish, poultry, tomatoes, cruciferous vegetables, fruits, salad dressing, and dark green, and leafy vegetables, as well as a lower intake of high-fat dairy products, red meat, organ meat, and butter, had a much reduced risk for Alzheimer's disease.Gu, Y., PhD et al. "Food Combination and Alzheimer Disease Risk: A Protective Diet." *Arch Neurol* 67, no. 6 (2010): 699–706. doi: 10./1001/archneurol.2010.84. Other scientific studies provide supporting evidence that foods rich in omega-3 fatty acids and/or antioxidants provide the brain with protection against Alzheimer's disease. One potential "brain food" is the blueberry. The protective effects of blueberries upon the brain are linked to their high content of anthocyanins, which are potent antioxidants and reduce inflammation. A small study published in the April 2010 issue of the *Journal of Agricultural and Food Chemistry* found that elderly people who consumed blueberry juice every day for twelve weeks had improved learning and memorization skills in comparison to other subjects given a placebo drink.Krikorian, R. et al. "Blueberry Supplementation Improves Memory in Older Adults." *J Agric Food Chem* 58, no. 7 (2010): 3996–4000. doi: 10.1021/jf9029332. More clinical trials are evaluating the effects of blueberries and other foods that benefit the brain and preserve its function as we age.

The Muscular System

The muscular system allows the body to move voluntarily, but it also controls involuntary movements of other organ systems such as heartbeat in the circulatory system and peristaltic waves in the digestive system. It consists of over six hundred skeletal muscles, as well as the heart muscle, the smooth muscles that surround your entire alimentary canal, and all your arterial blood vessels. Muscle contraction relies on energy delivery to the muscle. Each movement uses up cellular energy and without an adequate energy supply, muscle function suffers. Muscle, like the liver, can store the energy from glucose in the large polymeric molecule glycogen. But unlike the liver, muscles use up all of their own stored energy and do not export it to other organs in the body. When muscle energy stores are diminished, muscle contraction weakens. However, muscle is not as susceptible to low levels of blood glucose as the brain because it will readily use alternate fuels, such as fatty acids and protein to produce cellular energy.

"Hitting the Wall" or "Bonking"

If you are familiar with endurance sports, you may have heard of "hitting the wall" or "bonking." These colloquial terms refer to the extreme fatigue that sets in after about 120 minutes of performing an endurance sport, such as marathon running or long-distance cycling. The physiology underlying "hitting the wall" means that muscles have used up all their stored glycogen and are therefore dependent on other nutrients to support their energy needs. Fatty acids are transported from fat-storing cells to the muscle to rectify the nutrient deficit. However, fatty acids take more time to convert to energy than glucose, thus decreasing performance levels. To avoid "hitting the wall" or "bonking," endurance athletes load up on carbohydrates a few days before the event. This will maximize an athlete's amount of glycogen stored in their liver and muscle tissues. It is important not to assume that carbohydrate loading works for everyone. Without accompanied endurance training you will not increase the amount of stored glucose. If you plan on running a five-mile race for fun with your friend and decide to eat a large amount of carbohydrates in the form of a big spaghetti dinner the night before, the excess carbohydrates will be stored fat. Another way for athletes to avoid "hitting the wall" is to consume carbohydrate-containing drinks and foods during an endurance event. In fact, throughout the Tour de France—a twenty-two-day, twenty-four-hundred-mile race—the average cyclist consumes greater than 60 grams of carbohydrates per hour.



Figure 2.4.4: In order to avoid “hitting the wall,” athletes consume large amounts of carbohydrates before and during events to ensure enough glucose is available for optimal performance, especially during endurance activities such as cycling. © Shutterstock

The Endocrine System

The functions of the endocrine system are intricately connected to the body’s nutrition. This organ system is responsible for regulating appetite, nutrient absorption, nutrient storage, and nutrient usage, in addition to other functions, such as reproduction. The glands in the endocrine system are the pituitary, thyroid, parathyroid, adrenals, thymus, pineal, pancreas, ovaries, and testes. The glands secrete hormones, which are biological molecules that regulate cellular processes in other target tissues, so they require transportation by the circulatory system. Adequate nutrition is critical for the functioning of all the glands in the endocrine system. A protein deficiency impairs gonadal-hormone release, preventing reproduction. Athletic teenage girls with very little body fat often do not menstruate. Children who are malnourished usually do not produce enough growth hormone and fail to reach normal height for their age group. Probably the most popularized connection between nutrition and the functions of the endocrine system is that unhealthy dietary patterns are linked to obesity and the development of Type 2 diabetes. The Centers for Disease Control and Prevention (CDC) estimates that twenty-six million Americans have Type 2 diabetes as of 2011. This is 8.3 percent of the US population. The maps in Note 3.35 show the percentage of adults who are obese, and those with diagnosed Type 2 diabetes within all American counties. You can see that those counties with the highest incidence of obesity also have the highest incidence of Type 2 diabetes.

Video 2.4.1: Obesity and Type 2 Diabetes

Watch the National Health video to see the relationship between the rise in obesity and the rise in Type 2 diabetes.



What is the causal relationship between overnutrition and Type 2 diabetes? The prevailing theory is that the overconsumption of high-fat and high-sugar foods causes changes in muscle, fat, and liver cells that leads to a diminished response from the pancreatic hormone insulin. These cells are called “insulin-resistant.” Insulin is released after a meal and instructs the liver and other tissues to take up glucose and fatty acids that are circulating in the blood. When cells are resistant to insulin they do not take up enough

glucose and fatty acids and so glucose and fatty acids remain at high concentrations in the blood. The continuously high amounts of glucose and fatty acids in the blood impair the release of insulin from the pancreas, further exacerbating the situation. The chronic elevation of glucose and fatty acids in the blood also causes damage to other tissues over time, so that people who have Type 2 diabetes are at increased risk for cardiovascular disease, kidney disease, nerve damage, and eye disease.

Tools for Change

Do your part to slow the rising tide of obesity and Type 2 diabetes in this country. On the individual level, improve your own family's diet; at the local community level, support the development of more nutritious school lunch programs; and at the national level, support your nation's nutrition goals. Visit the CDC Diabetes Public Health Resource website at http://www.cdc.gov/diabetes/. It provides information on education resources, projects, and programs, and spotlights news on diabetes and obesity. The CDC also has a new workplace program called CDC's LEAN *Works!* (LEAN: Leading Employees to Activity and Nutrition). The program provides free web-based resources with the mission of designing worksites that prevent obesity. See http://www.cdc.gov/leanworks/ for more details.

The Immune System

The immune system is comprised of several types of white blood cells that circulate in the blood and lymph. Their jobs are to seek, recruit, attack, and destroy foreign invaders, such as bacteria and viruses. Other less realized components of the immune system are the skin (which acts as a barricade), mucus (which traps and entangles microorganisms), and even the bacteria in the large intestine (which prevent the colonization of bad bacteria in the gut). Immune system functions are completely dependent on dietary nutrients. In fact, malnutrition is the leading cause of immune-system deficiency worldwide. When immune system functions are inadequate there is a marked increase in the chance of getting an infection. Children in many poor, developing countries have protein- and/or energy-deficient diets that are causative of two different syndromes, kwashiorkor and marasmus. These children often die from infections that their bodies could normally have fought off, but because their protein and/or energy intake is so low, the immune system cannot perform its functions.

Other nutrients, such as zinc, selenium, copper, folate, and vitamins A, B_6, C, D, and E, all provide benefits to immune system function. Deficiencies in these nutrients can cause an increased risk of infection and death. Zinc deficiency results in suppression of the immune system's barrier functions by damaging skin cells; it is also associated with a decrease in the number of circulating white blood cells. A review of several studies in the journal *Pediatrics* concluded that zinc supplements administered to children under age five for longer than three months significantly reduces the incidence and severity of diarrhea and respiratory illnesses.Aggarwal R., MD, DM, J. Sentz, MPH and M. A. Miller, MD. "Role of Zinc Administration in Prevention of Childhood Diarrhea and Respiratory Illnesses: A Meta-Analysis." *Pediatrics* 119, no. 6 (2007): 1120–30. doi: 10.1542/peds.2006–3481. Zinc supplementation has also been found to be therapeutically beneficial for the treatment of leprosy, tuberculosis, pneumonia, and the common cold. Equally important to remember is that multiple studies show that it is best to obtain your minerals and vitamins from eating a variety of healthy foods.

Tools for Change

To ensure that your diet includes zinc-friendly foods, try these foods high in zinc and other immune-system friendly nutrients: oysters, poultry, baked beans, chick peas, cashews, sesame seeds, peanuts, whole grains, and zinc-fortified cereals.



Figure 2.4.5: These are just some of the foods that are high in zinc.

Just as undernutrition compromises immune system health, so does overnutrition. People who are obese are at increased risk for developing immune system disorders such as asthma, rheumatoid arthritis, and some cancers. Both the quality and quantity of fat affect immune system function. High intakes of saturated and trans fats negatively affect the immune system, whereas increasing your intake of omega-3 fatty acids, found in salmon and other oily fish, decreases inflammatory responses. High intakes of omega-3 fatty acids are linked to a reduction in the risk of developing certain autoimmune disorders, such as rheumatoid arthritis, and are used as part of a comprehensive treatment for rheumatoid arthritis.

Key Takeaways

- Metabolic homeostasis occurs when the amount of nutrients consumed matches the energy required to carry out life's biological processes.
- The circulatory system transports nutrients to cells and transports wastes from them.
- The essential minerals sodium, potassium, calcium, and chloride, and the macronutrients protein and carbohydrates are required for central nervous system function. Fat is also critical for central nervous system function (see the Discussion Starter below).
- Without energy from nutrients, muscles cannot contract.
- Undernutrition and overnutrition compromise endocrine and immune system functions. Type 2 diabetes, increased rates of infection, and inflammatory disorders are symptoms of an imbalance in the diet.

Interactive 2.1

Take a look at the PowerPoint presentation prepared by the CDC that captures the concurrent rises of obesity and Type 2 diabetes in this country. Click on "Maps of Trends in Diabetes and Obesity." www.cdc.gov/diabetes/statistics/diabetes_slides.htm

Discussion Starter

1. Find out how fat supports brain function and protects nerves by visiting the Franklin Institute Resources for Science Learning website.

   www.fi.edu/learn/brain/fats.html

   Now look at the websites below to see how too much of the wrong kind of fats may be bad for the brain, while other types of fat are good for the brain.

   http://archneur.ama-assn.org/cgi/content/full/60/2/194

   http://www.sciencedaily.com/releases/2007/12/071210163251.htm

   http://www.webmd.com/alzheimers/news/20070418/omeg-3-fatty-acid-slows-alzheimers

   After viewing all of the videos, discuss the importance of "good fats" in the diet for optimizing brain function and preventing diseases such as Alzheimer's.

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2.5: Energy and Calories

Learning Objectives

- Estimate your total daily caloric /energy needs based upon your physical activity level.

Energy is essential to life. You must eat to have energy. You must go to bed at a decent time, so that when you wake up in the morning, you will not be too tired and you will have sufficient energy for the next day's activities. Energy is also everywhere in our environment: sunlight, wind, water, plants, and animals. All living things use energy every day. Energy can be defined as the quantity of work a particular system can perform, whether it be a growing child's body or a train transporting passengers from one place to another. Energy also helps us perform daily functions and tasks such as breathing, walking up a flight of steps, and studying for a test.

Energy is classified as either potential or kinetic. Potential energy is stored energy, or energy waiting to happen. Kinetic energy is energy in motion. To illustrate this, think of an Olympic swimmer standing at the pool's edge awaiting the sound of the whistle to begin the race. While he waits for the signal, he has potential energy. When the whistle sounds and he dives into the pool and begins to swim, his energy is kinetic (in motion).

Some basic forms of energy are:

1. **Thermal (heat) energy.** We can say that a cup of hot tea has thermal energy. Thermal energy is defined as the collective, microscopic, kinetic, and potential energy of the molecules within matter. In a cup of tea, the molecules have kinetic energy because they are moving and oscillating, but they also possess potential energy due to their shared attraction to each other.
2. **Chemical energy.** In your body, blood sugar (glucose) possesses chemical energy. When glucose reacts chemically with oxgen, energy is released from the glucose. Once the energy is released, your muscles will utilize it to produce mechanical force and heat.
3. **Electrochemical energy.** In the body, electrical impulses travel to and from the brain encoded as nerve impulses. Once the brain receives an electrical impulse it causes the release of a messenger chemical (glutamate, for example). This in turn facilitates electrical impulses as they move from one neuron to another.

The Calorie Is a Unit of Energy

The amount of energy in nutrients can be quantified into specific units that can be measured. The unit of measurement that defines the energy contained in a energy-yielding nutrient is called a calorie. A calorie is the amount of energy in the form of heat that is required to heat one gram of water one degree Celsius. To measure the number of calories in a particular food substance, a certain amount of food is burned in a device called a calorimeter. As the food burns, heat is created. The heat dissipates to the surrounding water while a thermometer detects the change in temperature of the water. You can even perform calorimetry at home with a more basic device. However, it is not likely that you will use this device to measure calorie content in the foods that you eat since mathematical formulas have been developed to estimate caloric content.

Estimating Caloric Content

The energy contained in energy-yielding nutrients differs because the energy-yielding nutrients are composed of different types of chemical bonds. A carbohydrate or a protein yields 4 kilocalories per gram, whereas a lipid yields 9 kilocalories per gram. A kilocalorie (Calorie) is the amount of heat generated by a particular macronutrient that raises the temperature of 1 kilogram of water 1 degree Celsius. A kilocalorie of energy performs one thousand times more work than a calorie. On the Nutrition Facts panel, the calories within a particular food are expressed as kilocalories, which is commonly denoted as "Calories" with a capital "C" (1 kcal = 1 Calorie = 1,000 calories).

Calculating the number of Calories in commercially prepared food is made fairly easy since the total number of Calories in a serving of a particular food is listed on the Nutrition Facts panel. If you wanted to know the number of Calories in the breakfast you consumed this morning just add up the number of Calories in each food. For example, if you ate one serving of yogurt that contained 150 Calories, on which you sprinkled one half of a cup of low-fat granola cereal that contained 209 Calories, and drank a glass of orange juice that contained 100 Calories, the total number of Calories you consumed at breakfast is 150 + 209 + 100 = 459

Calories. If you do not have a Nutrition Facts panel for a certain food, such as a half cup of blueberries, and want to find out the amount of Calories it contains, go to MyFood-a-pedia, a website maintained by the USDA.

Interactive 2.2

Try using "Fooducate" which will give each food a letter grade (A, B, C, D or F) for how healthy it is! Just type any food into the search box at the top. For example, Fig Newton Cookies get a C+.

Fooducate

Estimating the Amount of Energy from Each Macronutrient

Also listed on the Nutrition Facts panel are the amounts of total fat, total carbohydrate, and protein in grams. To calculate the contribution of each macronutrient to the total kilocalories in a serving, multiply the number of grams by the number of kilocalories yielded per gram of nutrient. For instance, from the Nutrition Facts panel for yogurt given in Figure 2.7, the protein content in one serving is 7 grams. Protein yields 4 kilocalories per gram. The number of kilocalories from protein is calculated by using the following equation:

of grams of protein × 4 kilocalories/gram of protein 7 grams × 4 kilocalories/gram = 28 kilocalories

(# kilocalories from protein ÷ total kilocalories per serving) × 100 (28 ÷ 150) × 100 = 18.7 percent

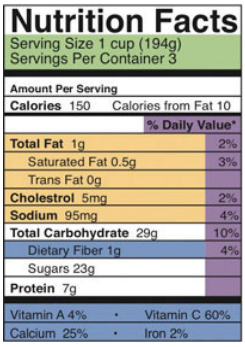


Figure 2.5.1: *A Nutrition Facts Panel for Yogurt: Because the total number of kilocalories in each serving of yogurt is 150, the percent of energy obtained from protein is calculated by using the following equation:*

Key Takeaways

- Energy is vital to life and is categorized into two types—kinetic and potential. There are also different forms of energy such as thermal, chemical, and electrochemical.
- Calories are a measurement of a specific quantity of energy contained in foods. The number of calories contained in a commercially prepared food is listed on the Nutrition Facts panel.

Discussion Starter

1. Estimate the total number of kilocalories that you have eaten so far today. What percentage of the kilocalories you consumed was obtained from carbohydrates? Protein? Fat?

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2.6: Gastrointestinal Tract and Your Health

Learning Objectives

- Interpret why certain disorders and diseases, such as gastroesophageal reflux disease (GERD), celiac disease, and irritable bowel syndrome compromise overall health.

When nutrients and energy are in short supply, cells, tissues, organs, and organ systems do not function properly. Unbalanced diets can cause diseases and, conversely, certain illnesses and diseases can cause an inadequate intake and absorption of nutrients, simulating the health consequences of an unbalanced diet. Overeating high-fat foods and nutrient-poor foods can lead to obesity and exacerbate the symptoms of gastroesophageal reflux disease (GERD) and irritable bowel syndrome (IBS). Many diseases and illnesses, such as celiac disease, interfere with the body getting its nutritional requirements. A host of other conditions and illnesses, such as food allergies, cancer, stomach ulcers, Crohn's disease, and kidney and liver disease, also can impair the process of digestion and/or negatively affect nutrient balance and decrease overall health.

Gastroesophageal Reflux Disease

Gastroesophageal reflux disease (GERD) is a persistent form of acid reflux that occurs more than two times per week. Acid reflux occurs when the acidic contents of the stomach leak backward into the esophagus and cause irritation. It is estimated that GERD affects 25 to 35 percent of the US population. An analysis of several studies published in the August 2005 issue of *Annals of Internal Medicine* concludes that GERD is much more prevalent in people who are obese.Hampel, H. MD, PhD, N. S. Abraham, MD, MSc(Epi) and H. B. El-Serag, MD, MPH. "Meta-Analysis: Obesity and the Risk of Gastroesophageal Reflux Disease and Its Complications." *Ann Intern Med* 143, no. 3 (2005): 199–211. http://www.ncbi.nlm.nih.gov/pubmed/16061918 While the links between obesity and GERD are not completely known, they likely include that excess body fat puts pressure on the stomach, overeating increases pressure in the stomach, and fatty foods are triggers for GERD symptoms. The most common GERD symptom is heartburn, but people with GERD may also experience regurgitation (flow of the stomach's acidic contents into the mouth), frequent coughing, and trouble swallowing. Approximately 35 percent of children born in the United States have GERD. In babies, the symptoms are more difficult to distinguish from what babies do normally. The symptoms are spitting up more than normal, incessant crying, refusal to eat, burping, and coughing. Most babies outgrow GERD before their first birthday but a small percentage do not.

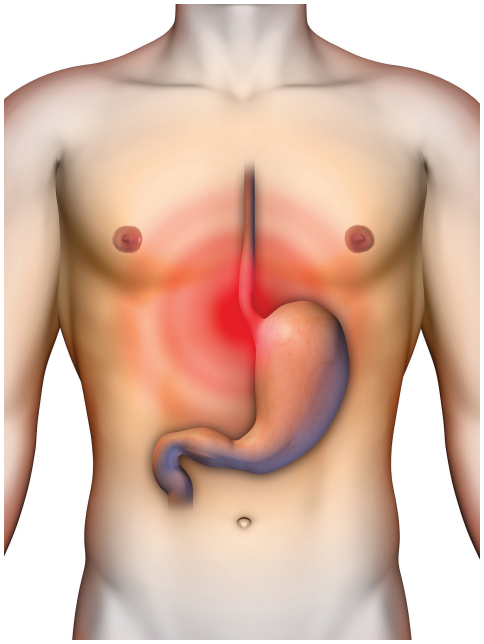


Figure 2.6.1: Heartburn is a burning sensation that radiates throughout the chest. © Shutterstock

Additional Facts about GERD

There are other causative factors of GERD that may be separate from or intertwined with obesity. The sphincter that separates the stomach's internal contents from the esophagus often does not function properly and acidic gastric contents seep upward. Sometimes the peristaltic contractions of the esophagus are also sluggish and compromise the clearance of acidic contents. In addition to having an unbalanced, high-fat diet, some people with GERD are sensitive to particular foods—chocolate, garlic, spicy foods, fried foods, and tomato-based foods—which worsen symptoms. Drinks containing alcohol or caffeine may also worsen GERD symptoms. GERD is diagnosed most often by a history of the frequency of recurring symptoms. A more proper diagnosis can be made when a doctor inserts a small device into the lower esophagus that measures the acidity of the contents during one's daily activities. Sometimes a doctor may use an endoscope, which is a long tube with a camera at the end, to view the tissue in the esophagus. About 50 percent of people with GERD have inflamed tissues in the esophagus. A condition known as Barrett's esophagus may develop over time in some people who have GERD. Barrett's esophagus refers to a structural difference in the tissue of the esophagus, which is caused by recurrent tissue damage. It occurs in 5 to 15 percent of patients diagnosed with GERD and less than 1 percent of these patients may develop cancer of the esophagus, a highly lethal cancer.

The first approach to GERD treatment is dietary and lifestyle modifications. Suggestions are to reduce weight if you are overweight or obese, avoid foods that worsen GERD symptoms, eat smaller meals, stop smoking, and remain upright for at least three hours after a meal. There is some evidence that sleeping on a bed with the head raised at least six inches helps lessen the symptoms of GERD. People with GERD may not take in the nutrients they need because of the pain and discomfort associated with eating. As a result, GERD can be caused by an unbalanced diet and its symptoms can lead to a worsening of nutrient inadequacy, a viscious cycle that further compromises health. Many medications are available to treat GERD, including antacids, histamine2 (H2) blockers, and proton-pump inhibitors. Some evidence from scientific studies indicates that medications used to treat GERD may accentuate certain nutrient deficiencies, namely zinc and magnesium. When these treatment approaches do not work surgery is an option. The most common surgery involves reinforcing the sphincter that serves as a barrier between the stomach and esophagus.

Ulcers

Ulcers occur when the top layer of the cells in the stomach, duodenum, and/or colon erode and expose the lower cell layer to the luminal contents. The number one cause of ulcers is the bacteria, *Helicobacter pylori* (*H. pylori*), which degrades the protective layer. Chronic use of anti-inflammatories can also erode the protective layer of the stomach and or small intestine, and cause ulcers. Ulcers are not caused by stress or smoking but these can make an ulcer worse. Avoiding coffee, caffeinated beverages like coffee, drinking alcohol, and foods that exacerbate the condition can help improve ulcers. Prescribed medicine is the best treatment.

Diverticulitis

Sometimes small pouches form in the colon wall at weakened spots. These are called diverticula and become inflamed from bacteria and irritants. There is a low incidence of diverticulitis in people who eat more fiber.

Inflammatory Bowel Disease (IBD)

The cause of inflammatory bowel disease is unknown. Crohn's disease and chronic ulcerative colitis are the most common types of IBD.

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Irritable Bowel Syndome (IBS)

Irritable bowel syndrome (IBS) is characterized by muscle spasms in the colon that result in abdominal pain, bloating, constipation, and/or diarrhea. Interestingly, IBS produces no permanent structural damage to the large intestine as often happens to patients who have Crohn's disease or inflammatory bowel disease. It is estimated that one in five Americans displays symptoms of IBS. The disorder is more prevalent in women than men. Two primary factors that contribute to IBS are an unbalanced diet and stress. There is no specific test to diagnose IBS, but other conditions that have similar symptoms (such as celiac disease) must be ruled out. This involves stool tests, blood tests, and having a colonoscopy (which involves the insertion of a flexible tube with a tiny camera on the end through the anus so the doctor can see the colon tissues).

Symptoms of IBS significantly decrease a person's quality of life as they are present for at least twelve consecutive or nonconsecutive weeks in a year. Large meals and foods high in fat and added sugars, or those that contain wheat, rye, barley, peppermint, and chocolate intensify or bring about symptoms of IBS. Additionally, beverages containing caffeine or alcohol may

worsen IBS. Stress and depression compound the severity and frequency of IBS symptoms. As with GERD, the first treatment approaches for IBS are diet and lifestyle modifications. People with IBS are often told to keep a daily food journal to help identify and eliminate foods that cause the most problems. Other recommendations are to eat slower, add more fiber to the diet, drink more water, and to exercise. There are some medications (many of which can be purchased over-the-counter) to treat IBS and the resulting diarrhea or constipation. Sometimes antidepressants and drugs to relax the colon are prescribed.

Celiac Disease

Celiac disease is an autoimmune disorder affecting between 0.5 and 1.0 percent of Americans—that is, one in every one- to two-hundred people. It is caused by an abnormal immune reaction of small intestine cells to a type of protein, called gluten. Gluten forms in the presence of water and is composed of two protein parts, glutenin and gliadin. Glutenin and gliadin are found in grains that are commonly used to make bread, such as wheat, rye, and barley. When bread is made, yeast eats the flour and makes a waste product, carbon dioxide, which forms bubbles in the dough. As the dough is kneaded, gluten forms and stretches. The carbon dioxide gas bubbles infiltrate the stretchy gluten, giving bread its porosity and tenderness. For those who are sensitive to gluten, it is good to know that corn, millet, buckwheat, and oats do not contain the proteins that make gluten. However, some people who have celiac disease also may have a response to products containing oats. This is most likely the result of cross-contamination of grains during harvest, storage, packaging, and processing.

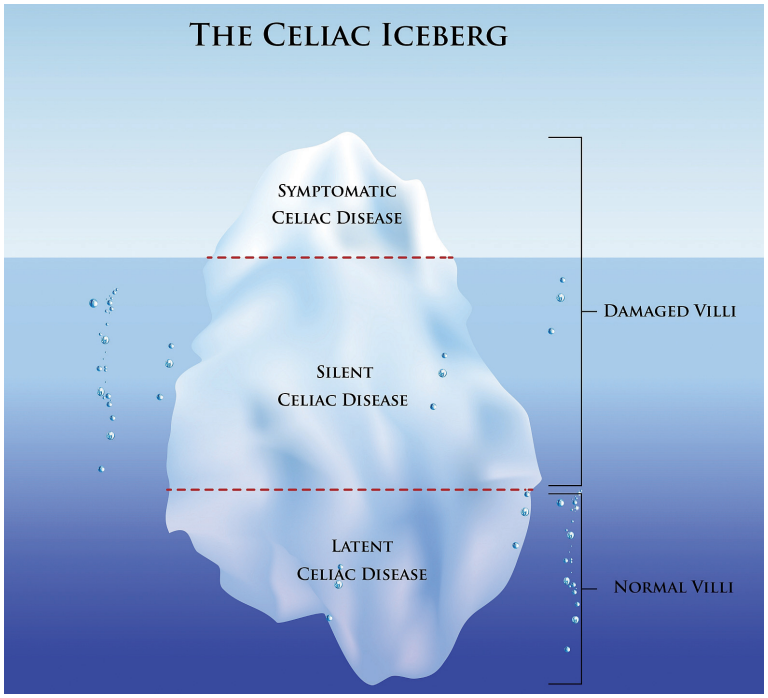


Figure 2.6.2: Celiac: Not everyone with celiac is diagnosed—many have “silent” or “latent” celiac disease. © Shutterstock

Celiac disease is most common in people of European descent and is rare in people of African American, Japanese, and Chinese descent. It is much more prevalent in women and in people with Type 1 diabetes, autoimmune thyroid disease, and Down and Turner syndromes. Symptoms can range from mild to severe and can include pale, fatty, loose stools, gastrointestinal upset, abdominal pain, weight loss and, in children, a failure to grow and thrive. The symptoms can appear in infancy or much later in life, even by age seventy. Celiac disease is not always diagnosed because the symptoms may be mild. A large number of people have what is referred to as “silent” or “latent” celiac disease (Figure 3.6.1).

Celiac disease diagnosis requires a blood test and a biopsy of the small intestine. Because celiac disease is an autoimmune disease, antibodies produced by white blood cells circulate in the body and can be detected in the blood. When gluten-containing foods are consumed the antibodies attack cells lining the small intestine leading to a destruction of the small villi projections. This tissue damage can be detected with a biopsy, a procedure that removes a portion of tissue from the damaged organ. Villi destruction is what causes many of the symptoms of celiac disease. The destruction of the absorptive surface of the small intestine also results in the malabsorption of nutrients, so that while people with this disease may eat enough, nutrients do not make it to the bloodstream because absorption is reduced. The effects of nutrient malabsorption are most apparent in children and the elderly as they are

especially susceptible to nutrient deficiencies. Over time these nutrient deficiencies can cause health problems. Poor absorption of iron and folic acid can cause anemia, which is a decrease in red blood cells. Anemia impairs oxygen transport to all cells in the body. Calcium and vitamin D deficiences can lead to osteoporosis, a disease in which bones become brittle.

If you think you or someone close to you may have celiac disease, do not despair; it is a very treatable disease. Once diagnosed, a person follows a gluten-free diet for life. This requires dedication and careful detective work to seek out foods with hidden gluten, but some stores carry gluten-free foods. After eliminating gluten from the diet, the tissues of the small intestine rapidly repair themselves and heal in less than six months.

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Gallstones

The gallbladder is a where bile is stored and bile is important for the digestion of fat. Sometimes pieces of solid matter form in the gallbladder and this material is called gallstones. Gallstones are mainly formed from cholesterol. If these "stones" block the ball duct or prevent the flow of bile into the small intestine, fat in your diet will not be absorbed.

Lactose Intolerance

Lactose intolerance is common and is estimated to occur in 70% of the population. It occurs when the enzyme lactase is missing, low, or ineffective at digesting the carbohydrate lactose. Bacteria then ferment the lactose causing bloating and discomfort. Lactose intolerance increases with age and people who experience this condition must avoid foods that contain lactose. Such foods would be milk and milk-based products. Several dairy products treated with lactase to remove lactose are available on the market as well as a variety of fermented products like yogurt and kefir. Each person is different so you will have to experiment to see which products you can tolerate and how much of that product.

Constipation

Constipation occurs when your bowel movements are infrequent and difficult, and there are many reasons why it occurs. These include but are not limited to some medications, changes in your usual diet or activities, eating a lot of dairy products, eating disorders, irritable bowel syndrome, not being active, not enough water or fiber in your diet, overuse of laxatives, stress, and atonic colon (weakened muscles). Treatment involves listening to defecation signals, high fluid, high fiber diet (as long as the cause is not spastic colon), and exercise. Including more whole grains, fruits and vegetables in your diet is a good way to prevent constipation. When adding more fiber to your diet, add more water too.

Hemorrhoids

Hemorrhoids occur when the veins in your lower rectum and/or anus become swollen. This condition occurs when you don't eat enough fiber, push too hard during defecation, stand or sit too long, labor during childbirth, lift too heavy a weight, or are overweight or obese. Avoiding the cause of the hemorrhoid is the best way to prevent their reoccurrence.

Diarrhea

Diarrhea is watery stools caused by reduced water absorption or reversed water transport, and shortened transit time through the gut. It is common and generally will resolve in a few days but one should be careful not to become dehydrated. There are many reasons why diarrhea occurs including food poisoning, infections, IBS, lactose intolerance, and allergies to cow's milk. The best treatment is bowel rest coupled with fluid and electrolyte replacement.

Food Allergies

Paying attention to the way individuals react to various foods is essential in determining what foods may specifically affect a person adversely. Food allergies are one of the many ways in which different body make-ups affect nutritional concerns. Although an estimated twelve million Americans have food allergies, there are likely many more people who say they have food allergies than actually do. This is because food sensitization is different from a medically-determined food allergy. When someone has a food allergy, the immune system mistakenly attacks a certain kind of food (usually the protein component of a food), such as peanuts, as if it were a threat and IgE antibodies are produced. Doctors sometimes test for food allergies by using skin-prick tests or blood tests to look for the presence of IgE antibodies. However, these types of tests are not always reliable as they can sometimes yield a false positive result. By far, the most valuable tests for determining a food allergy is the Double Blind Placebo Controlled

Food Challenge (DBPCFC), which involves administering the food orally and then denoting the signs and symptoms of the allergic response.



Figure 2.6.3: *Many people with food allergies experience skin rashes after eating an allergenic food. © Shutterstock*

Food allergy symptoms usually develop within a few minutes to two hours after a person has eaten a food to which they are allergic. These symptoms can range from the annoying to the potentially fatal, and include:

- A tingling mouth
- Swelling tongue and/or throat
- Difficulty breathing
- Hives
- Stomach cramps
- Diarrhea
- Vomiting
- Drop in blood pressure
- Loss of consciousness
- Death

There are no clear treatments for food allergies. Epinephrine is sometimes used to control severe reactions, and individuals with known and dangerous allergies may get prescriptions for self-injectable devices. The only certain way to avoid allergic reactions to food is to avoid the foods that cause them. Beyond avoidance, this can mean reading food labels carefully, or even calling manufacturers for product information.

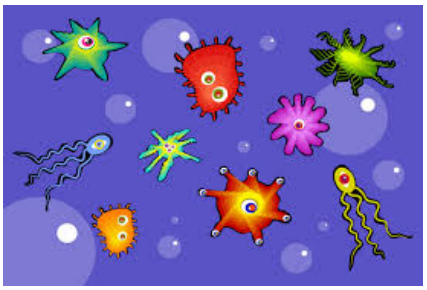
Ninety percent of food allergies are caused by these eight foods:

1. Milk
2. Eggs
3. Peanuts
4. Tree nuts
5. Fish
6. Shellfish
7. Wheat
8. Soy

The prevalence of food allergies is a complex and growing problem. In response to this situation, the National Institute of Allergy and Infectious Diseases (NIAID) collaborated with thirty-four professional organizations, federal agencies, and patient-advocacy groups to develop a comprehensive guide to diagnosing and managing food allergies and treating acute food allergy reactions. The guide defines various food allergies, allergens, and reactions, provides comprehensive information on the prevalence of different food allergies, tracks the history of food allergies, and reviews medical management techniques for people with food allergies.

Gut Microbiota

Our body is covered with small microorganisms we cannot see. Within our gut, it is estimated that there are 100 trillion bacteria, which 10 times more cells than we have in our body. Most bacteria do not cause us harm and, in fact, have a symbiotic relationship that keeps us healthy; for example, they produce vitamin B_6, vitamin B_{12}, biotin, vitamin K, and short chain fatty acids. Recent



studies have suggested a link between several chronic diseases (cancer, obesity, heart disease, depression, and autism, to name a few) and the microbes that reside in our gut. Diet plays a role in prominent role in determining the specific microbial communities found in our intestinal track. Prebiotic foods contain undigested material, like fiber, that our gut microbes digest while probiotic foods contain live bacteria.

https://www.youtube.com/watch?v=QE9QWFg-XNs

Figure 2.6.4: Cartoon of different types of bacteria.

Key Takeaways

- Unbalanced diets can cause diseases and, conversely, certain disorders and diseases can cause an inadequate intake and absorption of nutrients simulating the health consequences of an unbalanced diet.
- Unbalanced, high-fat diets can exacerbate the symptoms of GERD and IBS.
- Celiac disease and anorexia can lead to nutritional deficiencies, which compromise the functioning of the organ systems and decrease health.
- Food allergies affect roughly twelve million Americans, with symptoms that range from mild to deadly. Proper diagnosis leads to better management of food allergies and sensitivities.

Discussion Starter

1. The next time you visit the grocery store, be a “gluten detective” and use the ingredients list to identify all the foods you might normally purchase that contain gluten. Discuss how you can use food labels to avoid products containing gluten.

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2.E: Exercises

It's Your Turn

1. After watching the video on GERD, list the potential consequences of GERD.

   Understanding GERD (GERD #1)

   (click to see video)

Expand Your Knowledge

1. Find out how fat supports brain function and protects nerves by visiting the following website: www.fi.edu/learn/brain/fats.html. Now look at these other websites to see how too much of the wrong kind of fats may be bad for the brain, while other types of fat are good for the brain.

   http://archneur.ama-assn.org/cgi/content/full/60/2/194

   http://www.webmd.com/alzheimers/news/20070418/omeg-3-fatty-acid-slows-alzheimers.

   Discuss how a balanced fat intake that contains "good fats" helps optimize brain function and prevent diseases such as Alzheimer's.

2. Estimate the total number of kilocalories that you have eaten so far today. What percentage of the kilocalories you consumed was obtained from carbohydrates, protein, and fat? Compare the percentage of calories from carbohydrates, protein, and fat that you consumed to their Acceptable Macronutrient Distribution Ranges.
3. On your next trip to the grocery store, pretend you have a child with a peanut allergy and determine which foods you need to avoid purchasing to prevent your child from having an allergic response.

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3: Carbohydrates

In this Chapter we explore the many types of carbohydrates, including their functions. We also take a look at diabetes and at sugar substitutes.

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3.1: Introduction to Carbohydrates

You likely eat grains everyday—cereal, a sandwich, pasta, or your favorite rice dish. Whole grains are vital to a healthful diet. In addition to fiber, whole grains offer other slow-releasing carbohydrates, antioxidants, vitamins, and minerals, all of which are needed for good health. Maybe you are on a diet and have been told to limit or restrict your carbohydrate intake. How much is too much and which carbohydrates are better for you? Can you promote a healthy weight with a balanced intake of whole grains? Before we answer these questions, let's examine in brief the history of grain.

Video 3.1.1

Watch the History of Bread, part one, from The History Channel. To further satiate your interest go on to watch the other five parts, available on YouTube.

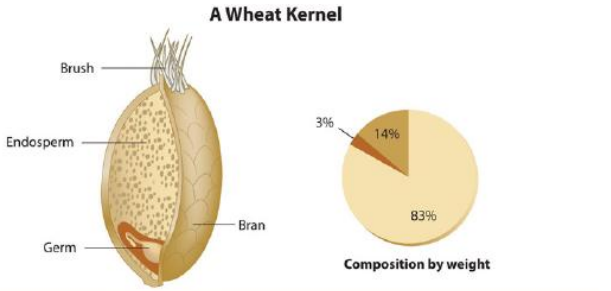


In ancient times whole grains were cracked open using quern stones that required hours of hand labor. As technology slowly advanced, the quern stone was modified into the millstone. It wasn't until the advent of water wheels that human labor to produce grains was reduced. About 2,500 years ago the Romans started milling flour by turning one millstone wheel against another that did not move. The turning was done by animals, slaves, and later by waterwheels. The process of milling breaks the hard outer bran coat of the wheat seeds. The bran and germ, which contain the majority of fiber, vitamins, and minerals, are removed by sifting. In the earliest days, the whitest flour was chosen to make bread for the wealthy, and the coarsest was given to the poor. One's economic status was depicted by the color of bread they ate. Wheat was the grain of choice for many cultures, as it not only produced white flour but also contained gluten which gives wheat bread its elasticity and lightness in texture. The word "flour" comes from a French word meaning "blossom" and is metaphoric for the finest part of the meal. Bakers highly prized their art and it was kept from the masses. In fact the baker's mark was one of the first trademarks.



Figure 3.1.1: The *2015 Dietary Guidelines* recommends that whole grains over refined grains. What percentage of your diet is whole grain? © Thinkstock

In America, Oliver Evans built the first flour mill, which was powered by a watermill. It used a series of elevators that moved grain through the mill, cleaning it first, then grinding and sifting it. Today, modern milling produces three types of flour; whole meal containing 100 percent of the grain, with nothing added or removed; brown flour, containing 85 percent of the original grain with some bran and germ and white flour, containing 75 percent of the wheat grain with the most bran and germ removed. The vast majority of flour milled and used in foods and cooking in America is white flour. The modern milling process of preparing white flour removes between 50 and 85 percent of B vitamins, vitamin E, calcium, iron, potassium, chromium, phosphorus, zinc, magnesium manganese, and cobalt.



	Carb/g	Protein/g	Fat/g	Fiber/g	Iron (% daily req.)	Others
Bran	63	16	3	43	59	vitamin Bs
Endosperm	79	7	0	4	7	
Germ	52	23	10	14	35	vitamin Bs omega-3/6 lipids

Nutritional value (per 100g)

Figure 3.1.2: Wheat kernel anatomy and composition.

In the early nineteenth century several diseases stemming from vitamin and mineral deficiencies, such as pellagra (niacin, B_3), beriberi (thiamine, B_1), and anemia (iron), plagued many inhabitants of the nation. One of the first public health campaigns was to improve the health of Americans by enriching flour, a dietary staple. The B vitamins, niacin, thiamine, riboflavin, and folate were added along with iron to combat dietary deficiencies and proved a successful strategy to improve public health. However, enriched flour contains only 6 percent or less of the recommended daily intake of the vitamins and minerals it "replaces." Overwhelming scientific evidence now shows that diets containing high amounts of whole grains rather than refined white flour decrease weight gain and the risk for many chronic diseases, including certain types of cancer and diabetes. Whole grains contain a whole nutrient package that is not replaced by enriched flour. Consumers are becoming more aware of the many health benefits of whole grains. However, the food industry has created a puzzle for consumers in determining if a product is made from 100 percent whole grains. "Whole wheat" does not always mean the product is made with 100 percent whole grains, and brown breads are not always healthier than white as the color may come from added caramel. The Food and Drug Administration (FDA) has provided the food industry with specifics on how to label whole-grain foods—to label it as made from 100 percent whole grains. The best method to ensure the product is made from 100 percent whole grains is to check the ingredient list. One-hundred percent whole-grain products

list whole grains or whole-wheat flour most often as the first ingredient and do not contain wheat flour, white flour, yellow corn flour, semolina flour, degerminated flour, or durum flour. In America, whole-grain choices are improving, but progress still needs to be made on reducing the added sugar content of many industrially prepared breads, assuring added fiber comes from good sources, eliminating ambiguous labels and claims on packaging, and reducing the costs of whole-grain breads, which still exceed that of white bread.

You Decide

What 100 percent whole-grain products can you include in your diet to improve health, prevent disease, and be tastefully satisfied?

As you read on, you will learn the different types of carbohydrates, their essential roles in the body, the potential health consequences and benefits of diets rich in particular carbohydrates, and the many foods available that are rich in carbohydrates as well as nutritious and satisfying. After reading this chapter, you will be better equipped to decide the best way to get your nutritional punch from various carbohydrates in your diet.

“If thou tastest a crust of bread, thou tastest all the stars and all the heavens.”

Robert Browning, English poet, and playwright (May 1812–December 1889)

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3.2: A Closer Look at Carbohydrates

Learning Objectives

- Describe some of the distinguishing features of carbohydrates.
- Describe the differences between fast-releasing and slow-releasing carbohydrates.
- What Exactly Are Carbohydrates and How Many Types Are There?

Carbohydrates are the perfect nutrient to meet your body's nutritional needs. They nourish your brain and nervous system, provide energy to all of your cells (and within proper caloric limits), and help keep your body fit and lean. Specifically, digestible carbohydrates provide bulk in foods, vitamins, and minerals, while indigestible carbohydrates provide a good amount of fiber with a host of other health benefits.

Plants synthesize the fast-releasing carbohydrate, glucose, from carbon dioxide in the air and water, and by harnessing the sun's energy. Recall that plants convert the energy in sunlight to chemical energy in the molecule, glucose. Plants use glucose to make other larger, more slow-releasing carbohydrates. When we eat plants we harvest the energy of glucose to support life's processes.

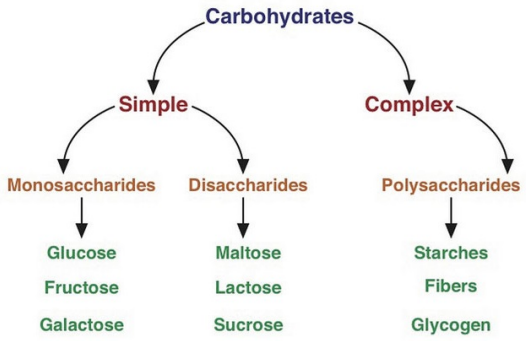


Figure 3.2.1: Carbohydrate Classification Scheme. Carbohydrates are broken down into the subgroups "fast-releasing" and "slow-releasing" carbohydrates. These subgroups are further categorized into mono-, di-, and polysaccharides.

Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Basically, they are hydrated carbons. The word "carbo" means carbon and "hydrate" means water. Glucose (also called dextrose), the most abundant carbohydrate in the human body, has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. The chemical formula for glucose is written as $C_6H_{12}O_6$. Synonymous with the term carbohydrate is the Greek word "saccharide," which means sugar. The simplest unit of a carbohydrate is a monosaccharide. Carbohydrates are broadly classified into two subgroups, "fast-releasing" and "slow-releasing." Fast-releasing carbohydrates are further grouped into the monosaccharides and disaccharides. Slow-releasing carbohydrates are long chains of monosaccharides. (Figure 3.2.1).

Fast-Releasing Carbohydrates

Fast-releasing carbohydrates are also known more simply as "sugars." Fast-releasing carbohydrates are grouped as either monosaccharides or disaccharides. Monosaccharides include glucose, fructose, and galactose, and the disaccharides include, lactose, maltose, and sucrose.

Monosaccharides

For all organisms from bacteria to plants to animals, glucose is the preferred fuel source. The brain is completely dependent on glucose as its energy source (except during extreme starvation conditions). The monosaccharide galactose differs from glucose only in that a hydroxyl (−OH) group faces in a different direction on the number four carbon (Figure 3.2.2). This small structural alteration causes galactose to be less stable than glucose. As a result, the liver rapidly converts it to glucose. Most absorbed galactose is utilized for energy production in cells after its conversion to glucose. (Galactose is one of two simple sugars that are bound together to make up the sugar found in milk. It is later freed during the digestion process.)

Fructose also has the same chemical formula as glucose but differs in its chemical structure, as the ring structure contains only five carbons and not six (Figure 4.2.2). Fructose, in contrast to glucose, is not an energy source for other cells in the body. Mostly found

in fruits, honey, and sugarcane, fructose is one of the most common monosaccharides in nature. It is also found in soft drinks, cereals, and other products sweetened with high fructose corn syrup.

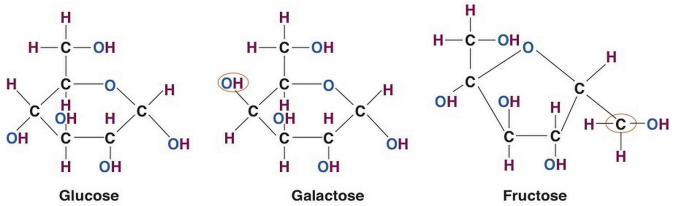


Figure 3.2.2: Structures of the Three Most Common Monosaccharides: Glucose, Galactose, and Fructose. Red circles indicate the structural differences between the three.

Less common monosaccharides are the pentoses, which have only five carbons and not six. The pentoses are abundant in the nucleic acids RNA and DNA, and also as components of fiber.

Lastly, there are the sugar alcohols, which are industrially synthesized derivatives of monosaccharides. Some examples of sugar alcohols are sorbitol, xylitol, and glycerol. (Xylitol is similar in sweetness to table sugar.) Sugar alcohols are often used in place of table sugar to sweeten foods as they are incompletely digested and absorbed, and therefore less caloric. The bacteria in your mouth opposes them, hence sugar alcohols do not cause tooth decay. Interestingly, the sensation of “coolness” that occurs when chewing gum that contains sugar alcohols comes from them dissolving in the mouth, a chemical reaction that requires heat from the inside of the mouth.

Disaccharides

Disaccharides are composed of pairs of two monosaccharides linked together. Disaccharides include sucrose, lactose, and maltose. All of the disaccharides contain at least one glucose molecule.

Sucrose, which contains both glucose and fructose molecules, is otherwise known as table sugar. Sucrose is also found in many fruits and vegetables, and at high concentrations in sugar beets and sugar cane, which are used to make table sugar. Lactose, which is commonly known as milk sugar, is composed of one glucose unit and one galactose unit. Lactose is prevalent in dairy products such as milk, yogurt, and cheese. Maltose consists of two glucose molecules bonded together. It is a common breakdown product of plant starches and is rarely found in foods as a disaccharide. It is formed because of the germination of grains.

Oligosaccharides

Oligosaccharides is a complex sugar that has three to ten monosaccharide molecules hooked in a chain. Examples are raffinose and stachyose which are found in some sports drinks and are a chain of glucose molecules. Raffinose and stachyose are digested and the resulting glucose is absorbed. Beans also contain raffinose and stachyose.

Slow-Releasing Carbohydrates

Slow-releasing carbohydrates are polysaccharides, long chains of monosaccharides that may be branched or not branched. There are two main groups of polysaccharides: starches and fibers.

Starches

Starch molecules (the carbohydrate storage form in plants) are found in abundance in grains, legumes, and root vegetables, such as potatoes. Amylose, a plant starch, is a linear chain containing hundreds of glucose units. Amylopectin, another plant starch, is a branched chain containing thousands of glucose units. These large starch molecules form crystals and are the energy-storing molecules of plants. These two starch molecules (amylose and amylopectin) are contained together in foods, but the smaller one, amylose, is more abundant. Eating raw foods containing starches provides very little energy as the digestive system has a hard time breaking them down. Cooking breaks down the crystal structure of starches, making them much easier to break down in the human body. The starches that remain intact throughout digestion are called resistant starches. Bacteria in the gut can break some of these down and may benefit gastrointestinal health. Isolated and modified starches are used widely in the food industry and during cooking as food thickeners.

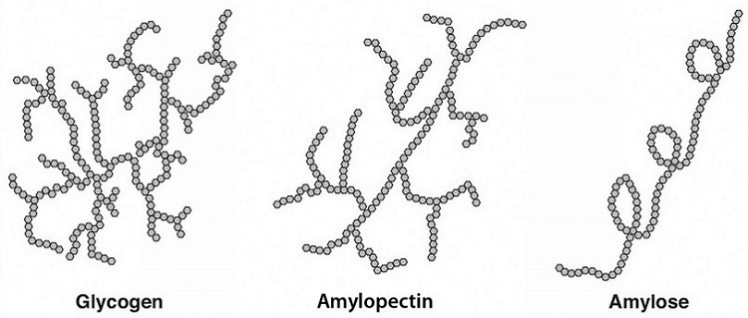


Figure 3.2.3: Structures of the Plant Starches and Glycogen

Humans and animals store glucose energy from starches in the form of the very large molecule, glycogen. It has many branches that allow it to break down quickly when energy is needed by cells in the body. It is predominantly found in liver and muscle tissue in animals.

Dietary Fibers

Dietary fibers are polysaccharides that are highly branched and cross-linked. Some dietary fibers are pectin, gums, cellulose, and lignin. Humans do not produce the enzymes that can break down dietary fiber; however, bacteria in the large intestine (colon) do. Dietary fibers are very beneficial to our health. The Dietary Guidelines Advisory Committee states that there is enough scientific evidence to support that diets high in fiber reduce the risk for obesity and diabetes, which are primary risk factors for cardiovascular disease.US Department of Agriculture. “Part D. Section 5: Carbohydrates.” In Report of the DGAC on the Dietary Guidelines for Americans, 2010. Accessed September 30, 2011. www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/D-5-Carbohydrates.pdf.

Dietary fiber is categorized as either water-soluble or insoluble. Soluble fibers dissolve and swell in water. Classes of soluble fibers are pectins, gums, mucilage and some hemicelluloses. Examples of soluble fibers you may see on ingredient lists are inulin, pectin, and guar gum while food sources are peas, beans, oats, barley, and rye.

Cellulose, hemicellulose, psyllium, and lignin are insoluble fibers and a few dietary sources of these fibers are whole-grain foods, flax, cauliflower, and avocados. Cellulose is the most abundant fiber in plants, making up the cell walls and providing structure.

Soluble fibers are more easily accessible to bacterial enzymes in the large intestine so they can be broken down to a greater extent than insoluble fibers, but even some breakdown of cellulose and other insoluble fibers occurs.

The last class of fiber is functional fiber. Functional fibers have been added to foods and have been shown to provide health benefits to humans. Functional fibers may be extracted from plants and purified or synthetically made. An example of a functional fiber is psyllium-seed husk. Scientific studies show that consuming psyllium-seed husk reduces blood-cholesterol levels and this health claim has been approved by the FDA. Total dietary fiber intake is the sum of dietary fiber and functional fiber consumed.

Dietary recommendations for dietary fiber are 25-35 g/day for adults and for children, 5 g + the child's age/day. A variety of fiber sources should be consumed with the focus on whole grain, not refined. Excessive intake of fiber, > 60 g/day, can cause intestinal blockage, bind minerals, and cause intestinal gas or cramping.

Key Takeaways

- Carbohydrates are a group of organic compounds containing a ratio of one carbon atom to two hydrogen atoms to one oxygen atom. Carbohydrates are broadly classified into two subgroups, fast-releasing, and slow-releasing carbohydrates.
- Fast-releasing carbohydrates are sugars and they include the monosaccharides and disaccharides. Slow-releasing carbohydrates include the polysaccharides, amylose, amylopectin, glycogen, dietary fiber, and functional fiber.
- Glucose is the most important monosaccharide in human nutrition. Many other monosaccharides and disaccharides become glucose in the body.
- Fiber-rich foods are scientifically proven to reduce the risk of obesity and diabetes. Functional fibers are added to foods because they are proven to have added health benefits.

Discussion Starters

1. What do you eat most of: fast-releasing carbohydrates, starches, or fiber?
2. Bring in the packages for the breads you eat and compare the different ingredients lists with your classmates. Are they labeled well? Do they contain any health claims? Are they made from 100 percent whole grain? Do they contain added sugars? For more help on defining products made with whole grains, visit the website of the Whole Grains Council. http://www.wholegrainscouncil.org/whole-grains-101/definition-of-whole-grains

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3.3: Digestion and Absorption of Carbohydrates

Learning Objectives

- Discuss how carbohydrates are digested and absorbed in the human body.

Sweetness is one of the five basic taste sensations of foods and beverages and is sensed by protein receptors in cells of the taste buds. Fast-releasing carbohydrates stimulate the sweetness taste sensation, which is the most sensitive of all taste sensations. Even extremely low concentrations of sugars in foods will stimulate the sweetness taste sensation. Sweetness varies between the different carbohydrate types—some are much sweeter than others. Fructose is the top naturally occurring sugar in sweetness value.



Figure 3.3.1: Blueberry pancakes. *Whole grains provide satisfaction from the beginning to the end of the digestion process. (CC-SA-BY-2.0;* jeffreyw)

See Table 3.3.1 for sweetness comparisons among different naturally-occurring carbohydrates. Sweetness is a pleasurable sensation and some people enjoy the taste more than others. In a colloquial sense, we identify such people as having a “sweet tooth.” This does not mean that the less-sweet whole grains containing more starches and fiber are less satisfying. Whole grains take longer to chew and get sweeter the more you chew them. Additionally, once in the stomach, whole-grain foods take longer to digest and keep you full longer. Remember too that they contain fiber which makes elimination much smoother. Whole-grain foods satisfy the body the entire way through the digestive tract and provide the nutrients that also better satisfy the body’s functional needs.

Table 3.3.1: Sweetness Comparison of Carbohydrates

Carbohydrate	Sweetness (percentage of sucrose)
Sucrose	100
Glucose	74
Galactose	33
Fructose	173
Maltose	33
Lactose	16
Starch	0
Fiber	0

Source: Carter, J. Stein. “Carbohydrates.” © 1996 by J. Stein Carter. All rights reserved. www.biology.clc.uc.edu/courses/bio104/carbohydrates.htm.

From the Mouth to the Stomach

The mechanical and chemical digestion of carbohydrates begins in the mouth. Chewing, also known as mastication, crumbles the carbohydrate foods into smaller and smaller pieces. The salivary glands in the oral cavity secrete saliva that coats the food particles. Saliva contains the enzyme, salivary amylase. This enzyme breaks the bonds between the monomeric sugar units of disaccharides, oligosaccharides, and starches. The salivary amylase breaks down amylose and amylopectin into smaller chains of glucose, called

dextrins and maltose. The increased concentration of maltose in the mouth that results from the mechanical and chemical breakdown of starches in whole grains is what enhances their sweetness. Only about five percent of starches are broken down in the mouth. (This is a good thing as more glucose in the mouth would lead to more tooth decay.) When carbohydrates reach the stomach no further chemical breakdown occurs because the amylase enzyme does not function in the acidic conditions of the stomach. But the mechanical breakdown is ongoing—the strong peristaltic contractions of the stomach mix the carbohydrates into the more uniform mixture of chyme.

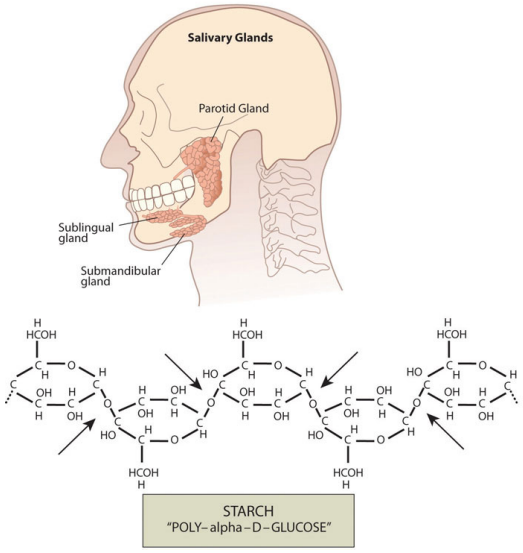


Figure 3.3.2: Salivary glands secrete salivary amylase, which begins the chemical breakdown of carbohydrates by breaking the bonds between monomeric sugar units.

From the Stomach to the Small Intestine

The chyme is gradually expelled into the upper part of the small intestine. Upon entry of the chyme into the small intestine, the pancreas releases pancreatic juice through a duct. This pancreatic juice contains the enzyme, pancreatic amylase, which starts again the breakdown of dextrins into shorter and shorter carbohydrate chains. Additionally, enzymes are secreted by the intestinal cells that line the villi. These enzymes, known collectively as disaccharides, are sucrase, maltase, and lactase. Sucrase breaks sucrose into glucose and fructose molecules. Maltase breaks the bond between the two glucose units of maltose, and lactase breaks the bond between galactose and glucose. Once carbohydrates are chemically broken down into single sugar units they are then transported into the inside of intestinal cells.

When people lack or do not have enough of the enzyme lactase, the beta bond between glucose and galactose in lactose is not sufficiently broken down resulting in a condition called lactose intolerance. The undigested lactose moves to the large intestine where bacteria are able to digest it. The bacterial digestion of lactose produces gases leading to symptoms of diarrhea, bloating, and abdominal cramps. Lactose intolerance usually occurs in adults and is associated with race. The National Digestive Diseases Information Clearing House states that African Americans, Hispanic Americans, American Indians, and Asian Americans have much higher incidences of lactose intolerance while those of northern European descent have the least.National Digestive Diseases Information Clearing House. "Lactose Intolerance." Last updated April 23, 2012. digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/. Most people with lactose intolerance can tolerate some amount of dairy products in their diet. The severity of the symptoms depends on how much lactose is consumed and the degree of lactase deficiency.

Absorption: Going to the Blood Stream

The cells in the small intestine have membranes that contain many transport proteins in order to get the monosaccharides and other nutrients into the blood where they can be distributed to the rest of the body. Fructose is absorbed by facilitated diffusion while glucose and galactose are actively transported. The first organ to receive glucose, fructose, and galactose is the liver. The liver takes them up and converts galactose to glucose, breaks fructose into even smaller carbon-containing units, and either stores glucose as glycogen or exports it back to the blood. How much glucose the liver exports to the blood is under hormonal control and you will soon discover that even the glucose itself regulates its concentrations in the blood.

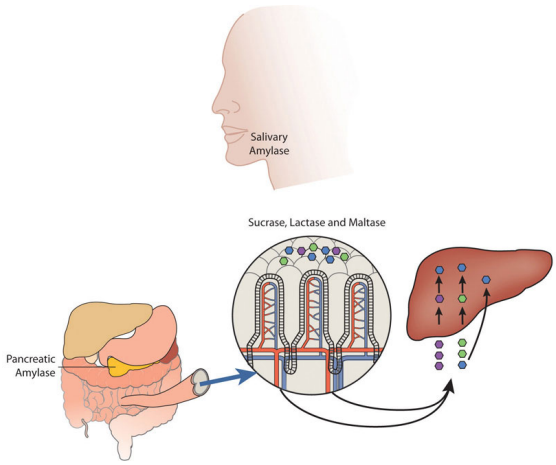


Figure 3.3.3: Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver.

Maintaining Blood Glucose Levels: The Pancreas and Liver

Glucose levels in the blood are tightly controlled, as having either too much or too little glucose in the blood can have health consequences. Glucose regulates its levels in the blood via a process called negative feedback. An everyday example of negative feedback is in your oven because it contains a thermostat. When you set the temperature to cook a delicious homemade noodle casserole at 375°F the thermostat senses the temperature and sends an electrical signal to turn the elements on and heat up the oven. When the temperature reaches 375°F the thermostat senses the temperature and sends a signal to turn the element off. Similarly, your body senses blood glucose levels and maintains the glucose "temperature" in the target range. The glucose thermostat is located within the cells of the pancreas. After eating a meal containing carbohydrates glucose levels rise in the blood.

Insulin-secreting cells in the pancreas (pancreatic beta cells) sense the increase in blood glucose and release the hormonal message, insulin, into the blood. Insulin sends a signal to the body's cells to remove glucose from the blood by transporting it into cells and within the cell to use glucose to make energy or for building macromolecules. In the case of muscle tissue and the liver, insulin sends the biological message to store glucose away as glycogen. The presence of insulin in the blood signifies to the body that it has just been fed and to use the fuel. Insulin has an opposing hormone called glucagon. As the time after a meal lengthens, glucose levels decrease in the blood. Glucagon-secreting cells in the pancreas (pancreatic alpha-cells) sense the drop in blood glucose and, in response, release the hormone glucagon into the blood. Glucagon communicates to the cells in the body to stop using glucose. More specifically, it signals the liver to break down glycogen and release the stored glucose into the blood, so blood glucose levels stay within the target range and all cells get the fuel the need to function properly.

Epinephrine or adrenaline is released in response to stress or exercise. It causes the breakdown of glycogen, or glycogenolysis, which releases glucose and increases blood glucose levels.

Our bodies work hard to maintain blood glucose in a specific range, 80-120 mg/dL. During fasting, blood glucose can fall below 80, so the body has several mechanisms to bring the blood sugar back to an acceptable level. The hormone glucagon is released from the pancreas and causes the breakdown of liver glycogen and the release of glucose. If the fasting lasts longer, early starvation (1-3 days), protein is broken down to release gluconeogenic amino acids. These travel to the liver and are converted to glucose. If starvation continues (>3 days), protein catabolism slows and fatty acids are released to provide ketones as the source of energy. The brain and other body cells use ketones as their main energy source in an effort to conserve glucose and muscle mass.

Leftover Carbohydrates: The Large Intestine

Almost all of the carbohydrates, except for dietary fiber and resistant starches, are efficiently digested and absorbed into the body. Some of the remaining indigestible carbohydrates are broken down by enzymes released by bacteria in the large intestine. The products of bacterial digestion of these slow-releasing carbohydrates are short-chain fatty acids and some gases. The short-chain fatty acids are either used by the bacteria to make energy and grow, are eliminated in the feces, or are absorbed into cells of the colon, with a small amount being transported to the liver. Colonic cells use the short-chain fatty acids to support some of their functions. The liver can also metabolize the short-chain fatty acids into cellular energy. The yield of energy from dietary fiber is about 2 kilocalories per gram for humans but is highly dependent upon the fiber type, with soluble fibers and resistant starches

yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other carbohydrate types (simple sugars, many starches) the rise in blood glucose after eating them is less, and slower. These physiological attributes of high-fiber foods (i.e. whole grains) are linked to a decrease in weight gain and reduced risk of chronic diseases, such as Type 2 diabetes and cardiovascular disease.

A Carbohydrate Feast



Figure 3.3.4: Thanksgiving dinner: A feast of high-carbohydrate foods. © Shutterstock

It's Thanksgiving and you have just consumed turkey with mashed potatoes, stuffing smothered in gravy, green beans topped with crispy fried onions, a hot roll dripping with butter, and cranberry sauce. Less than an hour later you top it all off with a slice of pumpkin pie and then lie down on the couch to watch the football game. What happens in your body after digesting and absorbing the whopping amount of nutrients in this Thanksgiving feast? The "hormone of plenty," insulin, answers the nutrient call. Insulin sends out the physiological message that glucose and everything else is in abundant supply in the blood, so cells absorb and then use or store it. The result of this hormone message is the maximization of glycogen stores and all the excess glucose, protein, and lipids are stored as fat.

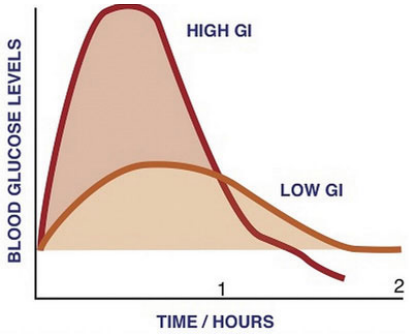


Figure 3.3.5: The glycemic index measures the effects of foods on blood-glucose levels.

A typical American Thanksgiving meal contains many foods that are dense in carbohydrates, with the majority of those being simple sugars and starches. These types of carbohydrate foods are rapidly digested and absorbed. Blood glucose levels rise quickly causing a spike in insulin levels. Contrastingly, foods containing high amounts of fiber are like time-release capsules of sugar. A measurement of the effects of a carbohydrate-containing food on blood-glucose levels is called the glycemic response (Figure 3.4).

Glycemic Index

The glycemic responses of various foods have been measured and then ranked in comparison to a reference food, usually, a slice of white bread (50 g) or just straight glucose, to create a numeric value called the glycemic index (GI). Foods that have a low GI do not raise blood-glucose levels as fast as foods that have a higher GI. A diet of low-GI foods has been shown in epidemiological and clinical trial studies to increase weight loss and reduce the risk of obesity, Type 2 diabetes, and cardiovascular disease.Brand-

Miller, J., PhD, et al. “Dietary Glycemic Index: Health Implications.” J Am Coll Nutr 28, no. 4, supplement (2009): 446S–49S. http://www.jacn.org/content/28/4_Supplement_1/446S.long.

Table 3.3.2: The Glycemic Index: Foods in Comparison to Glucose

Foods	GI Value
Low GI Foods (< 55)	
Apple	44
Pear	38
Banana (under-ripe)	51
Grapefruit	25
Barley	25
Navy beans	38
Green peas	48
Oat bran (Quaker Oats)	50
Spaghetti (whole wheat)	37
Mashed sweet potatoes	54
Baked beans	48
Butter beans	44
Banana bread	47
Bread (sourdough)	52
Soy milk	31
Skim milk	32
Whole milk	27
Yogurt (sweetened)	33
Yogurt (plain, artificial sweetener)	14
Medium GI Foods (56–69)	
Apricots	57
Cantaloupe	65
Mashed potatoes	70
Whole-wheat pita bread	57
Whole-wheat bread	69
Couscous	65
Brown rice	55
Cheese pizza	60
Rye bread	65
Hamburger bun	61
Black bean soup	64

Foods	GI Value
Macaroni and cheese	64
Coca-Cola	63
High GI Foods (70 and higher)	
Dates	103
Banana (over-ripe)	82
Parsnips	97
Corn chips	72
Pretzels	83
White bread	70
White rice	72
Spaghetti (durum flour)	78
White rice (instant)	87
French baguette	95
Bagel	72
Bread stuffing	74
Cheerios	74
Cream of wheat	71
Raisin Bran	73
Fruit roll-up	99
Gatorade	78

Source: University of Sydney. Glycemic Index Database. © 2011 The University of Sydney, all rights reserved. http://www.glycemicindex.com/.

The carbohydrate type within a food affects the GI, but so does its fat and fiber content (which reduce the GI). Increased fat and fiber in foods increases the time required for digestion and delays the rate of gastric emptying into the small intestine. Processing and cooking additionally affect a food's GI by increasing their digestibility. Advancements in the technologies of food processing and the high consumer demand for convenient, precooked foods in the United States have created foods that are digested and absorbed more rapidly, independent of the fiber content. Modern breakfast cereals, breads, pastas, and many prepared foods have a high GI. In contrast, most raw foods have a lower GI. (However, the more ripened a fruit or vegetable is, the higher its GI.) Table 3.2 provides the GI for various foods. The GI can be used as a guide for choosing healthier carbohydrate choices but has some limitations. One is that the GI does not take into account the amount of carbohydrates in a portion of food, only the type of carbohydrate. Another is that combining low- and high-GI foods changes the GI for the meal. Also, some nutrient-dense foods have higher GIs than less nutritious food. (For instance, oatmeal has a higher GI than chocolate because the fat content of chocolate is higher.) Lastly, meats and fats do not have a GI since they do not contain carbohydrates.

Interactive 3.3.1: Balancing the Thanksgiving Feast

Visit this online database of glycemic indices of foods. http://www.gilisting.com/

To balance the high-GI foods on the Thanksgiving table with low-GI foods, follow some of these suggestions:

- Serve a winter fruit salad.
- Leave the skins on the potatoes. The skin contains fiber and adds texture to mashed potatoes. Do not use instant potatoes.

- Instead of canned green beans with cream of mushroom soup and fried onions for a side dish, combine butter beans and green peas for a colorful, low-GI food.
- Make your stuffing with whole-grain bread and add mushrooms and extra celery and onions.
- Try a new low-sugar pumpkin pie recipe and make the crust from whole-grain flour.
- Offer homemade banana bread for dessert.

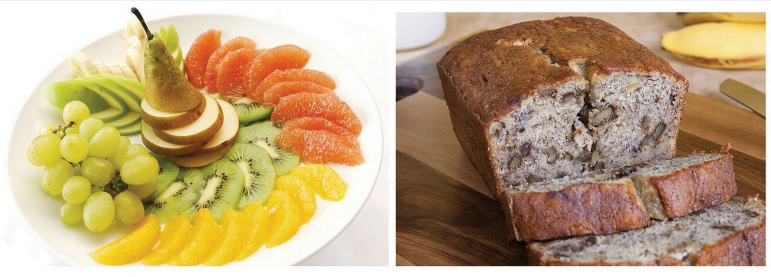


Figure 3.3.6: Balance the high-GI foods at the Thanksgiving table with low-GI foods. © Shutterstock

Key Takeaways

- Carbohydrate digestion begins in the mouth with the mechanical action of chewing and the chemical action of salivary amylase. Carbohydrates are not chemically broken down in the stomach, but rather in the small intestine. Pancreatic amylase and the disaccharidases finish the chemical breakdown of digestible carbohydrates.
- The monosaccharides are absorbed into the bloodstream and delivered to the liver.
- Some of the indigestible carbohydrates are digested by bacteria in the large intestine.
- Glucose itself participates in regulating its levels in the blood. Not all carbohydrates have the same effect on blood-glucose levels. The glycemic response is a measurement of the effects of a carbohydrate-containing food on blood-glucose levels.

Discussion Starters

1. Experience the taste sensations of different carbohydrates. What are some foods that satisfy your sweetness sensation?
2. Even though fiber contains calories, albeit less than half of other carbohydrates, why do we generally discount its caloric contribution from our diets?
3. How long a person feels full after eating a carbohydrate-rich meal depends on the type of carbohydrate consumed and what other nutrients are in the meal. Conduct an experiment and determine how long you feel full after eating a candy bar; after eating a slice of whole-grain bread; after eating an apple; and after eating a potato. Compare your results with your classmates and discuss why some of these carbohydrate foods make you feel full longer than others.

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3.4: The Functions of Carbohydrates in the Body

Learning Objectives

- List four primary functions of carbohydrates in the human body

There are five primary functions of carbohydrates in the human body. They are energy production, energy storage, building macromolecules, sparing protein, and assisting in lipid metabolism.

Energy Production

The primary role of carbohydrates is to supply energy to all cells in the body. Many cells prefer glucose as a source of energy versus other compounds like fatty acids. Some cells, such as red blood cells, are only able to produce cellular energy from glucose. The brain is also highly sensitive to low blood-glucose levels because it uses *only* glucose to produce energy and function (unless under extreme starvation conditions). About 70 percent of the glucose entering the body from digestion is redistributed (by the liver) back into the blood for use by other tissues. Cells that require energy remove the glucose from the blood with a transport protein in their membranes. The energy from glucose comes from the chemical bonds between the carbon atoms. Sunlight energy was required to produce these high-energy bonds in the process of photosynthesis. Cells in our bodies break these bonds and capture the energy to perform cellular respiration. Cellular respiration is basically a controlled burning of glucose versus an uncontrolled burning. A cell uses many chemical reactions in multiple enzymatic steps to slow the release of energy (no explosion) and more efficiently capture the energy held within the chemical bonds in glucose.

The first stage in the breakdown of glucose is called glycolysis, which occurs in an intricate series of ten enzymatic-reaction steps. The second stage of glucose breakdown occurs in the energy factory organelles, called mitochondria. One carbon atom and two oxygen atoms are removed, yielding more energy. The energy from these carbon bonds is carried to another area of the mitochondria, making the cellular energy available in a form cells can use.

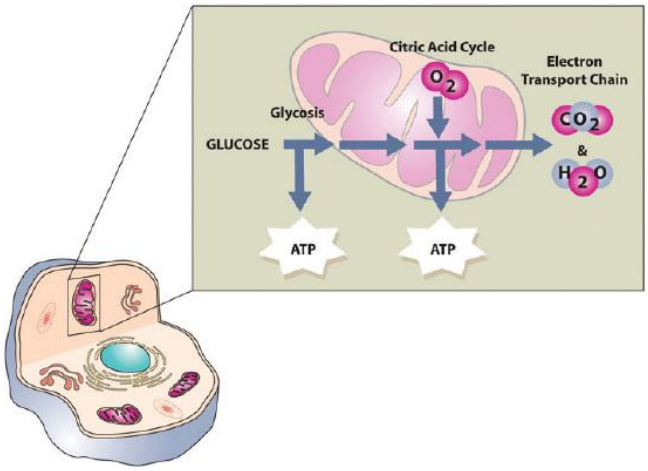


Figure 3.4.1: *Cellular respiration is the process by which energy is captured from glucose.*

Energy Storage

If the body already has enough energy to support its functions, the excess glucose is stored as glycogen (the majority of which is stored in the muscle and liver). A molecule of glycogen may contain in excess of fifty thousand single glucose units and is highly branched, allowing for the rapid dissemination of glucose when it is needed to make cellular energy (Figure 3.4.2).

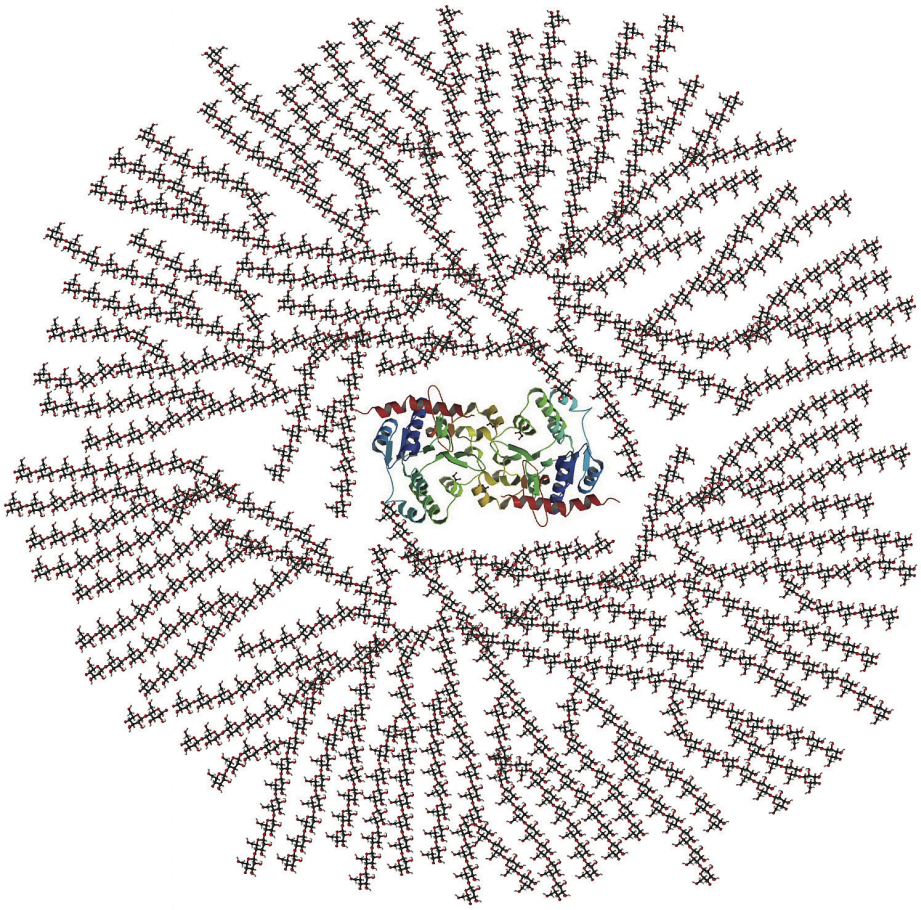


Figure 3.4.2: The structure of glycogen enables its rapid mobilization into free glucose to power cells.

The amount of glycogen in the body at any one time is equivalent to about 4,000 kilocalories—3,000 in muscle tissue and 1,000 in the liver. Prolonged muscle use (such as exercise for longer than a few hours) can deplete the glycogen energy reserve. This is referred to as “hitting the wall” or “bonking” and is characterized by fatigue and a decrease in exercise performance. The weakening of muscles sets in because it takes longer to transform the chemical energy in fatty acids and proteins to usable energy than glucose. After prolonged exercise, glycogen is gone and muscles must rely more on lipids and proteins as an energy source. Athletes can increase their glycogen reserve modestly by reducing training intensity and increasing their carbohydrate intake to between 60 and 70 percent of total calories three to five days prior to an event. People who are not hardcore training and choose to run a 5-kilometer race for fun do not need to consume a big plate of pasta prior to a race since without long-term intense training the adaptation of increased muscle glycogen will not happen.

The liver, like muscle, can store glucose energy as a glycogen, but in contrast to muscle tissue it will sacrifice its stored glucose energy to other tissues in the body when blood glucose is low. Approximately one-quarter of total body glycogen content is in the liver (which is equivalent to about a four-hour supply of glucose) but this is highly dependent on activity level. The liver uses this glycogen reserve as a way to keep blood-glucose levels within a narrow range between meal times. When the liver’s glycogen supply is exhausted, glucose is made from amino acids obtained from the destruction of proteins in order to maintain metabolic homeostasis.

-

Building Macromolecules

Although most absorbed glucose is used to make energy, some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP (Figure 3.4.3). Glucose is additionally utilized to make the molecule NADPH, which is important for protection against oxidative stress and is used in many other chemical reactions in the body. If all of the energy, glycogen-storing capacity, and building needs of the body are met, excess glucose can be used to

make fat. This is why a diet too high in carbohydrates and calories can add on the fat pounds—a topic that will be discussed shortly.

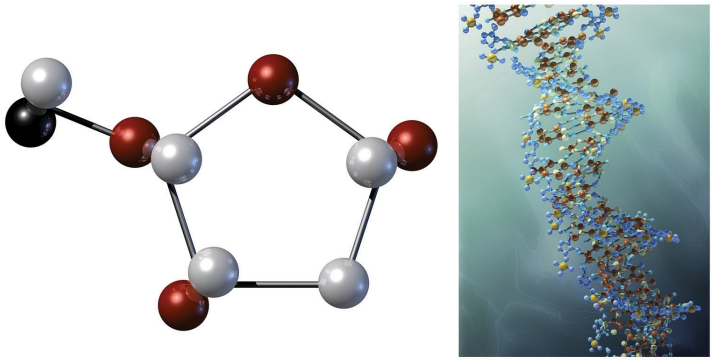


Figure 3.4.3: The sugar molecule deoxyribose is used to build the backbone of DNA.© Shutterstock

Sparing Protein

In a situation where there is not enough glucose to meet the body's needs, glucose is synthesized from amino acids. Because there is no storage molecule of amino acids, this process requires the destruction of proteins, primarily from muscle tissue. The presence of adequate glucose basically spares the breakdown of proteins from being used to make glucose needed by the body.

Lipid Metabolism

As blood-glucose levels rise, the use of lipids as an energy source is inhibited. Thus, glucose additionally has a "fat-sparing" effect. This is because an increase in blood glucose stimulates release of the hormone insulin, which tells cells to use glucose (instead of lipids) to make energy. Adequate glucose levels in the blood also prevent the development of ketosis. Ketosis is a metabolic condition resulting from an elevation of ketone bodies in the blood. Ketone bodies are an alternative energy source that cells can use when glucose supply is insufficient, such as during fasting. Ketone bodies are acidic and high elevations in the blood can cause it to become too acidic. This is rare in healthy adults, but can occur in alcoholics, people who are malnourished, and in individuals who have Type 1 diabetes. The minimum amount of carbohydrate in the diet required to inhibit ketosis in adults is 50 grams per day.

Carbohydrates are critical to support life's most basic function—the production of energy. Without energy none of the other life processes are performed. Although our bodies can synthesize glucose it comes at the cost of protein destruction. As with all nutrients though, carbohydrates are to be consumed in moderation as having too much or too little in the diet may lead to health problems.

Key Takeaways

- The four primary functions of carbohydrates in the body are to provide energy, store energy, build macromolecules, and spare protein and fat for other uses.
- Glucose energy is stored as glycogen, with the majority of it in the muscle and liver. The liver uses its glycogen reserve as a way to keep blood-glucose levels within a narrow range between meal times. Some glucose is also used as building blocks of important macromolecules, such as RNA, DNA, and ATP.
- The presence of adequate glucose in the body spares the breakdown of proteins from being used to make glucose needed by the body.

Discussion Starters

1. Discuss two reasons it is essential to include carbohydrates in your diet.
2. Why is it necessary for the body to spare protein?

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3.5: Looking Closely at Diabetes

Learning Objectives

- Summarize the long-term health implications and the dietary approaches to living with Type 1 and Type 2 diabetes.

Diabetes is one of the top three diseases in America. It affects millions of people and causes tens of thousands of deaths each year. Diabetes is a metabolic disease of insulin deficiency and glucose over-sufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person's risk for developing diabetes. One sure way to decrease your chances of getting diabetes is to maintain an optimal body weight by adhering to a diet that is balanced in carbohydrate, fat, and protein intake. There are three different types of diabetes: Type 1 diabetes, Type 2 diabetes, and gestational diabetes.

Type 1 Diabetes

Type 1 diabetes is a metabolic disease in which insulin-secreting cells in the pancreas are killed by an abnormal response of the immune system, causing a lack of insulin in the body. Its onset typically occurs before the age of thirty. The only way to prevent the deadly symptoms of this disease is to inject insulin under the skin. Before this treatment was discovered, people with Type 1 diabetes died rapidly after disease onset. Death was the result of extremely high blood-glucose levels affecting brain function and leading to coma and death. Up until 1921, patients with Type 1 diabetes, the majority of them children, spent their last days in a ward where they lapsed into a coma awaiting death. One of the most inspiring acts in medical history is that of the scientists who discovered, isolated, and purified insulin and then went on to find out that it relieved the symptoms of Type 1 diabetes, first in dogs and then in humans. Frederick Banting, Charles Best, and James Collip went into a hospital ward in Toronto, Canada and injected comatose children with insulin. Before they completed their rounds children were already awakening to the cheers of their families.

A person with Type 1 diabetes usually has a rapid onset of symptoms that include hunger, excessive thirst and urination, and rapid weight loss. Because the main function of glucose is to provide energy for the body, when insulin is no longer present there is no message sent to cells to take up glucose from the blood. Instead, cells use fat and proteins to make energy, resulting in weight loss. If Type 1 diabetes goes untreated individuals with the disease will develop a life-threatening condition called ketoacidosis. This condition occurs when the body uses fats and not glucose to make energy, resulting in a build-up of ketone bodies in the blood. It is a severe form of ketosis with symptoms of vomiting, dehydration, rapid breathing, and confusion and eventually coma and death. Upon insulin injection these severe symptoms are treated and death is avoided. Unfortunately, while insulin injection prevents death, it is not considered a cure. People who have this disease must adhere to a strict diet to prevent the development of serious complications. Type 1 diabetics are advised to consume a diet low in the types of carbohydrates that rapidly spike glucose levels (high-GI foods), to count the carbohydrates they eat, to consume healthy-carbohydrate foods, and to eat small meals frequently. These guidelines are aimed at preventing large fluctuations in blood glucose. Frequent exercise also helps manage blood-glucose levels. Type 1 diabetes accounts for between 5 and 10 percent of diabetes cases.

Type 2 Diabetes

The other 90 to 95 percent of diabetes cases are Type 2 diabetes. Type 2 diabetes is defined as a metabolic disease of insulin insufficiency, but it is also caused by muscle, liver, and fat cells no longer responding to the insulin in the body (Figure 3.5.1). In brief, cells in the body have become resistant to insulin and no longer receive the full physiological message of insulin to take up glucose from the blood. Thus, similar to patients with Type 1 diabetes, those with Type 2 diabetes also have high blood-glucose levels.

For Type 2 diabetics, the onset of symptoms is more gradual and less noticeable than for Type 1 diabetics. The symptoms are increased thirst and urination, unexplained weight loss, and hunger. The first stage of Type 2 diabetes is characterized by high glucose and insulin levels. This is because the insulin-secreting cells in the pancreas attempt to compensate for insulin resistance by making more insulin. In the second stage of Type 2 diabetes, the insulin-secreting cells in the pancreas become exhausted and die. At this point, Type 2 diabetics also have to be treated with insulin injections. Healthcare providers is to prevent the second stage from happening. As with Type 1 diabetes, chronically high-glucose levels cause big detriments to health over time, so another goal for patients with Type 2 diabetes is to properly manage their blood-glucose levels. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.

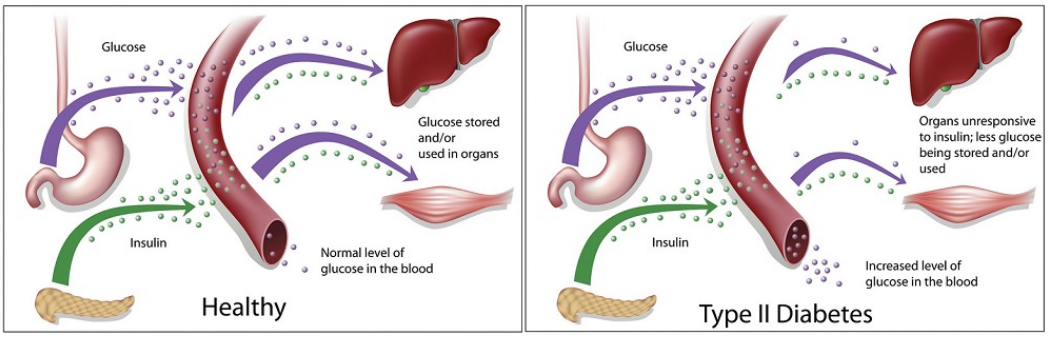


Figure 3.5.1: Type 2 diabetes is a metabolic disease characterized by high blood-glucose levels. © Shutterstock

The Centers for Disease Control Prevention (CDC) estimates that as of 2010, 25.8 million Americans have diabetes, which is 8.3 percent of the population. Centers for Disease Control and Prevention. “Diabetes Research and Statistics.” Accessed September 30, 2011. www.cdc.gov/diabetes/consumer/research.htm. In 2007 the cost of diabetes to the United States was estimated at $174 billion.Centers for Disease Control and Prevention. “CDC Statements on Diabetes Issues.” Accessed September 30, 2011. www.cdc.gov/diabetes/news/docs/dpp.htm. The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity in this country. Genetics, environment, nutrition, and lifestyle all play a role in determining a person’s risk for Type 2 diabetes. We have the power to change some of the determinants of disease, but not others. The Diabetes Prevention Trial that studied lifestyle and drug interventions in more than three thousand participants who were at high risk for Type 2 diabetes found that intensive lifestyle intervention reduced the chances of getting Type 2 diabetes by 58 %. Knowler, W. C. et al. “Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin.” N Engl J Med 346, no. 6 (2002): 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512.

Video 3.5.1: Do You Have High Blood Sugar?

A more in-depth view of blood sugar and your health.



Having more than one risk factor for Type 2 diabetes substantially increases a person’s chances for developing the disease. Metabolic syndrome refers to a medical condition in which people have three or more risk factors for Type 2 diabetes and cardiovascular disease (Figure 3.5.2). According to the International Diabetes Federation (IDF) people are diagnosed with this syndrome if they have central (abdominal) obesity and any two of the following health parameters: triglycerides greater than 150 mg/dL; high density lipoproteins (HDL) lower than 40 mg/dL; systolic blood pressure above 100 mmHg, or diastolic above 85 mmHg; fasting blood-glucose levels greater than 100 mg/dL.International Diabetes Federation. “The IDF Consensus Worldwide Definition of the Metabolic Syndrome.” Accessed September 30, 2011. www.idf.org/webdata/docs/IDF_Meta_def_final.pdf.

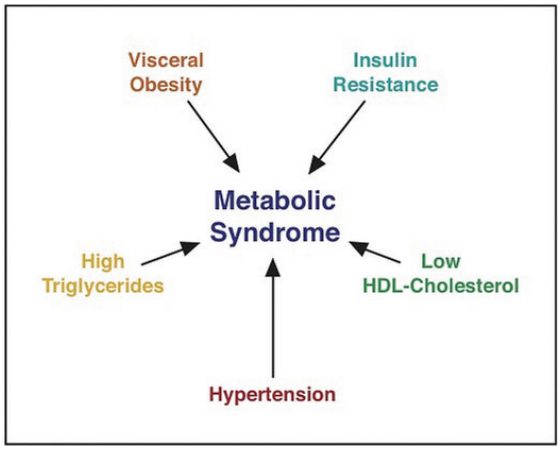


Figure 3.5.2: *Metabolic Syndrome: A Combination of Risk Factors Increasing the Chances for Chronic Disease*

The IDF estimates that between 20 and 25 percent of adults worldwide have metabolic syndrome. Studies vary, but people with metabolic syndrome have between a 9 and 30 times greater chance of developing Type 2 diabetes than those who do not have the syndrome.International Diabetes Federation. "The IDF Consensus Worldwide Definition of the Metabolic Syndrome." Accessed September 30, 2011. www.idf.org/webdata/docs/IDF_Meta_def_final.pdf.



Figure 3.5.3: Overview of the most significant possible symptoms of diabetes. (Public domain; Mikael Häggström)

Gestational Diabetes

During pregnancy, some women develop gestational diabetes. Gestational diabetes is characterized by high blood-glucose levels and insulin resistance. The exact cause is not known but does involve the effects of pregnancy hormones on how cells respond to insulin (like Type II diabetes). Gestational diabetes can cause pregnancy complications and it is common practice for healthcare practitioners to screen pregnant women for this metabolic disorder. The disorder normally ceases when the pregnancy is over, but the National Diabetes Information Clearing House notes that women who had gestational diabetes have between a 40 and 60 percent likelihood of developing Type 2 diabetes within the next ten years. National Diabetes Information Clearing House. "Diabetes Overview." Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/. Gestational diabetes not only affects the health of a pregnant woman but also is associated with an increased risk of obesity and Type 2 diabetes in her child.

Prediabetes

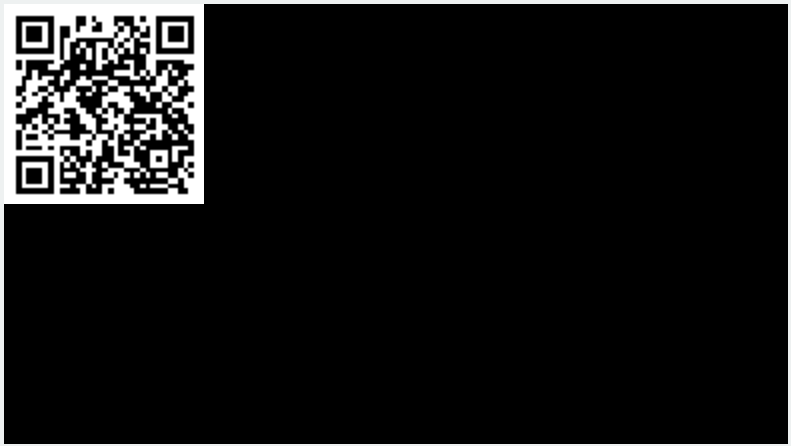
As the term infers, prediabetes is a metabolic condition in which people have moderately high glucose levels, but do not meet the criteria for diagnosis as a diabetic. Over seventy-nine million Americans are prediabetic and at increased risk for Type 2 diabetes and cardiovascular disease. National Diabetes Information Clearing House. “Diabetes Overview.” Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/. The National Diabetes Information Clearing House reports that 35 percent of adults aged twenty and older, and 50 percent of those over the age of sixty-five have prediabetes.National Diabetes Information Clearing House. “Diabetes Overview.” Accessed September 30, 2011. diabetes.niddk.nih.gov/dm/pubs/overview/.

Long-Term Health Consequences of Diabetes

The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood accompanied by other metabolic abnormalities such as high blood-lipid levels. People with diabetes are between two and four times more likely to die from cardiovascular disease. Diabetes is the number one cause of new cases of blindness, lower-limb amputations, and kidney failure. Many people with diabetes develop peripheral neuropathy, characterized by muscle weakness, loss of feeling and pain in the lower extremities. More recently, there is scientific evidence to suggest people with diabetes are also at increased risk for Alzheimer’s disease.

Video 3.5.2: Diabetes and Associated Complications

Watch this video to learn more about the whole-body complications associated with diabetes.



Diabetes Treatment

Keeping blood-glucose levels in the target range (70–130 mg/dL before a meal) requires careful monitoring of blood-glucose levels with a blood-glucose meter, strict adherence to a healthy diet, and increased physical activity. Type 1 diabetics begin insulin injections as soon as they are diagnosed. Type 2 diabetics may require oral medications and insulin injections to maintain blood-glucose levels in the target range. The symptoms of high blood glucose, also called hyperglycemia, are difficult to recognize, diminish in the course of diabetes, and are mostly not apparent until levels become very high. The symptoms are increased thirst and frequent urination. Having too low blood glucose levels, known as hypoglycemia, is also detrimental to health. Hypoglycemia is more common in Type 1 diabetics and is most often caused by injecting too much insulin or injecting it at the wrong time. The symptoms of hypoglycemia are more acute including shakiness, sweating, nausea, hunger, clamminess, fatigue, confusion, irritability, stupor, seizures, and coma. Hypoglycemia can be rapidly and simply treated by eating foods containing about ten to twenty grams of fast-releasing carbohydrates. If symptoms are severe a person is either treated by emergency care providers with an intravenous solution of glucose or given an injection of glucagon, which mobilizes glucose from glycogen in the liver. Some people who are not diabetic may experience reactive hypoglycemia. This is a condition in which people are sensitive to the intake of sugars, refined starches, and high GI foods. Individuals with reactive hypoglycemia have some symptoms of hypoglycemia. Symptoms are caused by a higher than normal increase in blood-insulin levels. This rapidly decreases blood-glucose levels to a level below what is required for proper brain function.



Insulin Syringe and Pen. (CC-SA-BY-3.0; BruceBlaus)

The major determinants of Type 2 diabetes that can be changed are overnutrition and a sedentary lifestyle. Therefore, reversing or improving these factors by lifestyle interventions markedly improve the overall health of Type 2 diabetics and lower blood-glucose levels. In fact, it has been shown that when people are overweight, losing as little as nine pounds (four kilograms) decreases blood-glucose levels in Type 2 diabetics. The Diabetes Prevention Trial demonstrated that by adhering to a diet containing between 1,200 and 1,800 kilocalories per day with a dietary fat intake goal of less than 25 percent and increasing physical activity to at least 150 minutes per week, people at high risk for Type 2 diabetes achieved a weight loss of 7 percent and significantly decreased their chances of developing Type 2 diabetes.Knowler, W. C. et al. “Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin.” N Engl J Med 346, no. 6 (2002): 393–403. http://www.nejm.org/doi/full/10.1056/NEJMoa012512.

The American Diabetes Association (ADA) has a website that provides information and tips for helping diabetics answer the question, “What Can I Eat” (see Note 4.34). In regard to carbohydrates, the ADA recommends diabetics keep track of the carbohydrates they eat and set a limit. These dietary practices will help keep blood-glucose levels in the target range.

Interactive 3.5.1

The ADA has a website containing great information and tips on how to eat a healthy diet that helps keep blood-glucose levels in the target range. Visit it to learn more about how to prevent serious complications of this disease.

http://www.diabetes.org/food-and-fitness/food/what-can-i-eat/?utm_source=WWW&utm_medium=DropDownFF&utm_content=WhatCanIEat&utm_campaign=CON

An unfortunate problem is that most diabetics do not adhere to the lifestyle interventions long-term. This is partly because of individual disinclination but is also because health insurance companies do not provide continued financial support for dietary guidance and because primary care physicians do not prescribe dietary guidance from a dietitian. This shifts the way diabetes is treated away from lifestyle intervention toward medications, as the goal still remains to manage blood-glucose levels. Numerous oral medications are available on the market and are often prescribed to Type 2 diabetics in combination.

Reactive (postprandial) Hypoglycemia

We have been discussing diabetes which is a disease characterized by high blood glucose. Below normal levels of blood glucose are dangerous too. Reactive hypoglycemia can occur 2-5 hours after eating and is characterized by fatigue, weakness, dizziness, irritability, tachycardia, anxiety, sweating, trembling, hunger and/or headaches. Treatment is small, frequent meals and reduced intake of carbohydrates.

Key Takeaways

- Diabetes is a disease of insulin deficiency and glucose over sufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person’s risk for developing diabetes.
- Type 1 diabetes was once a death sentence, but now can be treated with insulin injections. However, insulin injections do not cure the disease, and diabetics can suffer many disease complications. Diabetes complications can be relieved by strictly managing blood-glucose levels, adhering to a healthy diet, and increasing physical activity.
- The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.

- The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood and other metabolic abnormalities such as high blood-lipid levels.

Discussion Starters

1. If you owned a grocery store what are some practices you could introduce to combat the epidemic of Type 2 diabetes in this country?
2. What are some options for you to intervene in your lifestyle and decrease your risk for Type 2 diabetes?

3.5: Looking Closely at Diabetes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3.6: Health Consequences and Benefits of High-Carbohydrate Diets

Learning Objectives

- Identify the health benefits of eating a diet rich in whole grains.

Can America blame its obesity epidemic on the higher consumption of added sugars and refined grains? This is a hotly debated topic by both the scientific community and the general public. In this section, we will give a brief overview of the scientific evidence.

Added Sugars

The Food and Nutrition Board of the Institute of Medicine (IOM) defines added sugars as "sugars and syrups that are added to foods during processing or preparation." The IOM goes on to state, "Major sources of added sugars include soft drinks, sports drinks, cakes, cookies, pies, fruitades, fruit punch, dairy desserts, and candy." Processed foods, even microwaveable dinners, also contain added sugars. Added sugars do not include sugars that occur naturally in whole foods (such as an apple), but do include natural sugars such as brown sugar, corn syrup, dextrose, fructose, fruit juice concentrates, maple syrup, sucrose, and raw sugar that are then added to create other foods (such as cookies).

Currently, nutrition labels do not distinguish between added and naturally occurring sugars and give only the total sugar content, making it difficult for consumers to determine their consumption of added sugars. Results from a survey of forty-two thousand Americans reports that in 2008 the average intake of added sugars is 15 percent of total calories, a drop from 18 percent of total calories in 2000.Welsh J. A. et al. "Consumption of Added Sugars Is Decreasing in the United States." *Am J Clin Nutr* 94, no. 3 (2011): 726–34. http://www.ncbi.nlm.nih.gov/pubmed/21753067. This is still above the recommended intake of less than 10 percent of total calories. The US Department of Agriculture (USDA) reports that sugar consumption in the American diet in 2008 was, on average, 28 teaspoons per day (Figure3.6.1).

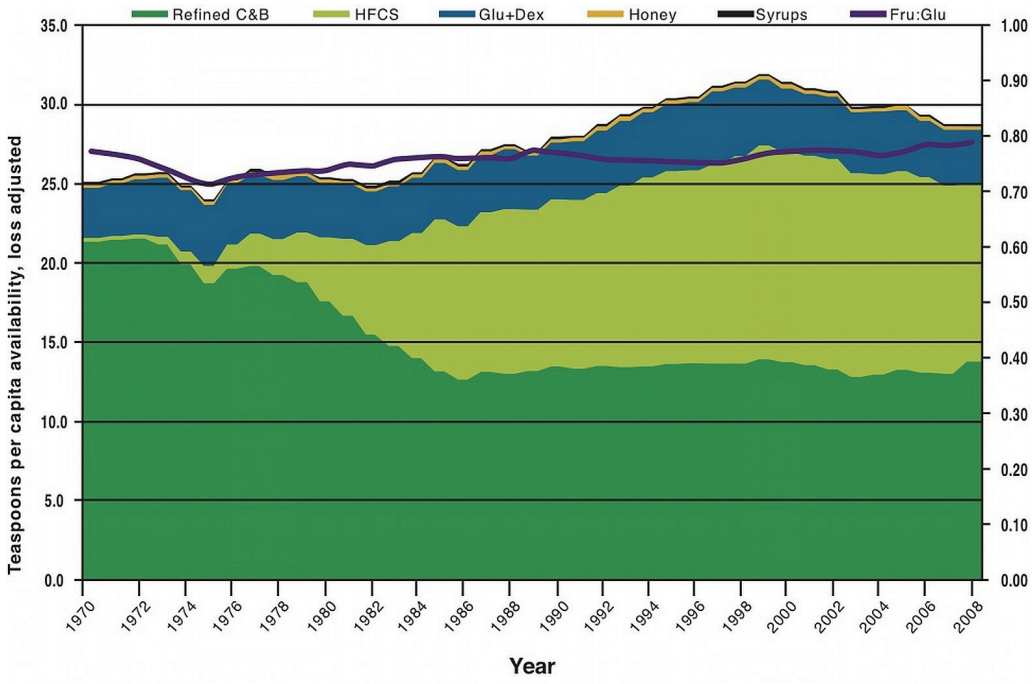


Figure 3.6.1: *Sugar Consumption (in Teaspoons) from Various Sources*

Obesity, Diabetes, and Heart Disease and Their Hypothesized Link to Excessive Sugar and Refined Carbohydrate Consumption

- To understand the magnitude of the health problem in the United States consider this—in the United States approximately 130 million adults are overweight, and 30 percent of them are considered obese. The obesity epidemic has reached young adults and children and will markedly affect the prevalence of serious health consequences in adulthood. Health consequences linked to being

overweight or obese include Type 2 diabetes, cardiovascular disease, arthritis, depression, and some cancers. An infatuation with sugary foods and refined grains likely contributes to the epidemic proportion of people who are overweight or obese in this country, but so do the consumption of high-calorie foods that contain too much saturated fat and the sedentary lifestyle of most Americans. There is much disagreement over whether high-carbohydrate diets increase weight-gain and disease risk, especially when calories are not significantly higher between compared diets. Many scientific studies demonstrate positive correlations between diets high in added sugars with weight gain and disease risk, but some others do not show a significant relationship. In regard to refined grains, there are no studies that show consumption of refined grains increases weight gain or disease risk. What is clear, however, is that getting more of your carbohydrates from dietary sources containing whole grains instead of refined grains stimulates weight loss and reduces disease risk.

A major source of added sugars in the American diet is soft drinks. There is consistent scientific evidence that consuming sugary soft drinks increases weight gain and disease risk. An analysis of over thirty studies in the *American Journal of Clinical Nutrition* concluded that there is much evidence to indicate higher consumption of sugar-sweetened beverages is linked with weight gain and obesity.Malik, V. S., M. B. Schulze, and F. B. Hu. "Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review." *Am J Clin Nutr* 84, no. 2 (2006): 274–88. http://www.ajcn.org/content/84/2/274.long. A study at the Harvard School of Public Health linked the consumption of sugary soft drinks to an increased risk for heart disease.Harvard School of Public Health. "Public Health Takes Aim at Sugar and Salt." Accessed September 30, 2011. www.hsph.harvard.edu/news/hphr/fall-2009/sugar-and-salt.html. While the sugar and refined grains and weight debate rages on, the results of all of these studies has led some public health organizations like the American Heart Association (AHA) to recommend even a lower intake of sugar per day (fewer than 9 teaspoons per day for men and fewer than 6 teaspoons for women) than what used to be deemed acceptable. After its 2010 scientific conference on added sugars, the AHA made the following related dietary recommendations:

- First, know the number of total calories you should eat each day.
- Consume an overall healthy diet and get the most nutrients for the calories, using foods high in added sugars as discretionary calories (those left over after getting all recommended nutrients subtracted from the calories used).
- Lower sugar intake, especially when the sugars in foods, such as in sugary drinks, candies, cakes, and cookies, are not tied to positive nutrients.
- Focus on calories in certain food categories such as beverages and confections, and encourage consumption of positive nutrients and foods such as cereals and low-fat or fat-free dairy products.Van Horn, L. et al. "Added Sugars and Health." Research reviewed at the AHA Added Sugars Conference, 2010. *Circulation* 122 (2010): 2470–90. doi: 10.1161/CIR.0b013e3181ffdcb0.
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The Most Notorious Sugar

Before high-fructose corn syrup (HCFS) was marketed as the best food and beverage sweetener, sucrose (table sugar) was the number-one sweetener in America. (Recall that sucrose, or table sugar, is a disaccharide consisting of one glucose unit and one fructose unit.) HFCS also contains the simple sugars fructose and glucose, but with fructose at a slightly higher concentration. In the production of HFCS, corn starch is broken down to glucose and fructose, and some of the glucose is then converted to fructose. Fructose is sweeter than glucose; hence many food manufacturers choose to sweeten foods with HFCS. HFCS is used as a sweetener for carbonated beverages, condiments, cereals, and a great variety of other processed foods.

Some scientists, public health personnel, and healthcare providers believe that fructose is the cause of the obesity epidemic and its associated health consequences. The majority of their evidence stems from the observation that since the early 1970s the number of overweight or obese Americans has dramatically increased and so has the consumption of foods containing HFCS. However, as discussed, so has the consumption of added sugars in general. Animal studies that fuel the fructose opponents show fructose is not used to produce energy in the body; instead, it is mostly converted to fat in the liver—potentially contributing to insulin resistance and the development of Type 2 diabetes. Additionally, fructose does not stimulate the release of certain appetite-suppressing hormones, like insulin, as glucose does. Thus, a diet high in fructose could potentially stimulate fat deposition and weight gain.

In human studies, excessive fructose intake has sometimes been associated with weight gain, but results are inconsistent. Moderate fructose intake is not associated with weight gain at all. Moreover, other studies show that some fructose in the diet actually improves glucose metabolism especially in people with Type 2 diabetes.Elliott, S. S. et al. "Fructose, Weight Gain, and the Insulin Resistance Syndrome." *Am J Clin Nutr* 76, no. 5 (2002): 911–22. http://www.ajcn.org/content/76/5/911.full. In fact, people with diabetes were once advised to use fructose as an alternative sweetener to table sugar. Overall, there is no good evidence that moderate fructose consumption contributes to weight gain and chronic disease. At this time conclusive evidence is not available on

whether fructose is any worse than any other added sugar in increasing the risk for obesity, Type 2 diabetes, and cardiovascular disease.

Interactive 3.6.1

The USDA is in the process of developing a database on the added sugars in many different foods and has made the information accessible. You might be frightened by what you discover when perusing it. For instance, one 6-ounce container (170 grams) of flavored yogurt contains 20 grams (5 teaspoons) of added sugars.

www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/Add_Sug/addsug01.pdf

Oral Disease

Oral health refers not only to healthy teeth and gums, but also to the health of all the supporting tissues in the mouth such as ligaments, nerves, jawbone, chewing muscles, and salivary glands. Over ten years ago the Surgeon General produced its first report dedicated to oral health, stating that oral health and health, in general, are not separate entities. Surgeon General. "National Call to Action to Promote Oral Health." Accessed September 30, 2011. ttp://www.surgeongeneral.gov/library...ltoaction.html. Instead, oral health is an integral part of overall health and well-being. Soft drinks, sports drinks, candies, desserts, and fruit juices are the main sources of "fermentable sugars" in the American diet. (Fermentable sugars are those that are easily metabolized by bacteria in a process known as fermentation. Glucose, fructose, and maltose are three examples.) Bacteria that inhabit the mouth metabolize fermentable sugars and starches in refined grains to acids that erode tooth enamel and deeper bone tissues. The acid creates holes (cavities) in the teeth that can be extremely painful (Figure 3.6.2). Gums are also damaged by bacteria produced by acids, leading to gingivitis (characterized by inflamed and bleeding gums). Saliva is actually a natural mouthwash that neutralizes the acids and aids in building up teeth that have been damaged.



Figure 3.6.2: *Gingivitis. One way to prevent gingivitis and subsequent tooth decay is to lower consumption of sugary drinks.Gingivitis before (top) and after (bottom) a thorough mechanical debridement of the teeth. (Public domain).*

According to Healthy People 2010, 23 percent of US children have cavities by the age of four, and by second grade, one-half of all children in this country have at least one cavity. Continuing MCH Education in Oral Health. "Oral Health and Health Care." Accessed September 30, 2011. http://ccnmtl.columbia.edu/projects/otm/index.html. Cavities are an epidemic health problem in the United States and are associated with poor diet, but other contributors include poor dental hygiene and the inaccessibility to regular oral health care. A review in *Academic Pediatrics* reports that "frequent consumption of fast-releasing carbohydrates, primarily in the form of dietary sugars, is significantly associated with increased dental caries risk."Mobley C., PhD, et al. "The Contribution of Dietary Factors to Dental Caries and Disparities in Caries." Acad Pediatr 9, no. 6 (2009): 410–14. doi: 10.1016/j.acap.2009.09.008. In regards to sugary soft drinks, the American Dental Association says that drinking sugary soft drinks increases the risk of decay formation (American Dental Association. "Diet and Oral Health." Accessed September 30, 2011. www.ada.org/2984.aspx#eatoothdecay).

Interactive 3.6.2

The Harvard School of Public Health *Nutrition Source* has developed a guide called "How Sweet Is It?" that notes the calories and sugar contents of many popular beverages. Visit the site to determine drinks that are better for your oral and overall health.

www.hsph.harvard.edu/nutritionsource/files/how-sweet-is-it-color.pdf

Tools for Change

Save your teeth and gums and choose to drink a beverage that does not contain excess added sugars. An idea: brew some raspberry tea, add some sparkling mineral water, a raspberry or two, some ice, and a mint leaf. Then sit back and refresh.

Do Low-Carbohydrate Diets Affect Health?

Since the early 1990s, marketers of low-carbohydrate diets have bombarded us with the idea that eating fewer carbohydrates promotes weight loss and that these diets are superior to others in their effects on weight loss and overall health. The most famous of these low-carbohydrate diets is the Atkin's diet. Others include the "South Beach" diet, the "Zone" diet, and the "Earth" diet. Despite the claims these diets make, there is little scientific evidence to support that low-carbohydrate diets are significantly better than other diets in promoting long-term weight loss. A study in *The Nutritional Journal* concluded that all diets, (independent of carbohydrate, fat, and protein content) that incorporated an exercise regimen significantly decreased weight and waist circumference in obese women (Kerksick, C. M. et al. "Changes in Weight Loss, Body Composition, and Cardiovascular Disease Risk after Altering Macronutrient Distributions During a Regular Exercise Program in Obese Women." *J Nutr* 9, no. 59 (2010). doi: 10.1186/1475-2891-9-59). Some studies do provide evidence that in comparison to other diets, low-carbohydrate diets improve insulin levels and other risk factors for Type 2 diabetes and cardiovascular disease. The overall scientific consensus is that consuming fewer calories in a balanced diet will promote health and stimulate weight loss, with significantly better results achieved when combined with regular exercise.

Health Benefits of Whole Grains in the Diet

While excessive consumption of fast-releasing carbohydrates is potentially bad for your health, consuming more slow-releasing carbohydrates is extremely beneficial to health. There is a wealth of scientific evidence supporting that replacing refined grains with whole grains decreases the risk for obesity, Type 2 diabetes, and cardiovascular disease. Whole grains are great dietary sources of fiber, vitamins, minerals, healthy fats, and a vast amount of beneficial plant chemicals, all of which contribute to the effects of whole grains on health. Americans typically do not consume the recommended amount of whole grains, which is 50 percent or more of grains from whole grains (Figure 3.6.3).

Diets high in whole grains have repeatedly been shown to decrease weight. A large group of studies all support that consuming more than two servings of whole grains per day reduces one's chances of getting Type 2 diabetes by 21 percent (de Munter, J. S. L. et al. "Whole Grain, Bran, and Germ Intake and Risk of Type 2 Diabetes: A Prospective Cohort Study and Systematic Review." PLoS Medicine, no. 8 (2007): e261. doi: 10.1371/journal.med.0040261). The Nurses' Health Study found that women who consumed two to three servings of whole grain products daily were 30 percent less likely to have a heart attack (Liu, S. et al. "Whole-Grain Consumption and Risk of Coronary Heart Disease: Results from the Nurses' Health Study." *Am J Clin Nutr* 70, no. 3 (1999): 412–19. http://www.ajcn.org/content/70/3/412.long). The AHA makes the following statements on whole grains:

- "Dietary fiber from whole grains, as part of an overall healthy diet, helps reduce blood cholesterol levels and may lower risk of heart disease."
- "Fiber-containing foods, such as whole grains, help provide a feeling of fullness with fewer calories and may help with weight management."American Heart Association ("Whole Grains and Fiber." Accessed September 30, 2011. http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Whole-Grains-and-Fiber_UCM_303249_Article.jsp).

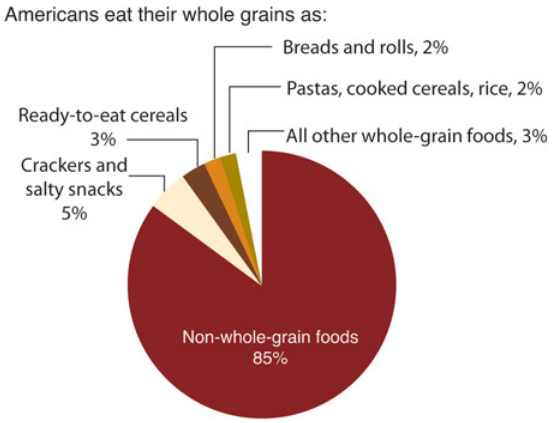


Figure 3.6.3: *Grain Consumption Statistics in America. Source: Economic Research Service. http://www.ers.usda.gov/data-products/commodity-consumption-by-population-characteristics/documentation.aspx.*

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Colon Health

A substantial health benefit of whole grain foods is that fiber actively supports digestion and optimizes colon health. (This can be more specifically attributed to the insoluble fiber content of whole grains.) There is good evidence supporting that insoluble fiber prevents the irritating problem of constipation and the development of diverticulosis and diverticulitis. Diverticulosis is a benign condition characterized by out-pocketings of the colon. Diverticulitis occurs when the out-pocketings in the lining of the colon become inflamed. Interestingly, diverticulitis did not make its medical debut until the early 1900s, and in 1971 was defined as a deficiency of whole-grain fiber. According to the National Digestive Diseases Information Clearinghouse, 10 percent of Americans over the age of forty have diverticulosis, and 50 percent of people over the age of sixty have the disorder.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. "Diverticulosis and Diverticulitis." *NIH Publication No. 08-1163* (July 2008). digestive.niddk.nih.gov/ddiseases/pubs/diverticulosis/. Ten to 25 percent of people who have diverticulosis go on to develop diverticulitis.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. "Diverticulosis and Diverticulitis." *NIH Publication No. 08-1163* (July 2008). Symptoms include lower abdominal pain, nausea, and alternating between constipation and diarrhea.

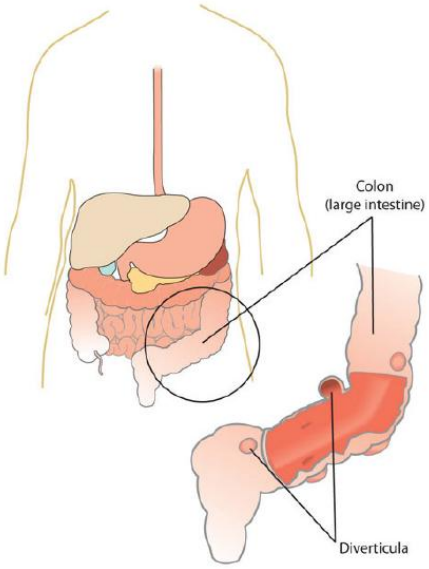


Figure 3.6.4: *Diverticulitis: A Disease of Fiber Deficiency*

The chances of developing diverticulosis can be reduced with fiber intake because of what the breakdown products of the fiber do for the colon. The bacterial breakdown of fiber in the large intestine releases short-chain fatty acids. These molecules have been found to nourish colonic cells, inhibit colonic inflammation, and stimulate the immune system (thereby providing protection of the colon from harmful substances). Additionally, the bacterial indigestible fiber, mostly insoluble, increases stool bulk and softness increasing transit time in the large intestine and facilitating feces elimination. One phenomenon of consuming foods high in fiber is increased gas, since the byproducts of bacterial digestion of fiber are gases.

Some studies have found a link between high dietary-fiber intake and a decreased risk for colon cancer. However an analysis of several studies, published in the *Journal of the American Medical Association* in 2005, did not find that dietary-fiber intake was associated with a reduction in colon cancer risk.Park, Y. et al. "Dietary Fiber Intake and Risk of Colorectal Cancer." *JAMA* 294, no. 22 (2005): 2849–57. doi: 10.1001/jama.294.22.2849. There is some evidence that specific fiber types (such as inulin) may protect against colon cancer, but more studies are needed to conclusively determine how certain fiber types (and at what dose) inhibit colon cancer development.

Key Takeaways

- Whole grain dietary sources stimulate weight loss and reduce disease risk. Excessive high fructose consumption has been shown to cause weight gain. A primary source of added sugars in the American diet is sugary soft drinks.
- While excessive consumption of some fast-releasing carbohydrates and refined grains is potentially bad for your health, consuming whole grains made up of nutrient-dense slow-releasing carbohydrates is extremely beneficial to health.

Discussion Starters

1. Have a debate in your classroom on the USDA restriction on the sale of carbonated beverages in schools. Find out more information about this topic by reading "Soft Drinks and School-Age Children: Trends, Effects, Solutions," developed by the North Carolina School Nutrition Action Committee.

   nepc.colorado.edu/files/CERU-0203-41-OWI.pdf

2. Learn about the "Australian Paradox:" How decreased sugar consumption paralleled increased rates of overweight and obese people. Read the study and have a classroom debate over the weight of evidence that supports that diets high in added sugars actually increase weight gain.

   http://www.mdpi.com/2072-6643/3/4/491/pdf

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3.7: Carbohydrates and Personal Diet Choices

Learning Objectives

- Define the Acceptable Macronutrient Distribution Range for carbohydrates, the Adequate Intake for fiber, and recommended intake of added sugars.
- List five foods that are good sources of slow-releasing carbohydrates.
- Identify three to five foods high in fiber and carbohydrates from whole, unrefined sources.

In this chapter, you learned what carbohydrates are, the different types of carbohydrates in your diet and that excess consumption of some types of carbohydrates cause disease while others decrease disease risk. Now that we know the benefits of eating the right carbohydrate, we will examine exactly how much should be eaten to promote health and prevent disease.

How Many Carbohydrates Does a Person Need?

The Food and Nutrition Board of IOM has set the Recommended Dietary Allowance (RDA) of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates is between 45 and 65 percent. This means that on a 2,000 kilocalorie diet, a person should consume between 225 and 325 grams of carbohydrates each day. According to the IOM, not more than 25 percent of total calories consumed should come from added sugars. The World Health Organization and the AHA recommend much lower intakes of added sugars—10 percent or less of total calories consumed. The IOM has also set Adequate Intakes for dietary fiber, which are 38 and 25 grams for men and women, respectively. The recommendations for dietary fiber are based on the intake levels known to prevent heart disease.

Table 3.7.1: Dietary Reference Intakes for Carbohydrates and Fiber

Carbohydrate Type	RDA (g/day)	AMDR (% calories)
Total Carbohydrates	130	45–65
Added Sugars		< 25
Fiber	38 (men),* 25 (women)*	
* denotes Adequate Intake		

When Carbohydrate Intake is Inadequate

Inadequate intake of carbohydrates lowers blood glucose. To maintain blood glucose, the liver breaks down glycogen to release glucose, and liver glycogen stores can become depleted. Also, certain amino acids are released from muscle protein and used to make glucose. This process is called catabolism. Finally, fat is mobilized from fat stores, and the released fatty acids are converted to ketones in the liver and used as an energy source. This is not the body's preferred energy source.

Low Carbohydrate Diets

Some weight-loss diets, for example, Atkins, South Beach, and Sugar Busters recommend a low carbohydrate intake. Since carbohydrate is low one of the other macronutrients is excessive, usually protein. Generally, these diets are also low in calories too and this promotes weight loss, not the reduced carbohydrate content. Side effects of these diets include halitosis (bad breath), constipation fatigue, nausea, dizziness, and bone loss.

Dietary Sources of Carbohydrates

Carbohydrates are contained in all five food groups: grains, fruits, vegetables, proteins (only in some processed meats and beans), and dairy products. Fast-releasing carbohydrates are more prevalent in fruits, fruit juices, and dairy products, while slow-releasing carbohydrates are more plentiful in starchy vegetables, beans, and whole grains. Fast-releasing carbohydrates are also found in large amounts in processed foods, soft drinks, and sweets. On average, a serving of fruits, whole grains, or starches contains 15 grams of carbohydrates. A serving of dairy contains about 12 grams of carbohydrates, and a serving of vegetables contains about 5 grams of carbohydrates. Table 3.7.2 gives the specific amounts of carbohydrates, fiber, and added sugar in various foods.

Table 3.7.2: Carbohydrates in Foods (grams/serving)

Foods	Total Carbohydrates	Sugars	Fiber	Added Sugars
Apple	19 (1 medium)	19.00	4.4	0
Banana	27 (1 medium)	14.40	3.1	0
Lentils	40 (1 c.)	3.50	16.0	0
Snap beans	8.7 (1 c.)	1.60	4.0	0
Green pepper	5.5 (1 medium)	2.90	2.0	0
Corn tortilla	10.7 (1)	0.20	1.5	0
Bread, wheat bran	17.2 (1 slice)	3.50	1.4	3.4
Bread, rye	15.5 (1 slice)	1.20	1.9	1.0
Bagel (plain)	53 (1 medium)	5.30	2.3	4.8
Brownie	36 (1 square)	20.50	1.2	20.0
Oatmeal cookie	22.3 (1 oz.)	12.00	2.0	7.7
Cornflakes	23 (1 c.)	1.50	0.3	1.5
Pretzels	47 (10 twists)	1.30	1.7	0
Popcorn (homemade)	58 (100 g)	0.50	10.0	0
Skim milk	12 (1 c.)	12.00	0	0
Cream (half and half)	0.65 (1 Tbs.)	0.02	0	0
Cream substitute	1.0 (1 tsp.)	1.00	0	1.0
Cheddar cheese	1.3 (1 slice)	0.50	0	0
Yogurt (with fruit)	32.3 (6 oz.)	32.30	0	19.4
Caesar dressing	2.8 (1 Tbs.)	2.80	0	2.4

Sources: US Department of Agriculture. National Nutrient Database for Standard Reference. Last modified December 7, 2011. http://www.nal.usda.gov/fnic/foodcomp/search/, and US Department of Agriculture. "Database for the Added Sugars Content of Selected Foods." February 2006. http://www.nal.usda.gov/fnic/foodcomp/search/.

It's the Whole Nutrient Package

In choosing dietary sources of carbohydrates the best ones are those that are nutrient-dense, meaning they contain more essential nutrients per calorie of energy. In general, nutrient-dense carbohydrates are minimally processed and include whole-grain breads and cereals, low-fat dairy products, fruits, vegetables, and beans. In contrast, empty-calorie carbohydrate foods are highly processed and often contain added sugars and fats. Soft drinks, cakes, cookies, and candy are examples of empty-calorie carbohydrates. They are sometimes referred to as 'bad carbohydrates,' as they are known to cause health problems when consumed in excess.

Interactive 3.7.1

This interactive USDA tool allows you to enter the foods and serving size of what you're eating and find out the whole nutrient package.

http://www.ars.usda.gov/Services/docs.htm?docid=17032

Understanding Carbohydrates from Product Information

While nutrition facts label aids in determining the amount of carbohydrates you eat, they do not help in determining whether a food is refined or not. The ingredients list provides some help in this regard. It identifies all of the food's ingredients in order of concentration, with the most concentrated ingredient first. When choosing between two breads, pick the one that lists whole wheat (not wheat flour) as the first ingredient, and avoid those with other flour ingredients, such as white flour or corn flour. (Enriched wheat flour refers to white flour with added vitamins.) Eat less of products that list HFCS and other sugars such as sucrose, honey, dextrose, and cane sugar in the first five ingredients. If you want to eat less processed foods then, in general, stay away from products with long ingredient lists. On the front of food and beverages, the manufacturers may include claims such as "sugar-free," "reduced sugar," "high fiber," etc. The Nutrition and Labeling Act of 1990 has defined for the food industry and consumers what these labels mean (Table 4.7.3).

Table 3.7.3: Food Labels Pertaining to Carbohydrates

Label	Meaning
Sugar-free	Contains less than 0.5 grams of sugar per serving
Reduced sugar	Contains 25 percent less sugar than similar product
Less sugar	Contains 25 percent less sugar than similar product, and was not altered by processing to become so
No sugars added	No sugars added during processing
High fiber	Contains at least 20 percent of daily value of fiber in each serving
A good source of fiber	Contains between 10 and 19 percent of the daily value of fiber per serving
More fiber	Contains 10 percent or more of the daily value of fiber per serving

Source: US Food and Drug Administration. "Appendix A: Definitions of Nutrient Claims." *Guidance for Industry: A Food Labeling Guide*. September 1994. Last revised October 2009. www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

In addition, the FDA permits foods that contain whole oats (which contain soluble fiber) to make the health claim on the package that the food reduces the risk of coronary heart disease. The FDA no longer permits Cheerios to make the claim that by eating their cereal "you can lower your cholesterol four percent in six weeks."

The Bottom Line

Read the labels and ingredient lists of foods to determine your carbohydrate intake and know the types of carbohydrate you consume.

- ## Personal Choices

  Carbohydrates are in most foods so you have a great variety of choices with which to meet the carbohydrates recommendations for a healthy diet. The *2020 Dietary Guidelines* recommend eating more unrefined carbohydrates and more fiber and reducing consumption of foods that are high in added sugars. To accomplish these recommendations use some or all of the following suggestions:

  - Get more daily carbohydrate servings from whole grains by eating a whole-grain cereal for breakfast, using whole-grain bread to make a sandwich for lunch, and eating a serving of beans and/or nuts with dinner.
  - Make sure to get at least three servings (or more) of all the grains you eat as whole grains every day. A serving of whole grains is equal to one slice of whole-wheat bread, one ounce of whole-grain cereal, and one-half cup of cooked cereal, brown rice, or whole-wheat pasta.
  - Food products made with cornmeal use whole grain so choose tortillas, corn cereals, and cornbread with cornmeal listed as the first ingredient.
  - When baking, substitute whole-wheat flour or other whole-grain flour for some of the refined white flour.

- If you like bread at dinner, choose a whole-grain muffin over a Kaiser roll or baguette.
- Add beans, nuts, or seeds to salad—they add texture and taste.
- Choose whole-grain pastas and brown rice, cook al dente, and add some beans and vegetables in equal portions.
- Change it up a bit and experience the taste and satisfaction of other whole grains such as barley, quinoa, and bulgur.
- Eat snacks high in fiber, such as almonds, pistachios, raisins, and air-popped popcorn.
- Add an artichoke and green peas to your dinner plate more often.
- Calm your "sweet tooth" by eating fruits, such as berries or an apple.
- Replace sugary soft drinks with seltzer water, tea, or a small amount of 100 percent fruit juice added to water or soda water.

Key Takeaways

- The IOM has set the Recommended Dietary Allowance of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range for total carbohydrates is 45 to 65 percent.
- Carbohydrates are contained in all five food groups: grains, fruits, vegetables, meats and beans (only in some processed meats and beans), and dairy products.
- The *2020 Dietary Guidelines* recommend eating more whole grains and more fiber and reducing consumption of foods that are high in added sugars. This involves choosing carbohydrate sources that are nutrient-dense, with more essential nutrients per calorie of energy.

Discussion Starters

1. Are you getting the recommended amount of dietary fiber in your diet?
2. Visit the USDA "Database for the Added Sugars Content of Selected Foods" and find the added sugar contents of foods common in your diet. Discuss some of the "surprises" that you discover with your classmates.

   www.nal.usda.gov/fnic/foodcomp/Data/add_sug/addsug01.pdf

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3.8: The Food Industry- Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

Learning Objectives

- Discuss the usefulness (or lack thereof) of consuming foods containing sugar substitutes

In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes, including increased sweetness, viscosity, bulk, coating ability, solubility, consistency, texture, body, and browning capacity. The differences in chemical structure between the different carbohydrates confer their varied functional uses in foods. Starches, gums, and pectins are used as thickening agents in making jam, cakes, cookies, noodles, canned products, imitation cheeses, and a variety of other foods. Molecular gastronomists use slow-releasing carbohydrates, such as alginate, to give shape and texture to their fascinating food creations (Video 4.8.1). Adding fiber to foods increases bulk. Simple sugars are used not only for adding sweetness, but also to add texture, consistency, and browning. In ice cream, the combination of sucrose and corn syrup imparts sweetness as well as a glossy appearance and smooth texture. Added sugars include white, brown, and raw sugar, corn syrup, HFCS, malt and maple syrups, liquid fructose, honey, molasses, agave nectar, and crystal dextrose.

Video 3.8.1: Ferran Adrian Demonstrates Alginates

Watch this video to see how molecular gastronomist Ferran Adrian uses the polysaccharide alginate to give shape and texture to olive puree.



Due to the potential health consequences of consuming too many added sugars, sugar substitutes have replaced them in many foods and beverages. Sugar substitutes may be from natural sources or artificially made. Those that are artificially made are called artificial sweeteners and must be approved by the FDA for use in foods and beverages. The artificial sweeteners approved by the FDA are saccharin, aspartame, acesulfame potassium, neotame, and sucralose. Stevia is an example of a naturally derived sugar substitute. It comes from a plant commonly known as sugarleaf and does not require FDA approval. Sugar alcohols, such as xylitol, sorbitol, erythritol, and mannitol, are carbohydrates that occur naturally in some fruits and vegetables. However, they are industrially synthesized with yeast and other microbes for use as food additives.



Figure 3.8.1: *Pectin (a carbohydrate) is added to jam to give it its consistency. © Shutterstock*

The FDA requires that foods disclose the fact that they contain sugar alcohols, but does not require scientific testing of it. (Though many of them have undergone studies anyway.) In comparison to sucrose, artificial sweeteners are significantly sweeter (in fact, by several hundred times), but sugar alcohols are more often less sweet than sucrose (Table 3.8.1). Artificial sweeteners and Stevia are not digested or absorbed in significant amounts and therefore are not a significant source of calories in the diet. Sugar alcohols are somewhat digested and absorbed and, on average, contribute about half of the calories as sucrose (4 kilocalories/gram). These attributes make sugar substitutes attractive for many people—especially those who want to lose weight and/or better manage their blood-glucose levels.

Table 3.8.1: Sweetness Comparison of Sugar Substitutes

Sweetener	Trade Names	Times that of Sucrose
Acesulfame-K	“Sunette,” "Sweet One"	200.0
Aspartame	“NutraSweet,” “Equal”	180.0–220.0
Erythritol		1.0
Mannitol		0.5
Neotame		7,000.0–13,000.0
Saccharine	“Sweet-N-Lo," "SugarTwin"	600.0
Sorbitol		0.6
Stevia		250.0–300.0
Sucralose	“Splenda”	600.0
Xylitol		0.8

Sources: University of North Texas. “Sugar Substitutes.” Accessed November 6, 2012. dining.unt.edu/nutrition/nutrition_brochures/Sugar%20Substitutes.pdf, and Yale-New Haven Hospital. “Eat Any Sugar Alcohol Lately?” Accessed November 6, 2012. http://www.ynhh.org/about-us/sugar_alcohol.aspx.

Benefits of Sugar Substitutes

Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. Artificial sweeteners are basically nonnutrients though not all are completely calorie-free. However, because they are so intense in sweetness they are added in very small amounts to foods and beverages. Artificial sweeteners and sugar alcohols are not “fermentable sugars” and therefore they do not cause tooth decay. Chewing gum with artificial sweeteners is the only proven way that artificial sweeteners promote oral health. The American Dental Association (ADA) allows manufacturers of chewing gum to label packages with an ADA seal if they have convincing scientific evidence demonstrating their product either reduces plaque acids, cavities, gum disease, or promotes tooth remineralization.

There is limited scientific evidence that consuming products with artificial sweeteners decreases weight. In fact, some studies suggest the intense sweetness of these products increases appetite for sweet foods and may lead to increased weight gain. Also, there is very limited evidence that suggests artificial sweeteners lower blood-glucose levels. Additionally, many foods and beverages containing artificial sweeteners and sugar alcohols are still empty-calorie foods (i.e. chewing sugarless gum or drinking diet soda pop) are not going to better your blood-glucose levels or your health.

Health Concerns

The most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion. Since the introduction of sugar substitutes to the food and beverage markets, the public has expressed concern about their safety. The health concerns of sugar substitutes originally stemmed from scientific studies, which were misinterpreted by both scientists and the public.

In the early 1970s, scientific studies were published that demonstrated that high doses of saccharin caused bladder tumors in rats. This information fueled the still-ongoing debate of the health consequences of all artificial sweeteners. In actuality, the results from the early studies were completely irrelevant to humans. The large doses (2.5 percent of diet) of saccharine caused a pellet to form in the rat’s bladder. That pellet chronically irritated the bladder wall, eventually resulting in tumor development. Since this study, scientific investigation in rats, monkeys, and humans have not found any relationship between saccharin consumption and bladder cancer. In 2000, saccharin was removed from the US National Toxicology Program’s list of potential carcinogens.National Cancer Institute. “Artificial Sweeteners and Cancer.” Accessed September 30, 2011. http://www.cancer.gov/cancertopics/factsheet/Risk/artificial-sweeteners.

There have been health concerns over other artificial sweeteners, most notably aspartame (sold under the trade names of NutraSweet and Equal). The first misconception regarding aspartame was that it was linked with an increase in the incidence of brain tumors in the United States. It was subsequently discovered that the increase in brain tumors started eight years prior to the introduction of aspartame to the market. Today, aspartame is accused of causing brain damage, autism, emotional disorders, and a myriad of other disorders and diseases. Some even believe aspartame is part of a governmental conspiracy to make people dumber. The reality is there is no good scientific evidence backing any of these accusations, and that aspartame has been the most scientifically tested food additive. It is approved for use as an artificial sweetener in over ninety countries.

Aspartame is made by joining aspartic acid and phenylalanine to amino acids. When digested, it is broken down to aspartic acid, phenylalanine, and methanol. People who have the rare genetic disorder phenylketonuria (PKU) have to avoid products containing aspartame. Individuals who have PKU do not have a functional enzyme that converts phenylalanine to the amino acid tyrosine. This causes a build-up of phenylalanine and its metabolic products in the body. If PKU is not treated, the build-up of phenylalanine causes progressive brain damage and seizures. The FDA requires products that contain aspartame to state on the product label, “Phenylketonurics: Contains Phenylalanine.” For more details on sugar substitutes please refer to Table 3.8.2.

Table 3.8.2: Sweeteners

Sweeteners with Trade Name	Calories	Source/Origin	Consumer Recommendations	Controversial Issues	
Aspartame • NutraSweet • Equal	4 kcal/g	Composed of two amino acids (phenylalanine + aspartic acid) + methanol. Two hundred times sweeter than sucrose.	FDA set maximum Acceptable Daily Intakes (ADI): 50 mg/kg body weight = 16 12 oz. diet soft drinks for adults. ***Cannot be used in products requiring cooking.** People with PKU should not consume aspartame.	Children have potential to reach ADI if consuming many beverages, desserts, frozen desserts, and gums containing aspartame routinely.	Beverages, spreads.
Saccharin • Sweet ‘n’ Low	0 kcal/g	Discovered in 1878. The basic substance is benzoic sulfinide. Three hundred times sweeter than sucrose.	ADI: 5 mg/kg body weight. ***Can be used in cooking.**	1970s, high doses of saccharin associated with bladder cancer in laboratory animals. In 1977, FDA proposed banning saccharin from use in food • protest launched by consumer & interest groups • warning label listed on products about saccharin and cancer risk in animals until 2001 when studies concluded that it did not cause cancer in humans	General p and bevera Sold as S States; al pharmaceu
Acesulfame K • Sunnette • Sweet One	0 kcal/g	Discovered in 1967. Composed of an organic salt, potassium (K). The structure is very similar to saccharin. It passes through the body unchanged which means it does not provide energy. Two hundred times sweeter than sucrose.	ADI: 15 mg/kg body weight. The body cannot digest it. ***Can be used in cooking.**		Chewing g nondairy instant tea
Cyclamates • Sugar Twin (Canada only)	0 kcal/g	Thirty times sweeter than sucrose. Discovered in 1937.	No ADI available.	1949, cyclamate approved by FDA for use. Cyclamate was classified as GRAS (Generally Recognized As Safe) until 1970 when it was removed from GRAS status and banned from use in all food and beverage products within the United States on the basis of one study that indicated it caused bladder cancer in rats. Approval still pending for use in the United States since the ban. Canada and other countries use this type of sweetener.	Recommer sugar for d
Sucralose • Splenda	One Splenda packet contains 3.31 calories = 1g	First discovered in 1976. Approved for use in 1998 in the United States and in 1991 in Canada. Derived from sucrose in which three of its hydroxyl (OH) groups are replaced by chlorine (Cl−). Six hundred times sweeter than sugar.	ADI: 5 mg/kg body weight. ***Can be used in cooking.**		General pu beverages, desserts, dietary recommen sugar and

Sweeteners with Trade Name	Calories	Source/Origin	Consumer Recommendations	Controversial Issues	
Stevioside • Stevia • Sweet Leaf	N/A	Derived from stevia plant found in South America. *Stevia rebaudianan* leaves.	Classified as GRAS. Considered to be a dietary supplement and approved not as an additive, but as a dietary supplement.	Used sparingly, stevia may do little harm, but FDA could not approve the extensive use of this sweetener due to concerns regarding its effect on reproduction, cancer development, and energy metabolism.	Sold in h supplemen
Sucrose • Sugar	~4 kcal/g	Extracted from either sugar beets or sugar cane, which is then purified and crystallized.	It is illegal to sell true raw sugar in the United States because when raw it contains dirt and insect parts, as well as other byproducts. Raw sugar products sold in the United States have actually gone through more than half of the same steps in the refining process as table sugar.	Over-consumption has been linked to several health effects such as tooth decay or dental caries and contributes to increased risk for chronic diseases.	Biscuits, canes, ice preservativ
Honey	3 kcal/g	Made from sucrose. Contains nectar of flowering plants. Made by bees. Sucrose is fructose + glucose; however, honey contains more calories than sucrose because honey is denser.	*Considered safe for baking and cooking. Infants under twelve months old should not be given honey because their digestive tracts cannot handle the bacteria found in honey. Older children and adults are immune to these effects. Honey contains some harmful bacteria that can cause fatal food poisoning in infants.		Sweetener beverages beverages,
HFCS • high fructose corn syrup	Dry form: 4 kcal/g; Liquid form: 3 kcal/g	Corn is milled to produce corn starch, then the corn starch is further processed to yield corn syrup.		Controversial because it is found ubiquitously in processed food products, which could lead to over-consumption. Study results are varied regarding its role in chronic disease.	Soft drinks
Sugar Alcohols • Sorbitol • Xylitol • Mannitol	2–4 kcal/g. Not calorie free	Sugar alcohols. Sorbitol is derived from glucose.	Less likely to cause tooth decay than sucrose. Sugar alcohols have a laxative effect.	May cause diarrhea and gastrointestinal distress if consumed in large amounts.	Provide l following jellies, ch pharmaceu

Regulation

Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA. The FDA regulates artificial sweeteners along with other food additives, which number in the thousands. The FDA is responsible for determining whether a food additive presents “a reasonable certainty of no harm” to consumers when used as proposed. The FDA uses the best scientific evidence available to make the statement of no harm, but it does declare that science has its limits and that the “FDA can never be *absolutely* certain of the absence of any risk from the use of any substance.”US Food and Drug Administration. “Food Ingredients and Colors.” Accessed September 30, 2011. www.fda.gov/food/foodingredientspackaging/ucm094211.htm. The FDA additionally has established ADIs for artificial sweeteners. The ADIs are the maximum amount in milligrams per kilogram of body weight considered safe to consume daily (mg/kg bw/day) and incorporates a large safety factor. The following list contains the artificial sweeteners approved for use in foods and beverages in the United States, and their ADIs:

- **Acesulfame potassium (Sunett, Sweet One).** ADI = 15 mg/kg bw/day
- **Aspartame (Equal, NutraSweet).** ADI = 50 mg/kg bw/day
- **Neotame.** ADI = 18 mg/kg bw/day
- **Saccharin (SugarTwin, Sweet’N Low).** ADI = 5 mg/kg bw/day
- **Sucralose (Splenda).** ADI = 5 mg/kg bw/day

Carbohydrates in a Kernel

Referring back to the wheat kernel mentioned at the opening of this chapter, recall that all components of the wheat kernel are required in order to build an optimal healthy diet. The endosperm provides the carbohydrates, and the bran and germ contain the majority of protein, vitamins, minerals, and fiber. Eating foods made with whole grains provides a better nutritional punch for your health. Once whole grains are processed and refined, enrichment in only a few of these removed nutrients does not offset the gain from consuming whole-grain products. Other dietary sources of carbohydrates that maximize nutrient uptake are vegetables, fruits, beans, and low-fat dairy products. To avoid compromising your health, do not consume excessive amounts of carbohydrate foods that contain added sugars, or that are high in sodium and saturated fat. Processed foods contain all of these ingredients in an unwelcome nutrient package that negatively impacts health. Sugar substitutes provide one avenue of decreasing the intake of fast-releasing carbohydrates, but there are others. Know that consumer demand for healthy carbohydrate choices is on the rise, so in the future, you can expect decreased prices, more variety of whole-grain products, and less added sugars.

The Bottom Line

Choose more slow-releasing carbohydrates, eat more fiber, and reduce consumption of foods high in added sugars.

Key Takeaways

- In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes. The differences in chemical structure between the different carbohydrates confer their many different functional uses in foods.
- Due to the health consequences of consuming too many added sugars, sugar substitutes are widely used in many foods and beverages.
- Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. However, the most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion.
- Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA.

Discussion Starters

1. Conduct a taste test of sugar and its substitutes. What do your taste buds tell you? Do you prefer foods with sugar substitutes or the real thing?
2. Have a class discussion on the safety of aspartame. To fuel the debate, read the FDA’s report and watch the reactionary video, “Aspartame, Brain Cancer, and the FDA Approval Process.”

   www.fda.gov/Food/FoodIngredientsPackaging/FoodAdditives/ucm208580.htm

   Aspartame, Brain Cancer, and the FDA Approval Process

   (click to see video)

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3.E: Exercises

It's Your Turn

1. Learn more on glycolysis and cellular respiration by watching this video on YouTube, and describe in a short paragraph what happens in the body as it uses the process of glycolysis to fuel short bursts of activity.

   Glycolysis Cellular Respiration Overview

   (click to see video)
2. Conduct an experiment in the classroom that evaluates the sweetness and tastefulness of sugar substitutes. Try them in pure form by putting a small amount on your finger. Record the results from you and your classmates and make a sweetness and taste comparison chart.

Expand Your Knowledge

1. Design a Thanksgiving feast with at least ten items that help balance the GI of the meal.
2. Draw a flow chart that incorporates the concept of negative feedback in the regulation of blood glucose levels.
3. Visit the website of the CDC (apps.nccd.cdc.gov/DDTSTRS/default.aspx) and record the estimates of obesity, physical inactivity, and Type 2 diabetes in the county you live in. Make a list of five ways to curb the trends of obesity, physical inactivity, and Type 2 diabetes in your county.

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4: Lipids

In this chapter, we look at the types, structure, and roles of lipids, and we explain the different types of cholesterol in the blood. We also explore topics of interest such as omega-3 and omega-6 fatty acids and trans fats.

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4.1: Chapter Introduction

In the 1920s, anthropologist Vilhjalmur Stefansson lived with and studied a group of Inuit. The Inuit were fishers and hunters, primarily of sea mammals such as whales, walruses, and seals. They consumed a high-protein, high-fat diet. In fact, the Inuit consumed an average of 75 percent of their daily energy intake from fat. Patricia Gadsby, "*The Inuit Paradox," Discover*, 1 October 2004. http://discovermagazine.com/2004/oct/inuit-paradox/article_print. Stefansson's research focused on the fact that the Inuit diet had no adverse effects on either their health or his own.Lieb, C. W. "The Effects of an Exclusive Long-Continued Meat Diet." *JAMA* 87, no. 1 (1926): 25–26. doi:10.1001/jama.1926.02680010025006

Video 4.1.1: Why Omega-3 Fatty Acids Are Essential

Dr. Gerard L. Guillory reviews the benefits of omega-3 fatty acids in this video, as part of a "10 Steps to Better Health" series



These findings were supported by a later study in 1972, when the Greenland Inuit first caught the attention of Dr. H. O. Bang from Aalborg University in Denmark. He noted that although the Inuit consumed massive amounts of fatty ocean fish, which are packed with omega-3s, none of the Inuit tested showed signs of heart disease. In addition, there was significantly less evidence of joint disease and skin disease than found in Western countries. Further research led Bang and his associate, Dyerberg, to conclude that the omega-3 fatty acids (docosahexaenoic acid, or DHA, and eicosapentaenoic acid, or EPA) present in the diet offer significant health benefits:Bang, H.O. and J. Dyerberg. "Fatty Acid Composition of the Plasma Lipids in Greenland Eskimos." *Am J Clin Nutr* 28 (1975): 958–66.

- **Heart disease.** Further research supports Bang and Dyerberg's finding and shows DHA and EPA to be beneficial to heart health and human development. EPA and DHA tend to reduce blood pressure, prevent blood-clot formation (thereby reducing the risk of stroke), and protect against irregular heartbeats.
- **Inflammation and autoimmune diseases.** According to research published in the *Journal of the American College of Nutrition*, animal experiments and clinical intervention studies indicate that omega-3 fatty acids have anti-inflammatory properties.Sears, B. "Anti-Inflammatory Diets for Obesity and Diabetes." *J Am Coll Nutr* 21 (2008). The low incidence of autoimmune and inflammatory disorders such as psoriasis, asthma, and Type 1 diabetes and the complete absence of multiple sclerosis has been observed and studied in the Inuit population in Greenland.Brzezinski, A. "Review." *Gastroenterol Hepatol* 3, no. 10 (2007): 787–88. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3104160/. Subsequent studies concur with these findings and it is believed that omega-3 fats play an important role in the prevention and treatment of coronary artery disease, high blood pressure, arthritis, other inflammatory and autoimmune disorders, and cancer.Simopoulos, A. "Omega-3 Fatty Acids in Inflammation and Autoimmune Diseases." *J Am Coll Nutr* 21, no. 6 (2002): 495–505. http://www.jacn.org/content/21/6/495.full.
- **Brain health.** Omega-3 fats play an important role in maintaining mental health and are crucial for brain function. Omega-3 fatty acids may provide benefits such as expanding learning and memory capacities. Early evidence suggests that the consumption of omega-3 fats is essential for synaptic transmission in the brain. Furthermore, omega-3 fats seem to be most effective when obtained from foods rather than from supplements.

You Decide

What sources of omega-3 fatty acids would you include in your diet and why?

As you read further, you will learn the different types of fats, their essential roles in the body, and the potential health consequences and benefits of diets rich in particular lipids. You will be better equipped to decide the best way to get your nutritional punch from various fats in your diet.

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4.2: What Are Lipids?

Learning Objectives

- Explain the role of lipids in overall health.

Lipids are important fats that serve different roles in the human body. A common misconception is that fat is simply fattening. However, fat is probably the reason we are all here. Throughout history, there have been many instances when food was scarce. Our ability to store excess caloric energy as fat for future usage allowed us to continue as a species during these times of famine. So, normal fat reserves are a signal that metabolic processes are efficient and a person is healthy.

Lipids are a family of organic compounds that are mostly insoluble in water. Composed of fats and oils, lipids are molecules that yield high energy and have a chemical composition mainly of carbon, hydrogen, and oxygen. Lipids perform three primary biological functions within the body: they serve as structural components of cell membranes, function as energy storehouses, and function as important signaling molecules.

The three main types of lipids are triacylglycerols (also called triglycerides), phospholipids, and sterols. Triacylglycerols (also known as triglycerides) make up more than 95 percent of lipids in the diet and are commonly found in fried foods, vegetable oil, butter, whole milk, cheese, cream cheese, and some meats. Naturally occurring triacylglycerols are found in many foods, including avocados, olives, corn, and nuts. We commonly call the triacylglycerols in our food “fats” and “oils.” Fats are lipids that are solid at room temperature, whereas oils are liquid. As with most fats, triacylglycerols do not dissolve in water. The terms fats, oils, and triacylglycerols are discretionary and can be used interchangeably. In this chapter when we use the word fat, we are referring to triacylglycerols.

Phospholipids make up only about 2 percent of dietary lipids. They are water-soluble and are found in both plants and animals. Phospholipids are crucial for building the protective barrier, or membrane, around your body’s cells. In fact, phospholipids are synthesized in the body to form cell and organelle membranes. In blood and body fluids, phospholipids form structures in which fat is enclosed and transported throughout the bloodstream.

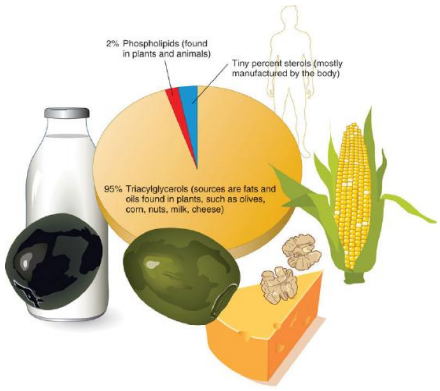


Figure 4.2.1: Types of Lipids

Sterols are the least common type of lipid. Cholesterol is perhaps the best well-known sterol. Though cholesterol has a notorious reputation, the body gets only a small amount of its cholesterol through food—the body produces most of it. Cholesterol is an important component of the cell membrane and is required for the synthesis of sex hormones, vitamin D, and bile salts.

Later in this chapter, we will examine each of these lipids in more detail and discover how their different structures function to keep your body working.

Functions of Lipids in the Body: Storing Energy

The excess energy from the food we eat is digested and incorporated into adipose tissue, or fatty tissue. Most of the energy required by the human body is provided by carbohydrates and lipids. As discussed in Chapter 3, glucose is stored in the body as glycogen. While glycogen provides a ready source of energy, lipids primarily function as an energy reserve. As you may recall, glycogen is quite bulky with heavy water content, thus the body cannot store too much for long. Alternatively, fats are packed together tightly without water and store far greater amounts of energy in a reduced space. A fat gram is densely concentrated with energy—it

contains more than double the amount of energy than a gram of carbohydrate. Energy is needed to power the muscles for all the physical work and play an average person or child engages in. For instance, the stored energy in muscles propels an athlete down the track, spurs a dancer's legs to showcase the latest fancy steps, and keeps all the moving parts of the body functioning smoothly.

Unlike other body cells that can store fat in limited supplies, fat cells are specialized for fat storage and are able to expand almost indefinitely in size. An overabundance of adipose tissue can result in undue stress on the body and can be detrimental to your health. A serious impact of excess fat is the accumulation of too much cholesterol in the arterial wall, which can thicken the walls of arteries and lead to cardiovascular disease. Thus, while some body fat is critical to our survival and good health, in large quantities it can be a deterrent to maintaining good health.

Functions of Lipids in the Body: Regulating and Signaling

Triacylglycerols control the body's internal climate, maintaining a constant temperature. Those who don't have enough fat in their bodies tend to feel cold sooner, are often fatigued and have pressure sores on their skin from fatty acid deficiency. Triacylglycerols also help the body produce and regulate hormones. For example, adipose tissue secretes the hormone leptin, which regulates appetite. In the reproductive system, fatty acids are required for proper reproductive health; women who lack proper amounts may stop menstruating and become infertile. Omega-3 and omega-6 essential fatty acids help regulate cholesterol and blood clotting and control inflammation in the joints, tissues, and bloodstream. Fats also play important functional roles in sustaining nerve impulse transmission, memory storage, and tissue structure. More specifically in the brain, lipids are focal to brain activity in structure and in function. They help form nerve cell membranes, insulate neurons, and facilitate the signaling of electrical impulses throughout the brain.



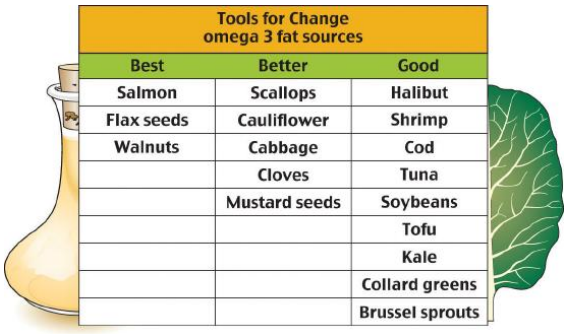
Figure 4.2.2: Lipids serve as signaling molecules; they are catalysts of electrical impulse activity within the brain. © Thinkstock

Functions of Lipids in the Body: Insulating and Protecting

Did you know that up to 30 percent of body weight is comprised of fat tissue? Some of this is made up of visceral fat or adipose tissue surrounding delicate organs. Vital organs such as the heart, kidneys, and liver are protected by visceral fat. The composition of the brain is outstandingly 60 percent fat, demonstrating the major structural role that fat serves within the body. You may be most familiar with subcutaneous fat, or fat underneath the skin. This blanket layer of tissue insulates the body from extreme temperatures and helps keep the internal climate under control. It pads our hands and buttocks and prevents friction, as these areas frequently come in contact with hard surfaces. It also gives the body the extra padding required when engaging in physically demanding activities such as ice- or roller skating, horseback riding, or snowboarding.

Functions of Lipids in the Body: Aiding Digestion and Increasing Bioavailability

The dietary fats in the foods we eat break down in our digestive systems and begin the transport of precious micronutrients. By carrying fat-soluble nutrients through the digestive process, intestinal absorption is improved. This improved absorption is also known as increased bioavailability. Fat-soluble nutrients are especially important for good health and exhibit a variety of functions. Vitamins A, D, E, and K—the fat-soluble vitamins—are mainly found in foods containing fat. Some fat-soluble vitamins (such as vitamin A) are also found in naturally fat-free foods such as green leafy vegetables, carrots, and broccoli. These vitamins are best absorbed when combined with foods containing fat. Fats also increase the bioavailability of compounds known as phytochemicals, which are plant constituents such as lycopene (found in tomatoes) and beta-carotene (found in carrots). Phytochemicals are believed to promote health and well-being. As a result, eating tomatoes with olive oil or salad dressing will facilitate lycopene absorption. Other essential nutrients, such as essential fatty acids, are constituents of the fats themselves and serve as building blocks of a cell.



Tools for Change omega 3 fat sources		
Best	Better	Good
Salmon	Scallops	Halibut
Flax seeds	Cauliflower	Shrimp
Walnuts	Cabbage	Cod
	Cloves	Tuna
	Mustard seeds	Soybeans
		Tofu
		Kale
		Collard greens
		Brussel sprouts

Figure 4.2.3: Food Sources of Fat-Soluble Vitamins

Note that removing the lipid elements from food also takes away the food's fat-soluble vitamin content. When products such as grain and dairy are processed, these essential nutrients are lost. Manufacturers replace these nutrients through a process called enrichment.

Tools for Change

Remember, fat-soluble nutrients require fat for effective absorption. For your next snack, look for foods that contain vitamins A, D, E, and K. Do these foods also contain fat that will help you absorb them? If not, think of ways to add a bit of healthy fat to aid in their absorption.

Role of Lipids in Food: High Energy Source

Fat-rich foods naturally have a high caloric density. Foods that are high in fat contain more calories than foods high in protein or carbohydrates. As a result, high-fat foods are a convenient source of energy. For example, 1 gram of fat or oil provides 9 kilocalories of energy, compared with 4 kilocalories found in 1 gram of carbohydrate or protein. Depending on the level of physical activity and on nutritional needs, fat requirements vary greatly from person to person. When energy needs are high, the body welcomes the high-caloric density of fats. For instance, infants and growing children require proper amounts of fat to support normal growth and development. If an infant or child is given a low-fat diet for an extended period, growth and development will not progress normally. Other individuals with high-energy needs are athletes, people who have physically demanding jobs, and those recuperating from illness.



Figure 4.2.4: Athletes have high-energy requirements. © Thinkstock

When the body has used all of its calories from carbohydrates (this can occur after just twenty minutes of exercise), it initiates fat usage. A professional swimmer must consume large amounts of food energy to meet the demands of swimming long distances, so eating fat-rich foods makes sense. In contrast, if a person who leads a sedentary lifestyle eats the same high-density fat foods, they will intake more fat calories than their body requires within just a few bites. Use caution—consumption of calories over and beyond energy requirements is a contributing factor to obesity.

Role of Lipids in Food: Smell and Taste

Fat contains dissolved compounds that contribute to mouth-watering aromas and flavors and increase palatability of food. Fat also adds texture to food. Baked foods are supple and moist. Frying foods locks in flavor and lessens cooking time. How long does it

take you to recall the smell of your favorite food cooking? What would a meal be without that savory aroma to delight your senses and heighten your preparedness for eating a meal?

Fat plays another valuable role in nutrition. Fat contributes to satiety, or the sensation of fullness. When fatty foods are swallowed the body responds by enabling the processes controlling digestion to retard the movement of food along the digestive tract, thus promoting an overall sense of fullness. Oftentimes before the feeling of fullness arrives, people overindulge in fat-rich foods, finding the delectable taste irresistible. Indeed, the very things that make fat-rich foods attractive also make them a hindrance to maintaining a healthful diet.

Tools for Change

While fats provide delicious smells, tastes, and textures to our foods, they also provide numerous calories. To allow your body to experience the satiety effect of the fat before you overindulge, try savoring rich foods. Eating slowly will allow you to both fully enjoy the experience and be sated with a smaller portion. Remember to take your time. Drink water in between bites or eat a lower fat food before and after a higher fat food. The lower-fat foods will provide bulk, but fewer calories.

Key Takeaways

- Lipids include triacylglycerols, phospholipids, and sterols.
- Triacylglycerols, the most common lipid, comprise most body fat and are described as fats and oils in food.
- Excess energy from food is stored as adipose tissue in the body.
- Fats are critical for maintaining body temperature, cushioning vital organs, regulating hormones, transmitting nerve impulses, and storing memory.
- Lipids transport fat-soluble nutrients and phytochemicals and promote bioavailability of these compounds.
- Fat is a convenient source of energy for people with high-energy requirements.
- Fat provides double the energy per gram than protein or carbohydrates, enhances the smell and flavor of food, and promotes satiety.

Discussion Starters

- Discuss the role of lipids in our diet and their critical functions in the body.
- Explain the importance of fats to the bioavailability of other nutrients.
- Discuss the role of fats as an energy source for the body.

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4.3: How Lipids Work

Learning Objectives

- Explain how the structure of each lipid impacts its function as it relates to health and disease.
- Compare and contrast the structure of the following types of fats: triacylglycerols (monounsaturated, polyunsaturated, omega-3, and omega-6), phospholipids, and sterols.
- Explain how the fatty acids you consume relate to the fatty-acid composition of your body fat.

Lipids are unique organic compounds, each serving key roles and performing specific functions within the body. As we discuss the various types of lipids (triacylglycerols, phospholipids, and sterols) in further detail, we will compare their structures and functions and examine their impact on human health.

Triacylglycerols Structure and Functions

Triacylglycerols are the main form of lipid found in the body and in the diet. Fatty acids and glycerol are the building blocks of triacylglycerols. Glycerol is a thick, smooth, syrupy compound that is often used in the food industry. To form a triacylglycerol, a glycerol molecule is joined by three fatty acid chains. Triacylglycerols contain varying mixtures of fatty acids.

Fatty Acids

Fatty acids determine if the compound is solid or liquid at room temperature. Fatty acids consist of a carboxylic acid (−OOH) group on one end of a carbon chain and a methyl group ($-CH_3$) on the other end. Fatty acids can differ from one another in two important ways—carbon chain length and degree of saturation.

It's All in the Chain

Fatty acids have different chain lengths and different compositions. Foods have fatty acids with chain lengths between four and twenty-four carbons and most of them contain an even number of carbon atoms. When the carbon chain length is shorter, the melting point of the fatty acid becomes lower—and the fatty acid becomes more liquid.

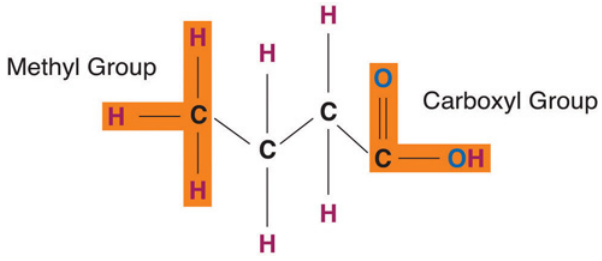


Figure 4.3.1: Structures of a Saturated, Monounsaturated, and Polyunsaturated Fat

Short-chain fatty acids (SCFAs) are 6 carbons or less in length. Medium-chain fatty acids (MCFAs) are eight to fourteen carbons in length while long chain fatty acids (LCFAS) are sixteen or more carbons.

Degrees of Saturation

Fatty acid chains are held together by carbon atoms that attach to each other and to hydrogen atoms. The term *saturation* refers to whether or not a fatty acid chain is filled (or "saturated") to capacity with hydrogen atoms. If each available carbon bond holds a hydrogen atom we call this a saturated fatty acid chain. All carbon atoms in such a fatty acid chain are bonded with single bonds. Sometimes the chain has a place where hydrogen atoms are missing. This is referred to as the point of unsaturation.

When one or more bonds between carbon atoms are a double bond (C=C), that fatty acid is called an unsaturated fatty acid, as it has one or more points of unsaturation. Any fatty acid that has only one double bond is a monounsaturated fatty acid, an example

of which is olive oil (75 percent of its fat is monounsaturated). Monounsaturated fats help regulate blood cholesterol levels, thereby reducing the risk of heart disease and stroke. A polyunsaturated fatty acid is a fatty acid with two or more double bonds or two or more points of unsaturation. Soybean oil contains high amounts of polyunsaturated fatty acids. Both monounsaturated fats and polyunsaturated fats provide nutrition that is essential for normal cell development and healthy skin.

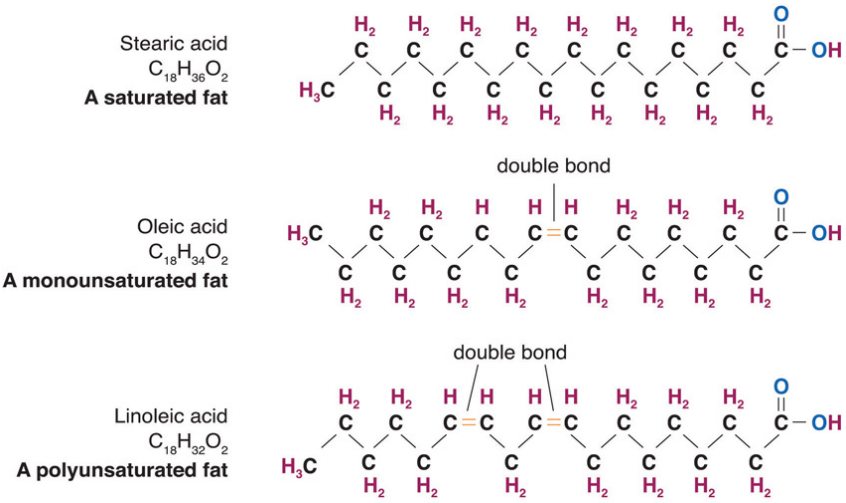


Figure 4.3.2: Chain structures of saturated fatty acids, monounsaturated, and polyunsaturated fatty acids

Foods that have a high percentage of saturated fatty acids tend to be solid at room temperature. Examples of these are fats found in chocolate (stearic acid, an eighteen-carbon saturated fatty acid is a primary component) and meat. Common saturated fatty acids are palmitic acid (16 carbon; palm kernel oil, coconut oil, and animal fat), stearic acid (18 carbon length; cocoa butter, animal fat), lauric acid (12 carbon length; coconut and palm kernel oil), and myristic acid (14 carbon length; butter fat, coconut oil).

Foods rich in unsaturated fatty acids, such as olive oil (oleic acid, an eighteen-carbon unsaturated fatty acid, is a major component) tend to be liquid at room temperature. Flaxseed oil is rich in alpha-linolenic acid, which is an unsaturated fatty acid and becomes a thin liquid at room temperature. Unsaturated fats have a lower temperature that they melt compared to saturated fats.

Knowing the connection between chain length, the degree of saturation and the state of the fatty acid (solid or liquid) is important for making food choices. If you decide to limit or redirect your intake of fat products, then choosing unsaturated fat is more beneficial than choosing a saturated fat. This choice is easy enough to make because unsaturated fats tend to be liquid at room temperature (for example, olive oil) whereas saturated fats tend to be solid at room temperature (for example, butter). Avocados are rich in unsaturated fats. Most vegetable and fish oils contain high quantities of polyunsaturated fats. Olive oil and canola oil are also rich in monounsaturated fats. Conversely, tropical oils are an exception to this rule in that they are liquid at room temperature yet high in saturated fat. Palm oil (often used in food processing) is highly saturated and has been proven to raise blood cholesterol. Shortening, margarine, and commercially prepared products (in general) report to use only vegetable-derived fats in their processing. But even so, much of the fat they use may be in the saturated and trans fat categories.

Cis or Trans Fatty Acids?

The introduction of a carbon double bond in a carbon chain, as in an unsaturated fatty acid, can result in different structures for the same fatty acid composition. When the hydrogen atoms are bonded to the same side of the carbon chain, it is called a cis fatty acid. Because the hydrogen atoms are on the same side, the carbon chain has a bent structure and melt at a lower temperature. Naturally occurring fatty acids usually have a cis configuration.

In a trans fatty acid, the hydrogen atoms are attached on opposite sides of the carbon chain. Unlike cis fatty acids, most trans fatty acids are not found naturally in foods, but are a result of a process called hydrogenation. Hydrogenation is the process of adding hydrogen to the carbon double bonds, thus making the fatty acid saturated (or less unsaturated, in the case of partial hydrogenation), the carbon chain straighter in shape, and increasing the melting point. This is how vegetable oils are converted into semisolid fats for use in the manufacturing process.

According to the ongoing Harvard Nurses Health Study, trans fatty acids have been associated with increased risk for coronary heart disease because of the way they negatively impact blood cholesterol levels.Harvard School of Public Health. “It’s Time to

End the Low-Fat Myth." Introduction to "Fats and Cholesterol: Out with the Bad, In with the Good" in *The Nutrition Source*. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/#references.

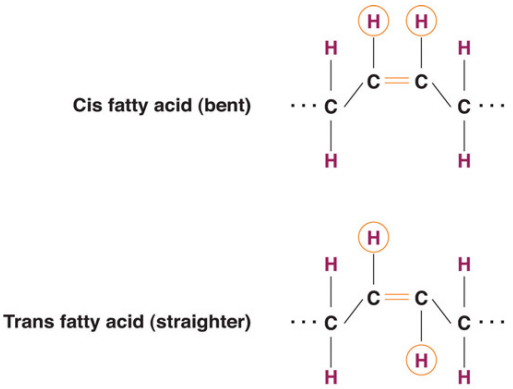


***Figure 4.3.3**: Cis and trans double bonds.*

Interestingly, some naturally occurring trans fats do not pose the same health risks as their artificially engineered counterparts. These trans fats are found in ruminant animals such as cows, sheep, and goats, resulting in trans fatty acids being present in our meat, milk, and other dairy product supply. Reports from the US Department of Agriculture (USDA) indicate that these trans fats comprise 15 to 20 percent of the total trans-fat intake in our diet. While we know that trans fats are not exactly harmless, it seems that any negative affect naturally occurring trans fats have are counteracted by the presence of other fatty acid molecules in these animal products, which work to promote human health.

Nonessential and Essential Fatty Acids

Fatty acids are vital for the normal operation of all body systems. The circulatory system, respiratory system, integumentary system, immune system, brain, and other organs require fatty acids for proper function. The body is capable of synthesizing most of the fatty acids it needs from food. These fatty acids are known as non-essential fatty acids. However, there are some fatty acids that the body cannot synthesize and these are called essential fatty acids. It is important to note that non-essential fatty acids don't mean unimportant; the classification is based solely on the ability of the body to synthesize the fatty acid. These fatty acids, alpha-linolenic acid, and linoleic acid are required in the diet. Without these fatty acids, infants fail to grow and have poor vision, the skin becomes scaly, reproductive processes fail, and one experiences poor immunity and susceptibility to infectious diseases.

Essential fatty acids must be obtained from food. They fall into two categories—omega-3 and omega-6. The 3 and 6 refer to the position of the first carbon double bond and the omega refers to the methyl end of the chain. Omega-3 and omega-6 fatty acids are precursors to important compounds called eicosanoids. Eicosanoids are powerful hormones that control many other hormones and important body functions, such as the central nervous system and the immune system. Eicosanoids derived from omega-6 fatty acids are known to increase blood pressure, immune response, and inflammation. In contrast, eicosanoids derived from omega-3 fatty acids are known to have heart-healthy effects. Given the contrasting effects of the omega-3 and omega-6 fatty acids, a proper dietary balance between the two must be achieved to ensure optimal health benefits.

Some linoleic acid (omega-6) is converted to arachidonic acid within our body .

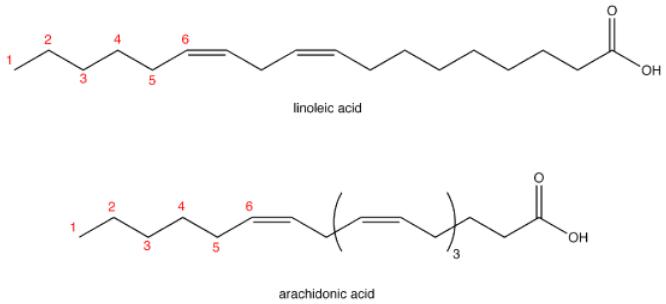


Figure 4.3.4: Omega-6 fatty acid showing first doubly bonded carbon atom from the methyl group is the sixth carbon atom.

A small percent, about 17%, of dietary alpha-linolenic acid is converted to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Omega-3 fatty acids are involved in regulating a variety of processes including blood pressure, muscle contractions, blood clotting, immune cell production and blood triglyceride.

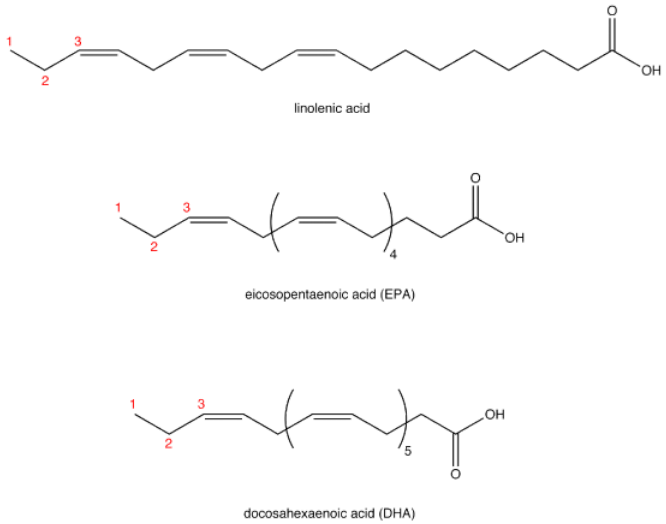


Figure 4.3.5*: Omega-3 fatty acids showing first doubly bonded carbon atom from the methyl group is the third carbon atom.*

Essential fatty acids play an important role in the life and death of cardiac cells, immune system function, and blood pressure regulation. Docosahexaenoic acid (DHA) is an omega-3 essential fatty acid shown to play important roles in synaptic transmission in the brain during fetal development.

Some excellent sources of omega-3 and omega-6 essential fatty acids are fish, flaxseed oil, hemp, walnuts, and leafy vegetables. Because these essential fatty acids are easily accessible, essential fatty acid deficiency is extremely rare.

Tools for Change

It is important to strike a proper balance between omega-3 and omega-6 fats in your diet. Research suggests that a diet that is too high in omega-6 fats distorts the balance of proinflammatory agents, promoting chronic inflammation and causing the potential for health problems such as asthma, arthritis, allergies, or diabetes. Omega-6 fats compete with omega-3 fats for enzymes and will actually replace omega-3 fats. The typical western diet is characterized by an excessive consumption of foods high in omega-6 fatty acids. To gain proper balance between the two, increase your omega-3 fat intake by eating more fatty fish or other sources of omega-3 fatty acids at least two times per week.

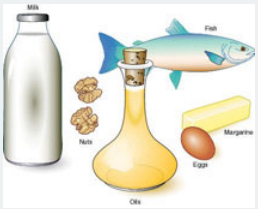


Figure 4.3.6: There are many sources of omega-3 foods.

Fatty-Acid Composition in the Diet and in the Body

The fatty-acid profile of the diet directly correlates to the tissue lipid profile of the body. It may not solely be the quantity of dietary fat that matters. More directly, the type of dietary fat ingested has been shown to affect body weight, composition, and metabolism. The fatty acids consumed are often incorporated into the triacylglycerols within the body. Evidence confirms that saturated fatty acids are linked to higher rates of weight retention when compared to other types of fatty acids. Alternatively, the fatty acids found in fish oil are proven to reduce the rate of weight gain as compared to other fatty acids.Mori, T. “Dietary fish oil upregulates intestinal lipid metabolism and reduces body weight gain in C57BL/6J mice.” *J Nutr*. 2007 Dec;137(12):2629-34. http://www.ncbi.nlm.nih.gov/pubmed/18029475

Phospholipids

Like triacylglycerols, phospholipids have a glycerol backbone. But unlike triacylglycerols, phospholipids are diglycerides (two fatty-acid molecules attached to the glycerol backbone) while their third fatty-acid chain has a phosphate group coupled with a nitrogen-containing group. This unique structure makes phospholipids water soluble. Phospholipids are what we call amphiphilic—the fatty-acid sides are hydrophobic (dislike water) and the phosphate group is hydrophilic (likes water). Egg yolks, liver, soybeans, and peanuts are rich in phospholipids.

In the body, phospholipids bind together to form cell membranes. The amphiphilic nature of phospholipids governs their function as components of cell membranes. The phospholipids form a double layer in cell membranes, thus effectively protecting the inside of the cell from the outside environment while at the same time allowing for transport of fat and water through the membrane. Phospholipids are also important for maintaining the cell's integrity and regulation of immune, cardiovascular, and muscular systems.

Phospholipids are ideal emulsifiers that can keep oil and water mixed. Emulsions are mixtures of two liquids that do not mix. Without emulsifiers, the fat and water content would be separated within the food. Lecithin (phosphatidylcholine), found in egg yolk, honey, and mustard, is a popular food emulsifier. Mayonnaise demonstrates lecithin's ability to blend vinegar and oil to create the stable, spreadable condiment that so many enjoy. Food emulsifiers play an important role in making the appearance of food appetizing. Adding emulsifiers to sauces and creams not only enhances their appearance but also increases their freshness.

Lecithin's crucial role within the body is clear because it is present in every cell throughout the body; 28 percent of brain matter is composed of lecithin and 66 percent of the fat in the liver is lecithin. Many people attribute health-promoting properties to lecithins, such as its ability to lower blood cholesterol and aid with weight loss. There are several lecithin supplements on the market broadcasting these claims. However, as the body can make most phospholipids, it is not necessary to consume them in a pill. The body makes all of the lecithin that it needs.

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Sterols

Sterols have a very different structure from triacylglycerols and phospholipids. Most sterols do not contain any fatty acids but rather multi-ring structures. They are complex molecules that contain interlinking rings of carbon atoms, with side chains of carbon, hydrogen, and oxygen attached. They may be a clear, waxy substance, soluble in lipid, and lipophilic (lipid friendly).

Cholesterol is the best-known sterol because of its role in heart disease. It forms a large part of the plaque that narrows the arteries in atherosclerosis. In stark contrast, cholesterol does have specific beneficial functions to perform in the body. Like phospholipids, cholesterol is present in all body cells as it is an important substance in cell membrane structure. Approximately 25 percent of the cholesterol in the body is localized in brain tissue. Cholesterol is used in the body to make a number of important things, including vitamin D, glucocorticoids, bile, and the sex hormones, progesterone, testosterone, and estrogens.

Although cholesterol is preceded by its infamous reputation, it is clearly a vital substance in the body that poses a concern only when there is an excess accumulation of it in the blood. Like lecithin, the body can synthesize cholesterol.

Phytosterols and phytostanols are two other forms of sterols found in our diet. You will find these in some plants and animals. Notably, the sterols found in plants resemble cholesterol in structure. However, plant sterols inhibit cholesterol absorption in the human body, which can contribute to lower cholesterol levels.

Key Takeaways

- Three fatty acids combine with one glycerol to make a triacylglycerol, the body's storage form of fat.
- The carbon chain of fatty acids can be saturated (filled with hydrogen), monounsaturated (with one point of unsaturation and possessing one carbon-carbon double bond), or polyunsaturated (with more than one point of unsaturation and possessing two or more double-carbon bonds)
- The structure and length of a fatty acid determines whether it is solid or liquid at room temperature.
- Essential fatty acids cannot be synthesized by the body and must be included in the diet. Omega-3 and omega-6 fatty acids have opposing functions and must be consumed in proper balance to promote health.
- Fatty acids in food influence the composition of fatty acids in the body.
- Phospholipids are diglycerides with a phosphate-nitrogen group in place of the third fatty-acid chain. They are ideal emulsifiers as they keep oil and water mixed.

- Sterols contain a multi-ring structure. Cholesterol serves important body functions such as vitamin D and hormone synthesis and is important in cell membrane and brain structure.

Discussion Starters

1. List the oils, snacks, spreads, or sauces in your home. Do they contain saturated or unsaturated fatty acids?
2. Name the characteristic that differentiates a triacylglycerol from a phospholipid. Describe the properties of phospholipids. Discuss their role in forming cell membranes. Explain their role as an emulsifier.
3. Think about your favorite restaurant and the food you like to order there. What type of fatty acids does a typical meal that you eat there have? Discuss the health benefits and possible drawbacks. What foods would you add to enhance your meal? What foods should you consider avoiding?

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4.4: Digestion and Absorption of Lipids

Learning Objectives

- Summarize the steps in lipid digestion and absorption.
- Explain how lipids are used for energy and stored in the body.

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-based, how does the body break down fat and make it available for the various functions it must perform in the human body?

From the Mouth to the Stomach

The first step in the digestion of triacylglycerols and phospholipids begins in the mouth as lipids encounter saliva. Next, the physical action of chewing coupled with the action of emulsifiers enables the digestive enzymes to do their tasks. The enzyme lingual lipase, along with a small amount of phospholipid as an emulsifier, initiates the process of digestion and starts the breakdown of triacylglycerides. These actions cause the fats to become more accessible to the digestive enzymes. As a result, the fats become tiny droplets and separate from the watery components.

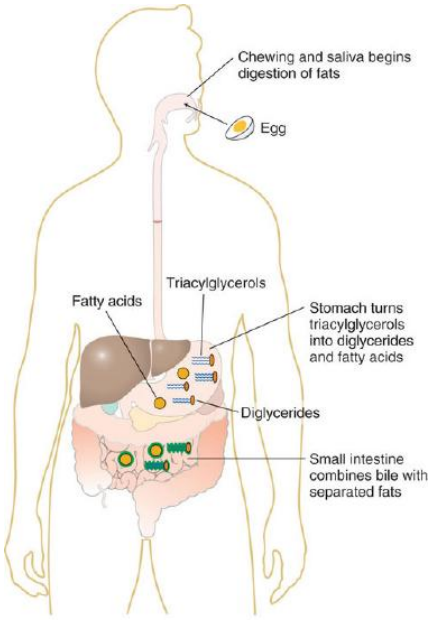


Figure 4.4.1: Lipid Digestion

In the stomach, gastric lipase starts to break down triacylglycerols into diglycerides and fatty acids. Within two to four hours after eating a meal, roughly 30 percent of the triacylglycerols are converted to diglycerides and fatty acids. The stomach's churning and contractions help to disperse the fat molecules, while the diglycerides derived in this process act as further emulsifiers. However, even amid all of this activity, very little fat digestion occurs in the stomach.

Going to the Bloodstream

As stomach contents enter the small intestine, the digestive system sets out to manage a small hurdle, namely, to combine the separated fats with its own watery fluids. The solution to this hurdle is bile. Bile contains bile salts, lecithin, and substances derived from cholesterol so it acts as an emulsifier. It attracts and holds on to fat while it is simultaneously attracted to and held on to by water. Emulsification increases the surface area of lipids over a thousand-fold, making them more accessible to the digestive enzymes.

Once the stomach contents have been emulsified, fat-breaking enzymes work on the triacylglycerols and diglycerides to severe fatty acids from their glycerol foundations. As pancreatic lipase enters the small intestine, it breaks down the fats into free fatty acids and monoglycerides. Yet again, another hurdle presents itself. How will the fats pass through the watery layer of mucus that coats the absorptive lining of the digestive tract? As before, the answer is bile. Bile salts envelop the fatty acids and

monoglycerides to form micelles. Micelles have a fatty acid core with a water-soluble exterior. This allows efficient transportation to the intestinal microvillus. Here, the fat components are released and disseminated into the cells of the digestive tract lining.

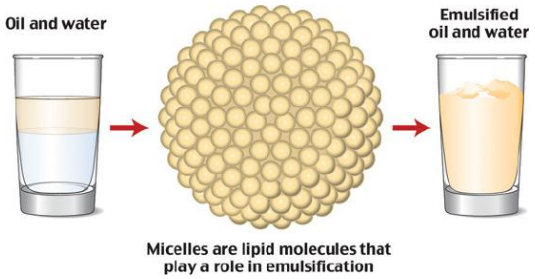


Figure 4.4.2: Fats can travel through the watery environment of the body due to the process of emulsification.

Just as lipids require special handling in the digestive tract to move within a water-based environment, they require similar handling to travel in the bloodstream. Inside the intestinal cells, the monoglycerides and fatty acids reassemble themselves into triacylglycerols. Triacylglycerols, cholesterol, and phospholipids form lipoproteins when joined with a protein carrier. Lipoproteins have an inner core that is primarily made up of triacylglycerols and cholesterol esters (a cholesterol ester is a cholesterol linked to a fatty acid). The outer envelope is made of phospholipids interspersed with proteins and cholesterol. Together they form a chylomicron, which is a large lipoprotein that now enters the lymphatic system, bypassing the liver, and will soon be released into the bloodstream via the jugular vein in the neck. Chylomicrons transport food fats perfectly through the body's water-based environment to specific destinations such as the liver and other body tissues. Entrance into the bloodstream can last up to 14 hours with the peak 30 to 3 hours post-meal.

Cholesterols are poorly absorbed when compared to phospholipids and triacylglycerols. Cholesterol absorption is aided by an increase in dietary fat components and is hindered by high fiber content. This is the reason that a high intake of fiber is recommended to decrease blood cholesterol. Foods high in fiber such as fresh fruits, vegetables, and oats can bind bile salts and cholesterol, preventing their absorption and carrying them out of the colon.

If fats are not absorbed properly as is seen in some medical conditions, a person's stool will contain high amounts of fat. If fat malabsorption persists the condition is known as steatorrhea. Steatorrhea can result from diseases that affect absorption, such as Crohn's disease and cystic fibrosis.

Brief Overview of Triacylglyceride Metabolism

Fat cells are located in special depots in your body and there are many different locations, for example, abdominal (belly fat) or the hips. Also, a small amount of fat is stored in skeletal muscle too. See Figure 4.4.3 to see an adipocyte in skeletal muscle.

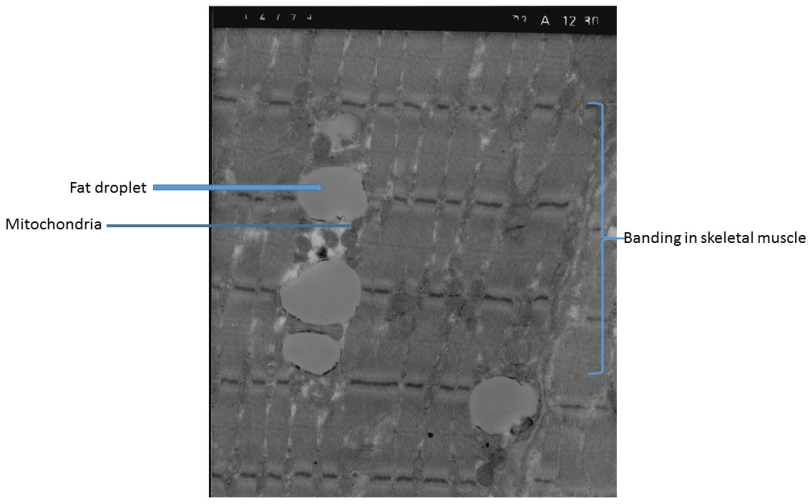


Figure 4.4.3: Adipocyte or fat cell within skeletal muscle.

Once stored in the adipocyte (fat cell), the fat will remain there until it is needed to produce energy. Lipolysis is the process by which the triacylglyceride is removed from the lipid droplet with the fat cells, broken into 3 fatty acids and glycerol. The glycerol is

secreted from the cells along with some but not all of the fatty acids. These are transported to the liver where the glycerol may be converted to glucose. The fatty acids may be converted to ketones or transported to other cells and burn to produce ATP.

The Truth about Storing and Using Body Fat

Before the prepackaged food industry, fitness centers, and weight-loss programs, our ancestors worked hard to even locate a meal. They made plans, not for losing those last ten pounds to fit into a bathing suit for vacation, but rather for finding food. Today, this is why we can go long periods without eating, whether we are sick with a vanished appetite, our physical activity level has increased, or there is simply no food available. Our bodies reserve fuel for a rainy day.

One way the body stores fat involves the body transforms carbohydrates into glycogen that is in turn stored in the muscles for energy. When the muscles reach their capacity for glycogen storage, the excess is returned to the liver, where it is converted into triacylglycerols and then stored as fat.

In a similar manner, much of the triacylglycerols the body receives from food is transported to fat storehouses within the body if not used for producing energy. The chylomicrons are responsible for shuttling the triacylglycerols to various locations such as the muscles, breasts, external layers under the skin, and internal fat layers of the abdomen, thighs, and buttocks where they are stored by the body in adipose tissue for future use. How is this accomplished? Recall that chylomicrons are large lipoproteins that contain a triacylglycerol and fatty-acid core. Capillary walls contain an enzyme called lipoprotein-lipase that dismantles the triacylglycerols in the lipoproteins into fatty acids and glycerol, thus enabling these to enter into the adipose cells. Once inside the adipose cells, the fatty acids and glycerol are reassembled into triacylglycerols and stored for later use. Muscle cells may also take up the fatty acids and use them for muscular work and for generating energy. When a person's energy requirements exceed the amount of available fuel presented from a recent meal or extended physical activity has exhausted glycogen energy reserves, fat reserves are retrieved for energy utilization.

As the body calls for additional energy, the adipose tissue responds by dismantling its triacylglycerols and dispensing glycerol and fatty acids directly into the blood. Upon receipt of these substances, the energy-hungry cells break them down further into tiny fragments. These fragments go through a series of chemical reactions that yield energy, carbon dioxide, and water.

Key Takeaways

- In the stomach fat is separated from other food substances. In the small intestines, bile emulsifies fats while enzymes digest them. The intestinal cells absorb the fats.
- Long-chain fatty acids form a large lipoprotein structure called a chylomicron that transports fats through the lymph system.
- Chylomicrons are formed in the intestinal cells and carry lipids from the digestive tract into circulation.
- Short- and medium-fatty chains can be absorbed directly into the bloodstream via the portal system from the intestinal microvillus because they are water-soluble.
- Cholesterol absorption is hindered by foods high in fiber.
- When energy supplies are low the body utilizes its stored fat reserves for energy.

Discussion Starters

- Explain the role of emulsifiers in fat digestion.
- Name the part of the digestive system where most fat digestion and absorption occurs.
- Describe the role of bile salts in the digestion of triacylglycerols and phospholipids.
- Define chylomicron.
- Explain how fiber-rich foods affect cholesterol absorption.
- Discuss the body's processes for using energy.

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4.5: Understanding Blood Cholesterol

Learning Objectives

- Compare and contrast the roles of LDLs and HDLs in your body.
- Explain the purpose of a blood lipid profile and identify healthy ranges.

You may have heard of the abbreviations LDL and HDL with respect to heart health. These abbreviations refer to low-density lipoprotein (LDL) and high-density lipoprotein (HDL), respectively. Lipoproteins are characterized by size, density, and composition. As the size of the lipoprotein increases, the density decreases. This means that HDL is smaller than LDL. Why are they referred to as “good” and “bad” cholesterol? What should you know about these lipoproteins? This section will help you answer these questions.

Short chain fatty acids and medium chain fatty acids can be carried in the bloodstream attached to the protein, albumin. Long chain fatty acids are much less water soluble so require special transport within lipoproteins. After a meal, during digestion and absorption, long chain fatty acids are packaged into chylomicrons and transported throughout the body in these micelles.

Cholesterol is found only in animal products. Also, our body makes cholesterol because it is important for the synthesis of bile and hormones. The amount of cholesterol synthesized is related to the amount found in the blood. This is also influenced by the amount of cholesterol in your diet.

Major Lipoproteins

Recall that chylomicrons are transporters of fats throughout the watery environment within the body. After about ten hours of circulating throughout the body, chylomicrons gradually release their triacylglycerols into cells until all that is left of their composition is cholesterol-rich remnants. These remnants are used as raw materials by the liver to formulate specific lipoproteins. Following is a list of the various lipoproteins and their functions:

- VLDLs. Very low-density lipoproteins are made in the liver from remnants of chylomicrons and transport triacylglycerols from the liver to various tissues in the body. As the VLDLs travel through the circulatory system, the lipoprotein lipase strips the VLDL of triacylglycerols. As triacylglycerol removal persists, the VLDLs become intermediate-density lipoproteins.
- IDLs. Intermediate-density lipoproteins transport a variety of fats and cholesterol in the bloodstream and are a little under half triacylglycerol in composition. While traveling in the bloodstream, cholesterol is gained from other lipoproteins while circulating enzymes strip its phospholipid component. When IDLs return to the liver, they are transformed into low-density lipoprotein.
- LDLs. As low-density lipoproteins are commonly known as the “bad cholesterol” it is imperative that we understand their function in the body so as to make healthy dietary and lifestyle choices. LDLs carry cholesterol and other lipids. They are comprised of very small amounts of triacylglycerols, and house over 50 percent cholesterol and cholesterol esters. LDL is developing as the lipid is removed from VLDL by the body's cells. How does the body receive the lipids contained therein? As the LDLs deliver cholesterol and other lipids to the cells, each cell’s surface has receptor systems specifically designed to bind with LDLs. Circulating LDLs in the bloodstream bind to these LDL receptors and are consumed. Once inside the cell, the LDL is taken apart and its cholesterol is released. In liver cells these receptor systems aid in controlling blood cholesterol levels as they bind the LDLs. A deficiency of these LDL binding mechanisms will leave a high quantity of cholesterol traveling in the bloodstream, which can lead to heart disease or atherosclerosis. Diets rich in saturated fats will prohibit the LDL receptors. Thus, LDL receptors are critical for regulating cholesterol levels.
- HDLs. High-density lipoproteins are responsible for carrying cholesterol out of the bloodstream and into the liver, where it is either reused or removed from the body with bile. HDLs have a very large protein composition coupled with low cholesterol content (20 to 30 percent) compared to the other lipoproteins. Hence, these high-density lipoproteins are commonly called “good cholesterol.”

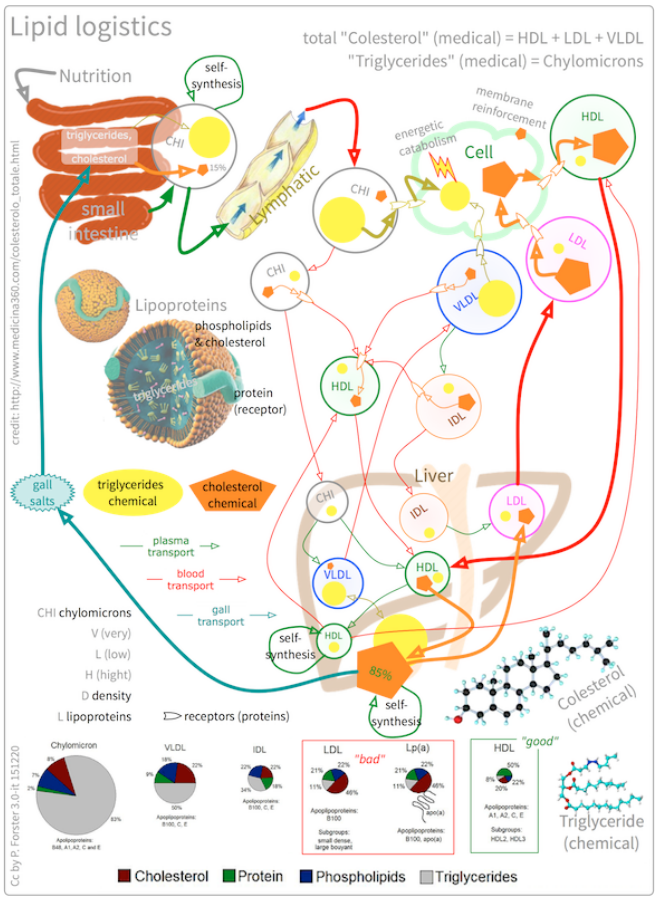


Figure 4.5.1: Formation of the major lipoproteins.

Contrasting LDL and HDL

Heart attack and atherosclerosis are conditions often caused by cholesterol that has accumulated and thickened in the walls of arteries. HDLs and LDLs are directly connected to these life-threatening ailments. By comparing and contrasting the roles each of these lipoproteins serves in the health of heart and blood vessels, you will be able to construct and evaluate a plan of action for your personal health. Consider the following lipoprotein facts:

- **LDL/HDL composition**. LDL is approximately 25 percent protein and 75 percent cholesterol and other fats. LDL is bigger (yet lighter) and richer in cholesterol than HDL. HDL is 50 percent protein and 50 percent cholesterol and other fats. HDL is smaller, more dense, and richer in protein.
- **LDL/HDL function**. LDLs carry cholesterol into cells for normal usage, but LDLs can also deposit cholesterol into the walls of blood vessels, which can lead to harmful disease. HDLs scavenge excess cholesterol from the cells, tissues, and blood vessels and deliver these back to the liver, where these are either reused or excreted.
- **LDL/HDL and inflammation**. LDLs carry lipids that are proinflammatory and may contribute to heart disease. HDLs transport lipids that are anti-inflammatory and may reduce the occurrence of heart disease.
- **LDL/HDL warnings**. High LDL values warn of increased health risks for heart disease, while high HDL values indicate a reduced risk for heart disease.
- **Oxidized LDL**. LDLs become more dangerous when oxidized. Oxidation is defined as the loss of electrons between two substances via a chemical reaction. If an LDL oxidation occurs, the oxidized LDL is left unstable. Oxidized LDL can speed up the process of plaque formation in the arteries. It is believed to hasten the deposition of cholesterol into the arterial walls and to induce a chronic inflammatory effect throughout the body's vast network of vessels. This activity promotes atherosclerosis and significantly increases risks for heart attack or stroke.

Blood Cholesterol Recommendations

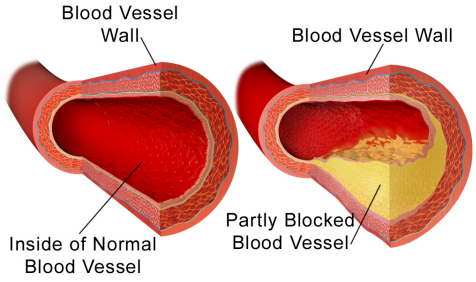
For healthy total blood cholesterol, the desired range you would want to maintain is under 200 mg/dL. More specifically, when looking at individual lipid profiles, a low amount of LDL and a high amount of HDL prevents excess buildup of cholesterol in the arteries and wards off potential health hazards. An LDL level of less than 100 milligrams per deciliter is ideal while an LDL level above 160 milligrams per deciliter would be considered high. In contrast, a low value of HDL is a telltale sign that a person is living with major risks for disease. Values of less than 40 milligrams per deciliter for men and 50 milligrams per deciliter for women mark a risk factor for developing heart disease. In short, elevated LDL blood lipid profiles indicate an increased risk of heart attack, while elevated HDL blood lipid profiles indicate a reduced risk. An excellent resource for more

information is the following guide from the National Cholesterol Education Program: ATP III Guidelines At-A-Glance Quick Desk Reference - National Heart, Lung, and Blood Institute

The University of Maryland Medical Center reports that omega-3 fatty acids promote lower total cholesterol and lower triacylglycerols in people with high cholesterol.University of Maryland Medical Center. “Omega-3 fatty acids.” http://www.umm.edu/altmed/articles/omega-3-000316.htm It is suggested that people consume omega-3 fatty acids such as alpha-linolenic acid in their diets regularly. Polyunsaturated fatty acids are especially beneficial to consume because they both lower LDL and elevate HDL, thus contributing to healthy blood cholesterol levels. The study also reveals that saturated and trans fatty acids serve as catalysts for the increase of LDL cholesterol. Additionally, trans fatty acids lower HDL levels, which can impact negatively on total blood cholesterol.

Cardiovascular Disease

According to the Centers for Disease Control and Prevention (CDC), heart disease is the leading cause of death in the United States (Centers for Disease Control and Prevention. “Leading Causes of Death.” Last updated September 6, 2011. http://www.cdc.gov/nchs/fastats/lcod.htm). The disease generally starts with arteriosclerosis, or a thickening, loss of elasticity, and calcification of the arterial walls. Atherosclerosis is a type of arteriosclerosis often defined as a "hardening of the arteries." It is a chronic condition so common that most people show signs of it by the time they turn thirty. Arteries start to narrow and harden when fats accumulate along their inner walls and form plaques. A plaque is made of fat, cholesterol, calcium, and other substances found in blood.



Normal and Partly Blocked Blood Vessel

Figure 4.5.2: Illustration comparing a normal blood vessel and partially blocked vessel due to atherosclerotic plaque build-up. Plaque formation along arterial walls impedes blood flow and can create a thrombus, or stationary blood clot. from BruceBlaus (via Wikipedia). For a video of the process click here.

Plaque formation causes arteries to narrow and harden, which elevates blood pressure because the vessels can’t expand effectively to accommodate blood pulses. Higher blood pressure strains the heart and causes more damage. Arterial walls can become so weakened due to high blood pressure that they balloon and form what is known as an aneurysm. If the aneurysm bursts, it becomes a life-threatening event. The plaques themselves can also rupture due to a spike in blood pressure or a tremor along an arterial wall, and the body responds to this perceived injury by forming blood clots. These clots are serious health threats, whether they are stationary (a thrombus) or moving (an embolus). A stable clot can slowly kill off surrounding tissue by restricting oxygen (called ischemia) to the area, or grow so big that it blocks blood circulation and causes thrombosis. When a moving clot becomes stuck in an artery too small for its passage, it cuts off blood flow and causes cell death. This is referred to as an embolism. Blood clots in heart and brain arteries can cause heart attacks or strokes, respectively.

Table 4.5.1: The Risk Factors for Cardiovascular Disease

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases for men at forty-five, and for women at fifty-five. • **Sex.** Men have a higher risk than women, though the risk for women steeply rises after menopause. • **Family history.** The more family members who have heart disease, the greater the risk.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of atherosclerosis. • **Obesity.** Excess weight worsens other risk factors. • **Diabetes.** This condition is associated with an increased risk of heart disease. Both types have certain risk factors in common, including obesity and high blood pressure. • **Physical inactivity.** Lack of exercise is associated with heart disease. • **Cholesterol levels.** High levels of blood cholesterol can increase the risk. A high level of low-density lipoprotein (LDL), or the “bad” cholesterol, is a common contributing factor. However, a low level of high-density lipoprotein (HDL), or “good” cholesterol, can also promote atherosclerosis. • **Stress**. Excess stress is a risk factor for heart disease. • **Hypertension**. High blood pressure left untreated can cause heart disease.

-

Steps to Reducing the Risk of Cardiovascular Disease

Diet and nutrition can play a significant role in reducing the risk of cardiovascular disease. It is helpful to lower sodium intake, increase consumption of dietary fiber, and limit consumption of saturated fat which promotes plaque formation. In addition, it is important to replace refined starches and added sugar, which can boost triglycerides, with whole grains, fruits, and vegetables. Eating foods rich in omega-3 fatty acids, especially fish, using alcohol in moderation, and opting for low or no-fat dairy products can all help reduce your cardiovascular disease risk. Emphasizing vegetable-based sources of protein, such as beans and legumes, can be beneficial, as well as consuming more soy products. It is also important to maintain a healthy weight, manage cholesterol levels, and avoid smoking or chewing tobacco.

Your total fat intake should be less than 35% of your total energy intake and that fat should be distributed 1/3 saturated, 1/3 monounsaturated, and 1/3 polyunsaturated fat. Here are suggestions on ways to reduce your saturated fat intake: 1) reduce your animal fat intake by selecting lean cuts of meat, trimming the fat, removing the skin and/or baking and broiling instead of frying; 2) drink fat-free or 1% milk, and 3) reduce your intake of coconut and palm oils which are rich in saturated fat. You will find these fats in commercial baked goods. Also, replace your saturated fat intake with monounsaturated fat such as canola oil, olive oil and/or nuts. Polyunsaturated fats should comprise 1/3 of your dietary fat intake. You find these fats in vegetable oil and fish oil. Finally, reduce your intake of trans fatty acids which are found in hydrogenated or partially hydrogenated vegetable oil, deep fried foods, hard margarine and commercial baked goods.

Tools for Change

Being conscious of the need to reduce cholesterol means limiting the consumption of saturated fats and trans fats. Remember that saturated fats found in some meat, whole-fat dairy products, and tropical oils elevate your total cholesterol. Trans fats, such as the ones often found in margarines, processed cookies, pastries, crackers, fried foods, and snack foods also elevate your cholesterol levels. Read and select from the following suggestions as you plan ahead:

Soluble fiber reduces cholesterol absorption in the bloodstream. Try eating more oatmeal, oat bran, kidney beans, apples, pears, citrus fruits, barley, and prunes.

Fatty fish are heart-healthy due to high levels of omega-3 fatty acids that reduce inflammation and lower cholesterol levels. Consume mackerel, lake trout, herring, sardines, tuna, salmon, and halibut. Grilling or baking is best to avoid unhealthy trans fats that could be added from frying oil.

Walnuts, almonds, peanuts, hazelnuts, pecans, some pine nuts, and pistachios all contain high levels of unsaturated fatty acids that aid in lowering LDL. Make sure the nuts are raw and unsalted. Avoid sugary or salty nuts. One ounce each day is a good amount.

Olive oil contains a strong mix of antioxidants and monounsaturated fat, and may lower LDL while leaving HDL intact. Two tablespoons per day in place of less healthy saturated fats may contribute to these heart-healthy effects without adding extra calories. Extra virgin olive oil promises a greater effect, as the oil is minimally processed and contains more heart-healthy antioxidants.

Testing Your Lipid Profile

The danger of consuming foods rich in cholesterol and saturated and trans fats cannot be overemphasized. Regular testing can provide the foreknowledge necessary to take action to help prevent any life-threatening events.

Current guidelines recommend testing for anyone over age twenty. If there is a family history of high cholesterol, your healthcare provider may suggest a test sooner than this. Testing calls for a blood sample to be drawn after nine to twelve hours of fasting for an accurate reading. (By this time, most of the fats ingested from the previous meal have circulated through the body and the concentration of lipoproteins in the blood will have stabilized.)

According to the National Institutes of Health (NIH), the following total cholesterol values are used to target treatment:National Heart, Lung, and Blood Institute, National Institutes of Health. “High Blood Cholesterol: What You Need to Know.” NIH Publication No. 05-3290. (Revised June 2005). Section 2.01. www.nhlbi.nih.gov/health/public/heart/chol/wyntk.htm.

- Desirable. Under 200 milligrams per deciliter
- Borderline high. 200–239 milligrams per deciliter
- High risk. 240 milligrams per deciliter and up

According to the NIH, the following desired values are used to measure an overall lipid profile:

- LDL. Less than 160 milligrams per deciliter (if you have heart disease or diabetes, less than 100 milligrams per deciliter)
- HDL. Greater than 40–60 milligrams per deciliter
- Triacylglycerols. 10–150 milligrams per deciliter
- VLDL. 2–38 milligrams per deciliter



***Video 4.5.1**: Understanding Cholesterol (www.youtube.com/v/hjv5OnbcjE8)*

Key Takeaways

- Some of the major lipoproteins are VLDL, IDL, LDL, and HDL.
- VLDL delivers triacylglycerols and other lipids to the body's tissues and slowly becomes IDL. The liver uses IDL to create LDL, the main transporter of cholesterol.
- LDL, or "bad" cholesterol, has low protein composition and high cholesterol content. High levels of LDL have been shown to increase the risks for heart disease.
- HDL or "good'' cholesterol has a larger proportion of protein and a small cholesterol composition. HDL scavenges excess cholesterol and returns it to the liver for reuse or disposal. A high level of HDL reduces the risk for heart disease.
- It is important to maintain a healthy lipid profile with values as recommended by the NIH in order to minimize the risk of heart disease. Consuming omega-3 fatty acids can help maintain a healthy blood lipid profile.

Discussion Starters

1. Summarize the roles of LDL and HDL. Explain why LDL is termed "bad" cholesterol and why HDL is termed "good" cholesterol.
2. Explain oxidation and how it affects LDL and contributes to heart disease.
3. Describe the procedure and blood test for testing your lipid profile.
4. Recall the desired lipid values set out by the NIH. Identify the desired total cholesterol, LDL, HDL, VLDL, and triacylglycerol values.
5. How has learning this information affected your motivation to eat a more healthy diet?

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4.6: Balancing Your Diet with Lipids

Learning Objectives

- Describe the current recommended intake levels for lipids.
- Recognize sources of saturated and unsaturated fats, essential fatty acids, and trans fats.
- Discuss the functions of essential fatty acids, such as omega-3, and where to find them in foods.

You may reason that if some fats are healthier than other fats, why not consume as much healthy fat as desired? Remember, everything in moderation. As we review the established guidelines for daily fat intake, the importance of balancing fat consumption with proper fat sources will be explained.

Recommended Fat Intake

The acceptable macronutrient distribution range (AMDR) from the Dietary Reference Intake Committee for adult fat consumption is as follows:Institute of Medicine. "Dietary Reference Intakes: Macronutrients." Accessed October 5, 2012. www.iom.edu/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI _Macronutrients.pdf

- Fat calories should be limited to 20–35 percent of total calories with most fats coming from polyunsaturated and monounsaturated fats, such as those found in fish, nuts, and vegetable oils.
- Consume fewer than 10 percent of calories from saturated fats. Some studies suggest that lowering the saturated fat content to less than 7 percent can further reduce the risk of heart disease.
- Keep the consumption of trans fats (any food label that reads hydrogenated or partially hydrogenated oil) to a minimum, less than 1 percent of calories.
- Think lean and low-fat when selecting meat, poultry, milk, and milk products.

The current AMDR for child and adolescent fat consumption (for children over four) are as follows:

- For children between ages four and eighteen years, between 25 and 35 percent of caloric intake should be from fat.
- For all age groups, most fats should come from polyunsaturated and monounsaturated fats such as fish, nuts, and vegetable oils.
-

Identifying Sources of Fat

Population-based studies of American diets have shown that intake of saturated fat is more excessive than the intake of trans fat and cholesterol. Saturated fat is a prominent source of fat for most people as it is so easily found in animal fats, tropical oils such as coconut and palm oil, and full-fat dairy products. Oftentimes the fat in the diet of an average young person comes from foods such as cheese, pizza, cookies, chips, desserts, and animal meats such as chicken, burgers, sausages, and hot dogs. To aim for healthier dietary choices, the American Heart Association (AHA) recommends choosing lean meats and vegetable alternatives, choosing dairy products with low-fat content, and minimizing the intake of trans fats. The AHA guidelines also recommend consuming fish, especially oily fish, at least twice per week.American Heart Association. "Frequently Asked Questions About Fish." www.heart.org/HEARTORG/General/Frequently-Asked-Questions-About-Fish _UCM_306451_Article.jsp. These more appropriate dietary choices will allow for enjoyment of a wide variety of foods while providing the body with the recommended levels of fat from healthier sources. Evaluate the following sources of fat in your overall dietary pattern:

- **Monounsaturated fat.** This type of fat is found in plant oils. Common sources are nuts (almonds, cashews, pecans, peanuts, and walnuts) and nut products, avocados, extra virgin olive oil, sesame oil, high oleic safflower oil, sunflower oil, and canola oil.
- **Polyunsaturated fat.** This type of fat is found mainly in plant-based foods, oils, and fish. Common sources are nuts (walnuts, hazel nuts, pecans, almonds, and peanuts), soybean oil, corn oil, safflower oil, flaxseed oil, canola oil, and fish (trout, herring, and salmon).
- **Saturated fat.** This fat is found in animal products, dairy products (e.g. butter, cream), palm and coconut oils, and cocoa butter. Limit these products to less than 10 percent of your overall dietary fat consumption.
- **Trans fatty acids.** Stick margarines, fast foods, commercial baked goods, and some snack foods contain trans fats. Limit your consumption of these products to keep trans fats to less than 1 percent of your fat consumption.

- **Omega-3 fatty acids (alpha-linolenic acid).** Good sources of these are canola oil, flaxseed oil, soybean oil, olive oil, nuts, seeds, whole grains, legumes, and green leafy vegetables.
- **DHA and EPA.** Good sources of these are cod liver oil and fish such as tuna, herring, mackerel, salmon, and trout.
- **Omega-6 fatty acids (linoleic acid).** Eggs, poultry, most vegetable oils, wheat germ oil, whole grains, baked goods, and cereals contain these fatty acids. Omega-6 fatty acids are present abundantly in nuts and seeds such as flaxseeds, sunflower seeds, sesame seeds, and watermelon seeds.



Figure 4.6.1: Enjoy a delicious vegetable burger as an alternative to a traditional beef hamburger with French fries. (CC-SA_BY-2.0; divinemisscopa)

Omega-3 and Omega-6 Fatty Acids

Recall that the body requires fatty acids and is adept at synthesizing the majority of these from fat, protein, and carbohydrate. However, when we say *essential* fatty acid we are referring to the two fatty acids that the body cannot create on its own, namely, alpha-linolenic acid and linoleic acid.

- **Omega-3 Fatty Acids.** At the helm of the omega-3 fatty acid family is alpha-linolenic acid. From this fatty acid, the body can make eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Linolenic acid is found in nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed. EPA and DHA are found abundantly in fatty fish.
- **Omega-6 Fatty Acids.** At the helm of the omega-6 fatty acid family is linoleic acid. Like linolenic acid, the body uses linoleic acid to make other important substances such as arachidonic acid (ARA) that is used to make eicosanoids. Recall that eicosanoids perform critical roles in the body as they affect a broad spectrum of functions. The word *eicosanoid* originates from the Greek word *eicosa*, meaning twenty because this hormone is derived from ARA that is twenty carbon atoms in length. Eicosanoids affect the synthesis of all other body hormones and control all body systems, such as the central nervous system and the immune system. Among the many functions eicosanoids serve in the body, their primary function is to regulate inflammation. Without these hormones, the body would not be able to heal wounds, fight infections, or fight off illness each time a foreign germ presented itself. Eicosanoids work together with the body's immune and inflammation processes to play a major role in several important body functions, such as circulation, respiration, and muscle movement.

Attain the Omega-3 and Omega-6 Balance

As our food choices evolve, the sources of omega-6 fatty acids in our diets are increasing at a much faster rate than sources of omega-3 fatty acids. Omega-3s are plentiful in diets of nonprocessed foods where grazing animals and foraging chickens roam free, eating grass, clover, alfalfa, and grass-dwelling insects. In contrast, today's western diets are bombarded with sources of omega-6. For example, we have oils derived from seeds and nuts and from the meat of animals that are fed grain. Vegetable oils used in fast-food preparations, most snack-foods, cookies, crackers, and sweet treats are also loaded with omega-6 fatty acids. Also, our bodies synthesize eicosanoids from omega-6 fatty acids and these tend to increase inflammation, blood clotting, and cell proliferation, while the hormones synthesized from omega-3 fatty acids have just the opposite effect.

While omega-6 fatty acids are essential, they can be harmful when they are out of balance with omega-3 fatty acids. Omega-6 fats are required only in small quantities. Researchers believe that when omega-6 fats are out of balance with omega-3 fats in the diet they diminish the effects of omega-3 fats and their benefits. This imbalance may elevate the risks for allergies, arthritis, asthma, coronary heart disease, diabetes, and many types of cancer, autoimmunity, and neurodegenerative diseases, all of which are believed to originate from some form of inflammation in the body. The recommendations for the ratio of omega-3 to omega-6 fatty acids vary from 5:1 to 10:1.

What does this mean for you? If your diet is low in omega-3 fats to begin with, then most of your essential fatty acids are from omega-6s. Stop. Do not set up a proinflammatory environment. Attaining proper balance between omega-3 fatty acids and omega-6 fatty acids means learning to make healthy choices and replacing bad fats with good ones that promote health and well-being.

Key Takeaways

- The recommended fat intake for adults is 20–35 percent of your total caloric intake. Saturated fat must be less than 10 percent of your total caloric intake, and lowering this to 7 percent can further reduce the risks for heart disease. Trans fat should be less than 1 percent of total caloric intake.
- Nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed are excellent sources of monounsaturated and polyunsaturated fats.
- The polyunsaturated fatty acids linolenic and linoleic acids are used by the body to make substances that carry out many vital functions in the body.
- The omega-3 fatty-acid family includes alpha-linolenic acid, EPA, and DHA. The omega-6 fatty-acid family includes linoleic acid and ARA. DHA and ARA play crucial roles in brain and eye development. EPA and DHA found in fatty fish play important roles in inflammation reduction and disease prevention.
- Many people consume too many omega-6 fatty acids and not enough omega-3 fatty acids. Omega-3 fats and omega-6 fats are precursors to hormones that have opposing properties. A proper balance between both must be obtained to avoid health problems.

Discussion Starters

1. State the recommended intake of total fat, as well as saturated versus unsaturated fat, in the diet.
2. List sources of monounsaturated and polyunsaturated fats.
3. Summarize the important functions of essential fatty acids in the human body.
4. Explain why it is necessary to maintain a proper balance between omega-3 fat and omega-6 fat intake.
5. Record a food diary for one week. What foods do you most often consume? What type of fat dominates your diet? How can you alter your eating habits to promote better health? Outline steps you can take to replace saturated and trans fat in your diet.

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4.7: Lipids and the Food Industry

Learning Objectives

- Discuss reasons oils are hydrogenated and describe this process.
- Describe the health effects of trans fats.

What is the first thing that comes to mind when you read ingredients such as “partially hydrogenated oil” and “hydrogenated oil” on a food label? Do you think of heart disease, heart health, or atherosclerosis? Most people probably do not. As we uncover what hydrogenation is and why manufacturers use it, you will be better equipped to adhere to healthier dietary choices and promote your heart health.

Hydrogenation: The Good Gone Bad?

Figure Runaway argument for \eatSpaces?: The fatty acid, oleic acid, in its cis and trans form.

Food manufacturers are aware that fatty acids are susceptible to attack by oxygen molecules because their points of unsaturation render them vulnerable in this regard. When oxygen molecules attack these points of unsaturation the modified fatty acid becomes oxidized. The oxidation of fatty acids makes the oil rancid and gives the food prepared with it an unappetizing taste. Because oils can undergo oxidation when stored in open containers, they must be stored in airtight containers and possibly be refrigerated to minimize damage from oxidation. Hydrogenation poses a solution that food manufacturers prefer.

When lipids are subjected to hydrogenation, the molecular structure of the fat is altered. Hydrogenation is the process of adding hydrogen to unsaturated fatty-acid chains, so that the hydrogen atoms are connected to the points of saturation and results in a more saturated fatty acid. Liquid oils that once contained more unsaturated fatty acids become semisolid or solid (upon complete hydrogenation) and behave like saturated fats. Oils initially contain polyunsaturated fatty acids. When the process of hydrogenation is not complete, for example, not all carbon double bonds have been saturated the end result is a partially hydrogenated oil. The resulting oil is not fully solid. Total hydrogenation makes the oil very hard and virtually unusable. Some newer products are now using fully hydrogenated oil combined with nonhydrogenated vegetable oils to create a usable fat.

Manufacturers favor hydrogenation as a way to prevent oxidation of oils and ensure longer shelf life. Partially hydrogenated vegetable oils are used in the fast food and processed food industries because they impart the desired texture and crispness to baked and fried foods. Partially hydrogenated vegetable oils are more resistant to breakdown from extremely hot cooking temperatures. Because hydrogenated oils have a high smoking point they are very well suited for frying. In addition, processed vegetable oils are cheaper than fats obtained from animal sources, making them a popular choice for the food industry.

Trans fatty acids occur in small amounts in nature, mostly in dairy products. However, the trans fats that are used by the food industry are produced from the hydrogenation process. Trans fats are a result of the partial hydrogenation of unsaturated fatty acids, which cause them to have a trans configuration, rather than the naturally occurring cis configuration.

Health Implications of Trans Fats

No trans fats! Zero trans fats! We see these advertisements on a regular basis. So widespread is the concern over the issue that restaurants, food manufacturers, and even fast-food establishments proudly tout either the absence or the reduction of these fats within their products. Amid the growing awareness that trans fats may not be good for you, let’s get right to the heart of the matter. Why are trans fats so bad?

Processing naturally occurring fats to modify their texture from liquid to semisolid and solid forms results in the development of trans fats, which have been linked to an increased risk for heart disease. Trans fats are used in many processed foods such as cookies, cakes, chips, doughnuts, and snack foods to give them their crispy texture and increased shelf life. However, because trans fats can behave like saturated fats, the body processes them as if they were saturated fats. Consuming large amounts of trans fats has been associated with tissue inflammation throughout the body, insulin resistance in some people, weight gain, and digestive troubles. In addition, the hydrogenation process robs the person of the benefits of consuming the original oil because hydrogenation destroys omega-3 and omega-6 fatty acids. The AHA states that, like saturated fats, trans fats raise LDL “bad cholesterol,” but unlike saturated fats, trans fats lower HDL “good cholesterol.” The AHA advises limiting trans-fat consumption to less than 1 percent.

How can you benefit from this information? When selecting your foods, steer clear of anything that says “hydrogenated,” “fractionally hydrogenated,” or “partially hydrogenated,” and read food labels in the following categories carefully:

- cookies, crackers, cakes, muffins, pie crusts, pizza dough, and breads
- stick margarines and vegetable shortening
- premixed cake mixes, pancake mixes, and drink mixes
- fried foods and hard taco shells
- snack foods (such as chips), candy, and frozen dinners

Choose brands that don’t use trans fats and that are low in saturated fats.

Dietary-Fat Substitutes

In response to the rising awareness and concern over the consumption of trans fat, various fat replacers have been developed. Fat substitutes aim to mimic the richness, taste, and smooth feel of fat without the same caloric content as fat.

Fat substitutes can also be made from proteins (for example, egg whites and milk whey). However, these are not very stable and are affected by changes in temperature; hence, their usefulness is somewhat limited. You will find these incorporated into foods that are not cooked such as ice cream, dairy products, mayonnaise, salad dressings, baked goods, and spreads.

Olestra or Olean is a fat-based fat replacer in which fatty acids have been attached to the sucrose molecule. This complex is not sweet and contains zero calories because it cannot be digested by our enzymes for absorption into our body. This makes it a better fat substitute for using in cooked products like chips and crackers. It can cause diarrhea and fecal leakage from the anal. As well, fat-soluble nutrients and phytochemicals can bond to it causing these to be unavailable for absorption.

Salatrim is another fat-based fat replacer and is composed of short and long chain fatty acids. It contains 5 calories per g which is less than the 9 calories per gram fats have, and you will find Salatrim in confections, dairy products, and baked goods.

The carbohydrate-based replacers tend to bind water and thus dilute calories. These are modified starch, maltodextrins, fruit purees, and pastes. All contain 1-4 calories per gram, so these products may contain less fat but are not always calorie-reduced. Be sure to read the package label. Examples of foods that contain these fat-replacers in baked goods, candy, dairy products, butter-flavored sprinkles.

Gels, gums, oat fiber (Oatrim: Beta-Trim, TrimChoice) polydextrose, hulls of corn, oats, and rice (Z-Trim) are examples of fiber-based fat replacers. These contain 0-4 calories per gram, so products that contain these are calorically reduced (remember fat has 9 calories per gram). People who eat products containing these fat replacers may experience the same problems associated with carbohydrate-based fat replacers.

Tools for Change

One classic cinnamon roll can have 5 grams of trans fat, which is quite high for a single snack. Foods such as pastries, frozen bakery goods, cookies, chips, popcorn, and crackers contain trans fat and often have their nutrient contents listed for a very small serving size—much smaller than what people normally consume—which can easily lead you to eat many “servings.” Labeling laws allow foods containing trans fat to be labeled “trans-fat free” if there are fewer than 0.5 grams per serving. This makes it possible to eat too much trans fat when you think you’re not eating any at all because it is labeled trans-fat free.

Always review the label for trans fat per serving. Check the ingredient list, especially the first three to four ingredients, for telltale signs of hydrogenated fat such as partially or fractionated hydrogenated oil. The higher up the words “partially hydrogenated oil” are on the list of ingredients, the more trans fat the product contains.

Measure out one serving and eat one serving only. An even better choice would be to eat a fruit or vegetable. There are no trans fats and the serving size is more reasonable for similar calories. Fruits and vegetables are packed with water, fiber, and many vitamins, minerals, phytonutrients, and antioxidants. At restaurants be aware that phrases such as “cooked in vegetable oil” might mean hydrogenated vegetable oil, and therefore trans fat.

Key Takeaways

- Hydrogenation is the process of adding hydrogen to the points of unsaturation in unsaturated fatty acid chains. The resulting oil is very hard and unusable. Partial hydrogenation is the process of adding hydrogen to some of the points of unsaturation in unsaturated fatty acid chains. This produces oils that are more spreadable and usable in food products.

- Food manufacturers favor the use of hydrogenated oils because they do not succumb to oxidative damage, they increase the shelf life of food products, and they have a high smoking point.
- Fat replacers mimic fat but do not have the same chemical configuration as fat. Therefore the body does not process these the same way it would a naturally occurring fat. Fat substitutes such as Olestra have produced symptoms of fat malabsorption in some people.

Discussion Starters

1. Describe how trans fatty acids are created. Explain the drawbacks of consuming this type of fat and its impact on human health.
2. Make a list of the foods in your kitchen. Read each food label. List all of the food items that contain trans fat. Recall the recommendation that trans fat be less that 1 percent of your fat intake. About what percentage of your diet is currently trans fat? Do you see a need to adjust your trans fat intake?

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4.8: Lipids and Disease

Learning Objectives

- Describe how saturated fat and cholesterol intake can impact health.

Because heart disease, cancer, and stroke are the three leading causes of death in the United States, it is critical to address dietary and lifestyle choices that will ultimately decrease risk factors for these diseases. According to the US Department of Health and Human Services (HHS), the following risk factors are controllable: high blood pressure, high cholesterol, cigarette smoking, diabetes, poor diet, physical inactivity, being overweight, and obesity.

In light of that, we present the following informational tips to help you define, evaluate, and implement healthy dietary choices to last a lifetime. The amount and the type of fat that composes a person's dietary profile will have a profound effect upon the way fat and cholesterol is metabolized in the body.

Watch Out for Saturated Fat and Cholesterol

In proper amounts, cholesterol is a compound used by the body to sustain many important body functions. In excess, cholesterol is harmful if it accumulates in the structures of the body's vast network of blood vessels. High blood LDL and low blood HDL are major indicators of blood cholesterol risk. The largest influence on blood cholesterol levels rests in the mix of saturated fat and trans fat in the diet. According to the Harvard School of Public Health, for every extra 2 percent of calories from trans fat consumed per day—about the amount found in a midsize order of French fries at a fast-food establishment—the risk of coronary heart disease increases by 23 percent.Harvard School of Public Health. "Fats and Cholesterol: Out with the Bad, In with the Good." Section 2.02. http://www.hsph.harvard.edu/nutritionsource/what-should-you -eat/fats-full-story/. A buildup of cholesterol in the blood can lead to brittle blood vessels and a blockage of blood flow to the affected area.

How saturated is the fat in your diet? Is it really necessary to eat saturated fat when the body makes all the saturated fat that it needs? Saturated fats should fall into the "bad" category—the body does not demand this kind of fat and it is proven to be a forerunner of cardiovascular disease. In the United States and other developed countries, populations acquire their saturated fat content mostly from meat, seafood, poultry (with skin consumed), and whole-milk dairy products (cheese, milk, and ice cream). Some plant foods are also high in saturated fats, including coconut oil, palm oil, and palm kernel oil.

Food Cholesterol's Effect on Blood Cholesterol

Dietary cholesterol does have a small impact on overall blood cholesterol levels, but not as much as some people may think. The average American female consumes 237 milligrams of dietary cholesterol per day and for males the figure is slightly higher—about 358 milligrams. The 2015 USDA dietary guidelines suggest a daily limit intake of cholesterol not to exceed 300 milligrams for healthy people and 200 milligrams for those who may be suffering from high cholesterol. Most people display little response to normal dietary cholesterol intake as the body responds by halting its own synthesis of the substance in favor of using the cholesterol obtained through food. Genetic factors may also influence the way a person's body modifies cholesterol.

A Prelude to Disease

If left unchecked, improper dietary fat consumption can lead down a path to severe health problems. An increased level of lipids, triacylglycerols, and cholesterol in the blood is called hyperlipidemia. Hyperlipidemia is inclusive of several conditions but more commonly refers to high cholesterol and triacylglycerol levels. When blood lipid levels are high, any number of adverse health problems may ensue. Consider the following:

- **Cardiovascular disease**. According to the AHA, cardiovascular disease encompasses a variety of problems, many of which are related to the process of atherosclerosis. Over time the arteries thicken and harden with plaque buildup, causing restricted or at times low or no blood flow to selected areas of the body.
- **Heart attack**. A heart attack happens when blood flow to a section of the heart is cut off due to a blood clot. Many have survived heart attacks and go on to return to their lives and enjoy many more years of life on this earth. However, dietary and lifestyle changes must be implemented to prevent further attacks.
- **Ischemic stroke**. The most common type of stroke in the United States, ischemic stroke, occurs when a blood vessel in the brain or leading to the brain becomes blocked, again usually from a blood clot. If part of the brain suffers lack of blood flow and/or oxygen for three minutes or longer, brain cells will start to die.

- **Congestive heart failure**. Sometimes referred to as heart failure, this condition indicates that the heart is not pumping blood as well as it should. The heart is still working but it is not meeting the body's demand for blood and oxygen. If left unchecked, it can progress to further levels of malfunction.
- **Arrhythmia**. This is an abnormal rhythm of the heart. The heart may beat above one hundred beats per minute (known as tachycardia) or below sixty beats per minute (known as bradychardia), or the beats are not regular. The heart may not be able to pump enough volume of blood to meet the body's needs.
- **Heart valve problems**. Stenosis is a condition wherein the heart valves become compromised in their ability to open wide enough to allow proper blood flow. When the heart valves do not close tightly and blood begins to leak between chambers, this is called regurgitation. When valves bulge or prolapse back into the upper chamber, this condition is called mitral valve prolapse.
- **Obesity**. Obesity is defined as the excessive accumulation of body fat. According to US Surgeon General Richard Carmona, obesity is the fastest growing cause of death in America. The HHS reports that the number of adolescents who are overweight has tripled since 1980 and the prevalence of the disease among younger children has doubled.US Department of Health and Human Services. "Childhood Obesity." Accessed October 5, 2012. http://aspe.hhs.gov/health/reports/child_obesity/. Obesity has been linked to increased risks of developing diabetes and heart disease. To help combat this problem important dietary changes are necessary. Reducing the type and amount of carbohydrates and sugar consumed daily is critical. Limiting the intake of saturated fats and trans fats, increasing physical activity, and eating fewer calories are all equally important in this fight against obesity.



Figure 4.8.1: *A 4-ml sample of hyperlipidemic blood with lipids separated into the top fraction (Sample is in an EDTA collection tube.). This is a standard EDTA (cell count) tube, as may be used to obtain a full blood count or iron studies. The tube was set upright for four hours - it was not centrifuged. This sample was not analyzed; however, a similar sample showed a serum triglyceride of over 130mmol/L (over 5000mg/dl), and an LDL over 40mmol/L (over 1540mg/dl). (public domain) from Carmen Crisp-Obenhaus.*

What You Can Do

Remember that saturated fats are found in large amounts in foods of animal origin. They should be limited within the diet. Polyunsaturated fats are generally obtained from nonanimal sources. While they are beneficial for lowering bad cholesterol they also lower good cholesterol. They are better for you than saturated fats but are not to be consumed in excess. Monounsaturated fats are of plant origin and are found in most nuts, seeds, seed oils, olive oil, canola oil, and legumes. Monounsaturated fats are excellent because they not only lower bad cholesterol, but also they elevate the good cholesterol. Replace current dietary fats with an increased intake of monounsaturated fats.

Choose whole-grain and high-fiber foods. Reduced risk for cardiovascular disease has been associated with diets that are high in whole grains and fiber. Fiber also slows down cholesterol absorption. The AHA recommends that at least half of daily grain intake should originate from whole grains. The Adequate Intake value for fiber is 14 grams per 1,000 kilocalories. These amounts are based upon the amount of fiber that has been shown to reduce cardiovascular risk.

Do not be sedentary. Get more exercise on a regular basis. Increasing your energy expenditure by just twenty minutes of physical activity at least three times per week will improve your overall health. Physical exercise can help you manage or prevent high blood pressure and blood cholesterol levels. Regular activity raises HDL while at the same time decreases triacylglycerols and

plaque buildup in the arteries. Calories are burned consistently, making it easier to lose and manage weight. Circulation will improve, the body will be better oxygenated, and the heart and blood vessels will function more efficiently.

Key Takeaways

- Food cholesterol does not affect blood cholesterol as much as some people think. The main causes of unfavorable blood cholesterol values come from an overconsumption of saturated fats and trans fats.
- An increased intake of lipids is associated with heart disease, obesity, cardiovascular disease, and other problems.
- Making dietary choices that limit the intake of saturated and trans fats to the recommended levels, replacing saturated and trans fats with monounsaturated and polyunsaturated fats, increasing physical activity, and cessation of smoking can reduce the risk of developing heart disease and other ailments.

Discussion Starters

1. Explain why saturated fats and trans fats contribute to unfavorable blood cholesterol levels.
2. Discuss some of the diseases that can result from an unhealthy lipid profile for an extended period of time.
3. List the types of fat that will help you achieve a healthy blood lipid profile. List the sources of these fats.
4. Evaluate your personal dietary and lifestyle habits. Identify key areas where you need to improve. Construct an overall plan of diet and lifestyle choices that you implement to help you reach healthy goals.

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4.9: A Personal Choice about Lipids

Learning Objectives

- Discuss ways to decrease saturated fat and cholesterol intake and increase unsaturated fat intake in your diet.

A Guide to Making Sense of Dietary Fat

On your next trip to the grocery store prepare yourself to read all food labels carefully and to seriously consider everything that goes into your shopping cart. Create a shopping list and divide your list into columns for “Best,” “Better,” “Good,” “Least Desirable,” and “Infrequent Foods.” As you refine your sense of dietary fat, here are key points to bear in mind:

Shopping for groceries. Don’t be bombarded with gratuitous grams of saturated fats and empty grams of trans fats. Read and decipher food labels carefully so that you know exactly what types of fat a food item contains and how much fat it will contribute to your overall fat intake. For snacks and daily eating, gravitate toward foods that are lowest in or absent of harmful trans fats. Restrict other foods to occasional usage based upon their fat content. For example, if selecting prepared foods, choose the ones without high-fat sauces in favor of adding your own flavorings. If selecting precooked meats, avoid those that are fried, coated, or prepared in high-fat sauces. A popular and healthy precooked meat food choice is the rotisserie chicken that most supermarkets carry. When selecting meats be aware of the need to compare different cuts—notice their fat content, color, and marbling. Higher-fat meats tend to have whiter fat marbled throughout. Choose lean cuts and white meat as these are lower in saturated fat. Always choose plenty of fresh fruits, vegetables, nuts, and seeds, as their phytosterols are a good competitor for cholesterol. Keep a collection of nuts in your freezer that can be added to your salads, stir-fry, one-dish foods, soups, desserts, and yogurts.

Appearance. Saturated and trans fats are not good for you and must be placed in your “Least Desirable” column because they increase cholesterol levels and put you at risk for heart disease. Monounsaturated and polyunsaturated fats are better choices to replace these undesirable fats. The key in identifying the “Best” or “Better” fats from the “Least Desirable” fats while you shop is based upon appearance. When choosing fats remember that saturated fats and trans fats are solid at room temperature; think of butter. Monounsaturated and polyunsaturated fats are liquid at room temperature; think of vegetable oil.

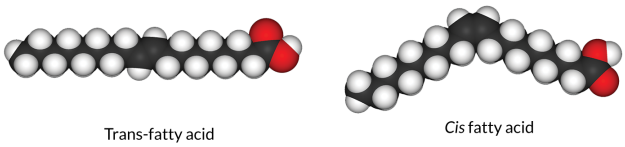


Figure 4.9.1: When a lipid molecule is unhydrogenated, the double bonds between the carbons keep it kinky and a liquid at room temperature. If that fat realigns into the trans formation, it gets straighter, forming up into a solid.

Note: Trans Fats

Stay away from trans fats. There is no amount of trans fats that are good for human health. Try to eliminate as much of these fats as possible from your food selections. Avoid commercially baked goods and fast foods. Make these your “Infrequent Foods.”

Choose unsaturated fats. Fatty fish, walnuts, flaxseeds, flaxseed oil, and canola oil all have good health benefits and should be on the “Best,” “Better,” and “Good” fat lists. They each provide essential omega-3 fatty acids necessary for overall body health. To derive the most benefit from including these foods, do not add them to an existing diet full of fat. Use these to replace the “Least Desirable” fats that are being removed from the diet. Be careful of exposing fats and oils to heat, light, and oxygen as they can be easily damaged. Exercise caution when heating oils. Polyunsaturated fats are the most fragile and lose beneficial properties when exposed to heat. For proper storage and freshness, place your oils in opaque containers and keep refrigerated. Do not use any oil if it has a bitter smell or taste.

Limit saturated fat intake. Reduce red meat consumption, processed meats, and whole-fat dairy products. A good replacement for red meat could be beans (black beans are very high in protein), nuts, poultry, and fish whenever possible. To reduce full-fat dairy items try their low-fat or nonfat counterparts such as mozzarella cheese.

Low fat does not equal healthy. Remember, a fat-free label does not provide you with a license to consume all the calories you desire. There will be consequences to your weight and your overall health. Common replacements for fat in many fat-free foods are

refined carbohydrates, sugar, and calories. Too much of these ingredients can also cause health problems. Choose and consume wisely.

Tools for Change

As a delicious alternative to red meat, try preparing and eating at least one meal each week using beans. For interesting ideas and tips, visit http://www.swbeans.com.

Helpful Suggestions

Keep the following in mind as you strive toward a healthier diet:

- **A "better-fat" diet will successfully support weight loss**. With the obesity rates in the United States more than tripling since 1980, it is interesting to note that this figure has presented itself and increased at a time when "low fat" advertising runs rampant throughout the food supply. While cutting "Least Desirable" fat calories are vital to weight loss, remember that "Better" fats are filling and just a handful of nuts can curb an appetite to prevent overeating.
- **Consume omega-3 fats each day**. For optimal health and disease prevention include a moderate serving of fish, walnuts, ground flaxseeds, flaxseed oil, or soybean oil in your diet every day.
- **Limit cholesterol-rich foods**. The following foods should be limited from the diet in order to reduce blood cholesterol: chicken livers, beef, pork, fast foods, pastries, butter, cheese, and ice cream.
- **How much saturated fat is too much?** Your goal is to keep your intake of saturated fat to no more than 10 percent of your total dietary calories on a daily basis. Thus, it is important to learn to reduce the intake of foods high in saturated fat. High-fat foods can be consumed but they must fall within the overall goal for a person's fat allowance for the day.
- **Home cooking**. Limit the use of saturated fats in home preparation of meals. Instead of butter try spreads made from unsaturated oils such as canola or olive oils and the use of cooking sprays. Couple this with the use of herbs and spices to add flavor. Avoid using high-fat meat gravies, cheese, and cream sauces. Limit adding extras to foods such as butter on a baked potato. Use nonfat sour cream instead. Grill, bake, stir-fry, roast, or bake your foods. Never fry in solid fats such as butter or shortening. Marinate foods to be grilled in fruit juices and herbs. Instead of relying upon commercial salad dressings, learn to make your own top-quality dressing from cold-pressed olive oil, flaxseed oil, or sesame oil.

Make sure the fat is flavorful. Adding flavor to food is what makes the eating experience enjoyable. Why not choose unsaturated fats and oils that have strong flavors? In this way you will add good flavor to your meals but use less fat in the process. Some examples are sesame oil, peanut oil, and peanut butter. Replace less flavorful cheeses with small amounts of strongly flavored cheeses such as romano, parmesan, and asiago.

Now that you have gained a wealth of information and food for thought to enable you to make changes to your dietary pattern we hope that your desire to pursue a healthier lifestyle has been solidified. While we realize that making grand strides in this direction may be awkward at first, even the smallest of accomplishments can produce noticeable results that will spur you on and perhaps spark the interest of friends and family to join you in this health crusade.

Becoming aware of the need to limit your total fat intake will facilitate your ability to make better choices. In turn, making better dietary choices requires gaining knowledge. As you understand that your food choices not only impact your personal physical health but also the delicate balance of our ecosystem, we are confident that you will successfully adapt to the dynamics of the ever-changing global food supply. Remember, the food choices you make today will benefit you tomorrow and into the years to come.

Key Takeaways

- To reduce saturated fat in your diet, eat less red and processed meat and more fish and chicken. Choose lean cuts of meat and white meat portions. Bake, broil, or grill instead of fry. Avoid deep-fried foods, cheeses, and creamy cheese sauces. Remove the skin from chicken and remove as much fat from meat as possible. Choose low-fat milk and lower fat cheeses, such as mozzarella, where possible. Use liquid vegetable oils such as olive oil or canola oil instead of shortening or butter.
- In order to reduce blood cholesterol, restrict the consumption of eggs, chicken livers, beef, pork, shrimp, crustaceans, fast foods, pastries, butter, cheese, and ice cream.
- To gain the most benefit from reducing your saturated fat intake, substitute unsaturated fats in the place of saturated fats and trans fats. Do not add unsaturated fats to an already fatty diet. Fill your plate with plant-based foods and use the foods containing fat more as an accompaniment.

Discussion Starters

1. Think of at least three ways to reduce, substitute, and eliminate from your diet foods that are higher in less-desirable fat. List some foods that you will add to your diet that will add bulk and help satisfy your need to eat, but do not contain the calories in fat-rich foods.
2. Make a list of your favorite snack foods. Then make a listing of the fat content in each. Decide what snack foods you should reduce or eliminate from your diet. Think of at least two replacement foods for these snacks. Tell what benefit these replacement foods will have on your overall health.
3. Make a list of all the common foods you eat that contain trans fats. Looking ahead, develop a plan of action for you to slowly eliminate as much of these fats from your diet as possible. What substitutes will you add in their place? How will you cut out trans fats from your diet?

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4.E: Exercises

It's Your Turn

1. Provide examples of three foods that are rich in unsaturated fats.
2. Assume you are reluctant to eat fish. Name three other sources of omega-3 fats.
3. Your friend tends to feel cold a lot of the time, is often tired, and has developed sores on her skin. Based on the content in this chapter, identify a nutritional reason for this condition.
4. Explain the role of lipids in your overall health.

Apply It

1. Make a chart of the three main types of lipids, their specific functions in the body, and where they are found.
2. Diagram the steps in lipid digestion and absorption.
3. Create a blood lipid profile with healthy ranges.

Expand Your Knowledge

1. You're making a concerted effort to begin eating more foods that will promote good health. Turn your attention to omega-3 fatty acids. What will you incorporate into your diet?
2. Obesity rates in the United States have more than tripled since 1980. At the same time, "low fat" advertising is all over the news. How would you explain this?
3. Review and analyze the Cholesterol Risk Chart on the following site: heartriskonline.com/CholesterolChart.htm. Check with three members of your family or close friends. Where do they "fit" into this chart?

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5: Proteins

In this chapter, we cover the structure and roles of protein, and explore the consequences of getting too little or too much protein in your diet. Tips for getting the right amount and quality of protein, as well as a look at special populations, such as the elderly and athletes, are also covered.

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5.1: Chapter Introduction

Big Idea

Protein is best used for vital body functions—eat just enough for your lifestyle needs.

Some dieters use protein bars as a prime part of their diet, with the hopes of slimming their waistlines. Exercise cafes serve protein shakes to many of their patrons, who drink them for building muscle and enhancing exercise recovery. Some people have stopped eating meat and feel the need to use protein supplements to ensure they are getting their required protein intake each day. After all, protein is a vital constituent of all organs in the body and is required to synthesize hormones, enzymes, and a variety of molecules.



Figure 5.1.1: Is protein supplement consumption a healthy way to supply your body with this vital macronutrient? Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement. (CC-SA-BY 3.0; Sandstein).

It is no wonder that so many people are preoccupied with optimizing their dietary protein intake. Dieters, athletes, physically active people, and vegetarians may worry that they lack protein in their diet and that they need to consume more from protein bars, shakes, or supplements to perform better and optimize health. This chapter will help address these concerns. First, let us take a look at vegetarian diets.

There are different types of vegetarians, but a common theme is that vegetarians do not eat meat. Four common forms of vegetarianism are:

1. **Lacto-ovo vegetarian.** This is the most common form. This type of vegetarian eats eggs and dairy.
2. **Lacto-vegetarian.** This type of vegetarian eats dairy products but not eggs.
3. **Ovo-vegetarian.** This type of vegetarian eats eggs but not dairy products.
4. **Vegan.** This type of vegetarian does not eat dairy, eggs, or any type of animal product or by-product.

People choose a vegetarian diet for various reasons, including religious doctrines, health concerns, ecological and animal welfare concerns, or simply because they dislike the taste of meat. Vegetarianism has been practiced for centuries. In the fourth century BC, great thinkers such as Pythagoras and Plato promoted vegetarian diets in their natural philosophies. Ancient Olympians were placed on vegetarian diets one month prior to the Olympic Games.

Gladiators were tough men who fought violently against each other during games sponsored by the Roman Empire's upper-class political rulers. In 1993, archeologists uncovered a gladiator burial ground not far from the Temple of Artemis. To their surprise, forensic analysis of the gladiators' bones revealed that they consumed a vegetarian diet. This information matches other historical accounts that gladiators ate a diet rich in barley and dried fruits. Hulled barley is a very nutritious whole grain; it is a complete protein source, containing more than 20 grams of protein and all nine essential amino acids in a one-cup serving.

Although the great philosophers, ancient Olympic athletes, and Roman gladiators saw vegetarianism as a means of maintaining optimal health, it took a while for the vegetarian dietary pattern to catch on in America. In 1987, John Robbins wrote *Diet for a New America* and popularized the vegan diet first introduced by Jay Dinshah in the United States in 1960. In the early 1990s, Dr. John McDougall wrote a series of books that promoted vegan dietary regimens to ward off chronic disease. Also during the 1990s, scientific evidence accumulated that supported that diets consisting of too much red meat were linked to chronic disease. This prompted many health organizations, such as the Academy of Nutrition and Dietetics (AND) and the American Heart Association (AHA), to issue statements endorsing the health benefits of vegetarian diets. These statements can be read at www.eatright.org/about/content.aspx?id=8357 and bit.ly/O2VQkC.

The US federal government was unable to ignore the health benefits of plant-based diets any longer, and consequently released the *2010 Dietary Guidelines* in which Americans were challenged to eat a more plant-based diet. Moreover, the *Dietary Guidelines* Advisory Committee stated, “In prospective studies of adults, compared to nonvegetarian eating patterns, vegetarian-style eating patterns have been associated with improved health outcomes—lower levels of obesity, a reduced risk of cardiovascular disease, and lower total mortality.”

You Decide

What are the best sources of protein and how much protein do I need to eat to have a healthy diet?

Whether you choose to consume protein from animal- or plant-derived products, an important factor to consider is the entire nutrient package of the food. What other fats, nutrients, additives, or preservatives come with the protein source? Red meat is a popular choice for protein, but it contains high amounts of saturated fat. Fish is another good protein choice, and it provides much less saturated fat than other meats, in addition to more healthy fats. Some plant-based sources of protein contain high amounts of protein per serving with just under one gram of less desirable fat in addition to good amounts of healthy fats. As you read through this chapter you will learn how to choose the best protein sources to support your health.

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5.2: Defining Protein

Learning Objectives

- Categorize the different types of amino acids.
- Describe how protein differs in structure from carbohydrates and lipids.

Protein makes up approximately 20 percent of the human body and is present in every single cell. The word protein is a Greek word, meaning “of utmost importance.” Proteins are called the workhorses of life as they provide the body with structure and perform a vast array of functions. You can stand, walk, run, skate, swim, and more because of your protein-rich muscles. Protein is necessary for proper immune system function, digestion, and hair and nail growth, and is involved in numerous other body functions. In fact, it is estimated that more than one hundred thousand different proteins exist within the human body. In this chapter, you will learn about the components of protein, the important roles that protein serves within the body, how the body uses protein, the risks and consequences associated with too much or too little protein, and where to find healthy sources of it in your diet.



Figure 5.2.1: Your protein-rich muscles allow for body strength and movement, which enable you to enjoy many activities. Australia v Japan on 24 March 2012 at Hawker International Softball Centre. (CC-SA-BY 3.0; LauraHale)

What Is Protein?

Proteins, simply put, are macromolecules composed of amino acids. Amino acids are commonly called protein’s building blocks. Proteins are crucial for the nourishment, renewal, and continuance of life. Proteins contain the elements carbon, hydrogen, and oxygen just as carbohydrates and lipids do, but proteins are the only macronutrient that contains nitrogen. Nitrogen makes up approximately 16% of the weight of an amino acid. In each amino acid, the elements are arranged into a specific conformation around a carbon center. Each amino acid consists of a central carbon atom connected to a side chain, a hydrogen, a nitrogen-containing *amino* group, a carboxylic *acid* group—hence the name “amino acid.” Amino acids differ from each other by which specific side chain is bonded to the carbon center.

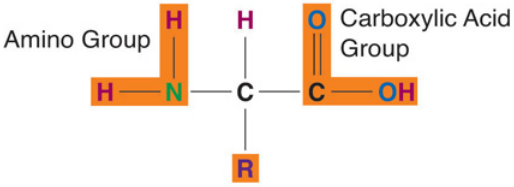


Figure 5.2.2: *Amino Acid Structure*

Amino acids contain four elements. The arrangement of elements around the carbon center is the same for all amino acids. Only the side chain (R) differs.

It's All in the Side Chain

The side chain of an amino acid, sometimes called the "R" group determines the name of the amino acid. It can be as simple as one hydrogen bonded to the carbon center, or as complex as a six-carbon ring bonded to the carbon center. Although each side chain of the twenty amino acids is unique, there are some chemical likenesses among them. Therefore, they can be classified into four different groups (Figure 5.2.2). These are nonpolar, polar, acidic, and basic.

- **Nonpolar amino acids.** Nonpolar amino acids include alanine (Ala), leucine (Leu), isoleucine (Ile), proline (Pro), tryptophan (Trp), valine (Val), phenylalanine (Phe), and methionine (Met). The side chains of these amino acids are long carbon chains or carbon rings, making them bulky. They are hydrophobic, meaning they repel water.
- **Polar amino acids.** Polar amino acids are glycine (Gly), serine (Ser), threonine (Thr), cysteine (Cys), tyrosine (Tyr), asparagine (Asn), and glutamine (Gln). The side chains of polar amino acids make them hydrophilic, meaning they are water-soluble.
- **Acidic amino acids.** Acidic amino acids are negatively charged, hydrophilic amino acids and include aspartic acid (Asp) and glutamic acid (Glu).
- **Basic amino acids.** Basic amino acids are positively charged, hydrophilic amino acids and include lysine (Lys), arginine (Arg), and histidine (His).

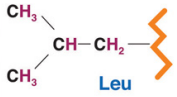
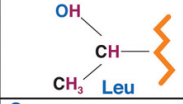
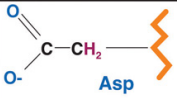
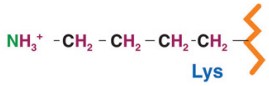
Group	Characteristics	Name	Example (-Rx)
non-polar	hydrophobic	Ala, Val, Leu, Ile, Pro, Phe Trp, Met	
polar	hydrophilic (non-charged)	Gly, Ser, Thr, Cys, Tyr, Asn Gln	
acidic	negatively charged	Asp, Glu	
basic	positively charged	Lys, Arg, His	
		Total = 20	

Figure 5.2.3: Amino acids are classified into four groups. These are nonpolar, polar, acidic, and basic.

Essential and Nonessential Amino Acids

Amino acids are further classified based on nutritional aspects. Recall that there are twenty different amino acids, and we require all of them to make the many different proteins found throughout the body (Table 6.1). Eleven of these are called nonessential amino acids because the body can synthesize them. However, nine of the amino acids are called essential amino acids because we cannot synthesize them either at all or in sufficient amounts. These must be obtained from the diet. Sometimes during infancy, growth, and in diseased states, the body cannot synthesize enough of some of the nonessential amino acids and more of them are required in the diet. These types of amino acids are called conditionally essential amino acids. The nutritional value of a protein is dependent on what amino acids it contains and in what quantities.

Table 5.2.1: Essential and Nonessential Amino Acids

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine*
*Conditionally essential	

Essential	Nonessential
Leucine	Asparagine
Lysine	Aspartic acid
Methionine	Cysteine*
Phenylalanine	Glutamic acid
Threonine	Glutamine*
Tryptophan	Glycine*
Valine	Proline*
	Serine
	Tyrosine*
*Conditionally essential	

The Many Different Types of Proteins

As discussed, there are over one hundred thousand different proteins in the human body. Different proteins are produced because there are twenty types of naturally occurring amino acids that are combined in unique sequences. Additionally, proteins come in many different sizes. Two amino acids bond together are called a dipeptide while ten or more amino acids bound together are called a polypeptide. The hormone insulin, which regulates blood glucose, is composed of only fifty-one amino acids; whereas collagen, a protein that acts like glue between cells consists of more than one thousand amino acids. Titin is the largest known protein. It accounts for the elasticity of muscles, and consists of more than twenty-five thousand amino acids! The abundant variations of proteins are due to the unending number of amino acid sequences that can be formed. To compare how so many different proteins can be designed from only twenty amino acids, think about music. All of the music that exists in the world has been derived from a basic set of seven notes C, D, E, F, G, A, B and variations thereof. As a result, there is a vast array of music and songs all composed of specific sequences from these basic musical notes. Similarly, the twenty amino acids can be linked together in an extraordinary number of sequences, much more than are possible for the seven musical notes to create songs. As a result, there are enormous variations and potential amino acid sequences that can be created. For example, if an amino acid sequence for a protein is 104 amino acids long the possible combinations of amino acid sequences is equal to 20^{104}, which is 2 followed by 135 zeros!

Building Proteins with Amino Acids

The building of a protein consists of a complex series of chemical reactions that can be summarized into three basic steps: transcription, translation, and protein folding (Figure 6.3). The first step in constructing a protein is the transcription (copying) of the genetic information in double-stranded deoxyribonucleic acid (DNA) into the single-stranded, messenger macromolecule ribonucleic acid (RNA). RNA is chemically similar to DNA, but has two differences; one is that its backbone uses the sugar ribose and not deoxyribose; and two, it contains the nucleotide base uracil, and not thymidine. The RNA that is transcribed from a given piece of DNA contains the same information as that DNA, but it is now in a form that can be read by the cellular protein manufacturer known as the ribosome. Next, the RNA instructs the cells to gather all the necessary amino acids and add them to the growing protein chain in a very specific order. This process is referred to as translation. The decoding of genetic information to synthesize a protein is the central foundation of modern biology.

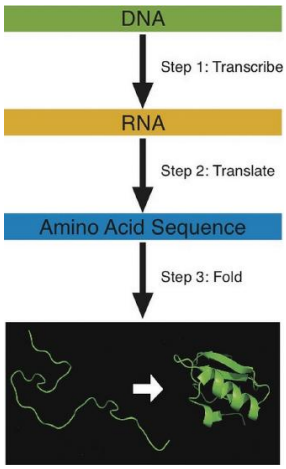


Figure 5.2.4: Building a protein involves three steps: transcription, translation, and folding.

During translation, each amino acid is connected to the next amino acid by a special chemical bond called a peptide bond (Figure 6.4). The peptide bond forms between the carboxylic acid group of one amino acid and the amino group of another, releasing a molecule of water. The third step in protein production involves folding it into its correct shape. Specific amino acid sequences contain all the information necessary to spontaneously fold into a particular shape. A change in the amino acid sequence will cause a change in protein shape. Each protein in the human body differs in its amino acid sequence and consequently, its shape. The newly synthesized protein is structured to perform a particular function in a cell. A protein made with an incorrectly placed amino acid may not function properly and this can sometimes cause disease.

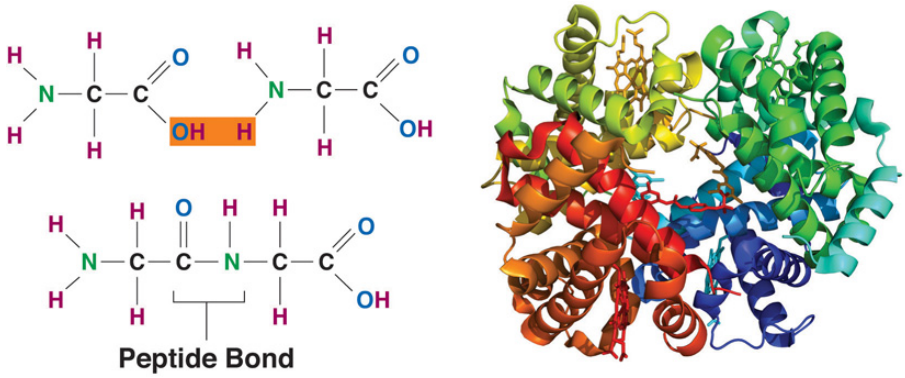


Figure 5.2.5: Connecting amino acids with peptide bonds builds proteins. In the process of translation, amino acids are sequentially strung along in a chain in a specific sequence that spontaneously folds into the correct protein shape.

Protein Organization

The structure and function of proteins are determined by their amino acid sequence. Protein's structure enables it to perform a variety of functions. Proteins are similar to carbohydrates and lipids in that they are polymers of simple repeating units; however, proteins are much more structurally complex. In contrast to carbohydrates, which have identical repeating units, proteins are made up of amino acids that are different from one another. Furthermore, a protein is organized into four different structural levels (Figure 6.5). The first level is the one-dimensional sequence of amino acids that are held together by peptide bonds. Carbohydrates and lipids also are one-dimensional sequences of their respective monomers, which may be branched, coiled, fibrous, or globular, but their conformation is much more random and is not organized by their sequence of monomers. In contrast, the two-dimensional level of protein structure is dependent on the chemical interactions between amino acids, which cause the protein to fold into a specific shape, such as a helix (like a coiled spring) or sheet. The third level of protein structure is three-dimensional. As the different side chains of amino acids chemically interact, they either repel or attract each other, resulting in the coiled structure. Thus, the specific sequence of amino acids in a protein directs the protein to fold into a specific, organized shape. The fourth level of structure (also known as its "quaternary" structure) is achieved when protein fragments called peptides combine to make one larger functional protein. The protein hemoglobin is an example of a protein that has quaternary structure. It is composed of four peptides that bond together to form a functional oxygen carrier. A protein's structure also influences its nutritional quality. Large

fibrous protein structures are more difficult to digest than smaller proteins and some, such as keratin, are indigestible. Because digestion of some fibrous proteins is incomplete, not all of the amino acids are absorbed and available for the body to utilize, thereby decreasing their nutritional value.

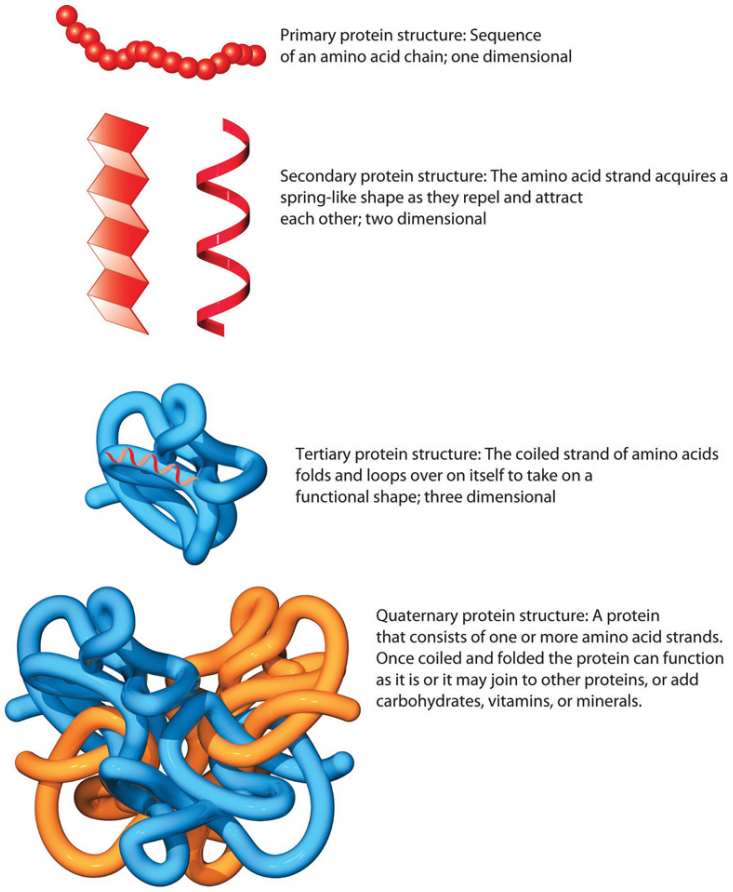
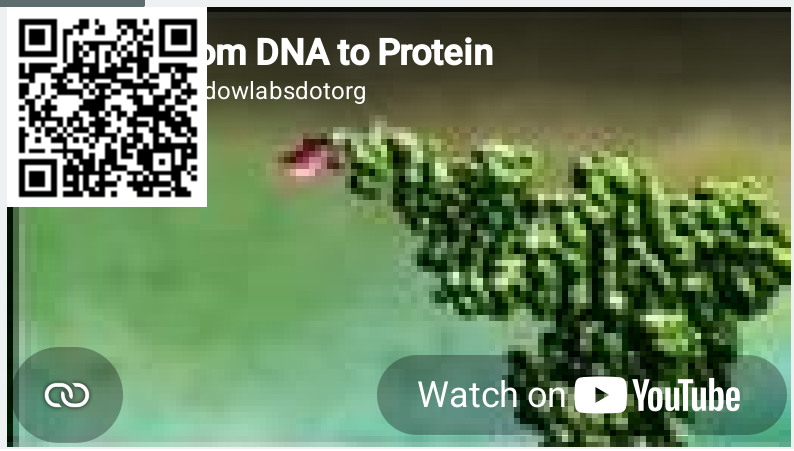


Figure 5.2.6: A protein has four different structural levels.

Video 5.1: From DNA to Protein



See the process of building a protein in real time in this animation. (click to see video)

Key Takeaways

- Amino acids differ chemically in the molecular composition of their side chains, but they do have some similarities. They are grouped into four different types: nonpolar, polar, acidic, and basic.
- Amino acids are also categorized based upon their nutritional aspects. Some are nonessential in the diet because the body can synthesize them, and some are essential in the diet because the body cannot make them.

- Proteins are polymers of amino acid monomers held together by peptide bonds. They are built in three steps; transcription, translation, and folding.
- Proteins have up to four different levels of structure, making them much more complex than carbohydrates or lipids.

Discussion Starters

1. There are over four thousand diseases caused by incorrectly built protein. Find out more about how one incorrectly placed amino acid causes the disease sickle cell anemia by watching this animation.

   http://www.dnalc.org/resources/3d/17-sickle-cell.html.

2. Why do you think protein-building diseases are rare? In every cell in your body over ten million ribosomes are at work constructing millions of proteins every minute. What can you say about the body's amazing track record in correctly building proteins?

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5.3: The Role of Proteins in Foods- Cooking and Denaturation

Learning Objectives

- Explain the process of denaturation and its consequences. Give an example.

In addition to having many vital functions within the body, proteins perform different roles in our foods by adding certain functional qualities to them. Protein provides food with structure and texture and enables water retention. For example, proteins foam when agitated. (Picture whisking egg whites to make angel food cake. The foam bubbles are what give the angel food cake its airy texture.) Yogurt is another good example of proteins providing texture. Milk proteins called caseins coagulate, increasing yogurt's thickness. Cooked proteins add some color to foods as the amino group binds with carbohydrates and produces a brown pigment. Eggs are between 10 and 15 percent protein by weight. Most cake recipes use eggs because the egg proteins help bind all the other ingredients together into a uniform cake batter. The proteins aggregate into a network during mixing and baking that gives cake structure.



Figure 5.3.1: Protein gives structure and texture to cakes. A layered pound cake, with alternating interstitial spaces filled with raspberry jam and lemon curd, finished with buttercream frosting. Image use with permission (Public domain; Scheinwerfermann).

Protein Denaturation: Unraveling the Fold

When a cake is baked, the proteins are denatured. Denaturation refers to the physical changes that take place in a protein exposed to abnormal conditions in the environment. Heat, acid, high salt concentrations, alcohol, and mechanical agitation can cause proteins to denature. When a protein denatures, its complicated folded structure unravels, and it becomes just a long strand of amino acids again. Weak chemical forces that hold tertiary and secondary protein structures together are broken when a protein is exposed to unnatural conditions. Because proteins' function is dependent on their shape, denatured proteins are no longer functional. During cooking the applied heat causes proteins to vibrate. This destroys the weak bonds holding proteins in their complex shape (though this does not happen to the stronger peptide bonds). The unraveled protein strands then stick together, forming an aggregate (or network).

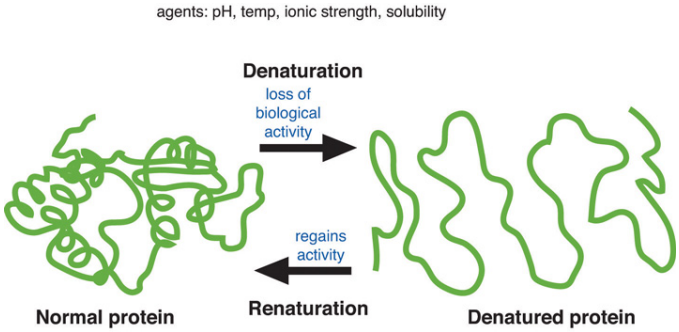


Figure 5.3.2: When a protein is exposed to a different environment, such as increased temperature, it unfolds into a single strand of amino acids.

Interactive 5.3.1: Denaturing of Egg Proteins

View this animation of egg proteins denaturing.
http://www.sumanasinc.com/webcontent/animations/content/proteinstructure.html

Key Takeaways

- Proteins provide food not only with nutrition, but also with structure and texture.
- When a protein denatures, its complicated structure unfolds into a strand of amino acids.

Discussion Starters

1. Gelatin is a mixture of collagen proteins. How does gelatin add texture and structure to foods? Conduct an experiment by making some Jell-O™ using different methods of denaturation and discuss what happens to the texture and structure.
    1. Make the first batch of Jell-O™ following the directions. Does it set?
    2. Next, make up the Jell-O™, but replace hot water with cold. Does it set?
    3. Instead of adding hot water, add 2 teaspoons of salt and only cold water. Does it set?
    4. Take the first batch (that is now set) and either whisk it by hand or use an electric mixer. What happens?
2. If pouring salt on a live slug produces a puddle of goo, how is it possible to cook snails with salt and get a delicious dish?

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5.4: Protein Digestion, Absorption and Metabolism

Learning Objectives

- Discuss how proteins are digested and absorbed by our bodies.

How do the proteins from foods, denatured or not, get processed into amino acids that cells can use to make new proteins? When you eat food the body's digestive system breaks down the protein into the individual amino acids, which are absorbed and used by cells to build other proteins and a few other macromolecules, such as DNA. Let's follow the specific path that proteins take down the gastrointestinal tract and into the circulatory system. Eggs are a good dietary source of protein and will be used as our example to describe the path of proteins in the processes of digestion and absorption. One egg, whether raw, hard-boiled, scrambled, or fried, supplies about six grams of protein.



Figure 5.4.1: The egg is a good dietary source of protein. White, speckled (red), and brown chicken eggs. (CC-SA-BY 3.0; Timothy Titus)

From the Mouth to the Stomach

Unless you are eating it raw, the first step in egg digestion (or any other protein food) involves chewing. The teeth begin the mechanical breakdown of the large egg pieces into smaller pieces that can be swallowed. The salivary glands provide some saliva to aid swallowing and the passage of the partially mashed egg through the esophagus. The mashed egg pieces enter the stomach through the esophageal sphincter. The stomach releases gastric juices containing hydrochloric acid and the enzyme, pepsin, which initiate the breakdown of the protein. The acidity of the stomach facilitates the unfolding of the proteins that still retain part of their three-dimensional structure after cooking and helps break down the protein aggregates formed during cooking. Pepsin, which is secreted by the cells that line the stomach, dismantles the protein chains into smaller and smaller fragments. Egg proteins are large globular molecules and their chemical breakdown requires time and mixing. The powerful mechanical stomach contractions churn the partially digested protein into a more uniform mixture called chyme. Protein digestion in the stomach takes a longer time than carbohydrate digestion, but a shorter time than fat digestion. Eating a high-protein meal increases the amount of time required to sufficiently break down the meal in the stomach. Food remains in the stomach longer, making you feel full longer.

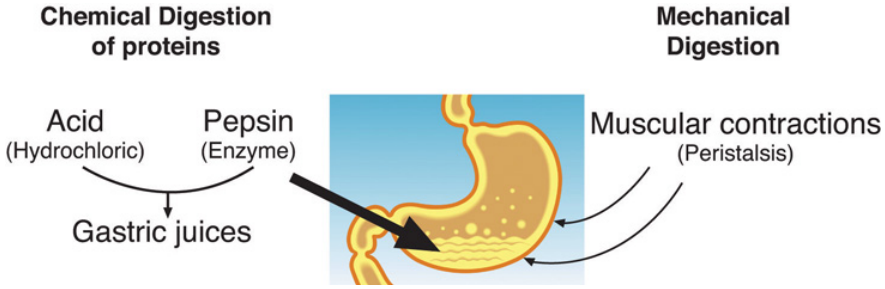


Figure 5.4.2: Protein digestion requires the chemical actions of gastric juice and the mechanical actions of the stomach.

From the Stomach to the Small Intestine

The stomach empties the chyme containing the broken down egg pieces into the small intestine, where the majority of protein digestion occurs. The pancreas secretes digestive juice that contains more enzymes that further break down the protein fragments. The two major pancreatic enzymes that digest proteins are chymotrypsin and trypsin. The cells that line the small intestine release additional enzymes that finally break apart the smaller protein fragments into the individual amino acids. The muscle contractions of the small intestine mix and propel the digested proteins to the absorption sites. The goal of the digestive process is to break the protein into dipeptides and amino acids for absorption.

In the lower parts of the small intestine, the amino acids are transported from the intestinal lumen through the intestinal cells to the blood. This movement of individual amino acids requires special transport proteins and the cellular energy molecule, adenosine triphosphate (ATP). Once the amino acids are in the blood, they are transported to the liver. As with other macronutrients, the liver is the checkpoint for amino acid distribution and any further breakdown of amino acids, which is very minimal. Recall that amino acids contain nitrogen, so further catabolism of amino acids releases nitrogen-containing ammonia. Because ammonia is toxic, the liver transforms it into urea, which is then transported to the kidney and excreted in the urine. Urea is a molecule that contains two nitrogens and is highly soluble in water. This makes it a good choice for transporting excess nitrogen out of the body. Because amino acids are building blocks that the body reserves in order to synthesize other proteins, more than 90 percent of the protein ingested does not get broken down further than the amino acid monomers.

Very little protein makes it to the large intestine if you are not eating excessive amounts. If you have smelly flatulence, this may be a sign you are eating too much protein because the excess is making it to the colon where you gut microbes are digesting it and producing smelly gas.

Protein Absorption

In adults, essentially all protein is absorbed as tripeptides, dipeptides or amino acids and this process occurs in the duodenum or proximal jejunum of the small intestine. The peptides and/or amino acids pass through the interstitial brush border by facilitative diffusion or active transport. Active transport sodium and ATP to actively transport the molecule through the cell membrane. The R group determines the type of transporter used. Once passed through the membrane, the amino acids or peptides are released into the intestinal blood stream and are transported to the liver by the hepatic (liver) portal vein. This is known as the enterohepatic circulation.

In the liver, 50-65% remain and are used to synthesize protein, nitrogen containing compounds and form purine/pyrimidine bases. In some cases, they may be converted to energy. The liver regulates the amino acid levels in the blood. The amino acids that do not stay in the liver, pass through and are transported to the rest of the body to be taken up and utilized by other cells. Most branch chain amino acids pass through the liver.

-

Nitrogen Metabolism Overview

Amino acids are unique because they contain nitrogen. Several things can happen to the nitrogen. First, it can remain on the molecule and be incorporated into the product that cell is making, for example, a polypeptide. The nitrogen may be transaminated, in other words, the amine group (NH_2) is transferred to another carbon skeleton to form a new amino acid. An example would be the transfer of the amine from the non-essential amino acid, alanine, to alpha-ketoglutaric acid to make glutamic acid, another non-essential amino acid. The water-soluble vitamin B_6 is needed for this process.

The amine group may be removed from the amino acid in a process known as deamination. This process is used for the excretion of the nitrogen, and the carbon skeleton is used to produce energy. Again, vitamin B_6 is needed for this process.

The nitrogen removed from amino acids is excreted via several different routes. The most familiar path is urine where most of the nitrogen is in the form of urea. Nitrogen is also excreted in the feces, skin, hair, and nails. In skin, hair, and nails the nitrogen is bound to protein as this is the building block of each.

Amino Acids Are Recycled

Just as some plastics can be recycled to make new products, amino acids are recycled to make new proteins. All cells in the body continually break down proteins and build new ones, a process referred to as protein turnover. Every day over 250 grams of protein in your body are dismantled and 250 grams of new protein are built. To form these new proteins, amino acids from food and those

from protein destruction are placed into a “pool.” Though it is not a literal pool, when an amino acid is required to build another protein it can be acquired from the additional amino acids that exist within the body. Amino acids are used not only to build proteins, but also to build other biological molecules containing nitrogen, such as DNA and RNA, and to some extent to produce energy. It is critical to maintaining amino acid levels within this cellular pool by consuming high-quality proteins in the diet, or the amino acids needed for building new proteins will be obtained by increasing protein destruction from other tissues within the body, especially muscle. This amino acid pool is less than one percent of total body protein content. Thus, the body does not store protein as it does with carbohydrates (as glycogen in the muscles and liver) and lipids (as triglycerides in adipose tissue).

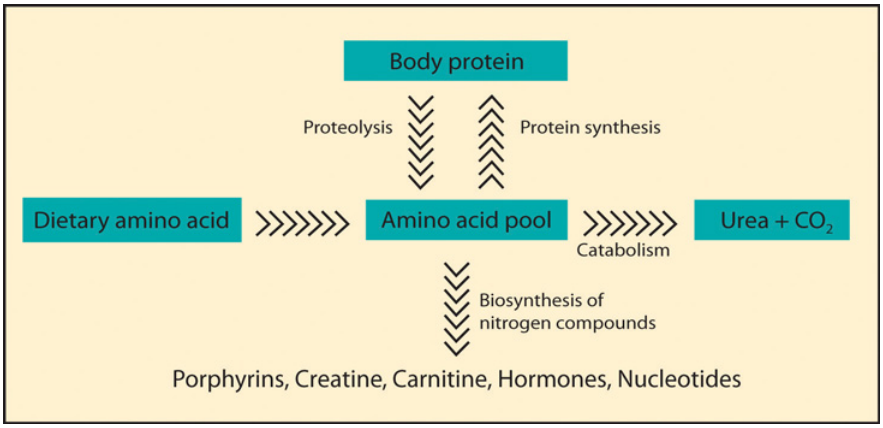


Figure 5.4.3: Amino acids in the cellular pool come from dietary protein and from the destruction of cellular proteins. The amino acids in this pool need to be replenished because amino acids are outsourced to make new proteins, energy, and other biological molecules.

Key Takeaways

- Mechanical digestion of protein begins in the mouth and continues in the stomach and small intestine.
- Chemical digestion of protein begins in the stomach and ends in the small intestine.
- The body recycles amino acids to make more proteins.

Discussion Starters

1. The next time you eat an egg, imagine it moving down the gastrointestinal tract and visualize what is happening to the proteins it contains. Does the amount of work required to digest a protein seem to be too much? How much energy does it take just to digest protein?
2. Why is it important to recycle amino acids?

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5.5: Protein's Functions in the Body

Learning Objectives

- List protein's functions in the body.

Proteins are the "workhorses" of the body and participate in many bodily functions. As you may recall, proteins come in all sizes and shapes and each is specifically structured for its particular function.

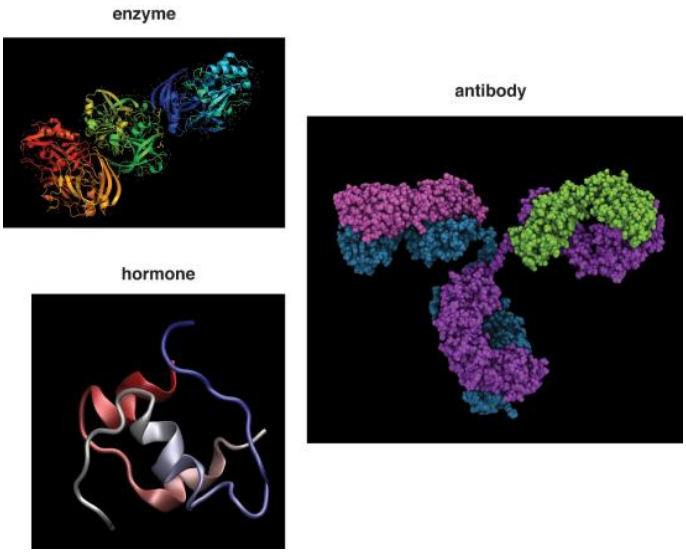


Figure 5.5.1: Proteins come in all sizes and shapes.

Structure and Motion

More than one hundred different structural proteins have been discovered in the human body, but the most abundant by far is collagen, which makes up about 6 percent of total body weight. Collagen makes up 30 percent of bone tissue and comprises large amounts of tendons, ligaments, cartilage, skin, and muscle. **Collagen** is a strong, fibrous protein made up of mostly glycine and proline amino acids. Within its quaternary structure three protein strands twist around each other like a rope and then these collagen ropes overlap with others. This highly ordered structure is even stronger than steel fibers of the same size. Collagen makes bones strong, but flexible. Collagen fibers in the skin's dermis provide it with structure, and the accompanying **elastin** protein fibrils make it flexible. Pinch the skin on your hand and then let go; the collagen and elastin proteins in the skin allow it to go back to its original shape. Smooth-muscle cells that secrete collagen and elastin proteins surround blood vessels, providing the vessels with structure and the ability to stretch back after blood is pumped through them. Another strong, fibrous protein is **keratin**, which is what skin, hair, and nails are made of.

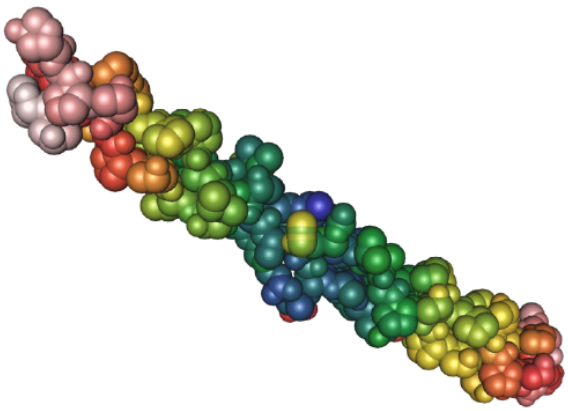


Figure 5.5.2: *Collagen: A strong protein made up of three intertwined peptides. (CC-SA-By; Nevit Dilmen).*

The closely packed collagen fibrils in tendons and ligaments allow for synchronous mechanical movements of bones and muscle and the ability of these tissues to spring back after a movement is complete. Move your fingers and watch the synchrony of your knuckle movements. In order to move, muscles must contract. The contractile parts of muscles are the proteins **actin** and **myosin**. When these proteins are stimulated by a nerve impulse they slide across each other, causing a shortening of the muscle cell. Upon stimulation, multiple muscle cells shorten at the same time, resulting in muscle contraction.

Video 5.5.1: Muscle Contraction: The Sliding Filament Model

- Watch this video to see actin and myosin in action. (click to see video)

Enzymes

- Although proteins are found in the greatest amounts in connective tissues such as bone, their most extraordinary function is as enzymes. Enzymes are proteins that conduct specific chemical reactions. An enzyme's job is to provide a site for a chemical reaction and to lower the amount of energy and time it takes for that chemical reaction to happen (this is known as "catalysis"). On average, more than one hundred chemical reactions occur in cells every single second and most of them require enzymes. The liver alone contains over one thousand enzyme systems. Enzymes are specific and will use only particular substrates that fit into their active site, similar to the way a lock can be opened only with a specific key. Nearly every chemical reaction requires a specific enzyme. Fortunately, an enzyme can fulfill its role as a catalyst over and over again, although eventually it is destroyed and rebuilt. All bodily functions, including the breakdown of nutrients in the stomach and small intestine, the transformation of nutrients into molecules a cell can use, and building all macromolecules, including protein itself, involve enzymes.

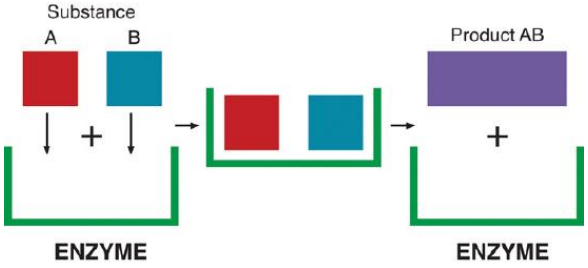


Figure 5.5.3: Enzymes are proteins. An enzyme's job is to provide a site for substances to chemically react and form a product and decrease the amount of energy and time it takes for this to happen.

Video 5.5.2: Enzyme

Watch this animation of an enzyme at work. (click to see video)

Hormones

Proteins are responsible for hormone synthesis. Recall that hormones are the chemical messages produced by the endocrine glands. When an endocrine gland is stimulated, it releases a hormone. The hormone is then transported in the blood to its target cell, where it communicates a message to initiate a specific reaction or cellular process. For instance, after you eat a meal, your blood glucose levels rise. In response to the increased blood glucose, the pancreas releases the hormone insulin. Insulin tells the cells of the body that glucose is available and to take it up from the blood and store it or use it for making energy or building macromolecules. A major function of hormones is to turn enzymes on and off, so some proteins can even regulate the actions of other proteins. While not all hormones are made from proteins, many of them are.

Fluid and Acid-Base Balance

Proper protein intake enables the basic biological processes of the body to maintain the status quo in a changing environment. Fluid balance refers to maintaining the distribution of water in the body. If too much water in the blood suddenly moves into a tissue, the

results are swelling and, potentially, cell death. Water always flows from an area of high concentration to one of a low concentration. As a result, water moves toward areas that have higher concentrations of other solutes, such as proteins and glucose. To keep the water evenly distributed between blood and cells, proteins continuously circulate at high concentrations in the blood. The most abundant protein in blood is the butterfly-shaped protein known as **albumin**. Albumin's presence in the blood makes the protein concentration in the blood similar to that in cells. Therefore, fluid exchange between the blood and cells is not in the extreme, but rather is minimized to preserve the status quo.

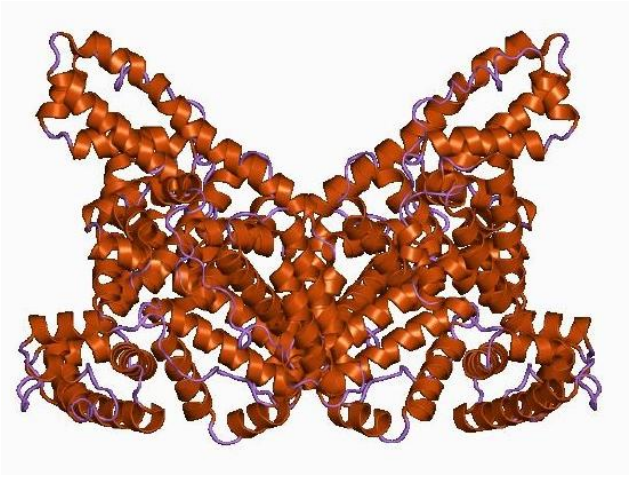


Figure 5.5.4: The butterfly-shaped protein, albumin, has many functions in the body including maintaining fluid and acid-base balance and transporting molecules. Cartoon representation of the molecular structure of protein registered with 1ao6 code. (Public Domain; Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute).

Protein is also essential in maintaining proper pH balance (the measure of how acidic or basic a substance is) in the blood. Blood pH is maintained between 7.35 and 7.45, which is slightly basic. Even a slight change in blood pH can affect body functions. Recall that acidic conditions can cause protein denaturation, which stops proteins from functioning. The body has several systems that hold the blood pH within the normal range to prevent this from happening. One of these is the circulating albumin. Albumin is slightly acidic, and because it is negatively charged it balances the many positively charged molecules, such as hydrogen protons (H^+), calcium, potassium, and magnesium which are also circulating in the blood. Albumin acts as a buffer against abrupt changes in the concentrations of these molecules, thereby balancing blood pH and maintaining the status quo. The protein hemoglobin also participates in acid-base balance by binding hydrogen protons.

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Transport

Albumin and hemoglobin also play a role in molecular transport. Albumin chemically binds to hormones, fatty acids, some vitamins, essential minerals, and drugs, and transports them throughout the circulatory system. Each red blood cell contains millions of hemoglobin molecules that bind oxygen in the lungs and transport it to all the tissues in the body. A cell's plasma membrane is usually not permeable to large polar molecules, so to get the required nutrients and molecules into the cell many transport proteins exist in the cell membrane. Some of these proteins are channels that allow particular molecules to move in and out of cells. Others act as one-way taxis and require energy to function (Figure 5.5.5).

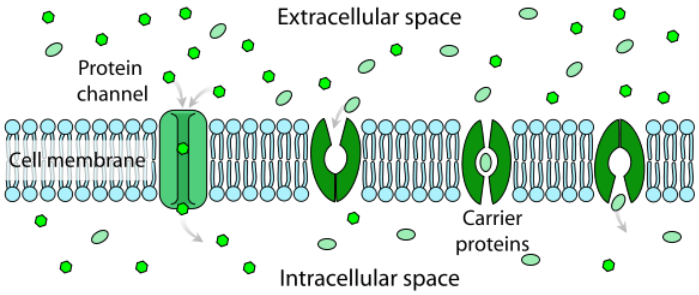


Figure 5.5.5: Molecules move in and out of cells through transport proteins, which are either channels or carriers. Facilitated diffusion in the cell membrane, showing ion channels (left) and carrier proteins (three on the right). (Public Domain; LadyofHats).

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Protection

Earlier we discussed that the strong collagen fibers in skin provide it with structure and support. The skin's dense network of collagen fibers also serves as a barricade against harmful substances. The immune system's attack and destroy functions are dependent on enzymes and antibodies, which are also proteins. An enzyme called **lysozyme** is secreted in the saliva and attacks the walls of bacteria, causing them to rupture. Certain proteins circulating in the blood can be directed to build a molecular knife that stabs the cellular membranes of foreign invaders. The antibodies secreted by the white blood cells survey the entire circulatory system looking for harmful bacteria and viruses to surround and destroy. Antibodies also trigger other factors in the immune system to seek and destroy unwanted intruders.

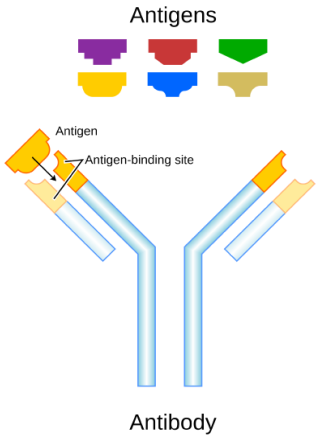


Figure 5.5.6: Proteins play a role in protecting the body against unwanted intruders. Antibodies surround and attack an influenza virus via "antigens" on their surface. Each antibody binds to a specific antigen; an interaction similar to a lock and key. (Public Domain; Fvasconcellos and USA government).

Video 5.5.4: Specific Immunity: Antibodies

- Watch this to observe how antibodies protect against foreign intruders.(click to see video)

Wound Healing and Tissue Regeneration

- Proteins are involved in all aspects of wound healing, a process that takes place in three phases: inflammatory, proliferative, and remodeling. For example, if you were sewing and pricked your finger with a needle, your flesh would turn red and become inflamed. Within a few seconds, bleeding would stop. The healing process begins with proteins such as bradykinin, which dilate blood vessels at the site of injury. An additional protein called fibrin helps to secure platelets that form a clot to stop the bleeding. Next, in the proliferative phase, cells move in and mend the injured tissue by installing newly made collagen fibers. The collagen fibers help pull the wound edges together. In the remodeling phase, more collagen is deposited, forming a scar. Scar tissue is only about 80 percent as functional as normal uninjured tissue. If a diet is insufficient in protein, the process of wound healing is markedly slowed.

While wound healing takes place only after an injury is sustained, a different process called tissue regeneration is ongoing in the body. The main difference between wound healing and tissue regeneration is in the process of regenerating an exact structural and functional copy of the lost tissue. Thus, old, dying tissue is not replaced with scar tissue but with brand new, fully functional tissue. Some cells (such as skin, hair, nails, and intestinal cells) have a very high rate of regeneration, while others, (such as heart-muscle cells and nerve cells) do not regenerate at any appreciable levels. Tissue regeneration is the creation of new cells (cell division), which requires many different proteins including enzymes that synthesize RNA and proteins, transport proteins, hormones, and collagen. In a hair follicle, cells divide and a hair grows in length. Hair growth averages 1 centimeter per month and fingernails about 1 centimeter every one hundred days. The cells lining the intestine regenerate every three to five days. Protein-inadequate diets impair tissue regeneration, causing many health problems including impairment of nutrient digestion and absorption and, most visibly, hair and nail growth.

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Energy Production

Some of the amino acids in proteins can be disassembled and used to make energy. Only about 10 percent of dietary proteins are catabolized each day to make cellular energy. The liver is able to break down amino acids to the carbon skeleton, which can then be fed into the citric acid cycle. This is similar to the way that glucose is used to make ATP. If a person's diet does not contain enough carbohydrates and fats their body will use more amino acids to make energy, which compromises the synthesis of new proteins and destroys muscle proteins. Alternatively, if a person's diet contains more protein than the body needs, the extra amino acids will be broken down and transformed into fat.

Key Takeaways

- The many shapes and sizes of proteins allow them to perform a vast array of functions, including acting as enzymes and hormones, providing for fluid and acid-base balance, transport, protection, wound healing and tissue regeneration, and energy production.
- Without adequate intake of protein containing all the essential amino acids, all protein functions will be impaired.

Discussion Starter

1. Given protein's critical roles in the immune system, what do you think might occur more frequently in a person whose diet is protein deficient?

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5.6: Diseases Involving Proteins

Learning Objectives

- Identify the potential health risks associated with abnormal protein levels in the diet.

As you may recall, moderation refers to having the proper amount of a nutrient—having neither too little nor too much. A healthy diet incorporates all nutrients in moderation. Low protein intake has several health consequences, and a severe lack of protein in the diet eventually causes death. Although severe protein deficiency is a rare occurrence in children and adults in the United States, it is estimated that more than half of the elderly in nursing homes are protein-deficient. The Acceptable Macronutrient Distribution Range (AMDR) for protein for adults is between 10 and 35 percent of kilocalories, which is a fairly wide range. The percent of protein in the diet that is associated with malnutrition and its health consequences is less than 10 percent, but this is often accompanied by deficiencies in calories and other micronutrients. There is some scientific evidence that shows that people with diets low in animal protein (< 8 percent of caloric intake), who get adequate protein from plant-based foods instead, may actually have improved health and increased longevity. On the other hand, diets rich in animal-derived protein (> 30 percent of caloric intake) are associated with increased early mortality, kidney and liver malfunction, cardiovascular disease, colon cancer, and osteoporosis. In this section we will discuss the health consequences of protein intake that is either too low to support life's processes or too high, thereby increasing the risk of chronic disease. In the last section of this chapter, we will discuss in more detail the personal choices you can make to optimize your health by consuming the right amount of high-quality protein.

Health Consequences of Protein Deficiency

Although severe protein deficiency is rare in the developed world, it is a leading cause of death in children in many poor, underdeveloped countries. There are two main syndromes associated with protein deficiencies: Kwashiorkor and Marasmus. Kwashiorkor affects millions of children worldwide. When it was first described in 1935, more than 90 percent of children with Kwashiorkor died. Although the associated mortality is slightly lower now, most children still die after the initiation of treatment. The name Kwashiorkor comes from a language in Ghana and means, "rejected one." The syndrome was named because it occurred most commonly in children who had recently been weaned from the breast, usually because another child had just been born. Subsequently, the child was fed watery porridge made from low-protein grains, which accounts for the low protein intake. Kwashiorkor is characterized by swelling (edema) of the feet and abdomen, poor skin health, growth retardation, low muscle mass, and liver malfunction. Recall that one of protein's functional roles in the body is fluid balance. Diets extremely low in protein do not provide enough amino acids for the synthesis of albumin. One of the functions of albumin is to hold water in the blood vessels, so having lower concentrations of blood albumin results in water moving out of the blood vessels and into tissues, causing swelling. The primary symptoms of Kwashiorkor include not only swelling, but also diarrhea, fatigue, peeling skin, and irritability. Severe protein deficiency in addition to other micronutrient deficiencies, such as folate (vitamin B_9), iodine, iron, and vitamin C all contribute to the many health manifestations of this syndrome.



Figure 5.6.1: Kwashiorkor is a disease brought on by a severe dietary protein deficiency. Symptoms include edema of legs and feet, light-colored, thinning hair, anemia, a pot-belly, and shiny skin. (Public domain; Centers for Disease Control and Prevention).

Children and adults with marasmus neither have enough protein in their diets nor do they take in enough calories often referred to as protein-energy malnutrition. Marasmus affects mostly children below the age of one in poor countries. Body weights of children with Marasmus may be up to 80 percent less than that of a normal child of the same age. Marasmus is a Greek word, meaning "starvation." The syndrome affects more than fifty million children under age five worldwide. It is characterized by an extremely emaciated appearance, poor skin health, and growth retardation. The symptoms are acute fatigue, hunger, and diarrhea.

Kwashiorkor and marasmus often coexist as a combined syndrome termed marasmic kwashiorkor. Children with the combined syndrome have variable amounts of edema and the characterizations and symptoms of marasmus. Although organ system function is compromised by undernutrition, the ultimate cause of death is usually an infection. Undernutrition is intricately linked with suppression of the immune system at multiple levels, so undernourished children commonly die from severe diarrhea and/or pneumonia resulting from bacterial or viral infection (Figure 6.7). The United Nations Children's Fund (UNICEF), the most prominent agency with the mission of changing the world to improve children's lives, reports that undernutrition causes at least one-third of deaths of young children. As of 2008, the prevalence of children under age five who were underweight was 26 percent. The percentage of underweight children has declined less than 5 percent in the last eighteen years despite the Millennium Development Goal of halving the proportion of people who suffer from hunger by the year 2015.

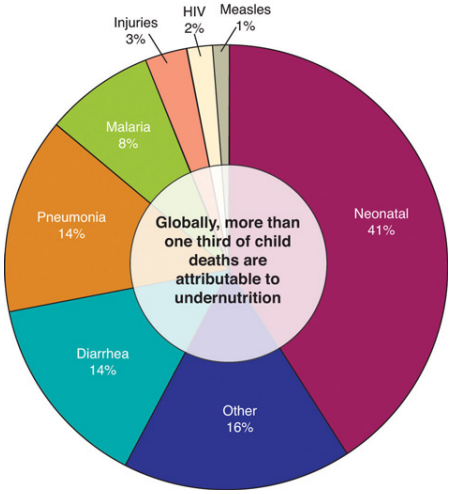


Figure 5.6.6: .2: Causes of death for children under the age of five, worldwide.

Interactive 5.6.1

If you are interested in finding out more about world hunger and what is being done about it, visit the UNICEF website. http://www.childinfo.org/index.html

Health Consequences of Too Much Protein in the Diet

- An explicit definition of a high-protein diet has not yet been developed by the Food and Nutrition Board of the Institute of Medicine (IOM), but typically diets high in protein are considered as those that derive more than 30 percent of calories from protein. Many people follow high-protein diets because marketers tout protein's ability to stimulate weight loss. It is true that following high-protein diets increases weight loss in some people. However, the number of individuals that remain on this type of diet is low and many people who try the diet and stop regain the weight they had lost. Additionally, there is a scientific hypothesis that there may be health consequences of remaining on high-protein diets for the long-term, but clinical trials are ongoing or scheduled to examine this hypothesis further. As the high-protein diet trend arose so did the intensely debated issue of whether there are any health consequences of eating too much protein. Observational studies conducted in the general population suggest diets high in animal protein, specifically those in which the primary protein source is red meat, are linked to a higher risk for kidney stones, kidney disease, liver malfunction, colorectal cancer, and osteoporosis. However, diets that include lots of red meat are also high in saturated fat and cholesterol and sometimes linked to unhealthy lifestyles, so it is difficult to conclude that the high protein content is the culprit.

High protein diets appear to only increase the progression of kidney disease and liver malfunction in people who already have kidney or liver malfunction, and not to *cause* these problems. However, the prevalence of kidney disorders is relatively high and underdiagnosed. In regard to colon cancer, an assessment of more than ten studies performed around the world published in the June 2011 issue of *PLoS* purports that a high intake of red meat and processed meat is associated with a significant increase in colon cancer risk.Chan, D. S., et al. "Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective

Studies." *PLoS One* 6, no. 6 (2011): e20456. doi: 10.1371/journal.pone.0020456. Although there are a few ideas, the exact mechanism of how proteins, specifically those in red and processed meats, causes colon cancer is not known and requires further study.

Some scientists hypothesize that high-protein diets may accelerate bone-tissue loss because under some conditions the acids in protein block absorption of calcium in the gut, and, once in the blood, amino acids promote calcium loss from bone; however, even these effects have not been consistently observed in scientific studies. Results from the Nurse's Health Study suggest that women who eat more than 95 grams of protein each day have a 20 percent higher risk for a wrist fracture (Harvard School of Public Health. "Protein: The Bottom Line." *The Nutrition Source*. © 2012 The President and Fellows of Harvard University. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein/ and Barzel, U. S. and L. K. Massey. "Excess Dietary Protein Can Adversely Affect Bone." *J Nutr* 128, no. 6 (June 1, 1998): 1051–53. http://jn.nutrition.org/content/128/6/1051.long). Other studies have not produced consistent results. The scientific data on high protein diets and increased risk for osteoporosis remain highly controversial and more research is needed to come to any conclusions about the association between the two (St. Jeor, S. T. et al. "Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association." *Circulation* 104 (2001): 1869–74.)

High-protein diets can restrict other essential nutrients. The AHA states that "High-protein diets are not recommended because they restrict healthful foods that provide essential nutrients and do not provide the variety of foods needed to adequately meet nutritional needs. Individuals who follow these diets are therefore at risk for compromised vitamin and mineral intake, as well as potential cardiac, renal, bone, and liver abnormalities overall ("St. Jeor, S. T. et al. "Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association." *Circulation* 104 (2001): 1869–74).

As with any nutrient, protein must be eaten in proper amounts. Moderation and variety are key strategies to achieving a healthy diet and need to be considered when optimizing protein intake. While the scientific community continues its debate about the particulars regarding the health consequences of too much protein in the diet, you may be wondering just how much protein you should consume to be healthy. Read on to find out more about calculating your dietary protein recommendations, dietary protein sources, and personal choices about protein.

Key Takeaways

- Protein deficiency syndromes are a leading cause of death in children under the age of five in poor, underdeveloped countries. Protein deficiency can cause swelling, fatigue, skin problems, irritability, muscle wasting, and eventual death from infection.
- The long-term health consequences of high-protein diets have not been adequately studied.

Discussion Starter

1. What are some diet changes you can make that are better, more sustainable, and easier to follow for the rest of your life than a high-protein diet?

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5.7: Proteins, Diet, and Personal Choices

Learning Objectives

- Calculate your Recommended Dietary Allowance for protein.
- Plan a one-day diet for each of the following: vegetarian, lacto-ovo vegetarian, and vegan. For each, calculate nutrient intake, then assess for adequacy, balance, and variety.
- Decide whether to take protein or amino acid supplements based on nutrition science studies.

We have discussed what proteins are, how they are made, how they are digested and absorbed, the many functions of proteins in the body, and the consequences of having too little or too much protein in the diet. This section will provide you with information on how to determine the recommended amount of protein for you, and your many choices in designing an optimal diet with high-quality protein sources.

How Much Protein Does a Person Need in Their Diet?

The recommendations set by the IOM for the Recommended Daily Allowance (RDA) and AMDR for protein for different age groups are listed in Table 5.7.1. A Tolerable Upper Intake Limit for protein has not been set, but it is recommended that you not exceed the upper end of the AMDR.

Table 5.7.1: Dietary Reference Intakes for Protein

Age Group	RDA (g/day)	AMDR (% calories)
Infants (0–6 mo)	9.1*	Not determined
Infants (7–12 mo)	11.0	Not determined
Children (1–3)	13.0	5–20
Children (4–8)	19.0	10–30
Children (9–13)	34.0	10–30
Males (14–18)	52.0	10–30
Females (14–18)	46.0	10–30
Adult Males (19+)	56.0	10–35
Adult Females (19+)	46.0	10–35

* Denotes Adequate Intake

Source: Institute of Medicine. “Dietary Reference Intakes: Macronutrients.” *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* September 5, 2002.

Protein Input = Protein Used by the Body + Protein Excreted

The appropriate amount of protein in a person’s diet is that which maintains a balance between what is taken in and what is used. The RDAs for protein were determined by assessing **nitrogen balance**. Nitrogen is one of the four basic elements contained in all amino acids. When proteins are broken down and amino acids are catabolized, nitrogen is released. Remember that when the liver breaks down amino acids, it produces ammonia, which is rapidly converted to non-toxic, nitrogen-containing urea, which is then transported to the kidneys for excretion. Most nitrogen is lost as urea in the urine, but urea is also excreted in the feces. Proteins are also lost in sweat and as hair and nails grow. The RDA, therefore, is the amount of protein a person should consume in their diet to balance the amount of protein used up and lost from the body. For healthy adults, this amount of protein was determined to be 0.8 grams of protein per kilogram of body weight. You can calculate your exact recommended protein intake per day based on your weight by using the following equation:

(Weight in lbs. ÷ 2.2 kg/lb) × 0.8 g/kg

Note that if a person is overweight, the amount of dietary protein recommended can be overestimated.

The IOM used data from multiple studies that determined nitrogen balance in people of different age groups to calculate the RDA for protein. A person is said to be in nitrogen balance when the nitrogen input equals the amount of nitrogen used and excreted. A person is in negative nitrogen balance when the amount of excreted nitrogen is greater than that consumed, meaning that the body is breaking down more protein to meet its demands. This state of imbalance can occur in people who have certain diseases, such as cancer or muscular dystrophy. Someone who has a low-protein diet may also be in negative nitrogen balance as they are taking in less protein than what they actually need. Positive nitrogen balance occurs when a person excretes less nitrogen than what is taken in by the diet, such as during child growth or pregnancy. At these times the body requires more protein to build new tissues, so more of what gets consumed gets used up and less nitrogen is excreted. A person healing from a severe wound may also be in positive nitrogen balance because protein is being used up to repair tissues.

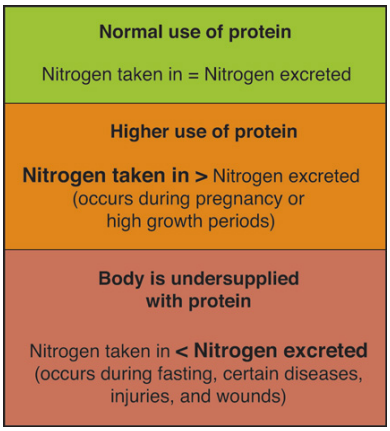


Figure 5.7.1: Nitrogen Balance

Dietary Sources of Protein

The protein food group consists of foods made from meat, seafood, poultry, eggs, soy, beans, peas, and seeds. According to the Harvard School of Public Health, “animal protein and vegetable protein probably have the same effects on health. It’s the protein package that’s likely to make a difference (”Harvard School of Public Health. “Protein: The Bottom Line.” *The Nutrition Source*. © 2012 The President and Fellows of Harvard University. http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/protein/). Simply put, different protein sources differ in their additional components, so it is necessary to pay attention to the whole nutrient “package.” Protein-rich animal-based foods commonly have high amounts of B vitamins, vitamin E, iron, magnesium, and zinc. Seafood often contains healthy fats, and plant sources of protein contain a high amount of fiber. Some animal-based protein-rich foods have an unhealthy amount of saturated fat and cholesterol. When choosing your dietary sources of protein, take note of the other nutrients and also the nonnutrients, such as cholesterol, dyes, and preservatives, in order to make good selections that will benefit your health. For instance, a hamburger patty made from 80 percent lean meat contains 22 grams of protein, 5.7 grams of saturated fat, and 77 milligrams of cholesterol. A burger made from 95 percent lean meat also contains 22 grams of protein but has 2.3 grams of saturated fat and 60 milligrams of cholesterol. A cup of boiled soybeans contains 29 grams of protein, 2.2 grams of saturated fat, and no cholesterol. For more comparisons of protein-rich foods, see Table 5.7.2. To find out the complete nutrient package of different foods, visit the US Department of Agriculture (USDA) website listed below.

Table 5.7.2: Sources of Dietary Protein

Food	Protein Content (g)	Saturated Fat (g)	Cholesterol (mg)	Calories
Hamburger patty 3 oz. (80% lean)	22.0	5.7	77	230
Hamburger patty 3 oz. (95% lean)	22.0	2.3	60	139
Top sirloin 3 oz.	25.8	2.0	76	158

Food	Protein Content (g)	Saturated Fat (g)	Cholesterol (mg)	Calories
Beef chuck 3 oz. (lean, trimmed)	22.2	1.8	51	135
Pork loin 3 oz.	24.3	3.0	69	178
Pork ribs (country style, 1 piece)	56.4	22.2	222	790
Chicken breast (roasted, 1 c.)	43.4	1.4	119	231
Chicken thigh (roasted, 1 thigh)	13.5	1.6	49	109
Chicken leg (roasted, 1 leg)	29.6	4.2	105	264
Salmon 3 oz.	18.8	2.1	54	175
Tilapia 3 oz.	22.2	0.8	48	109
Halibut 3 oz.	22.7	0.4	35	119
Shrimp 3 oz.	17.8	0.2	166	84
Shrimp (breaded, fried, 6–8 pcs.)	18.9	5.4	200	454
Tuna 3 oz. (canned)	21.7	0.2	26	99
Soybeans 1 c. (boiled)	29.0	2.2	0	298
Lentils 1 c. (boiled)	17.9	0.1	0	226
Kidney beans 1 c. (canned)	13.5	0.2	0	215
Sunflower seeds 1 c.	9.6	2.0	0	269

Interactive 5.7.1

This interactive USDA tool allows you to enter the foods you eat (with serving size) and find out the whole nutrient package. http://www.ars.usda.gov/Services/docs.htm?docid=17032

The USDA provides some tips for choosing your dietary protein sources. Their motto is, “Go Lean with Protein”. The overall suggestion is to eat a variety of protein-rich foods to benefit health. The USDA recommends lean meats, such as round steaks, top sirloin, extra lean ground beef, pork loin, and skinless chicken. Additionally, a person should consume 8 ounces of cooked seafood every week (typically as two 4-ounce servings) to assure they are getting the healthy omega-3 fatty acids that have been linked to a lower risk for heart disease. Another tip is choosing to eat beans, peas, or soy products as a main dish. Some of the menu choices include chili with kidney and pinto beans, hummus on pita bread, and black bean enchiladas. You could also enjoy nuts in a variety of ways. You can put them on a salad, in a stir-fry, or use them as a topping for steamed vegetables in place of meat or cheese. If you do not eat meat, the USDA has much more information on how to get all the protein you need from a plant-based diet. When choosing the best protein-rich foods to eat, pay attention to the whole nutrient package and remember to select from a variety of protein sources to get all the other essential micronutrients.

Interactive 5.7.2

The USDA manages the website choosemyplate.gov. The site provides a lot of tips and information about protein-rich foods. www.choosemyplate.gov/food-groups/protein-foods.html

Tools for Change

Try some new, healthy, protein-rich food recipes by visiting the Harvard School of Public Health website, http://hvrd.me/OJRkpV. You will find recipes for foods such as spicy lemongrass tofu with Asian basil, fish Creole, and spicy chicken kebabs.

Protein Quality

While protein is contained in a wide variety of foods, it differs in quality. High-quality protein contains all the essential amino acids in the proportions needed by the human body. The amino acid profile of different foods is, therefore, one component of protein quality. Foods that contain some of the essential amino acids are called incomplete protein sources, while those that contain all nine essential amino acids are called complete protein sources, or high-quality protein sources. Foods that are complete protein sources include animal foods such as milk, cheese, eggs, fish, poultry, and meat, and a few plant foods, such as soy and quinoa (Figure 5.7.2). The only animal-based protein that is not complete is gelatin, which consists of the protein, collagen.



Figure 5.7.2: Complete and Incomplete Protein Sources. Examples of complete protein sources include soy, dairy products, meat, and seafood. Examples of incomplete protein sources include legumes and corn. © Shutterstock

Most plant-based foods are deficient in at least one essential amino acid and therefore are incomplete protein sources. For example, grains are usually deficient in the amino acid lysine, and legumes do not contain methionine or tryptophan. Because grains and legumes are not deficient in the same amino acids they can complement each other in a diet. Incomplete protein foods are called **complementary foods** because when consumed in tandem they contain all nine essential amino acids at adequate levels. Some examples of complementary protein foods are given in Table 5.7.4. Complementary protein sources do not have to be consumed at the same time—as long as they are consumed within the same day, you will meet your protein needs.

Tools for Change

Explore some ethnic grocery markets to find new high-protein foods for your diet and/or experiment with the much cheaper plant-based protein sources. SeeTable 5.7.4 for complementing protein sources the vegan way.

Table 5.7.3: Complementing Protein Sources the Vegan Way

Foods	Lacking Amino Acids	Complementary Food	Complementary Menu

Foods	Lacking Amino Acids	Complementary Food	Complementary Menu
Legumes	Methionine, tryptophan	Grains, nuts, and seeds	Hummus and whole-wheat pita
Grains	Lysine, isoleucine, threonine	Legumes	Cornbread and kidney bean chili
Nuts and seeds	Lysine, isoleucine	Legumes	Stir-fried tofu with cashews

The second component of protein quality is digestibility, as not all protein sources are equally digested. In general, animal-based proteins are completely broken down during the process of digestion, whereas plant-based proteins are not. This is because some proteins are contained in the plant's fibrous cell walls and these pass through the digestive tract unabsorbed by the body.

Protein Digestibility Corrected Amino Acid Score (PDCAAS)

The PDCAAS is a method adopted by the US Food and Drug Administration (FDA) to determine a food's protein quality. It is calculated using a formula that incorporates the total amount of amino acids in the food and the amount of protein in the food that is actually digested by humans. The food's protein quality is then ranked against the foods highest in protein quality. Milk protein, egg whites, whey, and soy all have a ranking of one, the highest ranking. Other foods' ranks are listed in Table 5.7.5.

Table 5.7.4: PDCAAS of Various Foods

Food	PDCAAS*
Milk protein	1.00
Egg white	1.00
Whey	1.00
Soy protein	1.00
Beef	0.92
Soybeans	0.91
Chickpeas	0.78
Fruits	0.76
Vegetables	0.73
Legumes	0.70
Cereals	0.59
Whole wheat	0.42
*1 is the highest rank, 0 is the lowest	

Protein Needs: Special Considerations

Some groups may need to examine how to meet their protein needs more closely than others. We will take a closer look at the special protein considerations for vegetarians, the elderly, and athletes.

Vegetarians and Vegans

Vegan eat no animal products while vegetarian diets may include a variety of different animal products. Here are the different types:

- Vegan - no animal products
- Lacto-vegetarian - milk products are consumed

- Ovo-vegetarian - egg products are consumed
- Lacto-ovo-vegetarian - milk and egg product are consumed
- Pesco-vegetarian - fish is allowed
- Pseudo-vegetarian - consumes dairy products, eggs, chicken, and fish, but does not consume other animal flesh
- Semi-vegetarian; flexitarian; partial vegetarian - plant-based diet with the occasional inclusion of animal meat
- Macrobiotic diet - only brown rice, water and herbal tea (this diet is deficient in many nutrients)
- Fruitarian - raw or dried fruit, seeds, nuts, honey and vegetable oil (this diet can be deficient in nutrients)

Many different cultures practice vegetarianism. Examples are shown in this table.

Table 5.7.5: Examples of Cultures that practice vegetarianism.

Culture	Food
Indian (Asian)	Dhal (lentils) and rice
Mexican	Rice and beans
South East US	Black-eyed peas and corn
South East Asia	Tofu (soybean protein) and rice
United States	Peanut butter and bread

People who follow variations of the vegetarian diet and consume eggs and/or dairy products can easily meet their protein requirements by consuming adequate amounts of these foods. Vegetarians and vegans can also attain their recommended protein intakes if they give a little more attention to high-quality plant-based protein sources. However, when following a vegetarian diet, the amino acid lysine can be challenging to acquire. Grains, nuts, and seeds are lysine-poor foods, but tofu, soy, quinoa, and pistachios are all good sources of lysine. Following a vegetarian diet and getting the recommended protein intake is also made a little more difficult because the digestibility of plant-based protein sources is lower than the digestibility of animal-based protein.

To begin planning a more plant-based diet, start by finding out which types of food you want to eat and in what amounts you should eat them to ensure that you get the protein you need. The Dietary Guidelines Advisory Committee (DGAC) has analyzed how three different, plant-based dietary patterns can meet the recommended dietary guidelines for all nutrients (Jacobs, D. R. et al. “Food, Plant Food, and Vegetarian Diets in the US Dietary Guidelines: Conclusions of an Expert Panel.” *Am J Clin Nutr* 89, no. 5 (2009). http://ajcn.nutrition.org/content/89/5/1549S.short). The diets are defined in the following manner:

- **Plant-based.** Fifty percent of protein is obtained from plant foods.
- **Lacto-ovo vegetarian.** All animal products except eggs and dairy are eliminated.
- **Vegan.** All animal products are eliminated.

Table 5.7.6: Percentage of “Meat and Beans Group” Components in the USDA Base Diet, and Three Vegetarian Variations

Food Category	Base USDA (%)	Plant-Based (%)	Lacto-Ovo Vegetarian (%)	Vegan (%)
Meats	44.6	10.5	0	0
Poultry	27.9	8.0	0	0
Fish (high omega-3)	2.2	3.0	0	0
Fish (low omega-3)	7.1	10.0	0	0
Eggs	7.9	7.6	10.0	0
Soy products	0.9	15.0	30.0	25.0

*The dry beans and peas are in the vegetable food group of the base diet. Source: US Department of Agriculture. Appendix E-3.3, *“Vegetarian Food Patterns: Food Pattern Modeling Analysis.”* In *2010 Dietary Guidelines for Americans.*

Food Category	Base USDA (%)	Plant-Based (%)	Lacto-Ovo Vegetarian (%)	Vegan (%)
Nuts and seeds	9.4	20.9	35.0	40.0
Dry beans and peas	n/a*	25.0	25.0	35.0
Total	100.0	100.0	100.0	100.0

*The dry beans and peas are in the vegetable food group of the base diet. Source: US Department of Agriculture. Appendix E-3.3, *"Vegetarian Food Patterns: Food Pattern Modeling Analysis."* In *2010 Dietary Guidelines for Americans*.

These diets are analyzed and compared to the more common dietary pattern of Americans, which is referred to as the USDA Base Diet. Tables 5.7.6 and 5.7.7 can be used to help determine what percentage of certain foods to eat when following a different dietary pattern. The percentages of foods in the different groups are the proportions consumed by the population, so that, on average, Americans obtain 44.6 percent of their foods in the meat and beans group from meats. If you choose to follow a lacto-ovo vegetarian diet, the meats, poultry, and fish can be replaced by consuming a higher percentage of soy products, nuts, seeds, dry beans, and peas. As an aside, the DGAC notes that these dietary patterns may not exactly align with the typical diet patterns of people in the United States. However, they do say that they can be adapted as a guide to developing a more plant-based diet that does not significantly affect nutrient adequacy.

Table 5.7.7: Proportions of Milk Products and Calcium-Fortified Soy Products in the Base USDA Patterns and Three Vegetarian Variations

Food Category	Base USDA (%)	Plant-based (%)	Lacto-ovo vegetarian (%)	Vegan (%)
Fluid milk	54.6	54.6	54.6	0
Yogurt	1.6	1.6	1.6	0
Cheese	42.7	42.7	42.7	0
Soy milk (w/ calcium)	1.1	1.1	1.1	67.0
Rice milk (w/ calcium)	0	0	0	16.0
Tofu (w/ calcium)	0	0	0	15.0
Soy yogurt	0	0	0	2.0
Total	100.0	100.0	100.0	100.0

Source: US Department of Agriculture. Appendix E-3.3, *"Vegetarian Food Patterns: Food Pattern Modeling Analysis."* In *2010 Dietary Guidelines for Americans*. www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/AppendixE-3-3-Vegetarian.pdf#xml=65.216.150.153/texis/search/p...ead=500&rdepth =0&sufs=2&order=r&cq=&id=4d9cfcc17.

From these analysis, the DGAC concluded that the plant-based, lacto-ovo vegetarian, and vegan diets do not significantly affect nutrient adequacy. Additionally, the DGAC states that people who choose to obtain proteins solely from plants should include foods fortified with vitamins B_{12}, D, and calcium. Other nutrients of concern may be omega-3 fatty acids and choline. Two large observational studies with thousands of participants demonstrated that in comparison to regular meat-eaters, people who followed a vegetarian diet had a significantly decreased risk of dying from heart disease or cancer.Lindbloom, E. "Long-Term Benefits of a Vegetarian Diet." *Am Fam Physician* 79, no. 7 (April 1, 2009): 541–42. www.aafp.org/afp/2009/0401/p541.html.

Interactive 5.7.3

To read the full report on the nutrient adequacy of plant-based, lacto-ovo vegetarian, and vegan diets, go to the link to the *Dietary Guidelines* below, which takes you directly to Appendix E-3.3. In addition to the information in Tables 5.7.6 and 5.7.7,

> this document provides details on the actual amounts in ounces and cups of various food groups required to eat each day in order to meet the dietary guidelines. 1.usa.gov/ML3M8D

Tools for Change

Make a sustainable choice to go meatless more than once a week. To get some ideas on how to expand your dietary choices, visit the Eating Well website, which has a twenty-eight-day vegetarian meal plan that meets the US dietary guidelines. http://www.eatingwell.com/nutrition_health/weight_loss_diet_plans/diet_meal_plans /vegetarian_meal_plan

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The Elderly

As we age, muscle mass gradually declines. This is a process referred to as sarcopenia. A person is sarcopenic when their amount of muscle tissue is significantly lower than the average value for a healthy person of the same age. A significantly lower muscle mass is associated with weakness, movement disorders, and a generally poor quality of life. It is estimated that about half the US population of men and women above the age of eighty are sarcopenic. A review published in the September 2010 issue of *Clinical Intervention in Aging* demonstrates that higher intakes (1.2 to 1.5 grams per kilogram of weight per day) of high-quality protein may prevent aging adults from becoming sarcopenic.Waters, D. L. et al. “Advantages of Dietary, Exercise-Related, and Therapeutic Interventions to Prevent and Treat Sarcopenia in Adult Patients: An Update.” *Clin Interv Aging* 5 (September 7, 2010): 259–70. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2938033/?tool=pubmed Currently, the RDA for protein for elderly persons is the same as that for the rest of the adult population, but several clinical trials are ongoing and are focused on determining the amount of protein in the diet that prevents the significant loss of muscle mass specifically in older adults.

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Athletes

Muscle tissue is rich in protein composition and has a very high turnover rate. During exercise, especially when it is performed for longer than two to three hours, muscle tissue is broken down and some of the amino acids are catabolized to fuel muscle contraction. To avert excessive borrowing of amino acids from muscle tissue to synthesize energy during prolonged exercise, protein needs to be obtained from the diet. Intense exercise, such as strength training, stresses muscle tissue so that afterward, the body adapts by building bigger, stronger, and healthier muscle tissue. The body requires protein post exercise to accomplish this. The IOM does not set different RDAs for protein intakes for athletes, but the AND, the American College of Sports Medicine, and Dietitians of Canada have the following position statements:

- “Nitrogen balance studies suggest that dietary protein intake necessary to support nitrogen balance in endurance athletes ranges from 1.2 to 1.4 grams per kilogram of body weight per day.”
- “Recommended protein intakes for strength-trained athletes range from approximately 1.2 to 1.7grams per kilogram of weight per day.”American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada. “Joint Position Statement: Nutrition and Athletic Performance.” *Med Sci Sports Exerc* 41, no. 3 (March 2009). doi: 10.1249/MSS.0b013e31890eb86.



Figure 5.7.3: When the body is subjected to intensive strength-training, muscles adapt to the stress placed upon it by becoming bigger and stronger. Image of the Mr. Universe competition Dec. 2. (Public Domain)

An endurance athlete who weighs 170 pounds should take in 93 to 108 grams of protein per day ((170 ÷ 2.2) × 1.2 and (170 ÷ 2.2) × 1.4). On a 3,000-kilocalorie diet, that amount is between 12 and 14 percent of total kilocalories and within the AMDR. There is general scientific agreement that endurance and strength athletes should consume protein from high-quality sources, such as dairy, eggs, lean meats, or soy; however eating an excessive amount of protein at one time does not further stimulate muscle protein synthesis. Nutrition experts also recommend that athletes consume some protein within one hour after exercise to enhance muscle tissue repair during the recovery phase, but some carbohydrates and water should be consumed as well. The recommended ratio from nutrition experts for exercise-recovery foods is 4 grams of carbohydrates to 1 gram of protein.

Table 5.7.8: Snacks for Exercise Recovery

Foods	Protein (g)	Carbohydrates (g)	Calories
Whole grain cereal with nonfat milk	14	53	260
Medium banana with nonfat milk	10	39	191
Power bar	10	43	250

In response to hard training, a person's body also adapts by becoming more efficient in metabolizing nutrient fuels both for energy production and building macromolecules. However, this raises another question: if athletes are more efficient at using protein, is it necessary to take in more protein from dietary sources than the average person? There are two scientific schools of thought on this matter. One side believes athletes need more protein and the other thinks the protein requirements of athletes are the same as for nonathletes. There is scientific evidence to support both sides of this debate. The consensus of both sides is that few people exercise at the intensity that makes this debate relevant. It is good to remember that the increased protein intake recommended by the AND, American College of Sports Medicine, and Dietitians of Canada still lies within the AMDR for protein.

Interactive 5.7.4

- Visit "Nutrition 101, Eating for Exercise and Sports." This USDA site contains a wealth of nutritional information for active people. 1.usa.gov/ML3RJj

Protein Supplements

- Protein supplements include powders made from compounds such as whey or soy and amino acids that either come as a powder or in capsules. We have noted that the protein requirements for most people, even those that are active, is not high. Is taking protein supplements ever justified, then? Neither protein nor amino acid supplements have been scientifically proven to improve exercise performance or increase strength. In addition, the average American already consumes more protein than is required. Despite these facts, many highly physically active individuals use protein or amino acid supplements. According to the AND, American College of Sports Medicine, and Dietitians of Canada, "the current evidence indicates that protein and amino acid supplements are no more or no less effective than food when energy is adequate for gaining lean body mass ("American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada. "Joint Position Statement: Nutrition and Athletic Performance." *Med Sci Sports Exerc* 41, no. 3 (March 2009). doi: 10.1249/MSS.0b013e31890eb86). Branched-chain amino acids, such as leucine, are often touted as a way to build muscle tissue and enhance athletic performance. Despite these marketing claims, a review in the June 2005 issue of *The Journal of Nutrition* shows that most studies that evaluated a variety of exercise types failed to show any performance-enhancing effects of taking branched-chain amino acids (Gleeson, M. "Interrelationship between Physical Activity and Branched-Chain Amino Acids." *J Nutr* 135, no. 6, supplement (June 1, 2005): 1591S–5S. http://jn.nutrition.org/content/135/6/1591S.long). Moreover, the author of this review claims that high-quality protein foods are a better and cheaper source of branched-chain amino acids and says that a chicken breast (100 grams) contains the equivalent of seven times the amount of branched-chain amino acids as one supplement tablet. This means if you are interested in enhancing exercise performance or building muscle, you do not need to support the $20 billion supplement industry. Whole foods also provide other nutrients that supplements do not contain.

Although the evidence for protein and amino acid supplements impacting athletic performance is lacking, there is some scientific evidence that supports consuming high-quality dairy proteins, such as casein and whey, and soy proteins positively influence muscle recovery in response to hard training. If you choose to buy a bucket of whey protein, use it to make a protein shake after an

intense workout and do not add more than what is required to obtain 20 to 25 grams of protein. As always, choosing high-quality protein foods will help you build muscle and not empty your wallet as much as buying supplements. Moreover, relying on supplements for extra protein instead of food will not provide you with any of the other essential nutrients. The bottom line is that whether you are an endurance athlete or strength athlete, or just someone who takes Zumba classes, there is very little need to put your money into commercially sold protein and amino acid supplements. The evidence to show that they are superior to regular food in enhancing exercise performance is not sufficient.



Figure 5.7.4: Make a shake and use the AMDRs for macronutrients as a guide when filling up the blender. (CC-SA-BY 3.0; Sigurdas)

What about the numerous protein shakes and protein bars on the market? Are they a good source of dietary protein? Do they help you build muscle or lose weight as marketers claim? These are not such a bad idea for an endurance or strength athlete who has little time to fix a nutritious exercise-recovery snack. However, before you ingest any supplement, do your homework. Read the label, be selective, and don't use them to replace meals, but rather as exercise-recovery snacks now and then. Some protein bars have a high amount of carbohydrates from added sugars and are not actually the best source of protein, especially if you are not an athlete. Protein bars are nutritionally designed to restore carbohydrates and protein after endurance or strength training; therefore they are not good meal replacements. If you want a low-cost alternative after an intense workout, make yourself a peanut butter sandwich on whole-grain bread and add some sliced banana for less than fifty cents. Supermarket and health-food-store shelves offer an extraordinary number of high-protein shake mixes. While the carbohydrate count is lower now in some of these products than a few years ago, they still contain added fats and sugars. They also cost, on average, more than two dollars per can. If you want more nutritional bang for your buck, make your own shakes from whole foods. Use the AMDRs for macronutrients as a guide to fill up the blender. Your homemade shake can now replace some of the whole foods on your breakfast, lunch, or dinner plate. Unless you are an endurance or strength athlete and consume commercially sold protein bars and shakes only post exercise, these products are not a good dietary source of protein.

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Proteins in a Nutshell

Proteins are long chains of amino acids folded into precise structures that determine their functions, which are in the tens of thousands. They are the primary construction materials of the body serving as building blocks for bone, skin, hair, muscle, hormones, and antibodies. Without them, we cannot break down or build macromolecules, grow, or heal from a wound. Eat proteins in moderation, at least 10 percent of the calories you take in and not more than 35 percent. Too little protein impairs bodily functions and too much can lead to chronic disease. Proteins are in a variety of foods. More complete sources are in animal-based foods, but choose those low in saturated fat and cholesterol. Some plant-based foods are also complete protein sources and don't add much to your saturated fat or cholesterol intake. Incomplete protein sources can easily be combined in the daily diet and provide all of the essential amino acids at adequate levels. Growing children and the elderly need to ensure they get enough protein in their diet to help build and maintain muscle strength. Even if you're a hardcore athlete, get your proteins from nutrient-dense foods as you need more than just protein to power up for an event.



Figure 5.7.5: Many Olympic athletes have adopted a vegetarian diet which, when implemented effectively, supports a very active and athletic lifestyle. The finish of a women's 100 m race. (CC-SA-BY 3.0; Wikipedia/flickr)

Nuts are one nutrient-dense food with a whole lot of protein. One ounce of pistachios, which is about fifty nuts, has the same amount of protein as an egg and contains a lot of vitamins, minerals, healthy polyunsaturated fats, and antioxidants. Moreover, the FDA says that eating one ounce of nuts per day can lower your risk for heart disease. Can you be a hardcore athlete and a vegetarian? Many Olympians are vegetarians: figure skater Charlene Wong, sprinter Leroy Burrell, hurdler Edwin Moses, and Carl Lewis, who won ten medals (nine of them gold) in track and field. The analysis of vegetarian diets by the DGAC did not find that they were inadequate in any nutrients, but did state that people who obtain proteins solely from plants should make sure they consume foods with vitamin B_{12}, vitamin D, calcium, omega-3 fatty acids, and choline. Iron and zinc may also be of concern, especially for female athletes. Being a vegetarian athlete requires that you pay more attention to what you eat, however, this is also a true statement for all athletes. For an exhaustive list that provides the protein, calcium, cholesterol, fat, and fiber content, as well as the number of calories, of numerous foods, go to the website, http://www.soystache.com/protein.htm.

Getting All the Nutrients You Need—The Plant-Based Way

Below are five ways to assure you are getting all the nutrients you need while working toward a more plant-based diet;

1. Get your protein from foods such as soybeans, tofu, tempeh, lentils, and beans, beans, and more beans. Many of these foods are high in zinc too.
2. Eat foods fortified with vitamins B_{12} and D and calcium. Some examples are soy milk and fortified cereals.
3. Get enough iron in your diet by eating kidney beans, lentils, whole-grain cereals, and leafy green vegetables.
4. To increase iron absorption, eat foods with vitamin C at the same time.
5. Don’t forget that carbohydrates and fats are required in your diet too, especially if you are training. Eat whole-grain breads, cereals, and pastas. For fats, eat an avocado, add some olive oil to a salad or stir-fry, or spread some peanut or cashew butter on a bran muffin.

Key Takeaways

- The RDA set for protein for adults is 0.8 grams per kilogram of body weight and represents the amount of protein in the diet required to balance the protein that is used up by the body and that is excreted.
- The protein foods group consists of foods made from meat, seafood, poultry, eggs, soy, beans, peas, and seeds.
- By determining a food’s amino acid content and the amount of protein that is actually digested and absorbed we can determine that food’s protein quality.
- Most animal-based proteins are complete protein sources and most plant-based proteins are incomplete protein sources. The exceptions are soy, which is a plant-based complete protein source, and gelatin, which is an incomplete animal-based protein source.
- A vegan’s protein needs are slightly higher because of the lower digestibility of plant-based sources. The elderly may require more protein in their diets to prevent significant muscle wasting. There is debate on whether athletes require more proteins in their diet.

- Protein and amino acid supplements do not enhance exercise performance and do not promote a gain in muscle mass anymore so than protein from foods.
- Unless you are an endurance or strength athlete, commercially sold protein bars and shakes are not a good dietary source of protein.

Discussion Starters

1. What is the consensus in your class on how easy it is to follow a more plant-based diet?
2. Even though high-protein diets may not cause significant health problems in healthy people, are they a sustainable option for losing weight? What are the consequences to the environment of consuming more and not less animal-based sources of protein?

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5.E: Proteins (Exercises)

It's Your Turn

1. Calculate your daily protein requirements.
2. List ten of your favorite protein-rich foods and find out the actual protein contents using the USDA National Nutrient Database, http://www.ars.usda.gov/Services/docs.htm?docid=8964. How easy is it for you to get all the protein you need? Are there some protein-rich food choices that you need to replace with a lower saturated fat alternative?
3. Design a more plant-based menu for a day that you are willing to follow. Make sure it is balanced and has variety. Give examples of the micronutrients (other than protein) the foods contain in appreciable amounts.

Apply It

1. In class or at home, use two inexpensive cake mixes. Make one without adding eggs and the other by following the recipe correctly. Bake them and summarize the differences in taste, texture, and structure.
2. Create a recipe for a shake made from your favorite whole foods that has the macronutrients in their recommended ranges. Also list the different micronutrients in your shake. Now that you know the shake is of good nutritional value, conduct a taste test on your friends or family.
3. Read these articles about nutrition in the future http://www.nature.com/nature/journal/v468/n7327_supp/full/468S21a.html and http://www.nature.com/nature/journal/v468/n7327_supp/full/468S10a.html.
4. Summarize three basic points about how tailoring the diet can reduce the risk for chronic disease.

Expand Your Knowledge

1. Take a trip to a nearby ethnic market and either write down the names of certain foods or purchase a few interesting ones. At home, use the USDA National Nutrient Database to find out the protein contents and other nutrients in the new food items. If you cannot find values for these new foods, try these websites: many-calories.com/, http://www.myfitnesspal.com/nutrition-facts-calories/chinese-food and http://caloriecount.about.com/calories-ethnic-foods-ic3500.
2. Plan a menu for one week that is completely plant-based. Look up the whole nutrient package for the items in your menu by visiting the website, http://www.ars.usda.gov/Services/docs.htm?docid=17032. Follow your diet plan. Record some basic health parameters, such as blood pressure and body weight, before and after following your menu plan. Assess how you feel in general after following the diet. Are you less tired or more? Are you irritable or happy? Did you exercise with more intensity or less?
3. Seafood is a good source of high-quality protein. The DGAC has assessed the nutrient adequacy of diets high in seafood. Read the following document and plan a weekly menu where you consume at least 8 ounces of seafood. 1.usa.gov/OXdk2X

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CHAPTER OVERVIEW

6: Energy Metabolism

In this chapter, we take a look at the obesity epidemic and eating disorders—the extremes of energy imbalance—and we look at evidence-based recommendations for maintaining a healthy weight. You will learn how to assess body weight and fatness and learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

6.1: Chapter Introduction
6.2: Metabolism Overview
6.3: Vitamins Important for Metabolism
6.4: Minerals Important for Metabolism and for Blood Function and Renewal
6.5: Balancing Energy Input with Energy Output
6.6: Too Little or Too Much Weight?
6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
6.E: Exercises

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CHAPTER OVERVIEW

Front Matter

TitlePage
InfoPage

Chapter 6: Energy Metabolism

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6.1: Chapter Introduction

As you probably already know, the number of people who struggle with being overweight and/or obese is rising rapidly in the United States of America and in many other countries around the world. There is a new term being used to try to understand this rapid rise in obesity. The new term is "obesogenic" environments. The Centers for Disease Control and Prevention (CDC) defines an obesogenic environment as “an environment that **promotes increased food intake of non-healthful foods, and physical inactivity**.” The CDC reports that in 2009 in the United States, 33 percent of adults and 16 percent of children were obese, a doubling and tripling of the numbers since 1980, respectively, while in Canada the obesity rate was 24.1 percent for 2007–2009. The health consequences of too much body fat are numerous, including increased risks for cardiovascular disease, Type 2 diabetes, and some cancers. The medical costs related to obesity are well over one hundred billion dollars and on the individual level, people who are obese spend $1,429 more per year for medical care than people of healthy weight. No one WANTS to become obese, so what are the factors causing rates of obesity to rise so rapidly? What can we do about these factors?



***Video Link 6.1.1**: The Obesity Epidemic: This video from the Centers for Disease Control and Prevention provides an overview of the burden of the obesity epidemic in the United States and its contributing causes.. www.cdc.gov/cdctv/ObesityEpidemic/*

Numerous obesogenic agents contribute to the immense public health problem that has become a part of everyday life in American society. Most agree that the **fast food** industry is playing a role. Fast food has been growing for decades and continues to grow, even when the economy struggles. In America today there are over twelve thousand McDonald’s restaurants, while in 1960 there was one. Another factor is that **food portions have been getting bigger** since the 1960s, and in the 1990s North American society experienced the “super-size” marketing boom, which is still very popular. **Another factor is physical inactivity is getting worse**. Between 1960 and 2000 more than 123 million vehicles were added to the American society. Escalators, elevators, and horizontal walkways now dominate shopping malls and office buildings, factory work has become increasingly mechanized and automated, the typical American watches more than four hours of television daily, and in many workplaces the only tools required to conduct work are a chair and a computer. **The list of all the societal obesogenic factors goes on and on**. They are the result of modernization, industrialization, and urbanization continuing on without individuals, public health officials, or government adequately addressing the concurrent rise in overweight and obesity.

With obesity at epidemic proportions in America it is critical we make changes that will help to remedy this growing problem. The good news is we can make a difference! Policies are being implemented and reinforced at all levels of society including education, agriculture, industry, urban planning, healthcare, and government. Reversing and stopping obesity are two different things. The former will require much more societal change and change on the individual level than the latter. The following are some ideas that are being demonstrated to work for constructing an environment in America that promotes health and confronts the obesity epidemic:

- **Individual Level: What you can do NOW**
  - Purchase less prepared foods and eat more whole foods.
  - Decrease portion sizes when eating or serving food.
  - Eat out less, and when you do eat out choose low-calorie options.
  - Walk or bike to work. If this is not feasible, walk while you are at work.
  - Take the stairs when you come upon them or better yet, seek them out.

- Walk your neighborhood and know your surroundings. This benefits both health and safety.
- Watch less television.

- **Community Level: What you and your friends, family, and co-workers can do together!**
  - Request that your college/workplace provides more access to healthy low-cost foods.
  - Support changes in school lunch programs—this is happening now but needs vocal parents to continue!
  - Participate in cleaning up local green spaces and then enjoy them during your leisure time, get outside!
  - Patronize local farms and fruit-and-vegetable stands.
  - Talk to your grocer and ask for better whole-food choices and seafood at a decent price.
  - Ask your favorite restaurant to serve more nutritious food and to accurately display calories of menu items.
- **National Level: What we can do as a country!**
  - Support policies that increase the walkability of cities.
  - Support national campaigns addressing obesity, such as America on the Move.
  - Support policies that support local farmers and the increased access and affordability of healthy food.

Interactive 6.1.1

Watch this video about "Shape up Sommerville" in which a city in Massachusetts was able to make some amazing changes to the health and wellness of its citizens!



You Decide

How can you assist in the American transition from an obesogenic environment to a healthier environment at the individual, community, and national levels?

In this chapter, you will learn how to assess body weight and fatness. You will also learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

“Thou seest I have more flesh than another man, and therefore more frailty.” -William Shakespeare (1564–1616)

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6.2: Metabolism Overview

Learning Objectives

- Summarize how energy from the energy-yielding nutrients is obtained and used, and how and where it is stored in the body for later use.
- Explain the role of energy in the process of building tissues and organs.

Throughout the various chapters in this text, we have explored the metabolism of carbohydrates, lipids, and proteins. In this next section, we will compile this information for a clear picture of the importance of metabolism in human nutrition.

Metabolism is defined as the sum of all chemical reactions required to support cellular function and hence the life of an organism. Metabolism is either categorized as catabolism, referring to all metabolic processes involved in molecule breakdown, or anabolism, which includes all metabolic processes involved in building bigger molecules. Generally, catabolic processes release energy and anabolic processes consume energy. The overall goals of metabolism are energy transfer and matter transport. Energy is transformed from food macronutrients into cellular energy, which is used to perform cellular work. Metabolism transforms the matter of macronutrients into substances a cell can use to grow and reproduce and also into waste products.

In Chapter 5, you learned that enzymes are proteins and that their job is to catalyze chemical reactions. (Recall that the word catalyzes means to speed up a chemical reaction and reduce the energy required to complete the chemical reaction, without the catalyst being used up in the reaction.) Without enzymes, chemical reactions would not happen at a fast enough rate and would use up too much energy for life to exist. A metabolic pathway is a series of enzymatic reactions that transform the starting material (known as a substrate) into intermediates, which are the substrates for the next enzymatic reactions in the pathway, until, finally, an end product is synthesized by the last enzymatic reaction in the pathway. Some metabolic pathways are complex and involve many enzymatic reactions, and others involve only a few chemical reactions.

To ensure cellular efficiency, the metabolic pathways involved in catabolism and anabolism are regulated in concert by energy status, hormones, and substrate and end-product levels. The concerted regulation of metabolic pathways prevents cells from inefficiently building a molecule when it is already available. Just as it would be inefficient to build a wall at the same time as it is being broken down, it is not metabolically efficient for a cell to synthesize fatty acids and break them down at the same time.

Catabolism of food molecules begins when food enters the mouth, as the enzyme salivary amylase initiates the breakdown of carbohydrates. The entire process of digestion converts the large polymers in food to monomers that can be absorbed. Carbohydrates are broken down to monosaccharides, lipids are broken down into fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with fatty acids and other fat-soluble molecules. Once absorbed, blood transports the nutrients to cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathway. The organ systems of the body require fuel and building blocks to perform the many functions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells.monosaccharides, lipids are broken down into fatty acids, and proteins are broken down to amino acids. These monomers are absorbed into the bloodstream either directly, as is the case with monosaccharides and amino acids, or repackaged in intestinal cells for transport by an indirect route through lymphatic vessels, as is the case with fatty acids and other fat-soluble molecules. Once absorbed, blood transports the nutrients to cells. Cells requiring energy or building blocks take up the nutrients from the blood and process them in either catabolic or anabolic pathway. The organ systems of the body require fuel and building blocks to perform the many functions of the body, such as digesting, absorbing, breathing, pumping blood, transporting nutrients in and wastes out, maintaining body temperature, and making new cells.

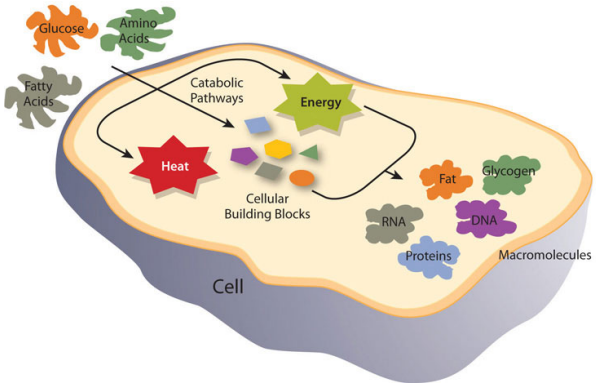


Figure 6.2.1: Metabolism is categorized into metabolic pathways that break down the molecules that release energy (catabolism) and the molecules that consume energy by building bigger molecules (anabolism).

Energy metabolism refers more specifically to the metabolic pathways that release or store energy. Some of these are catabolic pathways, like glycolysis (the splitting of glucose), β-oxidation (fatty-acid breakdown), and amino acid catabolism. Others are anabolic pathways, and include those involved in storing excess energy (such as glycogenisis), and synthesizing triglycerides (lipogenesis). Table 6.2.1 summarizes some of the catabolic and anabolic pathways and their functions in energy metabolism.

Table 6.2.1: Metabolic Pathways

Catabolic Pathways	Function	Anabolic Pathways	Function
Glycolysis	Glucose breakdown	Gluconeogenesis	Synthesize glucose
Glycogenolysis	Glycogen breakdown	Glycogenesis	Synthesize glycogen
β-oxidation	Fatty-acid breakdown	Lipogenesis	Synthesize triglycerides
Proteolysis	Protein breakdown to amino acids	Amino-acid synthesis	Synthesize amino acids

Catabolism: The Breakdown

All cells are in tune to their energy balance. When energy levels are high cells build molecules, and when energy levels are low catabolic pathways are initiated to make energy. Glucose is the preferred energy source by most tissues, but fatty acids and amino acids can also be catabolized to the cellular energy molecule, ATP. The catabolism of nutrients to energy can be separated into three stages, each containing individual metabolic pathways. The three stages of nutrient breakdown allow for cells to reassess their energy requirements, as end products of each pathway can either be further processed to energy or diverted to anabolic pathways. Additionally, intermediates of metabolic pathways can sometimes be diverted to anabolic pathways once cellular energy requirements have been met. The three stages of nutrient breakdown are the following:

- **Stage 1:** Glycolysis for glucose, β-oxidation for fatty acids, or amino acid catabolism
- **Stage 2:** Citric Acid Cycle (or Kreb cycle)
- **Stage 3:** Electron Transport Chain and ATP synthesis

The breakdown of glucose begins with glycolysis, which is a ten-step metabolic pathway yielding two ATP per glucose molecule; glycolysis takes place in the cytosol and does not require oxygen. In addition to ATP, the end products of glycolysis include two three-carbon molecules, called pyruvate. Pyruvate has several metabolic fates. One, if there is insufficient oxygen, it is converted to lactate then shunted to the liver. Two, if there is sufficient oxygen and the cell needs energy, it is shunted to the mitochondria and enters the citric acid cycle (or Cori cycle or Krebs cycle), or three, it may be converted to other molecules (anabolism).

Pyruvate that is transported into the mitochondria gets one of its carbons chopped off, yielding acetyl-CoA. Acetyl-CoA, a two-carbon molecule common to glucose, lipid, and protein metabolism enters the second stage of energy metabolism, the citric acid cycle. This is an irreversible process. The breakdown of fatty acids begins with the catabolic pathway, known as β-oxidation, which takes place in the mitochondria. In this catabolic pathway, four enzymatic steps sequentially remove two-carbon molecules from long chains of fatty acids, yielding acetyl-CoA molecules. In the case of amino acids, once the nitrogen is removed (deamination)

from the amino acid the remaining carbon skeleton can be enzymatically converted into acetyl-CoA or some other intermediate of the citric acid cycle.

In the citric acid, cycle acetyl-CoA is joined to a four-carbon molecule. In this multistep pathway, two carbons are lost as two molecules of carbon dioxide are formed. The energy obtained from the breaking of chemical bonds in the citric acid cycle is transformed into two more ATP molecules (or equivalents thereof) and high energy electrons that are carried by the molecules, nicotinamide adenine dinucleotide (NADH) and flavin adenine dinucleotide ($FADH_2$). NADH and $FADH_2$ carry the electrons (hydrogen) to the inner membrane of the mitochondria where the third stage of energy synthesis takes place, in what is called the electron transport chain. In this metabolic pathway, a sequential transfer of electrons between multiple proteins occurs and ATP is synthesized. Water is also formed.

The entire process of nutrient catabolism is chemically similar to burning, as carbon molecules are burnt producing carbon dioxide, water, and heat. However, the many chemical reactions in nutrient catabolism slow the breakdown of carbon molecules so that much of the energy can be captured and not transformed into heat and light. Complete nutrient catabolism is between 30 and 40 percent efficient, and some of the energy is therefore released as heat. Heat is a vital product of nutrient catabolism and is involved in maintaining body temperature. If cells were too efficient at transforming nutrient energy into ATP, humans would not last to the next meal, as they would die of hypothermia.

We measure energy in calories which are the amount of energy released to raise one gram of water one degree Celsius. Food calories are measured in kcal or Calories or 1000 calories. When burned, carbohydrates produce 4 kcal/gm.; protein produce 4 kcal/gm; fat produces 9 kcal/gm; and, alcohol produces 7 kcal/gm.

Some amino acids have the nitrogen removed then enter the citric acid cycle for energy production. The nitrogen is incorporated into urea and then removed in the urine. The carbon skeleton is converted to pyruvate or enters the citric acid cycle directly. These amino acids are called gluconeogenic because they can be used to make glucose. Amino acids that are deaminated and become acetyl-CoA are called ketogenic amino acids and can never become glucose.

Fatty acids can never be made into glucose but are a high source of energy. These are broken down into two carbon units by a process called beta-oxidation enter the citric acid cycle as acetyl-CoA. In the presence of glucose, these two carbon units enter the citric acid cycle and burned to make energy (ATP) and produce the by-product CO_2. If glucose is low, ketones are formed. Ketone bodies can be burned to produce energy. The brain can use ketones.

Anabolism: The Building

The energy released by catabolic pathways powers anabolic pathways in the building of macromolecules such as the proteins RNA and DNA, and even entire new cells and tissues. Anabolic pathways are required to build new tissue, such as muscle, after prolonged exercise or the remodeling of bone tissue, a process involving both catabolic and anabolic pathways. Anabolic pathways also build energy-storage molecules, such as glycogen and triglycerides. Intermediates in the catabolic pathways of energy metabolism are sometimes diverted from ATP production and used as building blocks instead. This happens when a cell is in positive energy balance. For example, the citric-acid-cycle intermediate, α-ketoglutarate can be anabolically processed to the amino acids glutamate or glutamine if they are required. Recall that the human body is capable of synthesizing eleven of the twenty amino acids that make up proteins. The metabolic pathways of amino acid synthesis are all inhibited by the specific amino acid that is the end-product of a given pathway. Thus, if a cell has enough glutamine it turns off its synthesis.

Anabolic pathways are regulated by their end-products, but even more so by the energy state of the cell. When there is ample energy, bigger molecules, such as protein, RNA, and DNA, will be built as needed. Alternatively, when energy is insufficient, proteins and other molecules will be destroyed and catabolized to release energy. A dramatic example of this is seen in children with Marasmus. These children have severely compromised bodily functions, often culminating in death by infection. Children with Marasmus are starving for calories and protein, which are required to make energy and build macromolecules. The negative-energy balance in children who have Marasmus results in the breakdown of muscle tissue and tissues of other organs in the body's attempt to survive. The large decrease in muscle tissue makes children with Marasmus look emaciated or "muscle-wasted."

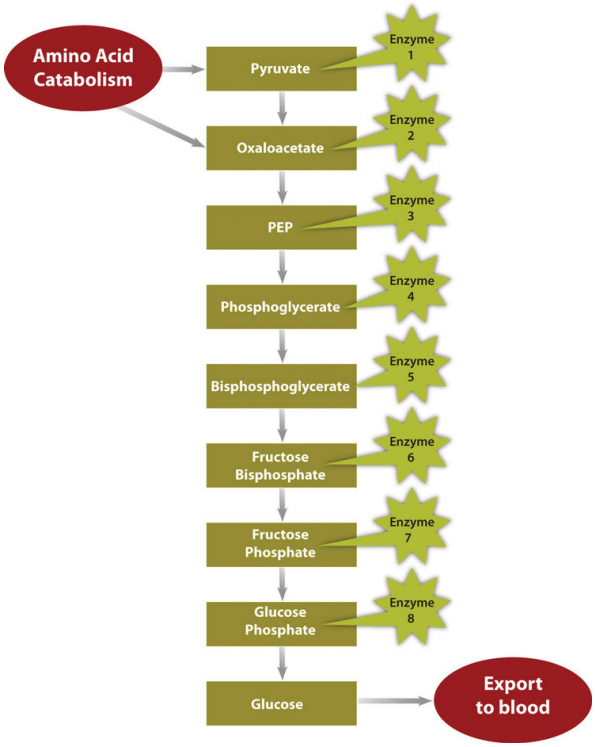


Figure 6.2.2: Metabolic Pathway of Gluconeogenesis

In a much less severe example, a person is also in negative energy balance between meals. During this time, blood glucose levels start to drop. In order to restore blood glucose levels to their normal range, the anabolic pathway, called gluconeogenesis, is stimulated. Gluconeogenesis is the process of building glucose molecules from certain amino acids and it occurs primarily in the liver (Figure 6.2.2). The liver exports the synthesized glucose into the blood for other tissues to use.

Energy Storage

In contrast, in the “fed” state (when energy levels are high), extra energy from nutrients will be stored. Glucose can be stored only in muscle and liver tissues. In these tissues, it is stored as glycogen, a highly branched macromolecule consisting of thousands of glucose monomers held together by chemical bonds. The glucose monomers are joined together by an anabolic pathway called glycogenesis. For each molecule of glucose stored, one molecule of ATP is used. Therefore, it costs energy to store energy. Glycogen levels do not take long to reach their physiological limit and when this happens excess glucose will be converted to fat. A cell in positive energy balance detects a high concentration of ATP as well as acetyl-CoA produced by catabolic pathways. In response, catabolism is shut off and the synthesis of triglycerides, which occurs by an anabolic pathway called lipogenesis, is turned on. The newly made triglycerides are transported to fat-storing cells called adipocytes. Fat is a better alternative to glycogen for energy storage as it is more compact (per unit of energy) and, unlike glycogen, the body does not store water along with fat. Water weighs a significant amount and increased glycogen stores, which are accompanied by water, would dramatically increase body weight. When the body is in positive energy balance, excess carbohydrates, lipids, and protein are all metabolized to fat.

Key Takeaways

- The overall goals of metabolism are energy transfer and matter transport. Metabolism is defined as the sum of all chemical reactions required to support cellular function and is either categorized as catabolism (referring to all metabolic processes involved in molecule breakdown) or anabolism (which includes all metabolic processes involved in building bigger molecules). Generally, catabolic processes release energy and anabolic processes consume energy.
- A metabolic pathway is a series of enzymatic steps that transforms a substrate (the starting material) into intermediates, which are substrates for the proceeding enzymatic reactions until finally an end-product is synthesized by the last enzymatic reaction in the pathway.
- The organ systems of the body require fuel and building blocks to digest, absorb, breathe, pump blood, transport nutrients in and wastes out, maintain body temperature, and make new cells amongst a multitude of other functions.

- When energy levels are high, cells build molecules, and when energy levels are low, catabolic pathways are stimulated to release energy.
- The energy released by catabolic pathways powers anabolic pathways in the building of bigger macromolecules.
- In the “fed” state (when energy levels are high), extra nutrient fuel will be stored as glycogen or triglycerides.

Discussion Starters

1. Discuss the practicality of storing energy in early human civilizations and the consequences of these metabolic processes in today’s world. Refer back to the story of the Pima Indians in Chapter 1 and the concept of the “thrifty gene.”
2. Can an overweight person blame their excess weight on having a slower metabolism?

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6.3: Vitamins Important for Metabolism

Learning Objectives

- Summarize the role of the B vitamins in metabolism.
- Explain how Vitamin K supports a life-saving function of blood.

While the macronutrients (carbohydrates, lipids, and proteins) and alcohol can be catabolized to release energy, vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage. Vitamins and minerals that make up part of enzymes are referred to as coenzymes and cofactors, respectively. Coenzymes and cofactors are required by enzymes to catalyze a specific reaction. They assist in converting a substrate to an end-product (Figure 6.3.1). Coenzymes and cofactors are essential in catabolic pathways and play a role in many anabolic pathways too.

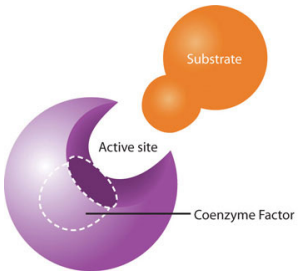


Figure 6.3.1: Coenzymes and cofactors are the particular vitamin or mineral required for enzymes to catalyze a specific reaction.

Vitamins: Functions in Catabolic Pathways and Anabolic Pathways

Thiamine (B_1)

Thiamine, one of the water-soluble vitamins, is especially important in glucose metabolism. It acts as a cofactor for enzymes that break down glucose for energy production (Figure 6.3.1). Additionally, thiamine plays a role in the synthesis of ribose from glucose and is therefore required for RNA, DNA, and ATP synthesis. The brain and heart are most affected by a deficiency in thiamine. Thiamine deficiency, also known as beriberi, can cause symptoms of fatigue, confusion, movement impairment, pain in the lower extremities, swelling, and heart failure. It is prevalent in societies whose main dietary staple is white rice. During the processing of white rice, the bran is removed, along with what were called in the early nineteenth century, “accessory factors,” that are vital for metabolism. Dutch physician Dr. Christiaan Eijkman cured chickens of beriberi by feeding them unpolished rice bran in 1897. By 1912, Sir Frederick Gowland Hopkins determined from his experiments with animals that the “accessory factors,” eventually renamed vitamins, are needed in the diet to support growth, since animals fed a diet of pure carbohydrates, proteins, fats, and minerals failed to grow. Encyclopedia Brittanica Blog. “Frederick Gowland Hopkins and his “Accessory Food Factors.” Accessed October 1, 2011. www.britannica.com/blogs/2011/06/frederick-gowland-hopkins-accessory-food-factors/. Eijkman and Hopkins were awarded the Nobel Prize in Physiology (or Medicine) in 1929 for their discoveries in the emerging science of nutrition. There are two forms of beriberi, wet and dry. Wet beriberi causes edema and heart failure while dry beriberi results in muscle wasting, weakness, and paralysis.

Another deficiency syndrome is the Wernicke-Korsakoff syndrome characterized by disorientation, amnesia, jerky eye movements, and staggering gait. It is the third most common dementia in the US and is due to alcohol excess and glucose excess. Excess alcohol intake increases thiamine excretion in the urine.

Thiamine is a water-soluble vitamin, so it is not stored in the body and excess consumption increases its excretion in the urine. Thiamine need is increased with exercise. Whole grains, enriched flour, green leafy vegetables, legumes, and pork are excellent dietary sources of thiamine but you need to select an appropriate cooking method because prolonged cooking and cooking in water will destroy thiamine. The best way to cook thiamine-containing foods is in the microwave or by steaming.

Riboflavin (B_2)

Riboflavin, also a water-soluble vitamin, is an essential component of flavoproteins, which are coenzymes involved in many metabolic pathways of carbohydrate, lipid, and protein metabolism. Flavoproteins aid in the transfer of electrons in the electron transport chain, thus the production of energy or ATP, and the active form is flavin adenine dinucleotide (FAD) or flavin

mononucleotide (FMN). Furthermore, the functions of other B-vitamin coenzymes, such as vitamin B_6 and folate, are dependent on the actions of flavoproteins. The “flavin” portion of riboflavin gives a bright yellow color to riboflavin, an attribute that help lead to its discovery as a vitamin. Riboflavin deficiency sometimes referred to as ariboflavinosis, is often accompanied by other dietary deficiencies (most notably protein) and can be common in people that suffer from alcoholism. Its signs and symptoms are numerous and can include weakness, dry, scaly skin, mouth inflammation and sores, cracks at the corner of the mouth, painful magenta (purplish-red) tongue, smoothness of the tongue (glossitis), sore throat, itchy eyes, and light sensitivity. Alcoholics, people with liver disease, and diabetics are particularly at risk of developing a riboflavin deficiency.

Whole grains, enriched flour products, milk and green leafy vegetables are good sources of this vitamin. Riboflavin is very sensitive to irradiation and UV light, so this is the reason milk is not sold in clear bottles. Cooking does not destroy riboflavin.

Niacin (B_3)

Niacin is a water-soluble vitamin and is found as nicotinamide (niacinamide) or nicotinic acid. It is a component of the coenzymes nicotinamide adenine dinucleotide (NAD) and its phosphorylated form (NADP), which are involved in the catabolism and/or anabolism of carbohydrates, lipids, and proteins. NADH is the predominant electron carrier and transfers electrons to the electron transport chain to make ATP. NADPH is required for the anabolic pathways of fatty acid and cholesterol synthesis. In contrast to other vitamins, niacin can be synthesized by humans from the amino acid tryptophan in an anabolic process requiring enzymes dependent on riboflavin, vitamin B_6, and iron. Niacin is made from tryptophan only after tryptophan has met all of its other needs in the body. The contribution of tryptophan-derived niacin to niacin needs in the body varies widely and a few scientific studies have demonstrated that diets high in tryptophan have very little effect on niacin deficiency. Niacin deficiency is commonly known as pellagra and is characterized by diarrhea, dermatitis, dementia, and sometimes death (Video 6.3.1). It is still seen in poor urban US, Africa and Asia. People at risk of developing pellagra are alcoholics, people consuming a low protein diet, and people using drugs used to treat tuberculosis and leukemia.

Dietary sources of niacin are whole grains, enriched flour, legumes and protein containing tryptophan such as meat and poultry. Of special note, nicotinic acid in lard amounts is used as a blood cholesterol lowering drug. If the dose is too high (3-4 times the RDA) the following can occur: flushing due to dilation of the capillaries, diarrhea, liver damage, impaired glucose tolerance, nausea and emesis, blurred vision, and/or edema of the eyes.

Pantothenic Acid (B_5)

Pantothenic acid, another water-soluble vitamin, forms coenzyme A, which is the main carrier of carbon molecules in a cell. Acetyl-CoA is the carbon carrier of glucose, fatty acids, and amino acids into the citric acid cycle (Figure 6.3.2). Coenzyme A is also involved in the synthesis of lipids, cholesterol, and acetylcholine (a neurotransmitter). Vitamin B_5 deficiency is exceptionally rare and may be caused by malabsorption. Signs and symptoms include fatigue or weakness, irritability, gastrointestinal distress, numbness, muscle pain, and cramps. You may have seen pantothenic acid on many ingredients lists for skin and hair care products; however, there is no good scientific evidence that pantothenic acid improves human skin or hair.

Pantothenic acid is found in all foods but better sources are whole grains, oats, tomatoes, broccoli, meat especially chicken, milk, and egg yolks. This vitamin is easily destroyed by food processing.

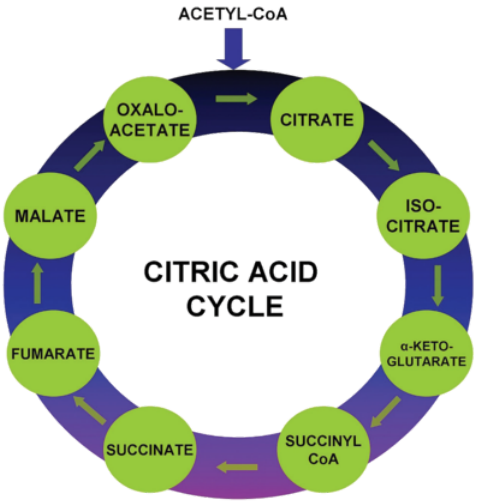


Figure 6.3.2: Vitamin B_5 makes up coenzyme A, which carries the carbons of glucose, fatty acids, and amino acids into the citric acid cycle as Acetyl-CoA.

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Pyroxidine (B_6)

Pyroxidine (water-soluble vitamin) is the coenzyme involved in nitrogen transfer between amino acids and therefore plays a role in amino-acid synthesis and catabolism. Also, it functions to release glucose from glycogen in the catabolic pathway of glycogenolysis and is required by enzymes for the synthesis of multiple neurotransmitters and hemoglobin. A deficiency in vitamin B_6 can cause signs and symptoms of muscle weakness, dermatitis, mouth sores, fatigue, and confusion.

Vitamin B_6 is a required coenzyme for the synthesis of hemoglobin. A deficiency in vitamin B_6 can cause anemia, but it is of a different type than that caused by insufficient folate, cobalamin, or iron; although the symptoms are similar. The size of red blood cells is normal or somewhat smaller but the hemoglobin content is lower. This means each red blood cell has less capacity for carrying oxygen, resulting in muscle weakness, fatigue, and shortness of breath.

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Biotin (B_7)

Biotin (water-soluble vitamin) is required as a coenzyme in the citric acid cycle and in lipid metabolism. It is also required as an enzyme in the synthesis of glucose, fatty acids, and some nonessential amino acids and carries carbon dioxide (CO_2) away from the citric acid cycle (TCA cycle). A specific enzyme, biotinidase, is required to release biotin from protein so that it can be absorbed in the gut. There is some bacterial synthesis of biotin that occurs in the colon; however, this is not a significant source of biotin. Biotin deficiency is rare but can be caused by eating large amounts of egg whites over an extended period of time. This is because a protein in egg whites tightly binds to biotin making it unavailable for absorption. A rare genetic disease-causing malfunction of the biotinidase enzyme also results in biotin deficiency. Biotin deficiency is very rare and deficiency symptoms are similar to those of other B vitamins such as weakness, but may also include hair loss when severe, a rash around the eyes, nose and mouth, depression, lethargy and hallucinations. People at risk of developing a biotin deficiency include individuals who eat a lot of raw egg whites (the uncooked protein binds biotin making it unavailable for absorption), and patients receiving total parental nutrition.

Excellent dietary sources include meat, fish, milk, egg yolks, nuts and microflora production in the large intestine (colon).

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Folate

Folate is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic, also called megaloblastic, anemia. Macrocytic and megaloblastic mean “big cell,” and anemia refers to fewer red blood cells or red blood cells

containing less hemoglobin. Macrocytic anemia is characterized by larger and fewer red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size.

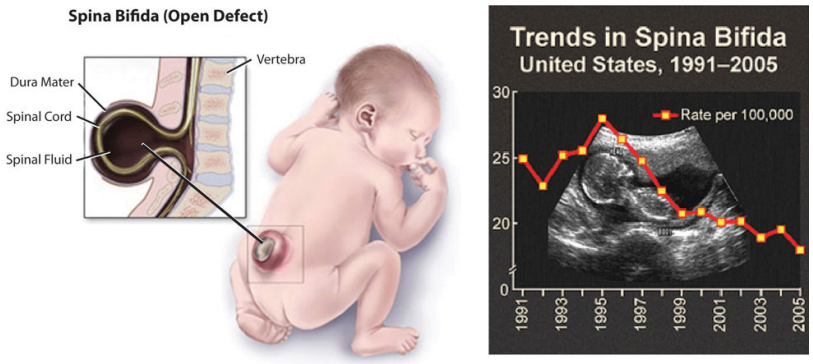


Figure 6.3.3: Spina bifida is a neural-tube defect that can have severe health consequences

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural-tube defect that occurs when the spine does not completely enclose the spinal cord. Spina bifida can lead to many physical and mental disabilities (Figure 6.3.3). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate (Figure 10.4.3). Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer, however scientific studies refute this hypothesis.

-

Cobalamin (B_{12})

Cobalamin contains cobalt, making it the only vitamin that contains a metal ion. Cobalamin is an essential part of coenzymes. It is necessary for fat and protein catabolism, for folate coenzyme function, and for hemoglobin synthesis. An enzyme requiring cobalamin is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in cobalamin has similar consequences to health as folate deficiency. In children and adults cobalamin deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers, there is an increased risk of neural-tube defects. In order for the human body to absorb cobalamin, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for cobalamin absorption, which occurs in the small intestine. Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Pernicious anemia is treated with large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the blood stream without passing through the intestine. In patients that do not respond to oral or sublingual treatment, vitamin B_{12} is given by injection.

A summary of the prominent functions of the B vitamins in metabolism and their deficiency syndromes is given in Table 6.3.1.

Table 6.3.1: *B-Vitamin Functions in Metabolism*

B Vitamin	Function	Deficiency: Signs and Symptoms
B_1 (thiamine)	Coenzyme: assists in glucose metabolism, RNA, DNA, and ATP synthesis	Beriberi: fatigue, confusion, movement impairment, swelling, heart failure
B_2 (riboflavin)	Coenzyme: assists in glucose, fat and carbohydrate metabolism, electron carrier, other B vitamins are dependent on	Ariboflavinosis: dry scaly skin, mouth inflammation and sores, sore throat, itchy eyes, light sensitivity
B_3 (niacin)	Coenzyme: assists in glucose, fat, and protein metabolism, electron carrier	Pellagra: diarrhea, dermatitis, dementia, death

B Vitamin	Function	Deficiency: Signs and Symptoms
B_5 (pantothenic acid)	Coenzyme: assists in glucose, fat, and protein metabolism, cholesterol, and neurotransmitter synthesis	Muscle numbness and pain, fatigue, irritability
B_6 (pyroxidine)	Coenzyme; assists in amino-acid synthesis, glycogenolysis, neurotransmitter and hemoglobin synthesis	Muscle weakness, dermatitis, mouth sores, fatigue, confusion
Biotin	Coenzyme; assists in glucose, fat, and protein metabolism, amino-acid synthesis	Muscle weakness, dermatitis, fatigue, hair loss
Folate	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural-tube defects
B_{12} (cobalamin)	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural-tube defects

Do B-Vitamin Supplements Provide an Energy Boost?

Although some marketers claim taking a vitamin that contains one-thousand times the daily value of certain B vitamins boosts energy and performance, this is a myth that is not backed by science. The “feeling” of more energy from energy-boosting supplements stems from the high amount of added sugars, caffeine, and other herbal stimulants that accompany the high doses of B vitamins. As discussed, B vitamins are needed to support energy metabolism and growth, but taking in more than required does not supply you with more energy. A great analogy of this phenomenon is the gas in your car. Does it drive faster with a half-tank of gas or a full one? It does not matter; the car drives just as fast as long as it has gas. Similarly, depletion of B vitamins will cause problems in energy metabolism, but having more than is required to run metabolism does not speed it up. Buyers of B-vitamin supplements beware; B vitamins are not stored in the body and all excess will be flushed down the toilet along with the extra money spent.

B vitamins are naturally present in numerous foods, and many other foods are enriched with them. In the United States, B-vitamin deficiencies are rare; however, in the nineteenth century, some vitamin-B deficiencies plagued many people in North America. Niacin deficiency, also known as pellagra, was prominent in poorer Americans whose main dietary staple was refined cornmeal (Video 6.3.1). Its symptoms were severe and included diarrhea, dermatitis, dementia, and even death. Some of the health consequences of pellagra are the result of niacin being in insufficient supply to support the body’s metabolic functions.



Video 6.3.1*: Pellagra Video. Review this video on how Dr. Joseph Goldberger discovered that pellagra was a diet-related illness . (click to see video)*

Dietary Reference Intakes and Sources of B Vitamins

B vitamins are water-soluble and are not stored in significant amounts in the body. Therefore, they must be continuously obtained from the diet. Fortunately, B vitamins are generally well-absorbed in the gut. The Recommended Dietary Allowances (RDA) or Adequate Intakes (AI) set by the IOM, for the B vitamins are listed in Table 6.3.2, which also gives some dietary sources for these micronutrients. It should be noted that B vitamins are lost from foods during storage, processing, and cooking. To maximize B vitamin uptake, fruits and vegetables should not be stored for long periods of time, should be eaten more as whole foods, and vegetables should be steamed rather than boiled. Also, alcohol disrupts intestinal absorption of B vitamins. The US Department of Agriculture has reports of the nutrient contents in foods, including all B vitamins, available at their website.

Table 6.3.2: Dietary Reference Intakes and Food Sources for B Vitamins

B Vitamin	RDA (mg/day)	Food Sources
B_1 (thiamine)	1.2 (males)	Whole grains, enriched grains, orange juice, milk, peanuts, dried beans and seeds
	1.1 (females)	
B_2 (riboflavin)	1.3 (males)	Milk, yogurt, fortified breakfast cereals, organ meats, mushrooms, eggs, clams, spinach
	1.1 (females)	
B_3 (niacin)	16 (males)	Meat, poultry, fish, whole grains, fortified breakfast cereals, enriched grains, mushrooms, peanuts
	14 (females)	
B_5 (pantothenic acid)	5 (males)	Eggs, sunflower seeds, peanuts, meat, milk, vegetables
	5 (females)*	
B_6 (pyroxidine)	1.3 (males)	Meats, whole grains, potatoes, fortified breakfast cereals, bananas, avocados
	1.3 (females)	
Biotin	0.03 (males)	Egg yolks, peanuts, cheese
	0.03 (females)*	
Folate	0.4 (males)	Green leafy vegetables, legumes, fortified breakfast cereals, orange juice, sunflower seeds, liver
	0.4 (females)	
B_{12} (cobalamin)	0.0024 (males)	Animal derived foods, some soy milks, and fortified breakfast cereals
	0.0024 (females)	

* denotes Adequate Intake

Source: Institute of Medicine. *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B_6, Folate, Vitamin B_{12}, Pantothenic Acid, Biotin, and Choline.* June 12, 2000. www.iom.edu/Reports/2000/Dietary-Reference-Intakes-for-Thiamin-Riboflavin-Niacin-Vitamin-B6-Folate-Vitamin-B12-Pantothenic-Acid-Biotin-and-Choline.aspx.

Interactive 6.3.1

The USDA has an interactive database of nutrient contents in food. To view reports of single nutrients simply click on the one you are interested in and view the report. http://www.ars.usda.gov/Services/docs.htm?docid=20958

Dietary Sources Rich in Folate and Vitamin B_{12}

To assist you in getting all the vitamin B_{12} and folate you need to support metabolism and blood cell synthesis look over Table 6.3.3 and 6.6 for good dietary sources of these micronutrients.

Table 6.3.3: Dietary Sources of Folate

Food	Micrograms per Serving	Percent Daily Value
Liver	185 (3 oz.)	45
Calf liver	650 (3 oz.)	160
Fortified breakfast cereals	400 (¾ c.)	100
Spinach	100 (½ c., boiled)	25
Northern beans	100 (½ c., boiled)	25
Asparagus	85 (4 spears, boiled)	20
Vegetarian baked beans	60 (1 c.)	15
Broccoli	45 (2 spears)	10
Avocado	45 (½ c.)	10
Bread (enriched)	25 (1 slice)	6

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Folate." Last reviewed April 15, 2009. http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/.

Table 6.3.4: Dietary Sources of Vitamins B_{12}

Food	Micrograms per Serving	Percent Daily Value
Liver	48 (1 slice)	800
Clams	34.2 (3 oz.)	570
Organic calf liver	31 (3 oz.)	520
Fortified breakfast cereals	6.0 (1 serving)	100
Trout (wild)	5.4 (3 oz.)	90
Trout (farmed)	3.5 (3 oz.)	58
Salmon (sockeye)	4.8 (3 oz.)	80
Cheeseburger	2.1	35
Yogurt (plain)	1.4 (1 c.)	23
Beef (top sirloin)	1.4 (3 oz.)	23
Milk	0.9 (1 c.)	15
Egg	0.6 (1 large)	10

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin B_{12}." Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/.

Vitamin K: Functions in Metabolism

There is emerging evidence that vitamin K may play a role in energy metabolism, but currently, the exact functions of vitamin K-dependent enzymes in energy metabolism remain elusive. Vitamin K is required for optimal bone metabolism. Vitamin K is also critical for blood function.

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug

warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins as discussed in the previous chapter.

Dietary Reference Intakes and Sources of Vitamin K

The RDA for vitamin K for adult males is 120 mcg/day and for adult females is 90 mcg/day. Vitamin K is present in many foods and most highly concentrated in green leafy vegetables. See Table 10.4.5 for a list of dietary sources of vitamin K.

Table 6.3.5: Dietary Sources of Vitamin K

Food	Micrograms per Serving	Percent Daily Value
Broccoli (½ c.)	160.0	133
Asparagus (4 spears)	34.0	28
Cabbage (½ c.)	56.0	47
Spinach (½ c.)	27.0	23
Green peas (½ c.)	16.0	13
Cheese (1 oz.)	10.0	8
Ham (3 oz.)	13.0	11
Ground beef (3 oz.)	6.0	5
Bread	1.1	<1
Orange	1.3	1

Key Takeaways

- Vitamins and minerals play a different kind of role in energy metabolism; they are required as functional parts of enzymes involved in energy release and storage.
- The water-soluble B vitamins are involved as coenzymes in the breakdown of nutrients and in the building of macromolecules, such as protein, RNA, and DNA.
- B-vitamin deficiencies are relatively rare especially in developed countries; although the health consequences can be severe as with folate deficiency during pregnancy and the increased risk of neural-tube defects in offspring.

Discussion Starters

1. Discuss how the actions of B vitamins are interdependent; meaning the level of one affects the function of another.
2. Have a classroom debate on whether it is prudent for the federal government to regulate claims on micronutrient supplements, such as those containing B vitamins.

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6.4: Minerals Important for Metabolism and for Blood Function and Renewal

Learning Objectives

- List the primary function of each of the minerals involved in metabolism.
- Summarize the roles of minerals important in blood function and renewal.

In a well-balanced diet, minerals are plentiful, and herbs are power-packed with minerals. Eat more plants, spice up your food, and drink herbal teas to obtain optimum mineral nutrition.



Figure 6.4.1: Several different minerals. Notice color and texture is different.

Magnesium

Magnesium is the eleventh most abundant element in the human body and is known to participate as a cofactor in hundreds of metabolic reactions. ATP exists as a complex with magnesium and therefore this mineral is involved in all reactions that synthesize or require ATP including carbohydrate, lipid, protein, RNA, and DNA synthesis. Many Americans do not get the recommended intake of magnesium from their diets. Some observational studies suggest mild magnesium deficiency is linked to increased risk for cardiovascular disease. Signs and symptoms of severe magnesium deficiency may include tremor, muscle spasms, loss of appetite, and nausea.

Iron

Red blood cells contain the oxygen carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 6.4.2). Iron is a key component of hundreds of metabolic enzymes. Many of the proteins of the electron transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

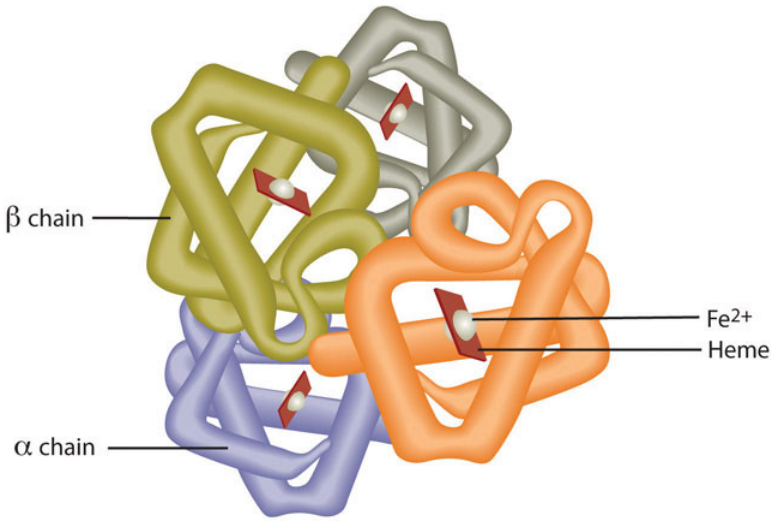


Figure 6.4.2: Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released (video below). If iron level is low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. When blood cells are decommissioned for use, the body recycles the iron back to the bone marrow where red blood cells are made. The body stores some iron in the bone marrow, liver, spleen, and skeletal muscle. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

Video: Oxygen Transport



Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.

The bioavailability of iron is highly dependent on dietary sources. In animal-based foods, about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the *American Journal of Clinical Nutrition* reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent and that from vegetarian diets ranges between 5 and 12 percent.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. Iron deficiency is the most common of all micronutrient deficiencies and will be explored in depth in Section 10.5.

Zinc

Zinc is a cofactor for over two hundred enzymes in the human body and plays a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world's population has a zinc-deficient diet.Prasad, Ananda. "Zinc deficiency." BMJ 2003 February 22; 326(7386): 409–410. doi: 10.1136/bmj.326.7386.409. Accessed October 2, 2011. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1125304/?tool=pmcentrez. This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, loss of appetite, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia.

Iodine

Iodine is a trace mineral that is an anion and part of thyroid hormone. Recall from Chapter 1 the information about the discovery of iodine and its use as a means of preventing goiter, a gross enlargement of the thyroid gland in the neck. Iodine is essential for the synthesis of thyroid hormone, which regulates basal metabolism, growth, and development. Low iodine levels and consequently hypothyroidism has many signs and symptoms including fatigue, sensitivity to cold, constipation, weight gain, depression, and dry, itchy skin and paleness. The development of goiter may often be the most visible sign of chronic iodine deficiency, but the consequences of low levels of thyroid hormone can be severe during infancy, childhood, and adolescence as it affects all stages of growth and development. Thyroid hormone plays a major role in brain development and growth and fetuses and infants with severe iodine deficiency develop a condition known as cretinism, in which physical and neurological impairment can be severe. The World Health Organization (WHO) estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.World Health Organization. "Iodine Status Worldwide." Accessed October 2, 2011. http://whqlibdoc.who.int/publications/2004/9241592001.pdf. People who live in areas with low soil iodine content are at a greater risk of developing an iodine deficiency. In the US, iodine deficiency is uncommon because salt has been iodized. You can also find iodine in seafood and baked goods. The upper limit of iodine intake is 1000 ug/day and this is close to the RDA.

Selenium

Selenium is a cofactor of enzymes that release active thyroid hormone in cells and therefore low levels can cause similar signs and symptoms as iodine deficiency. The other important function of selenium is an antioxidant, which was discussed in detail in Chapter 8.

Copper

Copper, like iron, assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport. The other important function of copper is an antioxidant, which was also discussed in Chapter 8. Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves.

Manganese

Manganese is a trace mineral that is a cofactor for enzymes involved in glucose production (gluconeogenesis), cholesterol synthesis, and formation of urea (amino-acid catabolism in the liver). Manganese deficiency is rare but signs and symptoms include impaired growth and reproduction, reduced bone mineral density, impaired skeletal growth, impaired glucose and lipid metabolism, and skin rash. Toxicity has been reported in individuals who inhale manganeses dust, water with high amounts. Manganese impairers the neuromuscular system causing muscle spasms and tremors. Dietary sources include whole grain foods, pineapples, pine nuts, okra, spinach, and raspberries.

Chromium

Chromium is called a trace mineral because you need very little amounts in your diet. It is a cation that is positively charged in its active form. The functioning of chromium in the body is less understood than that of most other minerals. It enhances the actions of

insulin so plays a role in carbohydrate, fat, and protein metabolism. Currently, the results of scientific studies evaluating the usefulness of chromium supplementation in preventing and treating Type 2 diabetes are largely inconclusive. It has also been proposed as a weight loss aid, but there is no scientific evidence for this use. More research is needed to better determine if chromium is helpful in treating certain chronic diseases and, if so, at what doses. Deficiency symptoms may include a diabetes-like condition but this has not been well studied and documented. Groups at risk of developing a chromium deficiency include individuals consuming excess sugar. Studies suggest 90% of the US population is below the recommended minimum intake of chromium.

Dietary sources of chromium include whole grains, liver, seafood, Brewer's yeast, mushrooms, prunes, dark chocolate, nuts, asparagus, red wine, and processed meats.

Summary of Minerals

A summary of the prominent functions of minerals in metabolism and their related deficiency syndromes is given in Table 6.4.1.

Table 6.4.1: Mineral Functions in Metabolism and Blood and Deficiency Syndrome

Mineral	Function	Deficiency: Signs and Symptoms
Macro		
Magnesium	ATP synthesis and utilization, carbohydrate, lipid, protein, RNA, and DNA synthesis	Tremor, muscle spasms, loss of appetite, nausea
Trace		
Iron	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate
Zinc	Assists in energy production, protein, RNA, and DNA synthesis; required for hemoglobin synthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss
Iodine	Making thyroid hormone, metabolism, growth and development	Goiter, cretinism, other signs, and symptoms include fatigue, depression, weight gain, itchy skin, low heart-rate
Selenium	Essential for thyroid hormone activity	fatigue
Copper	Assists in energy production, iron metabolism	Anemia: fatigue, paleness, faster heart rate
Manganese	Glucose synthesis, amino acid catabolism	Impaired growth, skeletal abnormalities, abnormal glucose metabolism
Chromium	Assists insulin in carbohydrate, lipid and protein metabolism	abnormal glucose metabolism

Dietary Reference Intakes for Minerals and Dietary Sources

The RDA set by the IOM for minerals involved in metabolism are listed for adults in Table 6.4.2. The table also lists dietary sources for these micronutrients. The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 6.4.2: Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism

Mineral	RDA (mg/day)	Food Sources

Mineral	RDA (mg/day)	Food Sources
Macro		
Magnesium	420.000 (males)	Nuts, vegetables, coffee and tea, cocoa
	320.000 (females)**	
Trace		
Iron	8.000 (males)	Animal products, fortified breakfast cereals, beans, spinach, peas
	18.000 (females)	
Zinc	11.000 (males)	Red meat, poultry, seafood, fortified breakfast cereals, beans, nuts, whole grains
	8.000 (females)	
Iodine	0.150 (males)	Seafood, dairy products
	0.150 (females)	
Selenium	0.055 (males)	Tuna, beef, chicken, nuts, dairy products
	0.055 (females)	
Copper	0.900 (males)	Whole grains, liver, legumes, seeds, cocoa
	0.900 (females)	
Manganese	2.300 (males)	Whole grains, brown rice, spinach, nuts, tea
	1.800 (females)*	
Chromium	0.035 (males)	Egg yolks, whole grains, meats, organ meats, mushrooms, nuts, broccoli
	0.025 (females)*	

* denotes Adequate Intake, **for ages 31–50 only

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, such as oxalate and phytate, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

Key Takeaways

- Minerals cannot be broken down to release energy.
- Minerals are cofactors for hundreds of enzymes involved in metabolism.
- Iron especially, but also copper and zinc are critical for blood function and renewal.
- Minerals are not as efficiently absorbed as most vitamins and bioavailability can be very low.

Discussion Starters

1. Discuss why “more is not always better,” especially how this saying pertains to micronutrient intake.
2. Look up the chemical structure of phytate and explain how it inhibits the absorption of positively charged minerals.

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6.5: Balancing Energy Input with Energy Output

Learning Objectives

- Estimate your daily energy requirement.
- Define basal metabolism and explain the factors that affect the basal metabolic rate.
- Summarize why the amount of food we eat (appetite) is not completely under our conscious control.

To Maintain Weight, Energy Intake Must Balance Energy Output

Before you begin your journey to learn about energy balance, we need to define a few terms. These are shown in Table 6.5.1.

Table 6.5.1: Terms for understanding energy balance.

Term	Definition
Hunger	physiological drive to eat
Appetite	psychological drive to eat
Satiety	State in which both drives are satisfied and there is no longer a desire to eat. Being satisfied.
Hypothalamus	A group of cells at the base of the brain which participates in many regulatory functions including hunger
Leptin	Hormone produced by body fat that plays a role in regulating food intake and physical activity
Ghrelin	Hormone produced by the stomach that regulates appetite
Peptide YY (PYY)	Protein produced by gastrointestinal tract that regulates appetite and food intake
Calorie or kilocalories	amount of heat energy needed to raise temperature of 1 kg of water 1 C (unit of energy measurement)

Recall that the macronutrients you consume are either converted to energy, stored, or used to synthesize macromolecules. A nutrient's metabolic path is dependent upon energy balance. When you are in a positive energy balance the excess nutrient energy will be stored or used to grow (e.g., during childhood, pregnancy, and wound healing). When you are in negative energy balance you aren't taking in enough energy to meet your needs, so your body will need to use its stores to provide energy. Energy balance is achieved when intake of energy is equal to the energy expended. Weight can be thought of as a whole body estimate of energy balance; body weight is maintained when the body is in energy balance, lost when it is in negative energy balance (intake or input < expenditure or output), and gained when it is in positive energy balance (intake or input > expenditure or output). When your energy intake matches your energy output, you will maintain your weight, whatever that is. People who are overweight or obese can be in energy balance. In other words, their intake matches their energy output but at some point in their life, their energy intake exceeded their energy intake. In general, weight is a good predictor of energy balance, but many other factors play a role in energy intake and energy expenditure. Some of these factors are under your control and others are not. Let us begin with the basics on how to estimate energy intake, energy requirement, and energy output. Then we will consider the other factors that play a role in maintaining energy balance and hence, body weight. In Figure 6.5.1, energy output exceeds energy input, so this person would be losing weight.

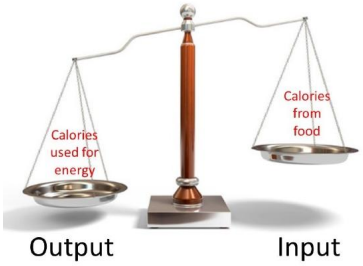


Figure 6.5.1: Energy is a balance between energy input and energy output. When one exceeds the other you will lose or gain weight.

One pound of body fat is approximately 3,500 kcal and 1 kg is 7,700 kcal. If you consume 10 more kcal per day than what you need, you will gain 1 lb per year. If you eat 100 kcal more than you expend per day, that is one slice of white bread, you will gain 10 lbs in a year. Portion sized have increased. In 1950, a burger, fry, and drink were 590 kcal. Today, a quarter-pound burger with cheese, large fries and drink is 1,550 kcal. Wow! What a huge increase in half a century - almost 300%.

Total Energy Expenditure (Output)

The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn while at rest (basal metabolism), the calories you burn when you digest food and heat production (minor). The sum of caloric expenditure is referred to as total energy expenditure (TEE). Basal metabolism refers to those metabolic pathways necessary to support and maintain the body's basic functions (e.g. breathing, heartbeat, liver, and kidney function) while at rest. The basal metabolic rate (BMR) is the amount of energy required by the body to conduct its basic functions over a certain time period. The great majority of energy expended (between 50 and 80 percent) daily is from conducting life's basic processes. Of all the organs, the liver requires the most energy (see Table 6.5.5). Unfortunately, you cannot tell your liver to ramp up its activity level to expend more energy so you can lose weight. BMR is dependent on body size, body composition, sex, age, nutritional status, and genetics. People with a larger frame size have a higher BMR simply because they have more mass. Muscle tissue burns more calories than fat tissue even while at rest and thus the more muscle mass a person has the higher their BMR. Since females typically have less muscle mass and a smaller frame size than men, their BMRs are generally lower than men's. As we get older muscle mass declines and thus so does BMR. Nutritional status also affects basal metabolism. Caloric restriction, as occurs while dieting, for example, causes a decline in BMR. This is because the body attempts to maintain homeostasis and will adapt by slowing down its basic functions to offset the decrease in energy intake. Body temperature, thyroid hormone levels, and pregnancy and lactation are additional determinants of BMR.

Usually, we measure RMR (resting metabolic rate) or REE (resting energy expenditure). Both are measured shortly after awakening in the morning after at least a twelve hour fast. RMR or REE are slightly higher than BMR because the individual may have ambulated, for example, walked to urinated before measuring RMR. BMR is measured with no ambulatory movement.

Table 6.5.2: Energy Breakdown of Organs

Organ	Percent of Energy Expended
Liver	27
Brain	19
Heart	7
Kidneys	10
Skeletal muscle (at rest)	18
Other organs	19

The energy required for all the enzymatic reactions that take place during food digestion and absorption of nutrients is called the "thermic effect of food" and accounts for about 5-10 percent of the total energy expended per day. Fat is metabolized more efficiently than protein or carbohydrate so the TEF for high-fat foods is less. Also, dietary fat is usually stored, not burned, after eaten.

The other energy required during the day is for physical activity. Depending on lifestyle, the energy required for this ranges between 15 and 50 percent of the total energy expended. The percent varies among individuals. The energy cost of physical activity depends on the activity, for example walking vs running, the length the activity is sustained, body weight, and training. The benefits of physical activity continue after the activity has stopped. The main control a person has over TEE is to increase physical activity.

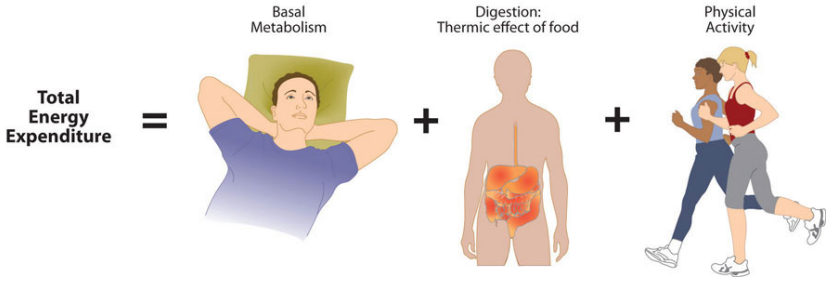


Figure 6.5.2: Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity.

Estimating Energy Requirement

To maintain body weight you have to balance the calories obtained from food and beverages with the calories expended every day. Here, we will discuss how to calculate your energy needs in kilocalories per day so that you can determine whether your caloric intake falls short, meets, or exceeds your energy needs. The Institute of Medicine has devised a formula for calculating your Estimated Energy Requirement (EER). It takes into account your age, sex, weight, height, and physical activity level (PA). The EER is a standardized mathematical prediction of a person's daily energy needs in kilocalories per day required to maintain weight. It is calculated via the following formulas:

- Adult male:

$$EER = 662 - [9.53 \times age(y)] + PA \times [15.91 \times wt(kg) + 5.39.6 \times ht(m)] \quad (6.5.1)$$

- Adult female:

$$EER = 354 - [6.91 \times age(y)] + PA \times [9.36 \times wt(kg) + 726 \times ht(m)] \quad (6.5.2)$$

Note: to convert pounds to kilograms, divide weight in pounds by 2.2. To convert feet to meters, divide height in feet by 3.3.

The **Harris Benedict Equation** is a way to calculate RMR. You must add additional kcal for activity.

- Men: RMR = 66.47 + 13.75(kg) + 5 (cm) - 6.76(age)
- Women: RMR = 6.55.1 + 9.56(kg) + 1.85(cm)-4.68(age)

Examples of physical activity adjustments are as follows. Multiple the RMR by this number you calculate above by this number to get the total energy requirement: males and females bed rest - 1.1-1.3; males and females very sedentary - 1.2-1.4; males and females sedentary/maintenance - 1.3-1.5; males and females light activity - 1.4-1.5.

Estimating Caloric Intake

In Chapter 2, you learned how to calculate the number of calories in food. To determine your caloric intake per day requires that you conduct a dietary assessment and record the number of calories you eat.

Interactive 6.5.1

To begin your dietary assessment, go to MyPlate, which is available on the US Department of Agriculture (USDA) website: http://www.choosemyplate.gov/.

Table 6.5.3: Physical Activity (PA) Categories and Values

Activity Level	Men PA Value	Women PA Value	Description
Sedentary	1.00	1.00	No physical activity beyond that required for independent living
These values only apply to normal-weight adults and not to children or pregnant or lactating women.			

Activity Level	Men PA Value	Women PA Value	Description
Low	1.11	1.12	Equivalent to walking 1.5 to 3 miles per day
Moderate	1.25	1.27	Equivalent to walking 3 to 10 miles per day
High	1.48	1.45	Equivalent to walking 10 or more miles per day
These values only apply to normal-weight adults and not to children or pregnant or lactating women.			

Source: Health Canada. "Dietary Reference Intake Tables." Last modified November 29, 2010. http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/index-eng.php#eeer.

The numbers within the equations for the EER were derived from measurements taken from a group of people of the same sex and age with similar body size and physical activity level. These standardized formulas are then applied to individuals whose measurements have not been taken, but who have similar characteristics in order to estimate their energy requirements. Thus, a person's EER is, as the name suggests, an estimate for an average person of similar characteristics. EER values are different for children, pregnant or lactating women, and for overweight and obese people. Also, remember the EER is calculated based on weight maintenance, not for weight loss or weight gain.

Table 6.5.4: Estimated Daily Calorie Needs

Sex	Age (years)	Sedentary	Moderately Active	Active
Child (female and male)	2–3	1,000–1,200	1,000–1,400	1,000–1,400
Female	4–8	1,200–1,400	1,400–1,600	1,400–1,800
	9–13	1,400–1,600	1,600–2,000	1,800–2,200
	14–18	1,800	2,000	2,400
	19–30	1,800–2,000	2,000–2,200	2,400
	31–50	1,800	2,000	2,200
	51+	1,600	1,800	2,000–2,200
Male	4–8	1,200–1,400	1400–1,600	1,600–2,000
	9–13	1,600–2,000	1,800–2,200	2,000–2,600
	14–18	2,000–2,400	2,400–2,800	2,800–3,200
	19–30	2,400–2,600	2,600–2,800	3,000
	31–50	2,200–2,400	2,400–2,600	2,800–3,000
	51+	2,000–2,200	2,200–2,400	2,400–2,800

Source: US Department of Agriculture. *2010 Dietary Guidelines for Americans.* 2010. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

The *2010 Dietary Guidelines* provides a table (Table 6.5.4) that gives the estimated daily calorie needs for different age groups of males and females with various activity levels. The *2010 Dietary Guidelines* also states that while knowing the number of calories you need each day is useful, it is also pertinent to obtain your calories from nutrient-dense foods and consume the various macronutrients in their Acceptable Macronutrient Distribution Ranges (AMDRs) (Table 6.5.5).

Table 6.5.5: Acceptable Macronutrient Distribution Ranges

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)
Young Children (1–3)	45–65	5–20	30–40
Older children/adolescents (4–18)	45–65	10–30	25–35
Adults (19 and older)	45–65	10–35	20–35

Source: Institute of Medicine. "Dietary Reference Intakes: Macronutrients." *Dietary Reference Intakes for Energy, Carbohydrate. Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* September 5, 2002. www.iom.edu/~/media/Files/Activity%20Files/Nutrition/DRIs/DRI_Macronutrients.pdf

How to Calculate Total Energy Expenditure

Calculating TEE can be tedious but has been made easier as there are now calculators available on the Web. TEE is dependent on age, sex, height, weight, and physical activity level. The equations are based on standardized formulas produced from actual measurements on groups of people with similar characteristics. To get accurate results from web-based TEE calculators, it is necessary to record your daily activities and the time spent performing them. A spreadsheet for doing so is available online at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf.

Interactive 6.5.1: Health-calc.com offers an interactive TEE calculator.

http://www.health-calc.com/diet/energy-expenditure-advanced

Factors Affecting Energy Intake

Physiology

In the last few decades, scientific studies have revealed that how much we eat and what we eat is controlled not only by our own desires but also is regulated physiologically and influenced by genetics. The hypothalamus in the brain is the main control point of appetite. It receives hormonal and neural signals, which determine if you feel hungry or full. Hunger is an unpleasant sensation of feeling empty that is communicated to the brain by both mechanical and chemical signals from the periphery. Conversely, satiety is the sensation of feeling full and it also is determined by mechanical and chemical signals relayed from the periphery. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety (Figure 6.5.2).

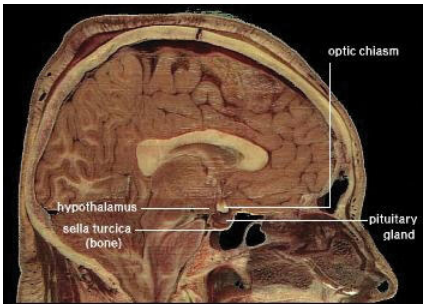


Figure 6.5.3: This is a scan of a brain. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety. Source: Diabesity, Sixth Framework Programme. "Novel Molecular Targets for Obesity and Type 2 Diabetes." 2002-2006. www.diabesity.eu/.honours.htm.

Hunger pangs are real and so is a "growling" stomach. When the stomach is empty it contracts, producing the characteristic pang and "growl." The stomach's mechanical movements relay neural signals to the hypothalamus, which relays other neural signals to parts of the brain. This results in the conscious feeling of the need to eat. Alternatively, after you eat a meal the stomach stretches and sends a neural signal to the brain stimulating the sensation of satiety and relaying the message to stop eating. The stomach also sends out certain hormones when it is full and others when it is empty. These hormones communicate to the hypothalamus and other areas of the brain either to stop eating or to find some food. Thus hunger signals change as we eat.

Fat tissue also plays a role in regulating food intake. Fat tissue produces the hormone leptin, which communicates to the satiety center in the hypothalamus that the body is in positive energy balance. The discovery of leptin's functions sparked a craze in the research world and in the diet pill industry as it was hypothesized that if you give leptin to a person who is overweight, they will decrease their food intake. Alas, this is not the case. In several clinical trials, it was found that people who are overweight or obese are actually resistant to the hormone, meaning their brain does not respond as well to it.Dardeno, T. A. et al. "Leptin in Human Physiology and Therapeutics." *Front Neuroendocrinol* 31, no. 3 (2010): 377–93. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2916735/?tool=pubmed. Therefore, when you administer leptin to an overweight or obese person there is no sustained effect on food intake.

Nutrients themselves also play a role in influencing food intake. The hypothalamus senses nutrient levels in the blood. When they are low the hunger center is stimulated, and when they are high the satiety center is stimulated. Furthermore, cravings for salty and sweet foods have an underlying physiological basis. Both undernutrition and overnutrition affect hormone levels and the neural circuitry controlling appetite, which makes losing or gaining weight a substantial physiological hurdle.

Genetic Influences

Genetics certainly play a role in body fatness and weight and also affects food intake. Children who have been adopted typically are similar in weight and body fatness to their biological parents. Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins. The scientific search for obesity genes is ongoing and a few have been identified, such as the gene that encodes for leptin. However, overweight and obesity that manifests in millions of people is not likely to be attributed to one or even a few genes but to rather the interactions of hundreds of genes with the environment. In fact, when an individual has a mutated version of the gene coding for leptin, they are obese, but only a few dozen people around the world have been identified as having a completely defective leptin gene.

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Psychological/Behavioral Influences

When your mouth waters in response to the smell of a roasting Thanksgiving turkey and steaming hot pies, you are experiencing a psychological influence on food intake. A person's perception of good-smelling and good-tasting food influences what they eat and how much they eat. Mood and emotions are associated with food intake. Depression, low self-esteem, compulsive disorders, and emotional trauma are sometimes linked with increased food intake and obesity.

Certain behaviors can be predictive of how much a person eats. Some of these are how much food a person heaps onto their plate, how often they snack on calorie-dense, salty foods, how often they watch television or sit at a computer, and how often they eat out. A study published in a 2008 issue of *Obesity* looked at characteristics of Chinese buffet patrons. The study found that those who chose to immediately eat before browsing the buffet, used larger plates, used a fork rather than chopsticks, and chewed less per bite of food, had higher BMIs than patrons who did not exhibit these behaviors.Levin, B. E. "Developmental Gene X Environment Interactions Affecting Systems Regulating Energy Homeostasis and Obesity." *Front Neuroendocrinol* 3 (2010): 270–83. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2903638/?tool=pubmed. Of course, many behaviors are reflective of what we have easy access to—a concept we will discuss next.

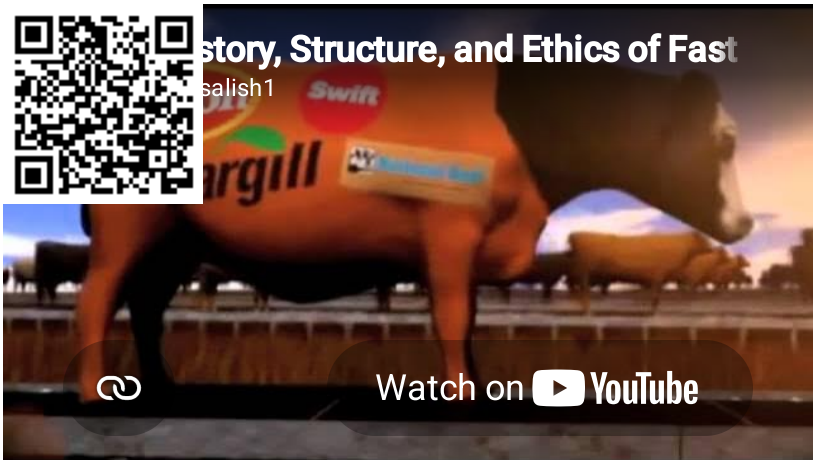
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Societal Influences

It is without a doubt that the American society affects what and how much we eat. Portion sizes have increased dramatically in the past few decades. For example, a bagel is now more than twice the size it was in the 1960s. Today, American teenagers have access to a massive amount of calorie-dense foods and beverages, which is a large contributor to the recent rapid increase in overweight and obesity in adolescents in this country. Even different cultures within the United States have different eating habits. For instance, southern Americans, in general, consume more foods high in fat, which is a contributing factor to their higher incidences of overweight and obesity than Americans who live in the northern states. (Alaska is an exception because it also has a high incidence of overweight and obesity, which is also partly attributed to diet.)

The fast food industry in America not only supplies Americans with a large proportion of their diet but because of its massive presence in society dominates the workings of the entire food system (Note 9.23 "Video 6.5.1). To generalize, most fast food items have little nutritional merit as they are highly processed and rich in saturated fat, salt, and added sugars. Despite fast foods being a poor source of nourishment, Americans spend over one hundred billion dollars per year on fast food, up from six billion dollars in the early 1970s. The fast food business is likely to continue to grow in North America (and the rest of the world) and greatly affect

the diets of whole populations. Because it is unrealistic to say that Americans should abruptly quit eating fast food to save their health (because they will not) society needs to come up with ideas that push nutrient-dense whole foods into the fast food industry. You may have observed that this largely consumer-driven push is having some effect on the foods the fast food industry serves (just watch a recent Subway commercial, or check the options now available in a McDonald's Happy Meal). Pushing the fast food industry to serve healthier foods is a realistic and positive way to improve the American diet.



Video 6.5.1. *History, Structure, and Ethics of the Fast Food Industry (click to see video) A brief clip about the fast food industry and its effect on the United States.*

Tools for Change

Support the consumer movement of pushing the fast food industry and your favorite local restaurants into serving more nutrient-dense foods. You can begin this task by starting simple, such as requesting extra tomatoes and lettuce on your burger and more nutrient-dense choices in the salad bar. Also, choose their low-calorie menu options and help support the emerging market of healthier choices in the fast food industry. In today's fast-paced society, it is difficult for most people to avoid fast food all the time. When you do need a quick bite on the run, choose the fast food restaurants that serve healthier foods. Also, start asking for caloric contents of foods so that the restaurant becomes more aware that their patrons are being calorie conscious.

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Factors Affecting Energy Expenditure

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Physiological and Genetic Influences

Why is it so difficult for some people to lose weight and for others to gain weight? One theory is that every person has a "set point" of energy balance. This set point can also be called a fat-stat or lipostat, meaning the brain senses body fatness and triggers changes in energy intake or expenditure to maintain body fatness within a target range. Some believe that this theory provides an explanation as to why after dieting, most people return to their original weight not long after stopping the diet. Another theory is referred to as the "settling" point system, which takes into account (more so than the "set-point" theory) the contribution of the obesogenic environment to weight gain. In this model, the reservoir of body fatness responds to energy intake or energy expenditure, such that if a person is exposed to a greater amount of food, body fatness increases, or if a person watches more television body fatness increases. A major problem with these theories is that they overgeneralize and do not take into account that not all individuals respond in the same way to changes in food intake or energy expenditure. This brings up the importance of the interactions of genes and the environment.

Not all individuals who take a weight-loss drug lose weight and not all people who smoke are thin. An explanation for these discrepancies is that each individual's genes respond differently to a specific environment. Alternatively, environmental factors can influence a person's gene profile, which is exemplified by the effects of the prenatal environment on body weight and fatness and disease incidence later in life. One of the first scientific investigations of prenatal control over energy balance was conducted in Germany. In this observational study, scientists found that offspring born to mothers who experienced famine were more likely to be obese in adulthood than offspring born to mothers who were pregnant just after World War II who lived in the same geographical locations.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J*

Epidemiol 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Other studies have shown that the offspring of women who were overweight during pregnancy have a greater propensity for being overweight and for developing Type 2 diabetes. Thus, undernutrition and overnutrition during pregnancy influence body weight and disease risk for offspring later in life. They do so by adapting energy metabolism to the early nutrient and hormonal environment in the womb.

Audio Link 6.5.1: Rethinking Thin: The Myths and Realities of Dieting

Listen to this NPR broadcast for scientific information about why it is so difficult for some people to lose weight. Rethinking Thin

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Psychological/Behavioral Influence

Sedentary behavior is defined as the participation in the pursuits in which energy expenditure is no more than one-and-one-half times the amount of energy expended while at rest and include sitting, reclining, or lying down while awake. Of course, the sedentary lifestyle of many North Americans contributes to their average energy expenditure in daily life. Simply put, the more you sit, the less energy you expend. A study published in a 2008 issue of the *American Journal of Epidemiology* reports that 55 percent of Americans spend 7.7 hours in sedentary behavior daily.Matthews, C. E. “Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004.” *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Fortunately, including only a small amount of low-level physical activity benefits weight control. A study published in the June 2001 issue of the *International Journal of Behavioral Nutrition and Physical Activity* reports that even breaking up sitting time with frequent, but briefly increased energy expenditure activities, such as walking for five minutes every hour, helps maintain weight and even aids in weight loss.Wu, Y. “Overweight and Obesity in China.” *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362. Americans partake in an excessive amount of screen time, which is a sedentary behavior that not only reduces energy expenditure but also contributes to weight gain because of the exposure to aggressive advertising campaigns for unhealthy foods.

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Societal Influence

In the United States, many societal factors influence the number of calories burned in a day. Escalators, moving walkways, and elevators (not to mention cars!) are common modes of transportation that reduce average daily energy expenditure. Office work, high-stress jobs, and occupations requiring extended working hours are all societal pressures that reduce the time allotted for the exercise of large populations of Americans. Even the remote controls that many have for various electronic devices in their homes contribute to the US society being less active. More “obesogenic” factors were discussed in the opening of this chapter.

Socioeconomic status has been found to be inversely proportional to weight gain. One reason for this relationship is that inhabitants of low-income neighborhoods have reduced access to safe streets and parks for walking. Another is that fitness clubs are expensive and few are found in lower-income neighborhoods. The recent and long-lasting economic crisis in this country is predicted to have profound effects on the average body weight of Americans. The number of homeless in this country is rising with many children and adults living in hotels and cars. As you can imagine neither of these “home spaces” has a kitchen, making it impossible to cook nutritious meals and resulting in increased economically-forced access to cheap, unhealthy foods, such as that at a nearby gas station.

Key Takeaways

Energy balance is achieved when energy intake is equal to the energy expended. Energy balance is essential for maintaining weight. Knowing the number of calories you need each day is a useful reference point, but it is also important to obtain your calories from nutrient-dense foods and consume the macronutrients in their AMDRs. The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn at rest (basal metabolism), and the calories you burn when you digest food. Basal metabolic rate (BMR) is dependent on body size, body composition, sex, age, nutritional status, genetics, body temperature, and thyroid hormone levels. The great majority of energy expended (between 50 and 70 percent) daily comes from conducting life’s basic processes. The main control a person has over TEE is to increase physical activity. Energy intake is regulated by complex physiological responses and is influenced by genetics, behavior, and society. Energy expenditure is also regulated by complex physiological responses and is influenced by genetics, behavior, and society.

Discussion Starters

1. Some types of transportation are becoming economically unfeasible for obese people. Discuss whether or not it is acceptable that air carriers can enforce that obese people (or what they politely call “passengers of size” or “passengers requiring extra space”) pay more for their seats.
2. Many people have a hard time understanding the difficulties of being too skinny. Discuss with your peers how to empathize with the weight problems of underweight people. Read the article to understand that being skinny does not mean a person necessarily has a lower risk of chronic disease.

   http://www.msnbc.msn.com/id/18594089/ns/health-fitness/t/thin-people-can-be-fat-inside/

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6.6: Too Little or Too Much Weight?

Learning Objectives

- Discern the differences in health risks associated with being underweight and being overweight.

The number of people considered overweight and obese in the world has now surpassed the number that is starving, with some officials estimating that the number of overweight people is nearly double the number of underweight people worldwide. Countries that have more recently modernized, industrialized, and urbanized are experiencing a surge in their overweight and obese populations. China, the most populous country in the world, now has more than 215 million people, approximately one-fifth of their population, that are considered overweight or obese (Wu, Yangfeng. "Overweight and obesity in China." BMJ. 2006 August 19; 333(7564): 362–363. doi: 10.1136/bmj.333.7564.362. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1550451/). The increase in China's waistline is partly attributed to changes in the traditional diet, more sedentary lives, and a massive increase in motor vehicle use. Moreover, China's recent famines in the 1950s, which affected the poor and lower classes to a greater extent than the upper class, has sanctioned lax social attitudes toward body fat and reinspired the age-old Chinese belief that excess body fat represents health and prosperity.

One of the worst statistics regarding overweight and obesity in China is that more than ten million adolescents between ages seventeen and eighteen were overweight in 2000, which is twenty-eight times the number that was overweight in 1985 (Wu, Y. "Overweight and Obesity in China." *Br Med J* 333, no. 7564 (2006): 362. doi: 10.1136/bmj.333.7564.362). The associated diseases of overweight and obesity happen over many years and signs and symptoms commonly take decades to manifest. With China's younger population and other developed countries experiencing a dramatic weight increase, the associated chronic diseases will come about much earlier in life than in previous generations. This will put an even greater burden on society.

Video 6.6.1

Chinese Obesity

(click to see video)

Watch this video on the surge in Chinese obesity and how the country's rapid increase in modernization contributes to its obesity epidemic.

Health Risks of Being Overweight and Being Obese

The health consequences of obesity are great and are responsible for more than one hundred thousand deaths per year in the United States. According to the CDC, in the United States in 2007–2008:

- 34 percent of adults aged twenty years and over are obese
- 34 percent of adults aged twenty years and over are overweight (but not obese)
- 18 percent of adolescents age twelve to nineteen years are obese
- 20 percent of children age six to eleven years are obese
- 10 percent of children age two to five years are obese (The Centers for Disease Control and Prevention. "Obesity and Overweight." Accessed October 8, 2011. http://www.cdc.gov/nchs/fastats/overwt.htm).

The health risks of being overweight include cardiovascular disease, hypertension (>140/90 mmHg), type 2 diabetes mellitus (risk is 3 times higher), metabolic syndrome (glucose intolerance, insulin resistance, hyperinsulinemia, hyperlipidemia, and hypertension), cancer, osteoarthritis (pressure placed on knees is 7x body weight), increased risk if surgery is needed, emotional disturbances and societal problems.

State Map of the Prevalence of Obesity in America

Visit www.cdc.gov/obesity/downloads/obesity_trends_2010.ppt to see the obesity trends from 1985 to 2010. As you will see, the percentages of obese adults are rising.

As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, postmenopausal breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. The WHO reports that overweight and obesity are the fifth leading cause for deaths globally, and estimates that more than 2.8 million adults die

annually as a result of being overweight or obese.World Health Organization. “Obesity and Overweight.” Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/. Moreover, overweight and obesity contribute to 44 percent of the Type 2 diabetes burden, 23 percent of the heart disease burden, and between 7 and 41 percent of the burden of certain cancers.World Health Organization. “Obesity and Overweight.” Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

Similar to other public health organizations, the WHO states the main causes of the obesity epidemic worldwide is the increased intake of energy-dense food and decreased level of physical activity that is mainly associated with modernization, industrialization, and urbanization. The environmental changes that contribute to the dietary and physical activity patterns of the world today are associated with the lack of policies that address the obesity epidemic in the health, urban planning, agriculture, food industry, and education sectors.

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Health Risks of Being Underweight

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight.Centers for Disease Control and Prevention. “NCHS Health E-Stat. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006.” Accessed October 8, 2011. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm. Being underweight is linked to nutritional deficiencies, especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. The most common underlying cause of underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men) and frequently co-occur with depression, substance abuse or anxiety disorders.

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Anorexia Nervosa

Anorexia nervosa, more often referred to as “anorexia,” is a psychiatric illness in which a person obsesses about their weight and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. Anorexia is relatively rare—the National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will have anorexia at some point in their lifetime, The National Institute of Mental Health. “Eating Disorders among Adults: Anorexia Nervosa.” Accessed October 8, 2011. http://mentalhealth.gov/statistics/1EAT_ADULT_ANX.shtml. but it is an extreme example of how an unbalanced diet can affect health. Anorexia frequently manifests during adolescence and it has the highest rate of mortality of all mental illnesses. People with anorexia consume, on average, fewer than 1,000 kilocalories per day (self-induced semi-starvation) and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may participate in binge eating, self-induced vomiting, and purging with laxatives or enemas. The very first time a person starves him- or herself may trigger the onset of anorexia. The exact causes of anorexia are not completely known, but many things contribute to its development including economic status, as it is most prevalent in high-income families. It is a genetic disease and is often passed from one generation to the next. Pregnancy complications and abnormalities in the brain, endocrine system, and immune system may all contribute to the development of this illness.

The primary signs of anorexia are fear of being overweight, extreme dieting, an unusual perception of body image, and depression. The secondary signs and symptoms of anorexia are all related to the caloric and nutrient deficiencies of the unbalanced diet and include excessive weight loss; reduced BMR; a multitude of skin abnormalities like dry, scaly, cold skin with or without languno; diarrhea; cavities and tooth loss; osteoporosis; anemia; and liver, kidney, and heart failure. They may be cold from lack of body fat for insulation. There is no physical test that can be used to diagnose anorexia and distinguish it from other mental illnesses. Therefore a correct diagnosis involves eliminating other mental illnesses, hormonal imbalances, and nervous system abnormalities. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined. Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviors associated with causing the eating disorder. Relapse to an unbalanced diet is high. Many people do recover from anorexia, however, most continue to have a lower-than-normal body weight for the rest of their lives (see Note 11.33 "Video 6.6.2").

Video 6.6.2: What I Gained in Recovery from Anorexia

On a more positive note, watch this personal account of what can be gained from anorexia recovery.(click to see video)

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Bulimia

Bulimia, like anorexia, is a psychiatric illness that can have severe health consequences. The NIMH reports that 0.5 percent of females and 0.1 percent of males will have bulimia at some point in their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Bulimia Nervosa.” Accessed October 8, 2011. mentalhealth.gov/statistics/1EAT_ADULT_RBUL.shtml. Bulimia is characterized by episodes of eating large amounts of food followed by purging, which is accomplished by vomiting and with the use of laxatives and diuretics. Unlike people with anorexia, those with bulimia often have a normal weight, making the disorder more difficult to detect and diagnose. The disorder is characterized by signs similar to anorexia such as fear of being overweight, extreme dieting, and bouts of excessive exercise. Secondary signs and symptoms include gastric reflux, severe erosion of tooth enamel, dehydration, electrolyte imbalances, lacerations in the mouth and esophagus from vomiting, and peptic ulcers. Repeated damage to the esophagus puts people with bulimia at an increased risk for esophageal cancer. The disorder is also highly genetic, linked to depression and anxiety disorders, and most commonly occurs in adolescent girls and young women. Treatment often involves antidepressant medications and, like anorexia, has better results when both the family and the individual with the disorder participate in nutritional and psychiatric counseling.

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Binge-Eating Disorder

Similar to those who experience anorexia and bulimia, people who have a binge-eating disorder have lost control over their eating. Binge-eating disorder is not currently diagnosed as a distinct psychiatric illness, although there is a proposal from the American Psychiatric Association to categorize it more specifically. People with binge-eating disorder will periodically overeat to the extreme, but their loss of control over eating is not followed by fasting, purging, or compulsive exercise. As a result, people with this disorder are often overweight or obese, and their chronic disease risks are those linked to having an abnormally high body weight such as hypertension, cardiovascular disease, and Type 2 diabetes. Additionally, they often experience guilt, shame, and depression. Binge-eating disorder is commonly associated with depression and anxiety disorders. According to the NIMH, binge-eating disorder is more prevalent than anorexia and bulimia, and affects 3.5 percent of females and 2.0 percent of males at some point during their lifetime.The National Institute of Mental Health. “Eating Disorders among Adults: Binge Eating Disorder.” Accessed October 8, 2011. www.nimh.nih.gov/statistics/1EAT_ADULT_RB.shtml. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

Key Takeaways

The number of people considered overweight and obese in the world has now surpassed the number that is starving. As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. Being underweight is linked to nutritional deficiencies. These deficiencies cause iron-deficiency anemia and also delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. Eating disorders resulting in being underweight can have severe consequences to health. The eating disorder anorexia nervosa has the highest mortality rate of all mental illnesses. All underweight people do not have anorexia and all overweight people do not have an eating disorder.

Discussion Starters

1. Visit the Food and Agriculture Organization of the United Nations website and discuss the impact of the rise in obesity in developing countries.

   www.fao.org/FOCUS/E/obesity/obes1.htm

2. Even as adults in this society we “profile” people with excess body fat as lazy and other disrespectful adjectives. Moreover, society commonly “profiles” people who are too skinny as being compulsive and vain. Propose ideas for improving body image during teenage years.

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6.7: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution

Learning Objectives

- Be able to calculate body mass index (BMI) given a particular weight and height.
- Name the factors that affect body composition and distribution.

What weight should you weigh? This has been a difficult question to answer because humans come in so many different sizes and shapes. We do know that carrying too much fat is not good for one's health. Ideal body weight (IBW) has been used to determine one's desirable weight. Usually, IBW is determined by reference weight-for-height charts and the most commonly used chart is the Metropolitan Life Insurance Tables which include data for men and women by height and frame size. Hamwi is another method which does not require reading a table. Instead, it is a calculation:

- Males: 106 lbs for 5' in height plus 6 lbs for every inch over
- Females: 100 lbs for 5' in height plus 5 lbs for every inch over

If the individual has a large from then the number is increased 10% and if that person's frame is small, then 10% is subtracted from the number. Once you have calculated their suggested weight, the following interpretative guidelines can be applied. If the person's weight is a certain percent over then they would be considered:

- Overweight if greater than 10% over IBW
- Mild obesity if greater than 20% over IBW
- Moderate obesity if greater than 40% over IBW
- Severe obesity if greater than 100% over IBW

There are limitations to both methods. Neither method is based on a representative population or all populations. The Metropolitan Life Insurance tables are based on mortality risk, not just obesity. Finally, there are many examples of people who are defined as overweight but don't have excess fat stores, for example, body builders and weight lifters.

Although the terms "overweight" and "obese" are often used interchangeably and considered as gradations of the same thing, they can denote different things. You weigh what you weigh because of your: water weight, lean muscle weight, bone weight, and weight from body fat (adipose). "Overweight" refers to having more weight than is typical for a particular height. That weight may be the result of water weight, muscle weight, or fat mass. "Obese" refers specifically to having excess body fat. In most cases, people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population.

> *The "ideal" healthy body weight for a particular person is dependent on many things, such as frame size, sex (hormone profile), muscle mass, bone density, age, and height. The perception of the "ideal" body weight can be additionally dependent on cultural factors and the mainstream societal advertisement of beauty.*

In this author's opinion, the concept of "ideal body weight" is concerning. I feel that each of us should be eating healthfully (not just saying it but doing it), exercising healthfully and then allowing our body weight to go where it wants to go. However, medical doctors, public health officials, and others needed to find a simple tool to look at patterns of weight gain in the U.S.A. and elsewhere. The easy tool that was developed is called the Body Mass Index (BMI). BMI is a tool meant to tell an individual if they weigh too much, too little or just right. BMI uses the information that we already have readily available from every doctor's visit: weight and height. The general idea is if you are very tall and have a low weight you are probably underweight. If you are very short and you weigh a lot you are probably overweight. It is a crude tool but one that can quickly, inexpensively give estimates of overweight and/or underweight.

The Body Mass Index (BMI) and Its Limitations

Body mass index (BMI) is calculated using **height** and **weight** measurements and is more predictive of a health risk than using weight alone. BMI measurements are used to indicate whether an individual may be underweight (with a BMI less than 18.5), overweight (with a BMI over 25), or obese (with a BMI over 30). Very high AND very low BMI's appear to increase a person's risk of dying. If you look at a graph of BMI (Figure 6.7.1) as it relates to your risk of dying, it has a "J-shaped Curve" or a "U-shaped

Curve" because being too low and/or too high both raise your risk of mortality. Instead, you'd like to be in the middle range of the BMI which is what they use for "Normal weight". You will notice that, even though you will be categorized as "overweight" at a BMI of 25 and "obese" at a BMI of 30, the risk of dying goes up gradually. Like a teacher assigning a letter grade, the decision of exactly where to draw the lines for underweight, normal weight, overweight and obese are somewhat arbitrary.

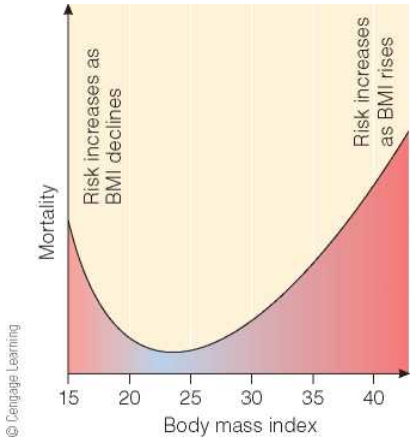


Figure 6.7.1: Relationship between body mass index and mortality.

To calculate your BMI, multiply your weight in pounds by 703 (conversion factor for converting to metric units) and then divide the product by your height in inches, squared.

$$BMI = \frac{weight\ (lb) \times 703}{height\ (in)^2} \tag{11.2.1a}$$

or

$$BMI = \frac{weight\ (kg)}{height\ (m)^2} \tag{11.2.1b}$$

Note

The National Heart, Lung, and Blood Institute and the CDC have automatic BMI calculators on their websites:

- www.nhlbisupport.com/bmi/
- http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html

To see how your BMI indicates the weight category you are in, see Table 6.7.1 or use a chart of weight and height to figure out your BMI.

Table 6.7.1: BMI Categories

Categories	BMI
Underweight	< 18.5
Normal weight	18.5–24.9
Overweight	25–29.9
Obese	30.0-34.9
Severe	35-40

Source: National Heart, Lung, and Blood Institute. Accessed November 4, 2012. http://www.nhlbi.nih.gov.

BMI Limitations

A BMI is a fairly simple measurement and does not take into account fat mass or fat distribution in the body, both of which are additional predictors of disease risk. Body fat weighs less than muscle mass. Therefore, BMI can sometimes underestimate the amount of body fat in overweight or obese people and overestimate it in more muscular people. For instance, a muscular athlete

will have more muscle mass (which is heavier than fat mass) than a couch potato of the same height. Based on their BMIs the muscular athlete would be less “ideal” and may be categorized as more overweight or obese than the couch potato; however, this is an infrequent problem with BMI calculation. Additionally, an older person with osteoporosis (decreased bone mass) will have a lower BMI than an older person of the same height without osteoporosis, even though the person with osteoporosis may have more fat mass. A BMI is a useful inexpensive tool to categorize people and is highly correlative with disease risk, but other measurements are needed to diagnose obesity and more accurately assess disease risk.

BMI is not a good measure for children and adolescents because they are growing. A new BMI for these ages was recently introduced in which the weight in kg is divided by the height in meters cubed. Its use is not well-established yet.

BMI does not consider where the fat is located. Individuals with abdominal fat or android shape have a greater risk of obesity associated diseases than individuals who carry their fat in the hips (gynoid or "pear shape"). Men tend to be "apple-shaped" while women tend to be "pear shaped." Gynoid shape tends to be associated with fewer health risks. For this reason, a ratio of body waist circumference to hip circumference may be measured and the ratio calculated. If you are male and your ratio is greater than 0.95, then you have excessive abdominal fat. If you are female and your ratio is greater than 0.86, then you have excessive abdominal fat.

Measuring Body Fat Content

Water, organs, bone tissue, fat, and muscle tissue make up a person’s weight. Having more fat mass may be indicative of disease risk, but fat mass also varies with sex, age, and physical activity level. Females have more fat mass, which is needed for reproduction and, in part, is a consequence of different levels of hormones. The optimal fat content of a female is between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent. Fat mass can be measured in a variety of ways. The simplest and lowest-cost way is the skin-fold test. A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. It is a noninvasive and fairly accurate method of measuring fat mass, but similar to BMI, is compared to standards of mostly young to middle-aged adults. Other methods of measuring fat mass are more expensive and more technically challenging. They include:

- **Underwater Weighing (Hydrostatic).** This technique requires a chamber full of water big enough for the whole body can fit in. First, a person is weighed outside the chamber and then weighed again while immersed in water. Bone and muscle weigh more than water, but fat does not—therefore a person with a higher muscle and bone mass will weigh more when in water than a person with less bone and muscle mass. This method is considered the gold standard but requires special facilities and not many places offer underwater weighing even for highly trained athletes. Also, this method is not easy or useful with children, the elderly or those afraid of water.
- **Bioelectric Impedance Analysis (BIA).** This device is based on the fact that fat slows down the passage of electricity through the body. When a small amount of electricity is passed through the body, the rate at which it travels is used to determine body composition. The percent of body fat is proportional to the body's resistance to the flow of current. A limitation of the method is BIA measures total body water which only estimates muscle and fat. Since water conducts the current, it is imperative that the individual is fully hydrated. These devices are also sold for home use and commonly called body composition scales.
- **Dual-energy x-ray absorptiometry.** This technique can be used to measure bone density. It also can determine fat content via the same method, which directs two low-dose x-ray beams through the body and determines the amount of the energy absorbed from the beams. The amount of energy absorbed is dependent on the body’s content of bone, lean tissue mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated.
- **Skinfold measurements.** This technique picks up the skin and measures the thickness. Calipers are used to measure the thickness of the fold which is bigger if there are abundant fat stores. A number of body sites are measured and the selection of sites depends on gender and which method is going to be used to estimate body fat percent. This method has several limitations and its accuracy is dependent on the training of the person completing the measurements. Several body sites must be measured and there is wide variation in the numbers obtained among different technicians.
- **BOD POD (Air Displacement)**. This machine measures how much air your body displaces within its chamber. Percent body fat is calculated based on the relationship between body weight, density, and volume. This machine requires a special facility and is not easy or useful for children and the elderly.

Measuring Fat Distribution

Total body fat mass is one predictor of health; another is how the fat is distributed in the body. You may have heard that fat on the hips is better than fat in the belly—this is true. Fat can be found in different areas in the body and it does not all act the same,

meaning it differs physiologically based on location. Fat deposited in the abdominal cavity is called visceral fat and it is a better predictor of disease risk than total fat mass. Visceral fat releases hormones and inflammatory factors that contribute to disease risk. The only tool required for measuring visceral fat is a measuring tape. The measurement (of waist circumference) is taken just above the belly button. Men with a waist circumference greater than 40 inches and women with a waist circumference greater than 35 inches are predicted to face greater health risks.

The waist-to-hip ratio is often considered a better measurement than waist circumference alone in predicting disease risk. To calculate your waist-to-hip ratio, use a measuring tape to measure your waist circumference and then measure your hip circumference at its widest part. Next, divide the waist circumference by the hip circumference to arrive at the waist-to-hip ratio. Observational studies have demonstrated that people with "apple-shaped" bodies, (who carry more weight around the waist) have greater risks for chronic disease than those with "pear-shaped" bodies, (who carry more weight around the hips). A study published in the November 2005 issue of *Lancet* with more than twenty-seven thousand participants from fifty-two countries concluded that the waist-to-hip ratio is highly correlated with heart attack risk worldwide and is a better predictor of heart attacks than BMI.Yusuf, S. et al. "Obesity and the Risk of Myocardial Infarction in 27,000 Participants from 52 Countries: A Case-Control Study." *Lancet* 366, no. 9497 (2005): 1640–9. Accessed October 5, 2011. http://www.ncbi.nlm.nih.gov/pubmed/16271645 ?dopt=AbstractPlus. Abdominal obesity is defined by the World Health Organization (WHO) as having a waist-to-hip ratio above 0.95 for males and above 0.85 for females.

Key Takeaways

Most people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population. To standardize the "ideal" body weight and relate it to health, scientists have devised some computational measurements to better define a healthy ideal weight. Body weight in relation to height is called BMI and is correlated with disease risk. Total body fat mass is another predictor of disease risk; another is where the fat is distributed. Fat deposits in different areas in the body and do not all act the same, meaning it differs physiologically based on location. Visceral fat contributes more to disease risk, for example.

Discussion Starters

1. Read the article, "Exercise Keeps Dangerous Visceral Fat Away a Year After Weight Loss, Study Finds," at http://www.sciencedaily.com/releases/2009/10/091029102740.htm. Then discuss the importance of exercise in eradicating excessive fat.
2. Based on what you learned, why would an individual with a high BMI have a decreased risk of osteoporosis?

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6.8: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management

Learning Objectives

- Explain the complementary actions of dietary changes and increased physical activity level on health.
- Formulate an exercise plan that fits your lifestyle and that follows the *2008 Physical Activity Guidelines for Americans*.

Theories of Obesity

Scientists have been looking for a cause of obesity for many decades now. Clearly, the evidence shows this is a multifaceted disease that is not explained by one cause, for example, one gene. Clearly, it is an energy imbalance - too many calories in for the calories expended. Yet, for some, there are other explanations that help contribute. These include genetic variation, metabolic, and environmental influences, and each interacts with the other. For example, since sequencing the human genome was completed, scientists have learned that the environment plays a powerful role in determining which genes are expressed.

Genetic Influences: A number of examples suggest genes can play a role in one's weight. There is an 80% propensity for offspring to gain weight if both parents are overweight, 60% chance if one parent is obese, and a 10% chance if neither parent is obese. Identical twins raised apart have similar weight gain patterns and gain fat in similar sites. Also, body shape is a heritable trait. The ectomorph tends to be lean, the mesomorph muscular and the endomorph large. Finally, rare genetic disorders give us insight into genes that control weight. There are several rare genetic defects that cause excessive weight gain. Examples are Prader-Willi syndrome (absence of chromosome 15) and Laurence-Moon syndrome. Individuals with Prader-Willi have an insatiable appetite.

Metabolic Influences: A number of metabolic theories have been proposed. A few are detailed here:

- Set-point theory: This theory states that a person is programmed to be a certain weight and have a certain body fat content. If a person weighs less than this set point, then their body will make adjustments in food intake or BMR to compensate and get the person back to their set point weight. If a person weighs more, again, their body will compensate to bring them back to the set point. People become obese because they have a high set point.
- Enzyme theory: Lipoprotein lipase (LPL) is an enzyme that breaks down LDL or VLDL at the cell surface to release the particles triglyceride into the cell. The activity of LPL increases when a fat cell is starving or seeking fat. Obese people have more LPL, but they also have more fat cells.
- Fat cell theory: This theory is based on the number of fat cells in your body. Fat cells want to store fat and body fat is related to the number of fat cells you have and the amount of fat they are storing. According to this theory, childhood overeating increases the number of fat cells. Obese children tend to have the same number of adipocytes as lean adults. Obese adults have more fat cells. We do not grow much more fat cells as an adult; these are laid down when we are children. When someone who is obese loses weight, they shrink the size of the fat cells and do not reduce the number of fat cells. These cells then are very hungry and hoard fat causing the person to gain back the weight they lost.
- Brown fat thermogenesis: Our body has white and brown fat. Brown fat makes heat from fat. It does not store fat like white fat. Newborns and true hibernators, like bears, have a lot of brown fat while adult humans have less. This theory states that obese people have less brown fat.

Environmental Influences: A wide variety of influences in our social and built environment encourage a lifestyle associated with fat accumulation. We call these environmental influences and examples include lack of activity such as walking 10,000 steps a day; lack of aerobic exercise; an excessive amount of time spent sitting at our computers, playing video games and/or watching television; excessive portion sizes; an infrastructure conducive to driving not walking or bike riding; and easy access to food high in calories.

Combating Excessive Fat

Throughout the years, many different weight loss programs have come and gone each promising quick weight loss. All weight-loss diets involve reducing one's caloric intake but the most successful programs also 1) meet the dieter's nutrient needs except energy, 2) meet the individual's tastes and habits, 3) favor the development and maintenance of changed eating patterns, and 4) is consistent with the improvement of overall health. The programs with the greatest probability of long-term success modify the dieter's eating behavior, encourage moderate portion control, and include moderate exercise most days of the week.

Weight loss should be slow to promote loss of fat, not muscle. A loss of two pounds or less a week is recommended. A pound of fat is approximately 3500 kcal so to lose 1 lbs of fat a week one should cut 500 calories from their diet without falling below 1,200 calories per day. This is the minimum amount of calories to assure adequate nutrient intake. At least 100 grams of carbohydrate is recommended per day, and this should be complex and include dietary fiber. Fat should provide between 10 and 30% of the total calories and protein near the RDA, 50 to 60 grams per day. It is essential to eat a variety of different foods to avoid boredom and assure one is getting all their micronutrients. The following are weight loss programs that do not meet some or all of these recommendations: very low energy diets (<1,000 calories per day), carbohydrate restrictive diets like the Atkins diet, diets that rely on special formulas or products, and diets that use appetite suppressant drugs. For some people, bariatric surgery has helped them reduce their body fat. These surgeries bypass part of the digestive tract. Other surgical procedures include stomach stapling or placing a band on the stomach to shrink its size.

Most dieters are not successful at keeping the weight they lost off and most gain the weight back plus more weight than they lost. This syndrome is called the yo-yo syndrome or weight cycling. It is a vicious cycle of weight loss, weight gain, weight loss, and weight gain in which the dieter ends up weighing more and has more body fat. Scientists theorize that the body becomes more efficient at storing calories once the dieter stops their weight loss diet.

We have just considered the gravity of the obesity problem in America and worldwide. How is America combating its weight problem on a national level and have the approaches been successful?

Successful weight loss is defined as individuals intentionally losing at least 10 percent of their body weight and keeping it off for at least one year.Wing, R. R. and J. O. Hill. "Successful Weight Loss Maintenance." *Annu Rev Nutr* 21 (2001): 323–41. Accessed October 8, 2011. http://www.ncbi.nlm.nih.gov/pubmed/11375440?dopt=Abstract. Results from lifestyle intervention studies suggest fewer than 20 percent of participants (3-5 year success is 5%) are successful at weight loss. An evaluation of successful weight loss, involving more than fourteen thousand participants published in the November 2011 issue of the *International Journal of Obesity* estimates that more than one in six Americans who were overweight or obese were successful in achieving long-term weight loss. Kraschnewski, J. L. et al. "Long-Term Weight Loss Maintenance in the United States." *Int J Obes* 34, no. 11 (2010): 1644–54. http://www.ncbi.nlm.nih.gov/pubmed/20479763. However, these numbers are on the high end because many similar studies report fewer than 10 percent of participants as successful in weight loss.

The National Weight Control Registry (NWCR) tracks over ten thousand people who have been successful in losing at least 30 pounds and maintaining this weight loss for at least one year. Their research findings are that 98 percent of participants in the registry modified their food intake and 94 percent increased their physical activity (mainly walking.)The National Weight Control Registry. "Research Findings." Accessed October 8, 2011. http://www.nwcr.ws/Research/default.htm. Although there are a great variety of approaches taken by NWCR members to achieve successful weight loss, most report that their approach involved adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day). Moreover, most members eat breakfast every day, watch fewer than ten hours of television per week, and weigh themselves at least once per week. About half of them lost weight on their own and the other half used some type of weight-loss program. In most scientific studies successful weight loss is accomplished only by changing the diet *and* by increasing physical activity. Doing one without the other limits the amount of weight lost and the length of time that weight loss is sustained. On an individual level, it is quite possible to achieve successful weight loss, as over ten thousand Americans can attest. Moreover, losing as little as 10 percent of your body weight can significantly improve health and reduce disease risk. National Heart, Lung, and Blood Institute. "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report." *Obes Res* 6 supplement (1998): 51S–210S. http://www.ncbi.nlm.nih.gov/books/NBK2003/. You do not have to be overweight or obese to reap benefits from eating a healthier diet and increasing physical activity as both provide numerous benefits beyond weight loss and maintenance.

- ## Evidence-Based Dietary Recommendations

  The *2010 Dietary Guidelines for Americans* offer specific, evidence-based recommendations for dietary changes aimed at keeping calorie intake in balance with physical activity, which is key for weight management. These recommendations include: US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

  - **Increase intake of whole grains, vegetables, and fruits.** Scientific evidence demonstrates that adults who have a higher intake of whole grains, mainly those high in dietary fiber, have lower body weights compared to adults who eat a smaller amount of whole grains. Moreover, diets incorporating more whole grains reduce chronic disease risk. A higher intake of fruits and vegetables is scientifically shown to protect against weight gain in adults and there is some evidence that this is also true for children and adolescents.
  - **Reduce intake of sugar-sweetened beverages.** There is good evidence that reducing the consumption of sugar-sweetened beverages, especially in children and adolescents, decreases body weight and reduces chronic disease risk.
  - **Monitor intake of 100 percent fruit juice for children and adolescents, especially those who are overweight or obese.** There is some evidence that increased intake of 100 percent juice exacerbates weight problems in children and adolescents who are already overweight or obese.
  - **Monitor calorie intake from alcoholic beverages for adults.** Drinking in moderation is not linked to weight gain; however, excessive intake of alcohol over time is associated with weight gain.

- ## Evidence-Based Behavioral Recommendations

  In addition to the dietary recommendations, the *2010 Dietary Guidelines for Americans* offers specific evidence-based recommendations that address behavioral changes aimed to keep calorie intake in balance with physical activity. The recommendations include:

  - **Focus on the total number of calories consumed.** Reducing calorie intake improves health and aids in weight management.
  - **Monitoring food and caloric intake.** Being more aware of the calories in foods and beverages by reading the Nutrition Facts panel is helpful for consumers to monitor intake. Vigilant monitoring of food and caloric intake assists in weight management.
  - **When eating out, choose smaller portions or lower-calorie options.** As mentioned in an earlier section of this chapter, eating out more often, especially at fast-food restaurants, contributes to weight gain. The *Dietary Guidelines* advise people that when they are eating out to order smaller portions, share meals when possible, or take home part of the meal.
  - **Prepare, serve, and consume smaller portions of foods and beverages, especially those high in calories.** Having less on your plate helps you eat less.
  - **Eat a nutrient-dense breakfast.** The old adage that "breakfast is the most important meal of the day" holds true when you consider that not eating breakfast is associated with higher body weights, especially among children and adolescents. Moreover, eating a nutrient-dense breakfast has in some scientific studies been shown to stimulate weight loss.
  - **Limit screen time.** In children, adolescents, and adults, the sedentary activities of watching television and spending time on the computer are linked to increased overweight and obesity. The *Dietary Guidelines* recommend children and adolescents spend no more than one to two hours

daily watching television, playing electronic games, or using the computer (other than for homework).US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

- ## Evidence-Based Physical Activity Recommendations

The other part of the energy balance equation is physical activity. The *2020 Dietary Guidelines* are complemented by the *2018 Physical Activity Guidelines for Americans* issued by the Department of Health and Human Services in an effort to provide evidence-based guidelines for appropriate physical activity levels. The *2018 Physical Activity Guidelines* provide guidance to Americans aged six and older about how to improve health and reduce chronic disease risk through physical activity. Increased physical activity has been found in scientific studies to lower the risk of heart disease, stroke, high blood pressure, Type 2 diabetes, colon, breast, and lung cancer, falls and fractures, depression, and dying early. Increased physical activity not only reduces disease risk, but also improves overall health by increasing cardiovascular and muscular fitness, increasing bone density and strength, improving cognitive function, and assisting in weight loss and weight maintenance. The key guidelines for adults are the following (those for pregnant women, children, and older people will be given elsewhere): US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

- Even small amounts of activity are beneficial to your health.
- More substantial health benefits are obtained by doing at least two hours and thirty minutes per week of moderate-intensity, or one hour and fifteen minutes per week of vigorous-intensity aerobic physical activity, or an equivalent combination thereof. Aerobic activity has better benefits if performed for at least ten minutes at a time, spread throughout the week.
- More extensive health benefits occur when moderate aerobic physical activity is increased to five hours per week of moderate-intensity, or to two hours and thirty minutes of vigorous-intensity aerobic physical activity, or a combination thereof. Additional health benefits are gained by going beyond these recommended amounts of physical activity.
- Muscle-strengthening activities at moderate or high intensity involving all major muscle groups two or more days per week provide additional health benefits to aerobic exercise.

The *2018 Physical Activity Guidelines* broadly classify moderate physical activities as those when “you can talk while you do them, but can’t sing” and vigorous activities as those when “you can only say a few words without stopping to catch your breath.”US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

Table 6.8.1: Moderate and Vigorous Physical Activities

Moderate Activities	Vigorous Activities
Ballroom/line dancing	Aerobic dance
Biking on level ground	Biking (more than 10 miles per hour)
Canoeing	Heavy gardening (digging, hoeing)
Gardening	Hiking uphill
Baseball, softball, volleyball	Fast dancing
Tennis (doubles)	Jumping rope
Walking briskly	Martial arts (karate)
Water aerobics	Race walking
Using hand cyclers	Jogging or running
	Sports with running (basketball, hockey, soccer)
	Swimming laps
	Tennis (singles)
	Ice hockey

Source: US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans.* 2008. http://www.health.gov/paguidelines/.

Interactive 11.5

To get started on ramping up your physical activity or following a new exercise program use the toolkit, “Be Active Your Way” available from HHS: www.health.gov/paguidelines/adultguide/activeguide.aspx.

- ## Campaigns for a Healthy-Weight America

On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies aimed to meet the

challenge of improving the health of all Americans.

In 2010 the national campaign to reduce obesity was reinforced when First Lady Michelle Obama launched the “Let’s Move” initiative, which has the goal of “solving the challenge of childhood obesity within a generation so that children born today will reach adulthood at a healthy weight.”The White House, Office of the First Lady. “First Lady Michelle Obama Launches Let’s Move: America’s Move to Raise a Healthier Generation of Kids.” February 9, 2010. www.whitehouse.gov/the-press-office/first-lady-michelle-obama-launches -lets-move-americas-move-raise-a-healthier-genera. Another campaign, “Campaign to End Obesity,” was recently established to try to enable more Americans to eat healthily and be active by bringing together leaders from academia and industry, as well as public health policy-makers in order to create policies that will reverse the obesity trend and its associated diseases. It remains to be seen whether these new initiatives will finally help improve American health.



Video Link 6.8.1*: View this brief video on the Campaign to End Obesity.*

- ## The “Small-Change” Approach

Currently, most people are not obese in this country. The gradual rise in overweight is happening because, on average, people consume slightly more calories daily than they expend, resulting in a gradual weight gain of one to two pounds a year. In 2003 the idea was first published that promoting small lifestyle changes to reduce weight gain occurring over time in all age groups may better reduce obesity rates in the American population.Hill, J. O. “Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council.” *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. Scientific studies have demonstrated that asking people to increase the number of steps they take each day while providing them with pedometers that count the steps they take each day successfully prevented weight gain. A “small-changes” study published in the October 2007 issue of *Pediatrics* evaluated whether families that made two small lifestyle changes, which were to walk an additional two thousand steps per day and to eliminate 100 kilocalories per day from their typical diet by replacing dietary sugar with a noncaloric sweetener, would prevent weight gain in overweight children.Rodearmel, S. J. et al. “Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study.” *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. The results of this study were that a higher percentage of children who made the small changes maintained or reduced their BMI in comparison to children of families given a pedometer but not asked to also make physical activity or dietary changes.Rodearmel, S. J. et al. “Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study.” *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.org/content/120/4/e869.long. Several more studies funded by the National Institutes of Health and USDA are ongoing and are evaluating the effectiveness of the “small-changes” approach in reducing weight gain.

In 2009, a report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council proposed that the “small-changes” approach when supported by the community, industry, and governmental levels will be more effective than current strategies in gradually reducing the obesity rate in America.Hill, J. O. “Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council.” *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. The HHS encouraged the approach and launched a “Small Step” website in 2008.

Key Takeaways

- Successful weight loss is defined as when individuals intentionally lose at least 10 percent of their body weight and keep it off for at least one year.
- Although there is a great variety of approaches to achieve successful weight loss most report that it involves adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day).
- The *2020 Dietary Guidelines for Americans* recommendations are based on scientific evidence.
- The other part of the energy balance equation is physical activity. The *2020 Dietary Guidelines* were complemented by the *2018 Physical Activity Guidelines for Americans* issued by the HHS in an effort to provide evidence-based guidelines for appropriate physical activity levels.
- On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies that aim to meet the challenge of improving the health of all Americans.

Discussion Starters

1. Discuss ways to address the childhood obesity problem in your own community.
2. Calculate your EER by using the formula in this chapter and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.

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6.E: Exercises

It's Your Turn

1. Summarize in a paragraph or two why (with respect to reducing future chronic disease burden) it is of utmost importance to combat childhood obesity. Watch this video of First Lady Michelle Obama's unveiling of the initiative to combat childhood obesity to assist you in this assignment.

   US First Lady Michelle Obama Unveils Initiative to Battle Childhood Obesity

   (click to see video)
2. The CDC website provides a list of physical activities and categorizes them as moderate or vigorous (http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf). Use this source to develop an exercise program that fits your lifestyle and follows the recommended amounts of physical activity.

Expand Your Knowledge

1. Make a daily log of your physical activities using the spreadsheet available at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf. Then calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced.
2. Harvard Health Publications has a document that lists the calories burned for various physical activities. It is available at http://www.health.harvard.edu/newsweek/Calories-burned-in-30-minutes-of-leisure-and -routine-activities.htm. Use it to develop a physical activity program that is attractive to you and follows the recommended physical activity guidelines.

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CHAPTER OVERVIEW

7: Food Drivers That Impact Your Nutrition

This chapter contains additional topics you may find interesting. The topics are not required for this class.

7.1: Foodborne Illness and Food Safety
7.2: The Politics of Food
7.3: The Food Industry
7.4: Food Cost and Inflation
7.5: Sustainability
7.6: A Fresh Perspective- Sustainable Food Systems
7.7: Start Your Sustainable Future Today
7.8: The Issue of Food Security
7.9: Diets around the World
7.10: Why Make Dietary Changes?
7.11: Nutrition and Your Health
7.12: Diet Trends and Health
7.13: Threats to Health
7.14: Careers in Nutrition

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7.1: Foodborne Illness and Food Safety

Learning Objectives

- Describe the ideal environment for microorganisms to reproduce.
- Give examples of bacteria, viruses, parasites, and molds that have the potential to cause foodborne illness.
- Discuss government efforts to protect the health of the population, and precautions consumers can take to protect themselves.

Foodborne illness is another serious threat to health. Sometimes called "food poisoning," foodborne illness is a common public health problem that can result from exposure to a pathogen or a toxin via food or beverages. Raw foods, such as seafood, produce, and meats, can all be contaminated during harvest (or slaughter for meats), processing, packaging, or during distribution, though meat and poultry are the most common source of foodborne illness. For all kinds of food, contamination also can occur during preparation and cooking in a home kitchen or in a restaurant. For example, you might use a utensil contaminated with a microorganism from one food on a second food contaminating it. In many developing nations, contaminated water is also a major source of foodborne illness.

Many people are affected by foodborne illness each year, making food safety a very important issue. Annually, one out of six Americans becomes sick after consuming contaminated foods or beverages.Centers for Disease Control and Prevention. "Food Safety at CDC." Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html. Foodborne illness can range from mild stomach upset to severe symptoms, or even fatalities. The problem of food contamination can not only be dangerous to your health, it can also be harmful to your wallet. Medical costs and lost wages due to salmonellosis, just one foodborne disease, are estimated at over $1 billion per year.

At-Risk Groups

No one is immune from consuming contaminated food. But, whether you become seriously ill depends on the microorganism, the amount you have consumed, and your overall health. In addition, some groups have a higher risk than others for developing severe complications to foodborne disease. Who is most at risk? Young children, elderly people, and pregnant women all have a higher chance of becoming very sick after consuming contaminated food. Other high-risk groups include people with compromised immune systems due to HIV/AIDS, immunosuppressive medications (such as after an organ transplant), and long-term steroid use for asthma or arthritis. Exposure to contaminated food could also pose problems for diabetics, cancer patients, people who have liver disease, and people who have stomach problems as a result of low stomach acid or previous stomach surgery. People in all of these groups should handle food carefully, make sure that what they eat has been cooked thoroughly, and avoid taking any chances that could lead to exposure.

The Major Types of Foodborne Illness

Foodborne illnesses are either infectious or toxic in nature. The difference depends on the agent that causes the condition. Microbes, such as bacteria, cause food infections, while toxins, such as the kind produced by molds, cause intoxication. Different diseases manifest in different ways, so signs and symptoms can vary with the source of contamination. However the illness occurs, the microbe or toxin enters the body through the gastrointestinal tract, and as a result, common symptoms include diarrhea, nausea, and abdominal pain. Additional symptoms may include vomiting, dehydration, lightheadedness, and rapid heartbeat. More severe complications can include a high fever, diarrhea that lasts more than three days, prolonged vomiting, bloody stools, and signs of shock.

One of the biggest misconceptions about foodborne illness is that it is always triggered by the last meal that a person ate. However, it may take several days or more before the onset of symptoms. If you develop a foodborne illness, you should rest and drink plenty of fluids. Avoid antidiarrheal medications, because they could slow the elimination of the contaminant.

Food Infection

According to the CDC, more than 250 different foodborne diseases have been identified.Centers for Disease Control and Prevention. "Food Safety at CDC." Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html. Most are food infections, which means they are caused by food contaminated by microorganisms, such as bacteria, by microscopic animals called parasites, or by viruses. The infection then grows inside the body and becomes the source of symptoms. Food infections can be sporadic and often are not reported to physicians. However, occasional outbreaks occur that put communities, states, and provinces, or even entire nations at risk. For example, in 1994, an outbreak of the infection salmonellosis occurred in the United States due to contaminated ice cream. An estimated 224,000 people became ill. In 1988, contaminated clams resulted in an outbreak of hepatitis A in China, which affected about 300,000 people.World Health Organization. "Food Safety and Foodborne Illness." *Fact Sheet*, no. 237. Last reviewed December 2015. http://www.who.int/mediacentre/factsheets/fs399/en/.

The Reproduction of Microorganisms

Bacteria, one of the most common agents of food infection, are single-celled microorganisms that are too small to be seen with the human eye. Microbes live, die, and reproduce, and like all living creatures, they depend on certain conditions to survive and thrive. In order to reproduce within a food, microorganisms require the following:

- **Temperature.** Between 40°F and 140°F, which is called the danger zone, bacteria grow rapidly.
- **Time.** More than two hours in the danger zone.
- **Water.** High moisture content is helpful. Fresh fruits and vegetables have the highest moisture content.

- **Oxygen.** Most microorganisms need oxygen to grow and multiply, but a few are anaerobic and do not.
- **Acidity and pH Level.** Foods that have a low level of acidity (or a high pH level) provide an ideal environment since most microorganisms grow best around 7.0 pH and not many will grow below 4.0 pH. Examples of higher pH foods include meat, seafood, milk, and corn. Examples of low pH foods include citrus fruits, sauerkraut, tomatoes, and pineapples.
- **Nutrient Content.** Microorganisms need protein, starch, sugars, fats, and other compounds to grow. Typically high-protein foods are better for bacterial growth.

Food Intoxication

Other kinds of foodborne illness are food intoxications, which are caused by natural toxins or harmful chemicals. These and other unspecified agents are major contributors to episodes of acute gastroenteritis and other kinds of foodborne illness.Scallan, E. et al. “Foodborne Illness Acquired in the United States—Unspecified Agents.” *Emerg Infect Diseases* 17, no. 1. Like pathogens, toxins and chemicals can be introduced to food during cultivation, harvesting, processing, or distribution. Some toxins can lead to symptoms that are also common to food infection, such as abdominal cramping, while others can cause different kinds of symptoms and complications, some very severe. For example, mercury, which is sometimes found in fish, can cause neurological damage in infants and children. Exposure to cadmium can cause kidney damage, typically in elderly people.

The Causes of Food Contamination

Both food infections and food intoxications can create a burden on health systems when patients require treatment and support, and on food systems, when companies must recall contaminated food or address public concerns. It all begins with the agent that causes the contamination. When a person ingests a food contaminant, it travels to the stomach and intestines. There, it can interfere with the body’s functions and make you sick. In the next part, we will focus on different types of food contaminants and examine common microbes, toxins, chemicals, and other substances that can cause food infections and intoxications. Let’s begin with pathogens, which include bacteria and viruses. About one hundred years ago, typhoid fever, tuberculosis, and cholera were common diseases caused by food and water contaminated by pathogens. Over time, improvements in food processing and water treatment eliminated most of those problems in North America. Today, other bacteria and viruses have become common causes of food infection.

Bacteria

All foods naturally contain small amounts of bacteria. However, poor handling and preparation of food, along with improper cooking or storage can multiply bacteria and cause illness. In addition, bacteria can multiply quickly when cooked food is left out at room temperature for more than a few hours. Most bacteria grow undetected because they do not change the color or texture of food or produce a bad odor. Freezing and refrigeration slow or stop the growth of bacteria, but does not destroy the bacteria completely. The microbes can reactivate when the food is taken out and thawed.

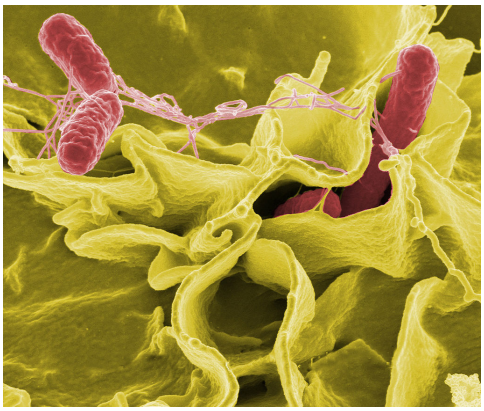


Figure 7.1.1: Salmonella was first identified in 1885 and many types of this kind of bacteria exist. The incidence of Salmonella infections has risen dramatically in the past few decades. Color-enhanced scanning electron micrograph showing Salmonella Typhimurium (red) invading cultured human cells (Credit: Rocky Mountain Laboratories, NIAID, NIH). Image is public domain.

Many different kinds of bacteria can lead to food infections. One of the most common is *Salmonella*, which is found in the intestines of birds, reptiles, and mammals. *Salmonella* can spread to humans via a variety of different animal-origin foods, including meats, poultry, eggs, dairy products, and seafood. The disease it causes, salmonellosis, typically brings about fever, diarrhea, and abdominal cramps within twelve to seventy-two hours after eating. Usually, the illness lasts four to seven days, and most people recover without treatment. However, in individuals with weakened immune systems, *Salmonella* can invade the bloodstream and lead to life-threatening complications, such as a high fever and severe diarrhea. Centers for Disease Control and Prevention. “Salmonella.” Last updated December 19, 2011. http://www.cdc.gov/salmonella/.

The bacterium *Listeria monocytogenes* is found in soft cheeses, unpasteurized milk, deli meats, and seafood. It causes a disease called listeriosis that can bring about fever, headache, nausea, and vomiting. *Listeria monocytogenes* mostly affects pregnant women, newborns, older adults, and people with cancer and compromised immune systems. This bacteria can grow at refrigerator temperatures.

The food infection *E. coli* is caused by *Escherichia coli*. Sources include raw or undercooked meat, raw vegetables, unpasteurized milk, minimally processed ciders and juices, and contaminated drinking water. Symptoms can occur a few days after eating and include watery and bloody diarrhea,

severe stomach cramps, and dehydration. More severe complications may include colitis, neurological symptoms, stroke, and hemolytic uremic syndrome. In young children, an *E. coli* infection can cause kidney failure and death.

The bacterium *Clostridium botulinum* is an anaerobic bacteria that causes botulism. Sources include improperly canned foods, lunch meats, and garlic. An infected person may experience symptoms within four to thirty-six hours after eating. Symptoms could include nerve dysfunction, such as double vision, inability to swallow, speech difficulty, and progressive paralysis of the respiratory system. Botulism can also be fatal.

Campylobacter jejuni causes the disease campylobacteriosis. It is the most commonly identified bacterial cause of diarrhea worldwide. Consuming undercooked chicken, or food contaminated with the juices of raw chicken, is the most frequent source of this infection. Other sources include raw meat and unpasteurized milk. Within two to five days after consumption, symptoms can begin and include diarrhea, stomach cramps, fever, and bloody stools. The duration of this disease is about seven to ten days.

The food infection shigellosis is caused by *Shigella*, of which there are several types. Sources include undercooked liquid or moist food that has been handled by an infected person. The onset of symptoms occurs one to seven days after eating and can include stomach cramps, diarrhea, fever, and vomiting. Another common symptom is blood, pus, or mucus in stool. Once a person has had shigellosis, the individual is not likely to get infected with that specific type again for at least several years. However, they can still become infected with other types of *Shigella*.

Staphylococcus aureus causes staphylococcal food poisoning. Food workers who carry this kind of bacteria and handle food without washing their hands can cause contamination. Coughing, sneezing, or handling foods with exposed infected cuts or sores can also promote the spread of *Staphylococcus aureus*. Other sources include meat and poultry, egg products, cream-filled pastries, tuna, potato, chicken salads, and macaroni salad, and foods left unrefrigerated for long periods of time. Symptoms can begin thirty minutes to eight hours after eating and include diarrhea, vomiting, nausea, stomach pain, and cramps. This food infection usually lasts one to two days.

Found in raw oysters and other kinds of seafood, *Vibrio vulnificus* belongs to the same family as the bacteria which cause cholera. This food contaminant can result in *Vibrio* infection. Symptoms can begin anywhere from six hours to a few days after consumption and include chills, fever, nausea, and vomiting. This disease is very dangerous and can result in fatalities, especially in people with underlying health problems.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated September 1, 2016. www.cdc.gov/foodsafety/foodborne-germs.html.

Viruses

Viruses are another type of pathogen that can lead to food infections, however they are less predominant than bacteria. **Hepatitis A** is one of the more well-known food-contaminating viruses. Sources include raw shellfish from polluted water, and food handled by an infected person. This virus can go undetected for weeks and, on average, symptoms do not appear until about one month after exposure. At first, symptoms include malaise, loss of appetite, nausea, vomiting, and fever. Three to ten days later, additional symptoms can manifest, including jaundice and darkened urine. Severe cases of a hepatitis A can result in liver damage and death.

The most common form of contamination from handled foods is the **norovirus**, which is also known as the Norwalk-like virus, or the calicivirus. Sources include raw shellfish from polluted water, salads, sandwiches, and other ready-to-eat foods handled by an infected person. The norovirus causes gastroenteritis and within one to three days it leads to symptoms, such as nausea, vomiting, diarrhea, stomach pain, headache, and a low-grade fever.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated September 1, 2016. https://www.cdc.gov/foodsafety/foodborne-germs.html.

Parasitic Protozoa

Food-contaminating parasitic protozoa are microscopic organisms that may be spread in food and water. Several of these creatures pose major problems to food production worldwide. They include *Anisakis*, microscopic worms that invade the stomach or the intestines. Sources of this parasite include raw fish. This parasite can result in the Anisakis infection, with symptoms that begin within a day or less and include abdominal pain, which can be severe.

Cryptosporidium lives in the intestines of infected animals. Another common source is drinking water when heavy rains wash animal wastes into reservoirs. One major problem with this pathogen is that it is extremely resistant to disinfection with chlorine. *Cryptosporidium* causes the disease cryptosporidiosis, with symptoms that begin one to twelve days after exposure and include watery stools, loss of appetite, vomiting, a low-grade fever, abdominal cramps, and diarrhea. For HIV/AIDS patients and others with weakened immune systems, the disease can be severe and sometimes can lead to death.

Giardia lamblia is another parasite that is found in contaminated drinking water. In addition, it lives in the intestinal tracts of animals and can wash into surface water and reservoirs, similar to *Cryptosporidium*. *Giardia* causes giardiasis, with symptoms that include abdominal cramping and diarrhea within one to three days. Although most people recover within one to two weeks, the disease can lead to a chronic condition, especially in people with compromised immune systems.

The parasite *Toxoplasma gondii* causes the infection toxoplasmosis, which is a leading cause of death attributed to foodborne illness in the United States. More than sixty million Americans carry *Toxoplasma gondii*, but very few have symptoms. Typically, the body’s immune system keeps the parasite from causing disease. Sources include raw or undercooked meat and unwashed fruits and vegetables. Handling the feces of a cat with an acute infection can also lead to the disease.Centers for Disease Control and Prevention. “Parasites.” Last updated October 6, 2015. https://www.cdc.gov/parasites/food.html.

Mold Toxins

Warm, humid, or damp conditions encourage mold to grow on food. **Molds** are microscopic fungi that live on animals and plants. No one knows how many species of fungi exist, but estimates range from ten- to three-hundred thousand. Unlike single-celled bacteria, molds are multicellular, and under a microscope look like slender mushrooms. They have stalks with spores that form at the ends. The spores give molds their color and can be transported by air, water, or insects. Spores also enable mold to reproduce. Additionally, molds have root-like threads that may grow deep into the food and may be difficult to see. The threads are very deep when the food shows heavy mold growth. Foods that contain mold may also have bacteria growing alongside it.



Figure 7.1.2: Mold can grow on fruits, vegetables, grains, meats, poultry, and dairy products, and typically appears as gray or green "fur." Moldy nectarines that were in a refrigerator. The nectarine with black mold is also affecting the nectarine underneath. from Roger McLassus 1951.

Some molds, like the kind found in blue cheese, are desirable in foods, while other molds can be dangerous. The spores of some molds can cause allergic reactions and respiratory problems. In the right conditions, a few molds produce mycotoxins, which are natural, poisonous substances that can make you sick if they are consumed. Mycotoxins are contained in and around mold threads, and in some cases, may have spread throughout the food. The Food and Agriculture Organization of the United Nations estimates that mycotoxins affect 25 percent of the world's food crops. They are found primarily in grains and nuts, but other sources include apples, celery, and other produce. Some molds can produce toxins that cause kidney and liver damage.

The most dangerous mycotoxins are **aflatoxins**, which are produced by strains of fungi called *Aspergillus* under certain temperature and humidity conditions. Contamination has occurred in peanuts, tree nuts, and corn. Aflatoxins can cause aflatoxicosis in humans, livestock, and domestic animals. Symptoms include vomiting and abdominal pain. Possible complications include liver failure, liver cancer, and even death. Many countries try to limit exposure to aflatoxins by monitoring their presence on food and feed products.US Department of Agriculture, Food Safety and Inspection Service. "Molds on Food: Are They Dangerous?" Last modified August 22, 2013. https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/molds-on-food-are-they-dangerous_/ct_index .

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Poisonous Mushrooms

Like molds, mushrooms are fungi and the poisonous kind produces mycotoxins that can cause food intoxication. Toxic mushrooms, also known as toadstools, can cause severe vomiting and other symptoms. However, only a few varieties are fatal. Toxic mushrooms cannot be made safe by cooking, freezing, canning, or processing. The only way to avoid food intoxication is to refrain from eating them. Mushroom guides can help wild gatherers distinguish between the edible and toxic kinds.US Department of Agriculture, Food Safety and Inspection Service. "Molds on Food: Are They Dangerous?" Last modified August 22, 2013. https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/molds-on-food-are-they-dangerous_/ct_index.

Pesticides

Pesticides are important in food production to control diseases, weeds, insects, and other pests. They protect crops and ensure a large yield. However, synthetic pesticides can leave behind residues, particularly on produce, that can be harmful to human health. Foods that contain the highest levels of pesticide residue include conventionally-grown peaches, apples, bell peppers, celery, nectarines, strawberries, cherries, pears, spinach, lettuce, and potatoes. Foods that contain the lowest levels of pesticide residue include avocados, pineapples, bananas, mangoes, asparagus, cabbage, and broccoli. Hoffman, M. MD. "Safer Foods for a Healthier You." Web MD. © 2009 WebMD, LLC. http://www.webmd.com/health-ehome-9/pesticides-hormones-in-food. Pesticide tolerance is the amount of pesticide that can be applied to a food and is permitted to remain on the food in the marketplace. In many cases, the amount of pesticide exposure is too small to pose a risk. However, harmful exposures can lead to certain health problems and complications, including cancer. Also, infants and young children are more susceptible to the hazards of pesticides than adults. In addition, using synthetic pesticides, herbicides, and fertilizers contributes to soil and water pollution and can be hazardous to farm workers.

To protect the public and their workers, many farmers now rely on alternatives to synthetic pesticide use, including crop rotation, natural pesticides, and planting nonfood crops nearby to lure pests away. Some consumers choose to reduce their exposure to pesticides by purchasing organic produce. Organic foods are grown or produced without synthetic pesticides or fertilizer, and all growers and processors must be certified by the US

Department of Agriculture (USDA). Although pesticides cannot be applied to organic foods, pesticide residues may still occasionally be found on foods. However, conventionally-grown produce should be fine for fruits and vegetables that appear on the low-residue list.

Pollutants

Pollutants are another kind of chemical contaminant that can make food harmful. Chemical runoff from factories can pollute food products and drinking water. For example, **dioxins** are chemical compounds created in industrial processes, such as manufacturing and bleaching pulp and paper. Fish that swim in dioxin-polluted waters can contain significant amounts of this pollutant, which causes cancer.

When metals contaminate food, it can result in serious and even life-threatening health problems. A common metal contaminant is lead, which can be present in drinking water, soil, and air. In our built environment, there are many different sources of lead including water pipes (for example, Flint, MI), paint in older homes, certain pottery, lead crystal food containers, and some dietary supplements. Lead exposure most often affects children, who can suffer from physical and mental developmental delays as a result. A healthy diet that is adequate in fruits and vegetables and iron may help reduce lead absorption, thus reducing exposure.

Methylmercury occurs naturally in the environment and is also produced by human activities. Fish can absorb it, and the predatory fish that consume smaller, contaminated fish can have very high levels. This highly toxic chemical can cause mercury poisoning, which leads to developmental problems in children, as well as autoimmune effects. A condition called Minamata disease was identified in 1956 in Japan. It was named for the town of Minamata, which was the site of an environmental disaster when methyl mercury was released into the surface water near a factory. Many residents experienced neurological issues, including numbness in hands and feet, muscle weakness, a narrowing of the field of vision, damage to hearing and speech, and ataxia, which is a lack of muscle coordination.Ministry of the Environment, Government of Japan. “Minamata Disease: The History and Measures.” © 2002. Accessed December 21, 2011. http://www.env.go.jp/en/chemi/hs/minamata2002/. Current guidelines are for pregnant, breastfeeding women, and young children to limit their exposure.

PCBs, or polychlorinated biphenyls, are man-made organic compounds that are used commercially. Like methyl mercury, higher concentrations of this contaminant are found in predatory fish. Health effects include physical and neurological development in children, and this compound is potentially a carcinogen. PCB contamination also can affect the immune, reproductive, nervous, and endocrine systems.US Environmental Protection Agency. “Health Effects of PCBs.” Last updated August 08, 2008. http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/effects.htm.

Protecting the Public Health

Most foodborne infections go unreported and undiagnosed. However, the CDC estimates that about seventy-six million people in the United States become ill from foodborne pathogens or other agents every year. In North America, a number of government agencies work to educate the public about food infections and intoxications, prevent the spread of disease, and quell any major problems or outbreaks. They include the CDC, the FDA, the USDA, and Health Canada, among other organizations.

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Efforts on the Governmental Level

A number of government agencies work to ensure food safety and to protect the public from foodborne illness. The USDA and the FDA enforce laws regarding the safety of domestic and imported food. In addition, the Federal Food, Drug, and Cosmetic Act of 1938 gives the FDA authority over food ingredients. The CDC tracks outbreaks, identifies the causes of food infection and intoxication, and recommends ways to prevent foodborne illness. Other government agencies that play a role in protecting the public include the Food Safety and Inspection Service, a division of the USDA, which enforces laws regulating meat and poultry safety. The Agricultural Research Service, which is the research arm of the USDA, investigates a number of agricultural practices, including those related to animal and crop safety. The National Institute of Food and Agriculture conducts research and education programs on food safety for farmers and consumers. Also, the Environmental Protection Agency (EPA) regulates public drinking water.

Government agencies also monitor the use of pesticides. The EPA approves pesticides and other chemicals used in agriculture and sets limits on how much residue can remain on food. The FDA analyzes food for surface residue and waxes. Processing methods can either reduce or concentrate pesticide residue in foods. Therefore, the Food Quality Protection Act, which was passed in 1996, requires manufacturers to show that pesticide levels are safe for children.

In Canada, Health Canada works with local governments, industries, and consumers to establish food safety throughout the nation. The agency’s scientists assess health risks from foodborne contaminants, conduct research, and evaluate data to better understand the effects of pathogens, chemicals, and other foodborne agents on the body. Health Canada also monitors the levels of contaminants in foods and estimates the exposure of consumers. Another organization, the Canadian Food Inspection Agency, enforces the safety policies and standards set by Health Canada. They safeguard livestock, along with crops and other plants, to protect the public.

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Efforts within the Food Industry

The Hazard Analysis Critical Control Points (HACCP) is a system within the food industry designed to promote food safety and prevent contamination by identifying all areas in food production and retail where contamination could occur. Companies and retailers determine the points during processing, packaging, shipping, or shelving where hazards could occur. Those companies or retailers must then take measures to prevent,

control, or eliminate the potential for food contamination. The USDA requires the food industry to follow HACCP for meat and poultry, while the FDA requires it for seafood, low-acid canned-food, and juice. HACCP is voluntary for all other food products.

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Efforts on the Consumer Level: What You Can Do

Consumers can also take steps to prevent foodborne illness and protect their health. Although you can often detect when mold is present, you can't see, smell, or taste bacteria or other agents of foodborne disease. Therefore, it is crucial to take measures to protect yourself from disease. The four most important steps for handling, preparing, and serving food are:

1. **Clean.** Scrub hands at least 20 seconds in warm soapy water before handling food. Clean surfaces often and wash utensils after each use. Scrub fruits and vegetables (even if you plan to peel them) under running water.
2. **Separate.** Don't cross-contaminate food during preparation and storage. Use separate cutting boards for produce and for meat, poultry, seafood, and eggs. Store food products separately in the refrigerator.
3. **Cook.** Heat food to proper temperatures. Use a food thermometer to check the temperature of food while it is cooking. Keep food hot after it has been cooked.
4. **Chill.** Refrigerate any leftovers within two hours. Never thaw or marinate food on the counter. Know when to keep food and when to throw it out. It can be helpful to check the website http://www.stilltasty.com, which explains how long refrigerated food remains fresh.US Department of Health and Human Services. "Keep Food Safe." Food Safety.gov. Accessed August 23, 2017. http://www.foodsafety.gov/keep/index.html.

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Buying Food

It is best to buy your food from reputable grocers with clean, sanitary facilities, that keep products at appropriate temperatures. Consumers should examine food carefully before they purchase it. It is important to look at food in glass jars, check the stems on fresh produce, and avoid bruised fruit. Do not buy canned goods with dents or bulges, which are at risk of contamination with *Clostridium botulinum*. Fresh meat and poultry are usually free from mold but cured and cooked meats should be examined carefully. Also, avoid torn, crushed, or open food packages, and do not buy food with frost or ice crystals, which indicates that the product has been stored for a long time, or thawed and refrozen. It is also a good idea to keep meat, poultry, seafood, and eggs separate from other items in your shopping cart as you move through the grocery store.



Video 1.18.1: *Start at the Store: Prevent Foodborne Illness. This video provides tips to follow when selecting and purchasing food at the supermarket to help to prevent foodborne illness and protect your health (click to see video).*

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Storing Food

Refrigerate perishable foods quickly; they should not be left out for more than two hours. The refrigerator should be kept at 40°F (or 4°C) or colder, and checked periodically with a thermometer. Store eggs in a carton on a shelf in the refrigerator, and not on the refrigerator door where the temperature is warmest. Wrap meat packages tightly and store them at the bottom of the refrigerator, so juices won't leak out onto other foods. Raw meat, poultry, and seafood should be kept in a refrigerator for only two days. Otherwise, they should be stored in the freezer, which should be kept at 0°F (or −18°C). Store potatoes and onions in a cool, dark place, but not under a sink because leakage from pipes could contaminate them. Empty

cans of perishable foods or beverages that have been opened into containers, and promptly place them in a refrigerator. Also, be sure to consume leftovers within three to five days, so mold does not have a chance to grow.

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Preparing Food

Wash hands thoroughly with warm, soapy water for at least twenty seconds before preparing food and every time after handling raw foods. Washing hands is important for many reasons. One is to prevent cross-contamination between foods. Also, some pathogens can be passed from person to person, so hand washing can help to prevent this. Fresh fruits and vegetables should also be rinsed thoroughly under running water to clean off pesticide residue.California Department of Pesticide Regulation. “Pesticides and Food: How We Test for Safety.” *Pesticide Info: What You Should Know about Pesticides*, no. #E09/REV. Accessed December 21, 2011. www.cdpr.ca.gov/docs/dept/factshts/residu2. This is particularly important for produce that contains a high level of residue, such as apples, pears, spinach, and potatoes. Washing also removes most dirt and bacteria from the surface of produce.

Other tips to keep foods safe during preparation include defrosting meat, poultry, and seafood in the refrigerator, microwave, or in a water-tight plastic bag submerged in cold water. Never defrost at room temperature because that is an ideal temperature for bacteria to grow. Also, marinate foods in the refrigerator and discard leftover marinade after use because it contains raw juices. Always use clean cutting boards, which should be washed with soap and warm water by hand or in a dishwasher after each use. Another way to sanitize cutting boards is to rinse them with a solution of 5 milliliters (1 teaspoon) chlorine bleach to about 1 liter (1 quart) of water. If possible, use separate cutting boards for fresh produce and for raw meat. Also, wash the top before opening canned foods to prevent dirt from coming into contact with food.

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Cooking Food

Cooked food is safe to eat only after it has been heated to a temperature that is high enough to kill bacteria. You cannot judge the state of “cooked” by color and texture alone. Instead, use a food thermometer to be sure. The appropriate minimum cooking temperature varies depending on the type of food. Seafood should be cooked to an internal temperature of 145°F, beef, lamb, and pork to 160°F, and chicken and turkey to 165°F. When microwaving, rotate the dish and stir contents several times to ensure even cooking.

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Serving Food

After food has been cooked, the possibility of bacterial growth increases as the temperature drops. So, food should be kept above the safe temperature of 140°F, using a heat source such as a chafing dish, warming tray, or slow cooker. Cold foods should be kept at 40°F or lower. When serving food, keep it covered to block exposure to any mold spores hanging in the air. Use plastic wrap to cover foods that you want to remain moist, such as fresh fruits, vegetables, and salads. After a meal, do not keep leftovers at room temperature for more than two hours. They should be refrigerated as promptly as possible. It is also helpful to date leftovers, so they can be used within a safe time, which is generally three to five days when stored in a refrigerator.

Key Takeaways

Foodborne illness is caused by pathogens, such as bacteria and viruses, toxins, such as those produced by molds and poisonous mushrooms, and chemical contaminants, such as pesticide residues and pollutants. A number of government agencies work to regulate food, manage outbreaks, and inform the public about foodborne illness and food safety. Consumers also should take measures to protect their health, including following the rules for four key steps: clean, separate, cook, and chill.

Discussion Starter

1. Discuss tactics that government agencies or consumer groups could take to educate the public about food safety. What key points do you think consumers need to know about foodborne illness and food safety? How do you think government organizations or other groups can best get that information out to the public?

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7.2: The Politics of Food

Learning Objectives

- Discuss how food has become politicized, and give specific examples of how food choices are related to food politics

Some people have begun to view their choices regarding diet and nutrition in light of their political views. More and more, consumers weigh their thoughts on the environment and the world, while making decisions about what to purchase in the grocery store. For example, many people choose to eat free-range chickens due to concerns about animal welfare. Others worry about the higher cost of organically produced food or find that those products are not available in their communities. As a result, feelings about food have become a political mine field.

Food Politics

The production and sale of food is an extremely big business and touches people in all industries and walks of life. Food is not only crucial for day-to-day survival, but also strongly affects overall health and well-being, as well as the economy and culture of a region or a country. So, it is no wonder that more and more producers and consumers alike are speaking out about food to ensure that their interests are protected. Food politics can influence many stakeholders and interests, but always involve the production, regulation, inspection, distribution, and/or retail of food.

Stakeholders

Stakeholders in food politics include large and small farmers, along with large and small food companies. Other important stakeholders include restaurants and other food-service providers, food distributors, grocery stores and other retail outlets, consumers, and trade associations. Antihunger advocates, nutrition advocates, and food-industry lobbyists also have important roles to play. Nongovernmental organizations, such as the American Cancer Society and the WHO, also work to promote good health and nutrition. Each group has its own perspective and its own agenda in disputes related to food.

Disputes

Food politics can be influenced by ethical, cultural, medical, and environmental disputes over agricultural methods and regulatory policies. They are also greatly influenced by manufacturing processes, marketing practices, and the pursuit of the highest possible profit margin by food manufacturers and distributers. Common disputes and controversies include the genetic modification of plants, the potential dangers of food additives, chemical run-off from large-scale farms, and the reliance on factory-farming practices, such as the use of pesticides in crop cultivation and antibiotics in livestock feed. Additional issues and concerns include the use of sugar, salt, and other potentially unhealthy ingredients, the promotion of fast food and junk food to children, and sanitary standards related to livestock.

The Nitrate Dispute

One current dispute relates to the use of nitrates in agriculture. At the dawn of the twentieth century, German chemists Fritz Haber and Carl Bosch invented a system that synthesizes ammonia to produce nitrates on an industrial scale. The compound could then be used to make fertilizers, which along with pesticides and herbicides, made large-scale, modern agriculture possible. However, when nitrates are used in excess, they can create runoff that pollutes surface- and groundwater. For example, chemical runoff has had a profound effect on the Aral Sea and the surrounding area in Kazakhstan and Uzbekistan. The Aral Sea, which was once one of the four largest lakes in the world, was crucial to irrigation projects in the former Soviet Union. But when the lake became contaminated by farm runoff, salinity increased and the lake dramatically shrank, crippling the area's fishing industry. Also, as the lakebed became exposed, dust storms spread contaminated soil, and thousands of people were forced out of the region.Grant, L. "Nitrates: Dangerous Necessity." Environmentalism @ Suite 101.com. May 7, 2011. larry-grant.suite101.com/nitrates-dangerous-necessity-a369949. Contaminated runoff from the use of nitrates not only leads to serious consequences for the environment, but also to human health. Nitrate poisoning reduces the oxygen-carrying capacity of the blood and can be fatal to infants.US Environmental Protection Agency. "Ag 101: Nitrate." Last updated September 10, 2009.

http://www.epa.gov/agriculture/ag101/impactnitrate.html. Therefore, significant efforts are being made to use nitrates and other agricultural chemicals in more environmentally friendly ways and to monitor drinking water for dangerous levels of contamination.

The Role of Government

Federal and state policy plays a major role in the politics of food production and distribution. As previously discussed, government agencies regulate the proper processing and preparation of foods, as well as overseeing shipping and storage. They pay particular attention to concerns related to public health. As a result, the enforcement of regulations has been strongly influenced by public concern over food-related events, such as outbreaks of food-bourne illnesses.

Food Production, Distribution, and Safety

Many consumers have concerns about safety practices during the production and distribution of food. This is especially critical given recent outbreaks of food-borne illnesses. For example, during fall 2011 in the United States, there was an eruption of the bacteria *Listeria monocytogenes* in cantaloupe. It was one of the deadliest outbreaks in over a decade and resulted in a number of deaths and hospitalizations.Centers for Disease Control and Prevention. "Multistate Outbreak of Listeriosis Associated with Jensen Farms Cantaloupe—United States." August–September, 2011. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6039a5.htm?s_cid= mm6039a5_w.



Figure 7.2.1: Whole chickens are suspended in a public market. (CC-BY-SA; 3.0; Tomás Castelazo)

In January 2011, the Food Safety Modernization Act was passed to grant more authority to the FDA to improve food safety. The FDA and other agencies also address consumer-related concerns about protecting the nation's food supply in the event of a terrorist attack.

Addressing Hunger

Government agencies also play an important role in addressing hunger via federal food-assistance programs. The agencies provide debit cards (formerly distributed in the form of food vouchers or food stamps) to consumers to help them purchase food and they also provide other forms of aid to low-income adults and families who face hunger and nutritional deficits. This topic will be discussed in greater detail later in this chapter.

The Dual Role of the USDA

The USDA has a dual role in the advancement of American agribusiness and the promotion of health and nutrition among the public. This can create conflicts of interest, and some question whether the USDA values the interests of the agriculture and food industries over consumer health.

However, there is no question that the USDA makes a great deal of effort to educate the public about diet and nutrition. Working with the US Department of Health and Human Services, the agency codeveloped the *Dietary Guidelines for Americans* to inform consumers about the ways their dietary habits affect their health. The USDA also implements all federal nutrition programs.

The Farm Bill

The Farm Bill (introduced in 1990) is a massive piece of legislation that determines the farm and food policy of the federal government. It addresses policy related to federal food programs and other responsibilities of the USDA. The Farm Bill also covers a wide range of agricultural programs and provisions, including farm subsidies and rural development. And, it influences international trade, commodity prices, environmental preservation, and food safety.

The massive Farm Bill is updated and renewed every five years. Over the decades, it has expanded to incorporate new issues, such as conservation and bioenergy. The Farm Bill passed in 2008, known as the Food, Conservation, and Energy Act, included new policy on horticulture and livestock provisions. The 2008 bill also differed from previous legislation in terms of the large number and scope of proposals that were raised.Johnson, R. and J. Monke, "What Is the 'Farm Bill'?" Congressional Research Service. *CRS Report for Congress*, no. RS22131 (January 3, 2011). www.nationalaglawcenter.org/assets/crs/RS22131.pdf.

Tools for Change

Start paying attention to the news when you hear about the next upcoming Farm Bill to learn about proposals that could affect the food that arrives in your local supermarket or that is served in your favorite restaurant. To learn more about the upcoming legislation, visit http://www.usda.gov/farmbill. You may also wish to "vote with your fork" and make choices about what you eat based on practices you approve of, such as choosing a vegetarian, vegan, organic, locavore, sustainable, slow-food movement or other type of diet.

Agricultural Subsidies

The Farm Bill can directly and indirectly have wide-ranging effects. For example, the bill dictates subsidies and other forms of agricultural funding or support. Farmers rely on this kind of support to offset varying crop yields and unfavorable weather conditions. The agricultural industry also depends on the federal government to provide some form of price control to guard against flooding the market and dragging down prices. As an example, major changes in the policy of agricultural subsidies were implemented in the 1970s to increase farm incomes and produce cheaper food. As a result of these policies and subsidies, much more corn was grown, giving rise to high fructose corn syrup as a primary sweetener in a number of products today, since corn syrup is cheaper to produce. It is also sweeter than cane sugar, which encouraged its widespread use.

Historically, Congress has pursued farm support programs to ensure that the US population has continued access to abundant and affordable food. However, some leaders worry about the effectiveness of government programs as well as the cost to taxpayers and consumers. Others question if continued farm support is even needed and wonder if it remains compatible with current economic objectives, domestic policy, trade policy, and regulatory restrictions.Johnson, R. and J. Monke, "What Is the 'Farm Bill'?" Congressional Research Service. *CRS Report for Congress*, no. RS22131 (January 3, 2011). www.nationalaglawcenter.org/assets/crs/RS22131.pdf. For example, federal dairy policies can raise the price of milk and other dairy products, which can detrimentally affect school lunch and food stamp programs. Regarding all of these issues, Congress must heed the demands of its constituents. In the end, it is inevitable that consumers' growing interest in food issues will affect not only the choices they make in the grocery store, but also the decisions they make in the voting booth.

Key Takeaways

Food politics reflect changing perspectives and policies in the areas of production, distribution, marketing, regulation, and consumption. Over the years, there have been a number of controversies and disputes over food, including concerns about additives and GM foods, the push for sustainable agriculture, and the need to alleviate hunger. In the United States, a massive piece of legislation known as the Farm Bill determines the agricultural and food policy of the federal government.

Discussion Starter

1. Debate a controversial issue related to food politics, such as sustainable agriculture, farm subsidies, or the Farm Bill. Identify the stakeholders involved with the issue and discuss the pros and cons of the differing sides.

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7.3: The Food Industry

Learning Objectives

- Explain what is meant by the term “the food industry” and identify the food technologies and innovations that have shaped the current food system

Agriculture is one of the world’s largest industries. It encompasses trillions of dollars and employs billions of people. In the United States alone, customers spent about $500 billion annually on food products at grocery stores and supermarkets.Plunkett Research, Ltd. “US Food Industry Overview.” Accessed December 5, 2011, http://www.plunkettresearch.com/food%20beverage%20grocery%20market %20research/industry%20statistics. The food industry includes a complex collective of businesses that touches on everything from crop cultivation to manufacturing and processing, from marketing and advertising to distribution and shipment, to food regulation.

The Food System

The food system is a network of farmers and related operations, including food processing, wholesale and distribution, retail, industry technology, and marketing. The milk industry, for example, includes everything from the farm that raises livestock, to the milking facility that extracts the product, to the processing company that pasteurizes milk and packages it into cartons, to the shipping company that delivers the product to stores, to the markets and groceries that stock and sell the product, to the advertising agency that touts the product to consumers. All of these components play a part in a very large system.



Figure 7.3.1: These cows are lined up at a Rotary milking parlor. (CC BY-SA 3.0; Gunnar Richter Namenlos.net).

Food Preservation and Processing

Two important aspects of a food system are preservation and processing. Each provides for or protects consumers in different ways. Food preservation includes the handling or treating of food to prevent or slow down spoilage. Food processing involves transforming raw ingredients into packaged food, from fresh-baked goods to frozen dinners. Although there are numerous benefits to both, preservation and processing also pose some concerns, in terms of both nutrition and sustainability.

Food Preservation

Food preservation protects consumers from harmful or toxic food. There are different ways to preserve food. Some are ancient methods that have been practiced for generations, such as curing, smoking, pickling, salting, fermenting, canning, and preserving fruit in the form of jam. Others include the use of modern techinques and technology, including drying, vacuum packing, pasteurization, and freezing and refrigeration. Preservation guards against food-bourne illnesses, and also protects the flavor, color, moisture content, or nutritive value of food.

Irradiation

Another method of preservation is irradiation, which reduces potential pathogens to enhance food safety. This process involves treating food with ionizing radiation, which kills the bacteria and parasites that cause toxicity and disease. Similar technology is used to sterilize surgical instruments to avoid infection.Centers for Disease Control and Prevention. “Food Irradiation.” Accessed October 11, 2005. www.cdc.gov/ncidod/dbmd/diseaseinfo/foodirradiation.htm. Foods currently approved for irradiation by the FDA include flour, fruits and vegetables, juices, herbs, spices, eggs, and meat and poultry.

Most forms of preservation can affect the quality of food. For example, freezing slightly affects the nutritional content, curing and smoking can introduce carcinogens, and salting greatly increases the sodium. There are also concerns about the effects of using irradiation to preserve food. Studies have shown that this process can change the flavor, texture, color, odor, and nutritional content of food. For example, the yolks of irradiated eggs have less color than nonirradiated eggs.nonirradiated eggs.

Food Processing

Food processing includes the methods and techniques used to transform raw ingredients into packaged food. Workers in this industry use harvested crops or slaughtered and butchered livestock to create products that are marketed to the public. There are different ways in which food can be processed, from a one-off product, such as a wedding cake, to a mass-produced product, such as a line of cupcakes packaged and sold in stores.

The Pros and Cons of Food Processing

Food processing has a number of important benefits, such as creating products that have a much longer shelf life than raw foods. Also, food processing protects the health of the consumer and allows for easier shipment and the marketing of foods by corporations. However, there are certain drawbacks. Food processing can reduce the nutritional content of raw ingredients. For example, canning involves the use of heat, which destroys the vitamin C in canned fruit. Also, certain food additives that are included during processing, such as high fructose corn syrup, can affect the health of a consumer. However, the level of added sugar can make a major difference. Small amounts of added sugar and other sweeteners, about 6 to 9 teaspoons a day or less, are not considered harmful.American Heart Association. “Sugar and Carbohydrates.” Last updated October 12, 2010. www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Sugars-and-Carbohydrates_UCM_303296_Article.jsp#.



Figure 16.2.2: *Industrial cheese production. 10,000 l milk in the left tank, the milk was mixed with rennet and is now broken for the production of Emmentaler.. (CC BY-SA 3.0; MatthiasKabel).*

Food Regulation and Control

Food regulatory agencies work to protect the consumer and ensure the safety of our food. Food and drug regulation in the United States began in the late nineteenth century when state and local governments began to enact regulatory policies. In 1906, Congress passed the Pure Food and Drugs Act, which led to the creation of the US Food and Drug Administration (FDA). Today, a number of agencies are in charge of monitoring how food is produced, processed, and packaged.EH.Net Encyclopedia. “History of Food and Drug Regulation in the United States.” February 4, 2010. eh.net/encyclopedia/article/Law.Food.and.Drug.Regulation.

Regulatory Agencies

Food regulation is divided among different agencies, primarily the FDA and the US Department of Agriculture (USDA). Regulatory agencies in Canada include the Canadian Food Inspection Agency and Health Canada. The North American public depends on these and other agencies to ensure that the food they purchase and consume from supermarkets, restaurants, and other sources is safe and healthy to eat. It can be confusing to know which agency monitors and manages which regulatory practice. For example, the FDA oversees the safety of eggs when they’re in the shells, while the USDA is in charge of the eggs once they are out of their shells.

The Food and Drug Administration

The FDA enforces the safety of domestic and imported foods. It also monitors supplements, food labels, claims that corporations make about the benefits of products, and pharmaceutical drugs. Sometimes, the FDA must recall contaminated foods and remove them from the market to protect public health. For example, in 2011 contaminated peanut butter led to the recall of thousands of jars of a few popular brands.US Food and Drug Administration. “FDA 101: Product Recalls—From First Alert to Effectiveness Checks.” Last updated September 9, 2011. http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm049070.htm. Recalls are almost always voluntary and often are requested by companies after a problem has been discovered. In rare cases, the FDA will request a recall. But no matter what triggers the removal of a product, the FDA’s role is to oversee the strategy and assess the adequacy and effectiveness of the recall. You will read more about this practice in Chapter 15.

Video 16.2.1: FDA 101: Product Recalls

This video explains how the FDA recalls contaminated products to protect consumers. (click to see video)

The US Department of Agriculture

Headed by the Secretary of Agriculture, the USDA develops and executes federal policy on farming and food. This agency supports farmers and ranchers, protects natural resources, promotes trade, and seeks to end hunger in the United States and abroad. The USDA also assures food safety, and in particular oversees the regulation of meat, poultry, and processed egg products.

The Environmental Protection Agency

A third federal government agency, the Environmental Protection Agency (EPA), also plays a role in the regulation of food. The EPA works to protect human health and the environment. Founded in 1970, the agency conducts an environmental assessment, education, research, and regulation. The EPA also works to prevent pollution and protect natural resources. Two of its many regulatory practices in the area of agriculture include overseeing water quality and the use of pesticides.

Food Safety and Hazard Analysis

Government regulatory agencies utilize HACCP programs to ensure food safety. HACCP, or hazard analysis and critical control points, is a system used to identify potential hazards and prevent foodbourne illnesses. Some of the seven aspects of an HACCP program include identifying the points in a manufacturing process during which potential hazards could be introduced, establishing corrective actions, and maintaining record-keeping procedures. The USDA uses HACCP to regulate meat, while the FDA uses the seven-point system to monitor seafood and juice. In these industries, HACCP systems are used in all stages of production, processing, packaging, and distribution.US Food and Drug Administration. “Hazard Analysis & Critical Control Points (HACCP).” Last updated April 27, 2011. www.fda.gov/food/foodsafety/hazardanalysiscriticalcontrolpointshaccp/default.htm. Currently, the use of HACCP is voluntary for all other food products.

Food Additives

If you examine the label for a processed food product, it is not unusual to see a long list of added materials. These natural or synthetic substances are food additives and there are more than three hundred used during food processing today. The most popular additives are benzoates, nitrites, sulfites, and sorbates, which prevent molds and yeast from growing on food.How Stuff Works. “The Dangers of Food Additives.” Accessed October 5, 2011. http://health.howstuffworks.com/wellness/food-nutrition/facts/dangers-of-food -additives.htm.

Food additives are introduced in the processing stage for a variety of reasons. Some control acidity and alkalinity, while others enhance the color or flavor of food. Some additives stabilize food and keep it from breaking down, while others add body or texture. Table 14.1 lists some common food additives and their uses:

Table 16.2.1: Food Additives

Additive	Reason for Adding
Beta-carotene	Adds artificial coloring to food
Caffeine	Acts as a stimulant
Citric acid	Increases tartness to prevent food from becoming rancid
Dextrin	Thickens gravies, sauces, and baking mixes
Gelatin	Stabilizes, thickens, or texturizes food
Modified food starch	Keeps ingredients from separating and prevents lumps
MSG	Enhances flavor in a variety of foods
Pectin	Gives candies and jams a gel-like texture
Polysorbates	Blends oil and water and keep them from separating
Soy lecithin	Emulsifies and stabilizes chocolate, margarine, and other items

Additive	Reason for Adding
Sulfites	Prevent discoloration in dried fruits
Xanthan gum	Thickens, emulsifies, and stabilizes dairy products and dressings

Source: Center for Science in the Public Interest. “Chemical Cuisine: Learn about Food Additives.” ©2012. Center for Science in the Public Interest. http://www.cspinet.org/reports/chemcuisine.htm.

The Pros and Cons of Food Additives

The FDA works to protect the public from potentially dangerous additives. Passed in 1958, the Food Additives Amendment states that a manufacturer is responsible for demonstrating the safety of an additive before it can be approved. The Delaney Clause that was added to this legislation prohibits the approval of any additive found to cause cancer in animals or humans. However, most additives are considered to be “generally recognized as safe,” a status that is determined by the FDA and referred to as GRAS.

Food additives are typically included in the processing stage to improve the quality and consistency of a product. Many additives also make items more “shelf stable,” meaning they will last a lot longer on store shelves and can generate more profit for store owners. Additives can also help to prevent spoilage that results from changes in temperature, damage during distribution, and other adverse conditions. In addition, food additives can protect consumers from exposure to rancid products and food-bourne illnesses.

Food additives aren’t always beneficial, however. Some substances have been associated with certain diseases if consumed in large amounts. For example, the FDA estimates that sulfites can cause allergic reactions in 1 percent of the general population and in 5 percent of asthmatics. Similarly, the additive monosodium glutamate, which is commonly known as MSG, may cause headaches, nausea, weakness, difficulty breathing, rapid heartbeat, and chest pain in some individuals.Sustainable Table. “The Issues: Additives.” Accessed October 10, 2011. www.sustainabletable.org/issues/additives/#fn14.

The Effect of New Technologies

As mentioned earlier, new technology has had a tremendous effect on the food we eat and the customs and culture related to food consumption. For example, microwaves are used to reduce cooking time or to heat up leftover food. Refrigerators and freezers allow produce to travel great distances and last longer. On the extreme end of making food last longer, there is special food for astronauts that is appropriate for consumption in space. It is safe to store, easy to prepare in the low-gravity environment of a spacecraft, and contains balanced nutrition to promote the health of people working in space. In the military, soldiers consume Meals Ready-to-Eat (MREs), which contain an entire meal in a single pouch.

Genetically Modified Foods

Genetically modified foods (also known as GM or GMO foods), are plants or animals that have undergone some form of genetic engineering. In the United States, much of the soybean, corn, and canola crop is genetically modified. The process involves the alteration of an organism’s DNA, which allows farmers to cultivate plants with desirable characteristics.Genomics.Energy.gov. “What Are Genetically Modified Foods?” Last modified November 5, 2008. http://www.ornl.gov/sci/techresources/Human_Genome/elsi/gmfood.shtml. For example, scientists could extract a gene that produces a chemical with antifreeze properties from a fish that lives in an arctic region (such as a flounder). They could then splice that gene into a completely different species, such as a tomato, to make it resistant to frost, which would enable farms to grow that crop year-round.Whitman, D. B. “Genetically Modified Foods: Harmful or Helpful?” *ProQuest Discovery Guides* (April 2000). www.csa.com/discoveryguides/gmfood/overview.php.

Certain modifications can be beneficial in resisting pests or pesticides, improving the ripening process, increasing the nutritional content of food, or providing resistance to common viruses. Although genetic engineering has improved productivity for farmers, it has also stirred up debate about consumer safety and environmental protection. Possible side effects related to the consumption of GM foods include an increase in allergenicity, or tendencies to provoke allergic reactions. There is also some concern related to the possible transfer of the genes used to create genetically engineered foods from plants to people. This could influence human health if antibiotic-resistant genes are transferred to the consumer. Therefore, the World Health Organization (WHO) and other groups

have encouraged the use of genetic engineering without antibiotic-resistance genes. Genetically modified plants may adversely affect the environment as well and could lead to the contamination of nongenetically engineered organisms.World Health Organization. “Food Safety: 20 Questions on Genetically Modified Foods.” © 2011. http://www.who.int/foodsafety/publications/biotech/20questions/en/.

Genetically modified foods fall under the purview of the EPA, the USDA, and the FDA. Each agency has different responsibilities and concerns in the regulation of GM crops. The EPA ensures that pesticides used for GM plants are safe for the environment. The USDA makes sure genetically engineered seeds are safe for cultivation prior to planting. The FDA determines if foods made from GM plants are safe to eat. Although these agencies act independently, they work closely together and many products are reviewed by all three.Whitman, D. B. “Genetically Modified Foods: Harmful or Helpful?” *ProQuest Discovery Guides* (April 2000).

Video 16.2.2: Too Much Controversy Over Genetically Modified Foods?

(click to see video)

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Food Enrichment and Fortification

Many foods are enriched or fortified to boost their nutritional value. Enrichment involves adding nutrients to restore those that were lost during processing. For example, iron and certain B vitamins are added to white flour to replace the nutrients that are removed in the process of milling wheat. Fortification is slightly different than enrichment and involves adding new nutrients to enhance a food’s nutritive value. For example, folic acid is typically added to cereals and grain products, while calcium is added to some orange juice.

-

The Health of the Population

Certain enrichment and fortification processes have been instrumental in protecting public health. For example, adding iodine to salt has virtually eliminated iodine deficiencies, which protects against thyroid problems. Adding folic acid to wheat helps increase intake for pregnant women, which decreases the risk of neural tube defects in their children. Also, vegans or other people who do not consume many dairy products are able to drink orange juice or soy milk that has been fortified with calcium to meet the daily recommendations. However, there is some concern that foods of little nutritive value will be fortified in an effort to improve their allure, such as soft drinks with added vitamins.

Key Takeaways

The food industry encompasses all aspects of food production: manufacturing, distribution, marketing, retail, regulation, and consumption. Food preservation and processing have a number of benefits including improving the quality of food products, making them more shelf-stable, and aiding the marketing and advertising of food. There are more than three hundred additives used during food processing today. Food preservation and processing also have some drawbacks, including potentially damaging the nutritive value of food. The cultivation and consumption of genetically modified foods are also highly controversial, with many people opposed to the genetic modification of crops. There are three key government agencies that regulate food in the United States: the US Department of Agriculture, the US Food and Drug Administration, and the US Environmental Protection Agency.

Discussion Starter

1. Discuss the debate about the use of food additives, such as beta-carotene and citric acid. What are the benefits to using them? What are the drawbacks? Do you believe that food additives are more helpful or more harmful, and why?

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7.4: Food Cost and Inflation

Learning Objectives

- Cite a recent event that has had a profound effect on how consumers feel about the food supply.
- Give a historical overview of the era of cheap food.

Statistics show that Americans spend more than $1.5 trillion on food each year at supermarkets, in restaurants, and from other food providers.Plunkett Research, Ltd. “US Food Industry Overview.” 2011. http://www.plunkettresearch.com/food%20beverage%20grocery%20market %20research/industry%20statistics. According to the USDA, a thrifty family of four spends about $540-$620 per month on groceries.US Department of Agriculture. “Official USDA Food Plans: Cost of Food at Home at Four Levels, US Average, August 2011.” Issued September 2011. www.cnpp.usda.gov/Publications/FoodPlans/2011/CostofFoodAug2011.pdf. A number of factors affect the rising cost of food. They include agricultural production, processing and manufacturing, wholesale distribution, retail distribution, and consumption.

Around the world, commodity prices rose sharply in 2010 as crop production shortfalls led to reduced supplies and a higher volatility in agricultural markets. Other factors that played a role in increasing food prices include a population boom that has drastically increased demand, droughts and other natural disasters that have crippled farmers, and trade policies and practices that are unfair to developing nations.

Rising agricultural commodity prices have led to concerns about food insecurity and hunger. In an agricultural outlook report for 2010–2020, the Secretary-General of the Organisation for Economic Co-operation and Development states, “While higher prices are generally good news for farmers, the effect on the poor in developing countries who spend a high proportion of their income on food can be devastating. That is why we are calling on governments to improve information and transparency of both physical and financial markets, encourage investments that increase productivity in developing countries, remove production and trade distorting policies, and assist the vulnerable to better manage risk and uncertainty.”Organisation for Economic Co-operation and Development. “OECD-FAO Agricultural Outlook 2010–2020.” June 17, 2011. www.oecd.org/document/31/0,3746,en_21571361_44315115_48182047_1_1_1_1,00.html.

Who Bears the Cost?

The cost of our food is influenced by the policies and practices of farms, food and beverage companies, food wholesalers, food retailers, and food service companies. These costs include the energy required to produce and distribute food products from farm field to supermarket to table. Rising prices also reflect the marketing and advertising of food. All of these factors affect all participants in a food system, but some participants are more affected than others. A 2011 report by the Economic Research Service of the USDA shows the division of the consumer food dollar among various aspects of the American food system. A far greater amount of the money you spend to buy a product goes toward the marketing components than toward the actual farmer.US Department of Agriculture, Economic Research Service. “Overview.” Last updated November 19, 2012. http://www.ers.usda.gov/data-products/food-expenditures.aspx.

The Consumer Price Index

The Consumer Price Index (CPI) measures changes in the price level paid for goods and services. This economic indicator is based on the expenditures of the residents of urban areas, including working professionals, the self-employed, the poor, the unemployed, and retired workers, as well as urban wage earners and clerical workers. The CPI has subindices for many different types of products, including food and beverages. It is a closely-watched statistic that is used in a variety of ways, including measuring inflation and regulating prices.

Implications Around the World

Food prices and inflation disproportionately affect people at lower income levels. For the poorest people of the world, increasing prices can raise levels of hunger and starvation. In many developing countries where the cost for staple crops steadily rises,

consumers have faced shortages or even the fear of shortages, which can result in hoarding and rioting. This happened in 2007 and 2008 during rice shortages in India and other parts of Asia. Rioters burned hundreds of food ration stores in the Indian region West Bengal. In the West African nation Burkina Faso, food rioters looted stores and burned government buildings as a result of rising prices for food and other necessities.Vivienne Walt, "The World's Growing Food-Price Crisis," *Time* Magazine, 27 February 2008. www.time.com/time/world/article/0,8599,1717572-1,00.html. In some poor countries, protests also have been fueled by concerns over corruption, because officials earned fortunes from oil and minerals, while locals struggled to put food on their tables. Bringing down prices would quell protests, but could take a decade or more to accomplish.

The End of the Era of Cheap Food

Concerns about food shortages and rising prices reflect the end of the era of cheap food. Following World War II, grain prices fell steadily around the world for decades. As farms grew in scale, factory-farm practices, such as the use of synthetic and mined fertilizers and pesticides, increased. Agribusinesses also invested in massive planting and harvesting machines. These practices pushed crop yields up and crop prices down. Food became so inexpensive that we entered what came to be called the "era of cheap food."

However, by 2008, economic experts had declared that the era of cheap food was over. The rapid growth in farm output had slowed to the point that it failed to keep pace with population increases and rising affluence in once-developing nations. Consumption of four staples—wheat, rice, corn, and soybeans—outstripped production and resulted in dramatic stockpile decreases. The consequence of this imbalance has been huge spikes felt moderately in the West and to a much greater degree in the developing world. As a result, hunger has worsened for tens of millions of poor people around the world.Justin Gillis, "A Warming Planet Struggles to Feed Itself," *The New York Times*, 4 June 2011. http://www.nytimes.com/2011/06/05/science/earth/05harvest.html?_r=2&hp.

Two major trends played a part in this shift. First, prosperity in India and China led to increased food consumption in general, but more specifically to increased meat consumption. Increased meat consumption has led to an increased demand for livestock feed, which has contributed to an overall rise in prices. The second trend relates to biofuels, which are made from a wide variety of crops (such as corn and palm nuts), which increasingly are used to make fuel instead of to feed people.

The world population in 2010 was 6.9 billion.United Nations. "World Population Prospects, the 2010 Revision." http://esa.un.org/wpp/Analytical-Figures/htm/fig_1.htm. It is projected to grow to 9.4 billion by 2050.Food and Agricultural Organization of the United Nations. "Executive Summary." www.fao.org/docrep/004/y3557e/y3557e03.htm. The rate of increase is particularly high in the developing world, and the increased population, along with poverty and political instability, are helping to foster long-term food insecurity. In the coming decades, farmers will need to greatly increase their output to meet the rising demand, while adapting to any future trends.Christian Science Monitor. "Why the Era of Cheap Food Is Over." December 31, 2007. http://www.csmonitor.com/2007/1231/p13s01-wogi.html.

Key Takeaways

Food prices are rising in the United States and around the world, which has greatly affected both agricultural producers and consumers. A number of factors have contributed to rising costs, including population booms, natural disasters, and the production of biofuels, among others. Economic experts have declared that the era of cheap food, which began after World War II, has ended due to rising population rates and decreased agricultural production worldwide. As a result, hunger has worsened for tens of millions of poor people globally.

Discussion Starter

1. Examine the graphics from http://www.ers.usda.gov/data-products/food-dollar-series/documentation.aspx. What does each image indicate about agriculture and the American economy?

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7.5: Sustainability

Big Ideas

- Sustainability promotes nutrition today and protects natural resources for tomorrow.

As discussed in previous chapters, sustainability is a word that's often talked about in the realm of food and nutrition. The term relates to the goal of achieving a world that meets the needs of its present inhabitants while preserving resources for future generations. As awareness about sustainability has increased among the media and the public, both agricultural producers and consumers have made more of an effort to consider how the choices they make today will impact the planet tomorrow.



Figure 7.5.1: Raising free-range chickens that feed out in the open is one example of a sustainable agricultural practice. Free Range Hens The eggs these hens produce will be pretty tasty. from Adam Ward (via Wikipedia).

However, defining sustainability can be difficult because the term means different things to different groups. For most, sustainable agriculture can best be described as an umbrella term that encompasses food production and consumption practices that do not harm the environment, that do support agricultural communities, and that are healthy for the consumer.Sustainable Table. "Introduction to Sustainability." Accessed October 10, 2011. www.sustainabletable.org/intro/. From factory farms to smaller-scale ranches and granges, sustainable farming practices are being implemented more and more as the long-term viability of the current production system has been called into question.

Yet, the concept of sustainability is not new to agricultural science, practice, or even policy. It has evolved throughout modern history as a way to achieve self-reliance. It is also a vehicle for maintaining rural communities and supporting the concept of conservation and protection of the land.Ecological Agriculture Projects. "A History of Sustainable Agriculture." © 1990 Rod MacRae. http://eap.mcgill.ca/AASA_1.htm. In 1990, the US federal government defined sustainable agriculture in a piece of legislation known as the Farm Bill. The practice was described as an integrated system of plant and animal production that satisfies human needs for food, along with fiber for fabric and other uses. The Farm Bill further defines sustainable agriculture as a practice that enhances environmental quality and also the natural resource base upon which the agricultural economy depends. Sustainable agriculture also makes the most efficient use of nonrenewable resources, sustains the economic viability of farm operations, and supports the quality of life for farmers and society as a whole.Gold, M.V. "Sustainable Agriculture: Definitions and Terms." US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1.

In other words, the practice of sustainable agriculture strives to eschew conventional farming methods, including the cultivation of single crops and row crops continuously over many seasons, the dependency on agribusiness, and the rearing of livestock in concentrated, confined systems.Gold, M.V. "Sustainable Agriculture: Definitions and Terms." US Department of Agriculture, National Agricultural Library. *Special Reference Briefs Series* no. SRB 99-02 (September 1999, August 2007). http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc1. Instead, sustainability includes a focus on biodiversity among both crops and livestock; conservation and preservation to replenish the soil, air, and water; animal welfare; and fair treatment and wages for farm workers.Sustainable Table. "What Is Sustainable Agriculture?" Accessed October 10, 2011. www.sustainabletable.org/intro/whatis/. Sustainable agriculture also encourages the health of consumers by rejecting extensive use of pesticides and fertilizers and promoting the consumption of organic, locally produced food. Although many farmers and food companies work to implement these practices, some use the idea of sustainability to attract consumers without completely committing to the concept. "Greenwashing" is a derisive term (similar to "whitewashing") for a corporation or industry falsely utilizing a proenvironmental image or message to expand its market base.

Sustainability depends not only on agricultural producers, but also on consumers. The average person can do a number of things to consume a more sustainable diet, from eating less meat to purchasing fruits and vegetables grown on nearby farms. For example, produce sold in the Midwest typically travels an average of more than fifteen hundred miles from farm to supermarket. However, increasing the consumption of more locally-grown produce by 10 percent would save thousands of gallons in fossil fuel each year.Heller, M. C., G. A. Keoleian. "US Food System Factsheet." Center for Sustainable Systems, University of Michigan. *CSS Factsheets*, no. CSS01-06 (2001). http://www.css.snre.umich.edu/publication/css-factsheets-us-food-system.

You Decide

How will you adapt your lifestyle and dietary choices to help promote sustainable agricultural practices?

Some consumers are choosing to make smarter nutritional choices, eat healthier foods, and enjoy fresh, locally grown products. They read the labels on products in their local stores, make more home-cooked meals using whole-food ingredients, and pay attention to the decisions that legislators and other officials make regarding food production and consumption. Will you be one of them? How you can adjust your dietary selections to benefit not only your body and mind but also to help sustain the planet for future generations?



Video 16.4.1: *Green Careers: Sustainable Agriculture. This video focuses on the role of a farm manager on a small farm that follows sustainable agricultural practices (click to see video).*

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7.6: A Fresh Perspective- Sustainable Food Systems

Learning Objective

- Discuss some approaches to building a sustainable food system in your community.

The science of nutrition includes the study of how organisms obtain food from their environment. An ecosystem is defined as the biological and physical environments and their interactions with the community of organisms that inhabit those environments as well as the interactions among the organisms. Human nutrition and the health of the world's ecosystem are interdependent, meaning that what we eat and where we get it from affects the world. In turn, the health of the earth influences our health. The term sustainability is used to indicate the variety of approaches aimed at improving our way of life. Sustainability promotes the development of conditions under which people and nature can interact harmoniously. It is based on the principle that everything needed for human survival depends upon the natural environment.

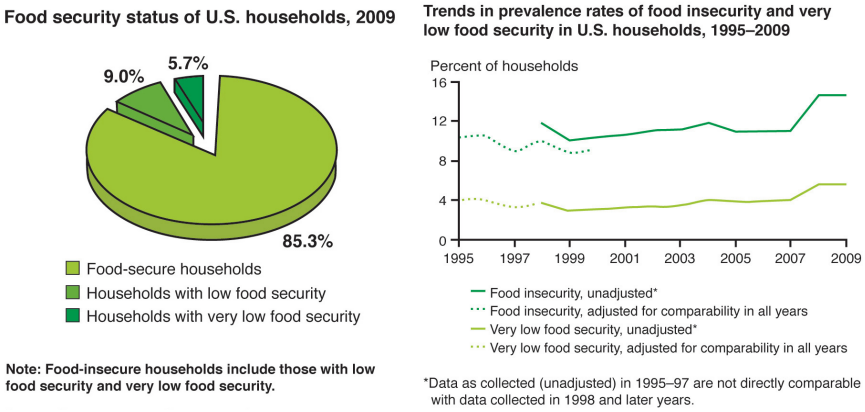


Figure 7.6.1: Food Security Status in the United States. Building a sustainable food system will help enforce measures to ensure that everyone on the planet has enough food to eat. Source: Calculated by ERS using data from the December 2009 Current Population Survey Food Security Supplement.

A major theme of sustainability is to ensure that the resources needed for human and environmental health will continue to exist. A healthy ecosystem, one that is maintained over time, is harmonious and allows for social and economic fulfillment for present and future generations. Nutritious foods come from our ecosystem and to ensure its availability for generations to come, it must be produced and distributed in a sustainable way. The American Public Health Association (APHA) defines a sustainable food system as "one that provides healthy food to meet current food needs while maintaining healthy ecosystems that can also provide food for generations to come with minimal negative impact to the environment."American Public Health Association. "Towards a Healthy, Sustainable Food System." *Policy Statement Database*. Policy no. 200712 (November 6, 2007). www.apha.org/advocacy/policy/policysearch/default.htm?id=1361 It also states that the attributes of a sustainable food system are:

- availability
- accessibility
- affordability to all
- humane
- just

A sustainable food system does not just include the food and those who consume the food, but also those that produce the food, like farmers and fishermen, and those who process, package, distribute, and regulate food. Unfortunately, we have a long way to go to build a sustainable food system.

The Challenges

The most prominent challenge to building a sustainable food system is to make food available and accessible to all. The Food and Agricultural Organization of the United Nations (FAO) states the right to food is a fundamental human right and its mission is to assist in building a food-secure world. Food security in America is defined as the "access by all people at all times to enough food for an active, healthy life."US Department of Agriculture, Economic Research Service. "Food Security in the United States: Key Statistics and Graphics." Last updated June 4, 2012. www.ers.usda.gov/Briefing/FoodSecurity/stats_graphs.htm#food_secure As of 2009, 14.9 percent of households, or 17.4 million people in the United States, had very low or low food security and these numbers have risen in recent years (Figure 1.7.2).Food and Agricultural Organization of the United Nations. "Food Security: Concepts and Measurement." In *Corporate Document Repository*, ID: 144369. 2003. www.fao.org/docrep/005/y4671e/y4671e06.htm

Food security is defined by the FAO as existing "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food which meets their dietary needs and food preferences for an active and healthy life."Food and Agriculture Organization of the United Nations. "How Does International Price Volatility Affect Domestic Economies and Food Security? In *The State of Food Insecurity in the World*. 2011. www.fao.org/publications/sofi/en/ The FAO estimates that 925 million worldwide were undernourished in 2010. Although there was a recent decline in overall food insecurity (attributable mostly to a decline in undernourished people in Asia), the number of undernourished people worldwide is still higher than it was in 1970, despite many national and international goals to reduce it.

Another challenge to building a sustainable food system is to supply high-quality nutritious food. The typical American diet does not adhere to dietary guidelines and recommendations, is unhealthy, and thus costs this country billions of dollars in healthcare. The average American diet contains too many processed foods with added sugars and saturated fats and not enough fruits, vegetables, and whole grains. Moreover, the average American takes in more kilocalories each day than ever before. This shift of the population toward unhealthy, high-calorie diets has fueled the obesity and diet-related disease crisis in this nation. Overall the cost of food for the average American household has declined since the 1970s; however, there has been a growth of "food deserts." A food desert is a location that does not provide access to affordable, high-quality, nutritious food. One of the best examples of a "food desert" is in Detroit, Michigan. The lower socioeconomic status of the people who live in this city does not foster the building of grocery stores in the community. Therefore, the most accessible foods are the cheap, high-caloric ones sold in convenience stores. As a result, people who live in Detroit have some of the highest incidences of obesity, Type 2 diabetes, and cardiovascular disease in the country.

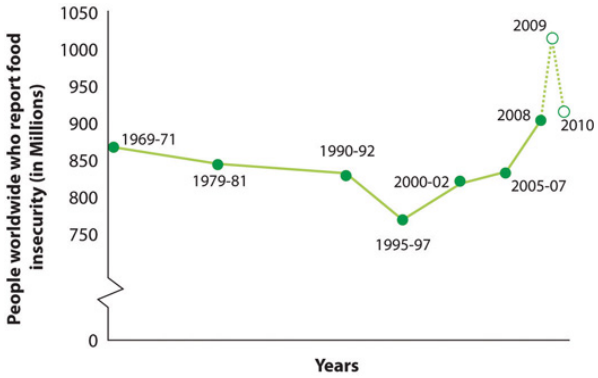


Figure 16.5.2: *Food Insecurity: A Global Perspective. Source: Calculated by ERS based on Current Population Survey Food Security Supplement data.*

A fourth challenge to building a sustainable food system is to change how we produce, process, and distribute food. Large agribusiness, complex industrial processing, and massive retail conglomerations distort the connection we have between the food on our plate and where it came from. More food is being produced in this nation than ever before, which might sound good at first. However, some factors that have contributed to higher food production include using genetically engineered plants, excessive use of herbicides and pesticides, and the selective promotion of only a few crops by the policy of crop-specific subsidies (money given to farmers by the federal government). The subsidies are given toward the support of only about eight crops, most notably corn and soybeans. This policy diminishes the variety of crops, decreases biodiversity among crops, and supports large agribusiness while disadvantaging small- and medium-sized farms. Additionally, the whole system of food production, processing, and distribution is lengthy, requiring a great deal of energy and fossil fuels, and promotes excessive use of chemicals to preserve foods during transportation and distribution. In fact, the current US food system uses approximately 22 percent of the energy in this country and is responsible for at least 20 percent of greenhouse gas emissions. Canning, P. et al. "Energy Use in the US Food System." US Department of Agriculture, *Economic Research Report, no. ERR-94* (March 2010).

Solutions to the Challenges

While these challenges are daunting there are many potential solutions that are gaining momentum in the United States. The APHA advocates expanding the infrastructure for locally grown food, improving access to healthy and local food for low-income Americans, providing education on food origin and production, building up the livelihoods of local farmers, and using sustainable farming methods. Detroit is currently a "food desert," but there is a fantastic example of how to positively impact the growth of a sustainable food system within the city. It is called the Eastern Market and it is a six-block inner city market with over 250 vendors marketing local produce, meat, seafood, plants, fresh-cut flowers and much, much more. Unlike many urban farmers' markets, it sells foods that are better quality and lower prices than grocery stores. Its forty-thousand visitors every Saturday demonstrate its success as a community-based way to foster good nutrition, good health, and social interaction.

Tools for Change

Ten Steps You Can Take to Help Build a Sustainable Food System in Your Community

1. Eat a "low-carbon diet." This is one where the foods that you eat require less energy and fuel to produce, process, and distribute than other foods.
2. Join a community-based farmers' market.
3. Have a garden at home and join a network of home gardeners. Find out how by visiting the USDA website on gardening: www.usda.gov/wps/portal/usda/usdahome?navid=GARDENING &parentnav=CONSUMER_CITIZEN&navtype=RT and the National Garden Association, http://www.garden.org/.
4. Compost your food and garden waste. Learn some of the essentials of composting by visiting "Composting at home," a fact sheet provided by Ohio State University (http://ohioline.osu.edu/hyg-fact/1000/1189.html).
5. Buy local food—make at least 10 percent of your food purchases local and share what you know about local food with friends and family.
6. Pool your resources with family and friends to purchase locally.
7. Drink tap water instead of bottled water.
8. When purchasing foods, choose the ones with less packaging.

9. Support state initiatives that support local farmers and build infrastructure to sell more healthy food.
10. When dining out, ask what nutrients are in the food and where the food labels are on the menu (to encourage the restaurants to label). Also, visit the restaurant's website as the information may be posted there with a space for comments.

These are some great steps to build a more sustainable food system for you and your family, friends, neighborhood, community, city, state, nation, and the world. For more solutions, watch Video 1.7.1. Throughout this book, we will highlight multiple steps you can take toward building a sustainable food system in the Tools for Change sections, so stay tuned.



Figure 7.6.3: You can do your part in building a sustainable environment by literally starting in your own backyard. © Shutterstock

Video 16.5.1: Sustainable Food Systems

This link brings you to an educational video on sustainable food systems.

Key Takeaways

- Sustainability promotes the ditions under which people and nature can interact harmoniously. It is based upon the principle that everything needed for huma upon the natural environment. A sustainable food system includes not only the food and those who consume the food, but also t ood (such as farmers and fishermen), and process, package, distribute, and regulate food.
- The challenges to building a stem are many, from providing affordable and accessible food, to supplying nutritious, high-quality, low-cost food regardless of socioeconomic status, to changing the ways foods are produced, processed, and distributed.
- There are many solutions to the challenges of building a sustainable food system. Some of the solutions are to: expand the infrastructure for locally grown food, improve access to healthy and local food for low-income Americans, provide education on food origin and production, build up the livelihoods of local farmers, and use sustainable farming methods.
- You can take action individually and locally to help build a sustainable food system.

Discussion Starters

1. Share with each other in the classroom some of the things you might have already done to help build a sustainable food system in your community.
2. Form debate teams in the classroom and have a formal debate on the topic of the regulation of food. One side must present the reasons it is beneficial for the government to regulate food. The other side will argue the reasons it is better for people to grow their food locally.

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7.7: Start Your Sustainable Future Today

Learning Objectives

- Discuss forms of activism in areas of food and nutrition.
- List steps individuals can take to support sustainable agriculture.

As we near the end of our journey in the world of health and nutrition, let's address how to adjust your lifestyle today to ensure better health and wellness tomorrow. Adopting sustainable practices can go a long way toward helping you achieve optimal health, while also helping to protect the health of our planet. Remember, that sustainability involves meeting present nutritional needs while preserving resources for the future. It includes agricultural practices and processes, along with the choices that consumers make when they shop for their food. Ideally, sustainable practices include methods that are healthy, conserve the environment, protect livestock, respect food industry workers, provide fair wages to farmers, and support farming communities. When a practice or a process is sustainable, it can be maintained for decades, or even centuries, to come.

Living a Sustainable Lifestyle

There are a number of steps you can take to live a more sustainable lifestyle. Utilizing an environmentally-friendly approach to good nutrition is a great way to remain and stay healthy. As an initial step, you might try to buy more whole foods rather than processed foods. You might also drink more water, rather than sodas and juices with added sugar. It is also a good idea to drink from a reusable water bottle to avoid adding more plastic to your local landfill, not to mention saving the fuel it takes to ship bottles of water. Here are some other suggestions to live a more sustainable lifestyle:

- **Learn more about food.** Learn about your local food system, what is native to the area, what is imported or shipped in, how food moves from farms to processors to retail in your area, and what practices are used. Read labels to see where food comes from and what the growing and processing practices are. You might also try taking a cooking class to learn more about food in general.
- **Eat a plant-based diet.** A plant-based diet is not necessarily vegetarian or vegan; it simply emphasizes whole grains, fruits, vegetables, and legumes over meat and poultry. Plant-based foods are good sources of carbohydrates, protein, fat, vitamins, and minerals. They also help to decrease your risk for cancer and other chronic conditions.
- **Support local farmers.** Purchase more locally grown food to promote sustainability. This could involve going to a farmer's market or a nearby farm. Locally grown food requires less fossil fuel because it does not have to travel great distances. Locally grown food also puts money back into your community and helps farmers in your area. Shopping at a farmer's market or a local farm may also provide an opportunity to talk to the farmer who grew the food to learn more about what you put on your plate.
- **Join a community garden.** You can't get more local than food that is grown in your own backyard. Consider growing your own food, or trying a community garden if you do not have the space at your home. Produce from a local garden will not only be fresher, it will often taste better. In addition, it will provide an opportunity to get to know like-minded individuals in your community.
- **Help spread the word.** Talk to friends and family members about food, nutrition, and living a sustainable lifestyle. Also, pay attention to food and nutrition policy at the federal, state, and local levels. Take a look at what foods are available in your community. Are there supermarkets or corner stores? What is available in the university dining hall? If healthy options are lacking, can you talk to someone to bring about changes?

Tools for Change

Another option to support local farmers is to sign up for a CSA (community-supported agriculture). Prior to a planting season, consumers who join a CSA purchase a produce share from a local farmer. When harvesting begins, farmers provide in-season, locally grown vegetables to shareholders at a local drop spot each week throughout the growing season. Some CSAs also include fruit, dairy products, meat, and more. CSA farmers often will allow you to visit the farm to learn more about the crops they grow or even volunteer to help with the harvest. Joining a CSA provides a direct connection between the local farming community and you.

Changing Your Behavior

Living a sustainable lifestyle and achieving optimal health is not easy. Taking steps to exercise more, eat healthier foods, and work harder to avoid food contamination may involve making major changes in your life. However, change is a process, and researchers

have long studied the various stages of that process, as well as what helps or hinders it. While creating and implementing change is not easy, the more conscious you are of the process, and the more you prepare, the greater the chances are for success. Learning about the different stages of behavioral change can help you take a proactive approach to living a sustainable lifestyle.

The Transtheoretical Model of Behavioral Change

The Transtheoretical Model of Behavioral Change identifies the five stages of change, along with things that can help people move through these different stages. It also includes strategies which help people make, create, and continue behavioral change. Learning about these different stages and techniques helps you decide how to best approach making healthy changes in your life.

The five stages of the Transtheoretical Model of Behavioral Change are (Figure 7.7.1):

1. **Precontemplation.** At this stage, an individual has no plans to make any changes and may not be aware that change is needed. For example, a person who has never thought of eating healthier or being more active is in the precontemplation stage. In this stage, a person often underestimates the pros of changing and underestimates the cons of maintaining the status quo.
2. **Contemplation.** An individual begins to see the importance of altering behavior and plans to do so within the next six months. Someone who has realized that they need to add more physical activity to their life, but hasn't made any concrete plans to start doing it, is in the contemplation stage. Although they may be more aware of the benefits of change, the individual may still exaggerate the negative aspects of change.
3. **Preparation.** At this stage, an individual becomes serious about making a change and plans to implement that change within thirty days. The person may have already started to alter behavior or told friends about any plans or intentions. For example, someone who wants to eat better and has started gathering healthier recipes is in the preparation stage.
4. **Action.** At this point, an individual is in the midst of change or has made a consistent change in behavior within the past six months. For example, someone in the action stage would have started eating better and exercising on a regular basis.
5. **Maintenance.** At this final stage, an individual has successfully changed their behavior for six months or more and intends to maintain it in the future.



Figure 7.7.1: *This is a graphic representation of the "Stages of Change" in the Transtheoretical Model of Behavior Change. from* Philciaccio (via Wikipedia).

Adopting a healthier lifestyle requires changes not only in behavior, but also in attitude and perception. The Transtheoretical Model calls them *decisional balance* and *self-efficacy*. Decisional balance means a person has realized that the benefits of making healthy changes outweigh any risks. Self-efficacy means a person has self-belief and the confidence to make and maintain positive changes. Both decisional balance and self-efficacy help people progress through the different stages of change. The Theoretical Model of Behavioral Change also includes ten techniques and strategies for bringing about change:

1. **Consciousness-raising.** Different methods that are used to raise awareness of healthier choices.
2. **Dramatic Relief.** The use of emotions through testimonials, role-playing, and the media to support change.
3. **Environmental Reevaluation.** Helping people become aware of how they affect others, and how a change on their part can also help those around them.
4. **Social Liberation.** Helping individuals realize that society may be more welcoming if they change their behavior.
5. **Self-Liberation.** Allowing people to believe in their ability to change, and make a commitment to it.
6. **Helping Relationships.** Providing connections between people seeking positive change with others who support their efforts.
7. **Counterconditioning.** Finding healthier substitutes for the unhealthy behavior.
8. **Reinforcement Management.** Increasing rewards for healthy behavior and reducing those for negative behavior.
9. **Stimulus Control.** Being aware of and eliminating cues for unhealthy behavior, and replacing them with cues for healthy choices.
10. **Self-reevaluation.** Changing your self-image to fit with a newer, healthier lifestyle.

Prochaska and colleagues state that their research related to the transtheoretical model shows that interventions to change behavior are more effective if they are "stage-matched," that is, "matched to each individual's stage of change (Figure 7.7.2).

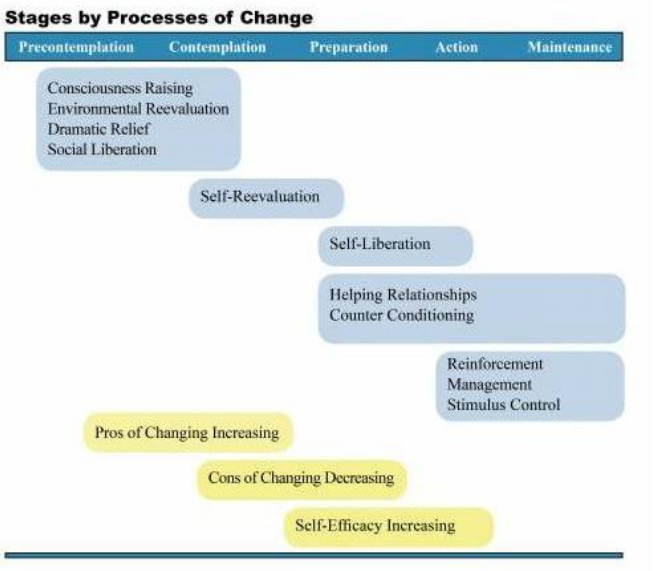


Figure 7.7.2: Processes of Change. from Wikipedia

Some of these processes of change are more effective at different points in the process. A person who is not even contemplating change could tune out emotional appeals or reinforcement management. However, combining knowledge of the change process with the effective use of strategies can help everyone turn their good intentions into healthier lifestyles.Center for Health Communications Research. “Transtheoretical Model (Stages of Change).” © 2009 The Regents of University of Michigan. Accessed December 21, 2011. chcr.umich.edu/how_we_do_it/health_theories/healththeories5/chcr_document_view.

Key Takeaways

Living a sustainable lifestyle can help you to work toward achieving optimal health. There are a number of steps you can take to promote sustainable practices, such as buying locally grown food, eating a plant-based diet, and becoming aware of food and nutrition issues in your community. The Transtheoretical Model of Behavioral Change outlines the different stages of the process of change, and provides tools and techniques to enable major changes.

Discussion Starter

1. Think of a change you might want to make in your life to become healthier, and discuss ways you can use the transtheoretical model to make this change.

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7.8: The Issue of Food Security

Learning Objectives

- Share an example of a food and nutrition program that seeks to mitigate hunger in the United States and/or Canada.

Physiologically, hunger relates to appetite and is the body's response to a need for nourishment. Through stomach discomfort or intestinal rumbling, the body alerts the brain that it requires food. This uneasy sensation is easily addressed with a snack or a full meal. However, the term "hunger" also relates to a weakened condition that is a consequence of a prolonged lack of food. People who suffer from this form of hunger typically experience malnourishment, along with poor growth and development.

- ## Hunger

  Adequate food intake that meets nutritional requirements is essential to achieve a healthy, productive lifestyle. However, millions of people in North America, not to mention globally, go hungry and are malnourished each year due to a recurring and involuntary lack of food. The economic crisis of 2008 caused a dramatic increase in hunger across the United States.World Hunger.org. "Hunger in America: 2011 United States Hunger and Poverty Facts." Accessed October 10, 2011. www.worldhunger.org/articles/Learn/us_hunger_facts.htm.

- ## Key Hunger Statistics

  In 2010, 925 million people around the world were classified as hungry. Although this was a decrease from a historic high of more than one billion people from the previous year, it is still an unbearable number. Every night, millions and millions of people go to sleep hungry due to a lack of the money or resources needed to acquire an adequate amount of food. This graph shows the division of hungry people around the globe.

- ## Key Hunger Terms

  A number of terms are used to categorize and classify hunger. Two key terms, food security and food insecurity, focus on status and affect hunger statistics. Another term, malnutrition, refers bad (or mal) nutrition. An individual may eat inappropriately so they do not consume an adequate amount of one or more nutrients. Overnutrition, the overconsumption of one or more nutrients such as energy, often masks malnutrition. Both food security and food insecurity can cause malnutrition.

- ## Food Security

  Most American households are considered to be food secure, which means they have adequate access to food and consume enough nutrients to achieve a healthy lifestyle. However, a minority of US households experiences food insecurity at certain points during the year, which means their access to food is limited due to a lack of money or other resources. This graphic shows the percentage of food-secure and food-insecure households in the United States during the year 2010.

- ## Food Insecurity

  Food insecurity is defined as not having adequate access to food that meets nutritional needs. We often think of food scarcity and insecurity happening in developing countries, not developed countries. While, to some extent, this is true, according to the USDA, about 11.1 percent (14.3 million) of US households were food insecure in 2018. With the COVID19 pandemic in 2020, the numbers will be much bigger. Four percent of US households had "very low food security," which means one or more people in the household had their food intake disrupted and reduced at times during the year due to insufficient money or resources to buy food. The difference between low and very low food security is that members of low insecurity households have reported problems of food access, but have reported only a few instances of reduced food intake if any. Coleman-Jensen, A. et al. "Key Statistics & Graphics" US Department of Agriculture, (September 2019). African American and Hispanic households experience food insecurity at much higher rates than the national average. Coleman-Jensen, A. et al. "Household Food Security in the United States in 2010." US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

  Food insecurity occurs for a variety of reasons. There is no single cause that can lead to an inability to meet one's daily food needs every day. Households with limited resources employ a variety of methods to increase their access to adequate food. Some families purchase junk food and fast food—cheaper options that are also very unhealthy. Other families who struggle

with food security supplement the groceries they purchase by participating in government assistance programs. They may also obtain food from emergency providers, such as food banks and soup kitchens in their communities. People who are impaired physically and/or mentally tend to have more food insecurity, particularly children.

- ## Malnutrition

  A person living in a food-insecure household may suffer from malnutrition, which results from a failure to meet nutrient requirements. This can occur as a result of consuming too little food or not enough key nutrients or too much of the wrong foods. The causes of malnutrition vary among developed and developing parts of the world. Weight is not a good predictor of malnutrition. There are two types of undernutrition/malnutrition. The first is protein-energy malnutrition (PEM) or lack of protein and energy. The second type is micronutrient deficiencies and relates to inadequate vitamin and mineral intake. The World Health Organization estimates about 815 million people in the world suffer from chronic undernourishment. About 22% of the world's children have stunted growth. World Hunger. “2018 World Hunger and Poverty Facts and Statistics.” Accessed May 26, 2020. http://www.worldhunger.org/articles/Learn/world%20hunger%20facts%202002.htm.

  Even people who are overweight or obese can suffer from malnutrition if they eat foods that do not meet all of their nutritional needs. There are 1.9 billion people in the world who are overweight or obese. World Health Organization. "Obesity and Overweight." Accessed May 26, 2020. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

- ## At-Risk Groups

  Worldwide, three main groups are most at risk of hunger: the rural poor in developing nations who also lack access to electricity and safe drinking water, the urban poor who live in expanding cities and lack the means to buy food, and victims of earthquakes, hurricanes, and other natural and man-made catastrophes.Food and Agriculture Organization of the United Nations. “Hunger: Frequently Asked Questions.” Accessed October 10, 2011. www.fao.org/hunger/en/

  In the United States, food insecurity varies among household types. Rates of food insecurity were higher than the national average (11.1 percent) for the following groups:

  - All households with children (13.9 percent),
  - Households with children under age 6 (14.3 percent),
  - Households with children headed by a single woman (27.8 percent),
  - Households with children headed by a single man (15.9 percent),
  - Women living alone (14.2 percent),
  - Men living alone (12.5 percent),
  - Black, non-Hispanic households (21.2 percent),
  - Hispanic households (16.2 percent), and
  - Low-income households with incomes below 185 percent of the poverty threshold (29.1 percent; the Federal poverty line was $25,465 for a family of four in 2018).

  Older adults are also a major at-risk group. Many elderly people are frail and isolated, which affects their ability to meet their dietary requirements. In addition, many have low incomes, limited resources, and difficulty purchasing or preparing food due to health issues or poor mobility. As a result, more than 8.6 million older citizens in the United States face the threat of hunger.National Council on Aging. “SNAP and Senior Hunger Facts.” Accessed May 26, 2020. https://www.ncoa.org/news/resources-for-reporters/get-the-facts/senior-hunger-facts/

- ## The Homeless

  One of the groups that struggles with hunger are the millions of homeless people across North America. According to a recent study by the US Conference of Mayors, the majority of reporting cities saw an increase in the number of homeless families.The United States Conference of Mayors. “Hunger and Homelessness Survey: A Status Report on Hunger and Homelessness in America’s Cities, a 27-City Survey.” December 2009. usmayors.org/pressreleases/uploads/USCMHungercompleteWEB2009.pdf. Hunger and homelessness often go hand-in-hand as homeless families and adults turn to soup kitchens or food pantries or resort to begging for food.

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Children

Rising hunger rates in the United States particularly affect children. Nearly one out of four children, or 21.6 percent of all American children, lives in a food-insecure household and spends at least part of the year hungry. Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011). Hunger delays their growth and development and affects their educational progress because it is more difficult for hungry or malnourished students to concentrate in school. In addition, children who are undernourished are more susceptible to contracting diseases, such as measles and pneumonia.World Hunger. “2011 World Hunger and Poverty Facts and Statistics.” Accessed October 10, 2011.

Video 16.7.1: Going Hungry in America

This video examines the effect of hunger on many American children. (click to see video)

- ### Government Programs

  The federal government has established a number of programs that work to alleviate hunger and ensure that many low-income families receive the nutrition they require to live a healthy life. A number of programs were strengthened by the passage of the Healthy, Hunger-Free Kids Act of 2010. This legislation authorized funding and set the policy for several key core programs that provide a safety net for food-insecure children across the United States. The United States Department of Agriculture oversees most of the food and nutrition assistance programs.

- ### The Federal Poverty Level

  The federal poverty level (FPL) is used to determine eligibility for food-assistance programs. This monetary figure is the minimum amount that a family would need to acquire shelter, food, clothing, and other necessities. It is calculated based on family size and is adjusted for annual inflation. Although many people who fall below the FPL are unemployed, the working poor can qualify for food programs and other forms of public assistance if their income is less than a certain percentage of the federal poverty level, along with other qualifications.

- ### USDA Food Assistance Programs

  Government food and nutrition assistance programs that are organized and operated by the USDA work to increase food security. They provide low-income households with access to food, the tools for consuming a healthy diet, and education about nutrition. The USDA monitors the extent and severity of food insecurity via an annual survey. This contributes to the efficiency of food assistance programs as well as the effectiveness of private charities and other initiatives aimed at reducing food insecurity. Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

- ### The Supplemental Nutrition Assistance Program

  Formerly known as the Food Stamp Program, the Supplemental Nutrition Assistance Program (SNAP) provides monthly benefits for low-income households to purchase approved food items at authorized stores. Clients qualify for the program based on available household income, assets, and certain basic expenses. In an average month, SNAP provides benefits to more than forty million people in the United States. Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

  The program provides Electronic Benefit Transfers (EBT) which work similarly to a debit card. Clients receive a card with a certain allocation of money for each month that can be used only for food. In 2010, the average benefit was about $134 per person, per month and total federal expenditures for the program were $68.2 billion. Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

- ### The Special, Supplemental Program for Women, Infants, and Children

  The Special, Supplemental Program for Women, Infants and Children (WIC) provides food packages and/or vouchers to pregnant and breastfeeding women, as well as to infants and children up to age five, to promote adequate intake for healthy growth and development. Most state WIC programs provide vouchers that participants use to acquire supplemental packages at authorized stores. In 2010, WIC served approximately 9.2 million participants per month at an average monthly cost of about

forty-two dollars per person. Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

- ## The National School Lunch Program

  The National School Lunch Program (NSLP) and School Breakfast Program (SBP) ensure that children in elementary and middle schools receive at least one healthy meal each school day, or two if both the NSLP and SBP are provided. According to the USDA, these programs operate in over 101,000 public and nonprofit private schools and residential child-care institutions.US Department of Agriculture. “National School Lunch Program.” October 2011. www.fns.usda.gov/cnd/Lunch/AboutLunch/NSLPFactSheet.pdf. In 2010, the programs provided meals to an average of 31.6 million children each school day. Fifty-six percent of the lunches served were free, and an additional 10 percent were provided at reduced prices.

- ## Other Food-Assistance Programs for Children

  Other government programs provide meals for children after school hours and during summer breaks. The Child and Adult Care Food Program (CACFP) offers meals and snacks at child-care centers, daycare homes, and after-school programs. Through CACFP, more than 3.2 million children and 112,000 adults receive nutritious meals and snacks each day.US Department of Agriculture. “Child & Adult Care Food Program.” Last modified June 10, 2011. www.fns.usda.gov/cnd/care/. The Summer Food Service Program provides meals to children during summer break. Sponsors include day camps and other recreation programs where at least half of the attendees live in households with incomes below the federal poverty level.US Department of Agriculture. “Summer Food Service Program.” st.TER 14 2011r Congressbrary. Last modified July 20, 2011. http://www.summerfood.usda.gov/default.htm. These and other programs help to fill in the gaps during the typical day of a food-insecure child.

- ## The Head Start Program

  Head Start is a health and development program for children ages three to five, from low-income families. The philosophy behind the organization is that early intervention can help address the educational, social, and nutritional deficiencies that children from lower-income families often experience. Launched in 1965, it is one of the longest-running, poverty-related programs in the United States. Today, Head Start programs include education, meals, snacks, and access to other social services and health guidance.US Department of Health and Human Services. “About the Office of Head Start.” Last reviewed February 23, 2011. www.acf.hhs.gov/programs/ohs/about/index.html.

- ## Other Forms of Assistance

  Other forms of assistance include locally-operated charitable organizations, such as food banks and food pantries, which acquire food from local manufacturers, retailers, farmers, and community members to give to low-income families. Neighborhood soup kitchens provide meals to the homeless and other people in need. These and other organizations are run by nonprofit groups, as well as religious institutions, to provide an additional safety net for those in need of food.

Meals on Wheels

An organization known as Meals on Wheels delivers meals to elderly people who have difficulty buying or making their own food because of poor health or limited mobility. It is the oldest and largest program dedicated to addressing the nutritional needs of senior citizens. Each day, Meals on Wheels volunteers deliver more than one million meals across the United States. The first Meals on Wheels program began in Philadelphia in the 1950s. In the decades since, the organization has expanded into a vast network that serves the elderly in all fifty states and several US territories. Today, Meals on Wheels remains committed to ending hunger among the senior citizen community.Meals on Wheels. “The Meals on Wheels Association of America.” Accessed October 10, 2011. www.mowaa.org/page.aspx?pid=212.

Key Takeaways

Around the world, nearly one billion people suffer the effects of constant hunger. Key terms related to hunger include food security, which means having continual access to safe, sufficient, nutritious food, and food insecurity, which means not having continual access to safe, sufficient, nutritious food. There are two types of malnutrition. The first is macronutrient deficiency and relates to the lack of adequate protein, which is required for cell growth, maintenance, and repair. The second type of malnutrition is micronutrient deficiency and relates to inadequate vitamin and mineral intake. There are a number of groups at

risk for hunger, including the unemployed and underemployed, poor families, the elderly, and the homeless. The United States has a number of federal and state programs, as well as local charities, which provide assistance and education for people who fall into the category of food insecurity.

Discussion Starter

1. Do you believe there are enough government programs currently in place to address the problem of hunger? Why or why not? If not, what additional solutions would you recommend?

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7.9: Diets around the World

Learning Objectives

- Give examples of how local taste preferences and availability influence food choices in different regions of the globe.
- Explain what is meant by Alice Waters' statement: "Food is precious."

In the past, people's culture and location determined the foods they ate and the manner in which they prepared their meals. For example, in the Middle East, wheat was a staple grain and was used to make flatbread and porridge, while halfway around the world in Mesoamerica, maize was the staple crop and was used to make tortillas and tamales. Today, most people have access to a wide variety of food and can prepare them any way they choose. However, customs and traditions still strongly influence diet and cuisine in most areas of the world.

Comparing Diets

There are a multitude of diets across the globe, in all regions and cultures. Each is influenced by the traditions of the past, along with the produce and livestock available. Local tastes, agricultural economics, and incomes still have a profound effect on what many people eat around the world. In this section, you will read a few examples of cuisines in different countries and regions, demonstrating differences in preferences. We will also compare common dietary choices in each region for a key meal—breakfast.

North America

The people of the United States and Canada consume a wide variety of food. Throughout both countries, people enjoy eating all kinds of cuisine from barbecue, pizza, peanut butter sandwiches, and pie to sushi, tacos, chow mein, and roti (an Indian flatbread). This is partly due to the influence of immigration. As people emmigrated to North America, they brought their dietary differences with them. In the 1800s, for example, Italian immigrants continued to cook spaghetti, pesto, and other cultural dishes after arriving in the United States. Today, Italian cuisine is enjoyed by many Americans from all backgrounds.

The variety of North American cuisine has also been impacted by regional variations. For example, fried chicken, cornbread, and sweet tea are popular in the southern states, while clam chowder, lobster rolls, and apple cider are enjoyed in New England. Also, as more people seek to support sustainable agriculture, locally grown crops and whole-food cooking practices often factor into what Americans eat and how they eat it.

Breakfast in North America

Meals can vary widely from one region of the world to another. Therefore, it can be interesting and informative to compare the choices made for a particular meal around the globe. Throughout this section, we will explore the kinds of foods that people consume as they begin their day. Breakfast is a vital meal in any part of the world because it breaks the long overnight fast. An adequate breakfast also provides fuel for the first part of the day and helps improve concentration and energy levels.

Let's begin with breakfast in North America. On weekdays, North Americans often eat breakfast in a hurry or on the go. Therefore, many people choose breakfast foods that are quick and easy to prepare or can be eaten during the trip to school or the office. As a result, breakfast cereals with milk are extremely popular, and also oatmeal, toast, or bagels. However, on the weekends, some people spend a longer time enjoying a hearty breakfast or going out for brunch. Typical choices emphasize hot foods and include egg dishes, such as omelettes and scrambled or fried eggs, along with pancakes, waffles, french toast, bacon or sausage, and orange juice, coffee, or tea to drink.

Central and South America

Both Central America and South America feature cuisines with rich Latin flavors. In addition, rice and corn are staples in both and form the basis for many dishes. Both regions are also affected by the mixture of influences from the native populations and the cultural traditions brought by Spanish and Portuguese immigrants during the 1600s and beyond.

South America has a diverse population, which is reflected in dietary choices across the continent. The northwestern region boasts some of the most exotic food in Latin America. In northeastern South America, many dishes feature a contrast of sweet and salty tastes, including raisins, prunes, capers, and olives. Also, rice grown in the area and seafood off the coast are key ingredients in South American-style paella. The north central part of the continent reflects a Spanish influence. Many of the dominant spices—cumin, oregano, cinnamon, and anise—came from Spain, along with orange and lime juices, wine, and olive oil. The south is cattle country and the locals enjoy grass-fed beef cooked in the form of asados, which are large cuts roasted in a campfire. Another popular meat dish is parrilladas, which are thick steaks grilled over oak.Cooking Light. “South American Cuisine.” © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/south-american-cuisine -00400000001391/.

From Mexico in the North to Panama in the South, Central American cuisine features some of the world’s favorite foods, including rice, beans, corn, peppers, and tropical fruits. This area combines a variety of culinary traditions derived from the native Maya and Aztec populations, arrivals from Spain, and African and Latin-influenced neighbors along the Caribbean. In this region of the world, tamales are common. Spicy seasonings, including hot chili peppers, are also very popular.

Typical Southern and Central American Foods

Typical foods in South and Central America include quinoa, which is a grain-like crop that is cultivated for its edible seeds. Quinoa has a high protein and fiber content, is gluten-free, and is particulary tasty cooked in pilafs. Another popular grain product is the tortilla, which is a flatbread made from wheat or corn. Tortillas are used to make a number of dishes, including burritos, enchiladas, and tacos. Fruits and vegetables that are common in Mexico, Central America, and South America include corn, avocados, yucca, peppers, potatoes, mangoes, and papayas. Rice, beans, and a soft cheese known as queso fresco are common to the cuisine in this area of the world as well.



Figure 7.9.1: Tamales, which are popular in Mexico and parts of Central and South America, are made from a shell called a masa that is stuffed with meat or vegetables and steamed or boiled in a wrapper of dried corn leaves. The wrapping is discarded prior to eating. Salvadorean tamales shown above are made in banana or plantain leaves, and the masa (corn meal) is often seasoned with chicken stock. (Public Domain; Ll1324).

Breakfast in Central America

In this region, the first meal of the day commonly includes huevos rancheros (fried eggs served over a tortilla and topped with tomato sauce). Other popular breakfast dishes include pan dulce (a sweetened bread), along with fried plantains, and a spicy sausage called chorizo. The typical beverage is coffee, which is available in many forms, including café con leche (which is sweetened with lots of milk) and café de olla (with cinnamon and brown sugar). Hot chocolate is also popular and tends to be thick, rich, and flavored with spices such as cinnamon or achiote. In the Yucatan region, huevos motulenos are prepared by spreading refried beans onto fresh tortillas with fried eggs, peas, chopped ham, and cheese.

Europe

European cuisine is extremely diverse. The diet in Great Britain is different from what people typically consume in Germany, for example. However, across the continent, meat dishes are prominent, along with an emphasis on sauces. Potatoes, wheat, and dairy products are also staples of the European diet.

The nations along the Mediterranean Sea are particularly renowned for their flavorful food. This part of the world boasts a number of famous dishes associated with their countries of origin. They include Italy's pasta, France's coq au vin, and Spain's paella.

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Italy

Although Italy is a relatively small nation, the difference in cuisine from one region to another can be great. For example, the people of northern Italy tend to rely on dairy products such as butter, cream, and cheeses made from cow's milk, because the land is flatter and better suited to raising cattle. In southern Italy, there is greater reliance on olive oil than butter, and cheeses are more likely to be made from sheep's milk.Cooking Light. "Regional Italian Cuisine." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/regional-italian-cuisine -00400000001340/.

However, there are a number of common ingredients and dishes across the country. Italian cuisine includes a variety of pasta, such as spaghetti, linguine, penne, and ravioli. Other well-known dishes are pizza, risotto, and polenta. Italians are also known for cooking with certain spices, including garlic, oregano, and basil.

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France

For centuries, the French have been famous for their rich, extravagant cuisine. Butter, olive oil, pork fat, goose fat, and duck fat are all key ingredients. Common French dishes include quiche, fondue, baguettes, and also creams and tarts. Frites, or French fries, are cut in different shapes and fried in different fats, depending on the region. Fresh-baked bread is also found across the nation from the skinny baguettes of Paris to the sourdough breads in other parts of the country.

Every region of France seems to have its version of coq au vin (braised chicken most often cooked with garlic, mushrooms, and pork fat in wine). For instance, in the northeast, the dish is prepared a la biere (in beer). In Normandy in the northwest, coq au vin is cooked au cidre (in apple cider).Cooking Light. "France's Regional Cuisine." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/frances-regional-cuisine -00400000001365/.

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Spain

One of the most popular Spanish dishes is paella, a gumbo of rice, seafood, green vegetables, beans, and various meats. The ingredients can vary wildly from one region to another, but rice is always the staple of the dish. Spain is also renowned for its tapas, which are appetizers or snacks. In restaurants that specialize in preparing and serving tapas, diners often order a number of different dishes from a lengthy menu and combine them to make a full meal.

Cooks in Spain rely on a variety of olive oils known for their flavors, ranging from smooth and subtle to fruity and robust. Spanish cuisine combines Roman, Moorish, and New World flavors. Key ingredients include rice, paprika, saffron, chorizo, and citrus fruits.Cooking Light. "Spanish Flavor." © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/world-cuisine/specialties-spanish -00400000001203/.

Video 16.8.1: The Mediterranean Diet

This video shows the cultural history of the cuisine enjoyed by many people who live in the Mediterranean region of Europe.(click to see video)

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Breakfast in Europe

In some countries, such as France, Italy, and Belgium, coffee and bread are common breakfast foods. However, the people of Great Britain and Ireland tend to enjoy a bigger breakfast with oatmeal or cold cereal, along with meats like bacon and sausage, plus eggs and toast. Tea is also popular in this area, not only for breakfast, but throughout the day. The continental-style breakfast is most

commonly associated with France and includes fresh-baked croissants, toast, or a rich French pastry called brioche, along with a hot cup of tea, coffee, or café au lait.

Africa

The continent of Africa is home to many different countries and cultural groups. This diversity is reflected in the cuisine and dietary choices of the African people. Traditionally, various African cusines combine locally grown cereals and grains, with fruits and vegetables. In some regions, dairy products dominate, while in others meat and poultry form the basis of many dishes.

Ethiopia

Ethiopia, located along the Horn of Africa, is one of the few African countries never colonized by a foreign nation prior to the modern era. So, outside influences on the culture were limited. Religious influences from Jewish, Islamic, and Catholic traditions played a larger role on the shaping of Ethiopian cuisine, because of the need to adhere to different dietary restrictions. For example, approximately half of Ethiopians are Muslim and must abstain from eating pork or using spices and nuts to flavor dishes. Ethiopia is also known for dishes that use local herbs and spices, including fenugreek, cumin, cardamom, coriander, saffron, and mustard. Many dishes also reflect a history of vegetarian cooking since meat was not always readily available.Cooking Light. “Ethiopian Tastes.” © 2012 Time Inc. Lifestyle Group. http://www.cookinglight.com/food/vegetarian/ethiopian-tastes-00400000037116/.

In addition, Ethiopians use their hands to eat. First, diners tear off pieces of injera, a spongy, tangy flatbread made from teff flour. Then, they use the pieces as utensils to scoop up vegetables, legumes, and meats from a communal plate.Ethiopian Restaurant.com. “Injera.” © 2004–2012. http://www.ethiopianrestaurant.com/injera.html Teff is a grass that grows in the highlands of Ethiopia and is a staple of the diet.

Central and West Africa

Stretching from mountains in the north to the Congo River, Central Africa primarily features traditional cuisine. Meals are focused on certain staples, including cassava, which is a mashed root vegetable, and also plantains, peanuts, and chili peppers. In West Africa, which includes the Sahara Desert and Atlantic coast, the cuisine features dishes made from tomatoes, onions, chili peppers, and palm nut oil. Popular dishes in both regions include stews and porridges, such as ground nut stew made from peanuts, and also fufu, a paste made from cassava or maize.

Breakfast in Africa

African breakfast choices are strongly influenced by the colonial heritage of a region. The people of West Africa typically enjoy the French continental-style breakfast. However, in the eastern and southern parts of the continent, the traditional English breakfast is more common. In North Africa, breakfast is likely to include tea or coffee, with breads made from sorghum or millet. In East and West Africa, a common breakfast dish is uji, a thick porridge made from cassava, millet, rice, or corn. Kitoza is a delicacy made from dried strips of beef that are eaten with porridge in Madagascar. In Algeria, French bread, jam, and coffee is a typical breakfast. The people of Cameroon eat beignets, which is a doughnut eaten with beans or dipped in a sticky, sugary liquid called bouilli.

Asia

Asia is a massive continent that encompasses the countries of the Middle East, parts of Russia, and the island nations of the southeast. Due to this diversity, Asian cuisine can be broken down into several regional styles, including South Asia, which is represented for our purposes here by India, and East Asia which is represented for our purposes by China, Korea, and Japan. Even with this variety, the Asian nations have some dietary choices in common. For example, rice is a staple used in many dishes across the continent.

India

In India, there is much variety between the different provinces. The nation's many kinds of regional cuisines can date back thousands of years and are influenced by geography, food availability, economics, and local customs. However, vegetarian diets are common across the nation for religious reasons, among others. As a result, Indian dishes are often based on rice, lentils, and vegetables, rather than meat or poultry. Indian cooking also features spicy seasonings, including curries, mustard oil, cumin, chili pepper, garlic, ginger, and garam masala, which is a blend of several spices.Curry Dishes.com. "Guide to Easy Indian Recipes, Curry Recipes and Curry Spices." © 2009. www.currydishes.com/. India is also known for its breads, including the flatbreads roti and chapati. Dishes that are popular not only in India but around the world include samosa, a potato-stuffed pastry; shahi paneer, a creamy curry dish made out of soft cheese and tomato sauce; and chana masala, chickpeas in curry sauce.Food-India.com. "Your Guide to Indian Food." © 2003–2011. http://www.food-india.com/.

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China

China has the world's most sizable population. As a result, there are many different culinary traditions across this vast country, which is usually divided into eight distinct cuisine regions. For example, Cantonese cuisine, which is also known as Guangdong, features light, mellow dishes that are often made with sauces, including sweet-and-sour sauce and oyster sauce. Cantonese-style cuisine has been popularized in Chinese restaurants around the world. Another cuisine is known as Zhejiang, which is often shortened to Zhe, and originates from a province in southern China. It features dishes made from seafood, freshwater fish, and bamboo shoots.eChinacities.com. "China's Eight Cuisines Revealed and How to Identify Them." ©2008–2011 www.echinacities.com/expat-corner/china-s-8-cuisines-revealed -and-how-to-indentify-them.html Key ingredients that are used in several, but not all, of the different regions include rice, tofu, ginger, and garlic. Tea is also a popular choice in most parts of the country.

Chinese use chopsticks as utensils. These small tapered sticks can be made from a variety of materials, including wood, plastic, bamboo, metal, bone, and ivory. Both chopsticks are held in one hand, between the thumb and fingers, and are used to pick up food.

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Korea

Korean cuisine is primarily centered around rice, vegetables, and meat. Commonly-used ingredients include sesame oil, soy sauce, bean paste, garlic, ginger, and red pepper. Most meals feature a number of side dishes, along with a bowl of steam-cooked, short grain rice. Kimchi, a fermented cabbage dish, is the most common side dish served in Korea and is consumed at almost every meal. Another signature dish, bibimbap, is a bowl of white rice topped with sautéed vegetables and chili pepper paste and can include egg or sliced meat. Bulgogi consists of marinated, barbecued beef.Korea Tourism Organization. "Food in Korea." Accessed October 10, 2011. visitkorea.or.kr/enu/1051_Food.jsp.

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Japan

As in other parts of Asia, rice is a staple in Japan, along with seafood, which is plentiful on this island nation. Other commonly-used ingredients include noodles, teriyaki sauce, dried seaweed, mushrooms and other vegetables, meat, and miso, which is soybean paste. Some favorite foods include the raw fish dishes sashimi and sushi, which are not only popular in Japan, but are also around the world. Typical beverages include green tea and also sake, which is a wine made of fermented rice.Web MD. "Diets of the World: The Japanese Diet." © 2005–2011. http://www.webmd.com/diet/features/diets-of-world-japanese-diet.

The traditional table setting in Japan includes placing a bowl of rice on the left and a bowl of miso soup on the right side. Behind the rice and the soup are three flat plates which hold the accompanying side dishes. Similar to China, chopsticks are used in Japan and are generally placed at the front of the table setting. At school or work, many Japanese people eat out of a bento lunch box, which is a single-portion takeout or home-cooked meal. Bento boxes typically include rice, fish or meat, and cooked or pickled vegetables.

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The Middle East

Middle Eastern cuisine encompasses a number of different cooking styles from Asian countries along the Mediterranean, as well as from North African nations, such as Egypt and Libya. In this part of the world, lamb is the most commonly consumed meat and is prepared in a number of ways, including as a shish kebab, in a stew, or spit-roasted. However, kosher beef, kosher poultry, and fish are eaten as well. Other staples include the fruits and vegetables that grow in the hills of many Middle Eastern countries, such as dates, olives, figs, apricots, cucumber, cabbage, potatoes, and eggplant. Common grains include couscous, millet, rice, and bulghur. Popular dishes include Syrian baba ganoush, which is pureed eggplant, and kibbeh, or lamb with bulghur wheat, from Lebanon.Saveur. “Middle Eastern Recipes.” Accessed December 5, 2011. www.saveur.com/solrSearchResults.jsp?fq=Cuisine:Middle\%20Eastern& sitesection=recipes. A flatbread called pita served with hummus, or pureed chickpeas, is another popular dish in this region of the world.

Most people who reside in the Arab countries of the Middle East are Muslim, which can affect their diet. Many Muslims do not consume alcohol or pork. They also observe certain diet-related religious traditions, such as a daytime fast during the month of Ramadan. Other residents of the Middle East include Jews and Christians, and their traditions also affect what foods they eat and how they prepare it. For example, many Jews in Israel keep kosher and follow a set of dietary laws that impact food choices, storage, and preparation.

Breakfast in Asia

To continue the comparison of breakfast around the world, let’s examine the first meal of the day in many parts of Asia. In India, the first meal of the day commonly includes eggs scrambled with spices, potatoes, and onions, as well as fresh fruit and yogurt. Breakfast in China often consists of rice complemented by vegetables, meat, or fish. In Korea, a traditional breakfast would include soup made of either beef ribs or pork intestines, a selection of bread and pastries, rice, and kimchi, which is believed to promote intestinal health. Breakfast in Japan does not greatly differ from any other meal. It typically consists of a bowl of steamed white rice, a small piece of fish, a bowl of miso soup with tofu, vegetables, green tea, and occasionally pickled plums called umeboshi. Hot bowls of noodles in broth topped with pork slices, scallions, and bamboo shoots are also common.



Figure 7.9.2: In the different regions of China, congee is prepared with various types of rice, which results in different consistencies. In Japan, Nanakusa-gayu (七草粥), seven-herb porridge. (CC BY-SA 3.0; Blue Lotus).

Congee is a common breakfast food across Asia. This dish is a porridge made of rice that is consumed in a number of Asian countries, including Vietnam, Thailand, Burma, and Bangladesh. Congee can be prepared both savory and sweet and contain a variety of ingredients, usually meats, vegetables, and herbs. It can be eaten alone or served as a side dish.

The Diversity of Palates and Habits

Around the globe, people enjoy different foods and different flavors. In some cultures, the main dishes are meat-based, while others focus on plant-based meals. You can also find different staples in different regions of the world, including rice, potatoes, pasta,

corn, beans, root vegetables, and many kinds of grains. Different flavors are also popular on different parts of the planet, from sweet to salty to sour to spicy.

Food Availability

People tend to eat what grows or lives nearby. For example, people in coastal areas tend to consume more seafood, while those in inland areas tend to structure their diet around locally-grown crops, such as potatoes or wheat. In many developing countries, a large part of the diet is composed of cereal grains, starchy roots, and legumes. However, a number of common staples are consumed worldwide, including rice, corn, wheat, potatoes, cassava, and beans.

Income and Consumption

In addition to regional dissimilarities in diets, income also plays a major role in what foods people eat and how they prepare them. The average global calorie consumption has increased to record levels in recent years. This is a consequence of rising incomes, which have allowed consumers in many regions to expand both the variety and the quantity of food they eat. Among developing countries, the daily intake of calories per person rose by nearly 25 percent from the early 1970s to the mid-1990s.US Department of Agriculture, Foreign Agricultural Service. “Diets Around the World: How the Menu Varies.” Last modified October 14, 2004. www.fas.usda.gov/info/agexporter/2000/Apr/diets.htm.' Centers for Disease Control and Prevention. “Caloric Consumption on the Rise in the United States, Particularly Among Women.” NCHS Press Room, February 5, 2004. http://www.cdc.gov/nchs/pressroom/04news/calorie.htm. People in the western world were able to increase their consumption of meat and poultry, fruits and vegetables, and fats and oils. However, those gains were minimal in the poorest countries, where many continue to struggle with hunger and a limited diet.US Department of Agriculture, Foreign Agricultural Service. “Diets Around the World: How the Menu Varies.” Last modified October 14, 2004. www.fas.usda.gov/info/agexporter/2000/Apr/diets.htm.

Different Ways of Eating

People from different parts of the world consume their food in different ways and what is common in one country may be considered impolite in another. For example, in some areas people eat with their fingers, while in others using a fork is much more acceptable. In some regions of the world, people slurp their soup, while in others they quietly sip it. In some places, diners eat off of individual plates, while in others people sit at a table with a large communal plate from which everyone eats.

No matter where you travel, you will find that food production, purchase, and preparation affect all facets of life, from health and economics to religion and culture. Therefore, it is vital for people from all walks of life to consider the choices they make regarding food, and how those decisions affect not only their bodies, but also their world. Alice Waters, an influential chef and founder of the nonprofit program Edible Schoolyard, as well as an advocate for sustainable production and consumption, has said, “Remember food is precious. Good food can only come from good ingredients. Its proper price includes the cost of preserving the environment and paying fairly for the labor of the people who produce it. Food should never be taken for granted.”Waters, A. “The Art of Eating.” PlanetGreen.com. March 31, 2009. http://planetgreen.discovery.com/feature/earth-day/alice-waters-eat-green.html.

Video 16.8.2: Alice Waters: Edible Education

In this video, Edible Schoolyard founder Alice Waters talks about the value of growing a garden and learning about food.(click to see video)

Key Takeaways

Many people around the world have access to a wide variety of food and can prepare it any way they choose. However, cuisine remains strongly influenced by location, culture, tradition, and economics. People from all cultures and all walks of life should consider the choices they make regarding food, and how those decisions affect not only their bodies, but also the world.

Discussion Starter

1. Compare and contrast breakfast in different parts of the world. What are common attitudes about the first meal of the day? How are the choices that people make the same? How are they different? Are there any breakfast dishes in common?

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7.10: Why Make Dietary Changes?

Big Idea

A groundbreaking study revealed the risk factors that can affect heart health.

The terms *risk factor*, *good cholesterol*, and *bad cholesterol* were not always on the tip of everyone's tongue when it came to cardiovascular disease. In fact, at one time doctors didn't even consider the concept of managing cholesterol levels to prevent heart disease. However, that was more than fifty years ago, before the Framingham Heart Study became one of the most important epidemiological studies in American health history. Conducted by what is now known as the National Heart, Lung, and Blood Institute in Massachusetts, the study changed the way healthcare professionals and consumers alike regard the prevention of heart disease.Framingham Heart Study. "History of the Framingham Heart Study." © 2011. www.framinghamheartstudy.org/about/history.html.



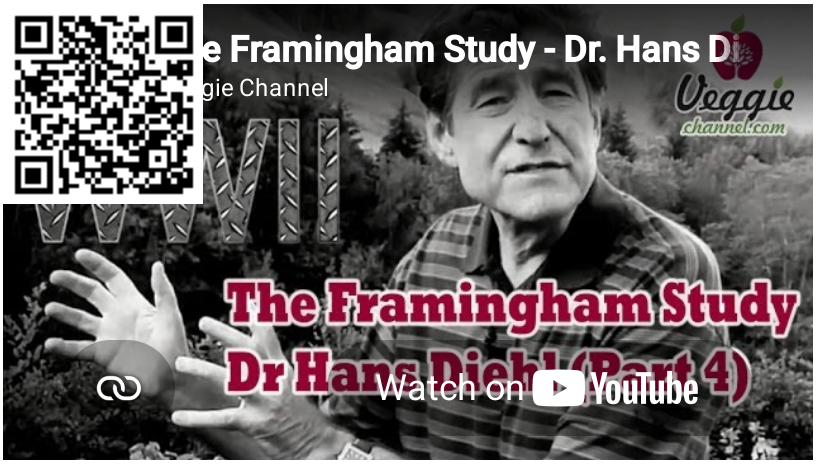
Figure 7.10.1: Scientific evidence continues to correlate the relationship between good dietary habits, adequate exercise, and a healthy body. Lance Corporal Anthony M. Madonia emerges from the water during the swimming portion of the triathlon. Marines and Sailors of Marine Security Company and the Naval Support Facility in Thurmont, Maryland, participated in the Catoctin Mountain Triathlon July 20, 2005. Image is Public Domain.

In the 1940s, little was known about the general causes of heart disease and stroke. Most doctors thought a hardening of the arteries was a natural part of aging, and that rising blood pressure with age was not a serious issue. Yet, the death rates for cardiovascular disease had been increasing steadily since the early 1900s and had become an American epidemic. Growing concern led the US Public Health Service to commission a study to determine which biologic and environmental factors were behind the growing problem. The objective was to follow the development of cardiovascular disease over a long period of time in a large group of participants who had not yet developed overt symptoms. Researchers believed this approach would enable them to identify common characteristics and factors.

In 1948, researchers enrolled more than five thousand participants between ages thirty and sixty-two from Framingham, Massachusetts. The participants returned to the study every two years for a detailed medical examination and laboratory tests. In 1971, the Framingham Heart Study enrolled a second generation—the original participants' adult children and their spouses. In 2002, a third generation—the grandchildren of the original group—joined the study. Recognizing the need to establish a new study reflecting a more diverse population, an additional group of participants was selected in 1994.Framingham Heart Study. "History of the Framingham Heart Study." © 2011. www.framinghamheartstudy.org/about/history.html.

The findings of these extensive, long-term studies have created a treasure trove of data for scientists that has revolutionized the way our nation looks at heart disease. The results revealed high blood pressure, diabetes, cholesterol, and LDL cholesterol in particular, as risk factors for heart disease. The study also identified lifestyle choices as factors which increased the risk of cardiovascular disease, including eating an unhealthy diet, remaining sedentary, and smoking. By utilizing new diagnostic technologies, the Framingham Study continues to make important strides in learning about heart disease. Framingham investigators also collaborate with leading researchers from around the world on projects related to osteoporosis, arthritis, and diabetes. In addition, they have

initiated the Framingham Nutrition Studies, which examine the connection between diet and nutrition to the risk and outcomes of cardiovascular disease. The discoveries of Framingham researchers can help discern opportunities for preventive nutrition intervention.Framingham Heart Study. “History of the Framingham Heart Study.” © 2011. www.framinghamheartstudy.org/about/history.html.



Video 16.9.1: *The Framingham Study. Dr. Hans Diehl discusses the driving forces behind the Framingham Heart Study. (click to see video)*

You Decide

Are you ready to make the necessary changes to achieve optimal health?

How will you benefit from the knowledge about nutrition that you have gained thus far? The link between good nutrition and good health is an undebatable scientific fact. Given the consequences of poor dietary choices and lifestyle habits, it is worthwhile to assess your current food and activity profile to determine areas for improvement. It is important to remember that there are no quick fixes, but with dedication, hard work, and persistence, much can be accomplished. Of course, giving up what we once found enjoyable may not be the easiest task. In fact, it can be very hard to develop new thinking patterns that will translate into better dietary and lifestyle choices. Are you willing to put forth the effort necessary to create change in your life? As you read this chapter, you will be presented with tools and concepts to help you with this task. After that, it will be up to you.

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7.11: Nutrition and Your Health

Learning Objectives

- Relate the research on home-cooked family meals to comprehensive health and wellness, taste, sustainability, and the strengthening of family bonds

The adage, “you are what you eat,” seems to be more true today than ever. In recent years, consumers have become more conscientious about the decisions they make in the supermarket. Organically grown food is the fastest growing segment of the food industry. Also, farmers’ markets and chains that are health-food-oriented are thriving in many parts of North America. Shoppers have begun to pay more attention to the effect of food on their health and well-being. That includes not only the kinds of foods that they purchase, but also the manner in which meals are cooked and consumed. The preparation of food can greatly affect its nutritional value. Also, studies have shown that eating at a table with family members or friends can promote both health and happiness.

Family Meals

In the past, families routinely sat down together to eat dinner. But in recent decades, that comfortable tradition has fallen by the wayside. In 1900, 2 percent of meals were eaten outside of the home. By 2010, that figure had risen to 50 percent. Mark Hyman, MD, “How Eating at Home Can Save Your Life,” Huffington Post.com, 9 January 2011. http://www.huffingtonpost.com/dr-mark-hyman/family-dinner-how _b_806114.html? Today, family members often go their own way at mealtimes and when they do sit down together, about three times a week, the meal often lasts less than twenty minutes and is spent eating a microwaved meal in front of a television.

However, recent studies have shown that home-cooked, family meals really matter. Family meals usually lead to the consumption of healthy food packed with nutrition, rather than an intake of empty calories. Other benefits include strengthening familial bonds, improving family communication, and helping young children learn table manners. Increased frequency of family meals has also been associated with certain developmental assets, such as support, boundaries and expectations, commitment to learning, positive values, and social competency.Rochford, M. “Do Family Meals Still Matter?” *Visions: Family and Community Health Sciences* (Rutgers University) 21, no. 3 (2009).

Home-prepared meals provide an opportunity for more balanced and better-portioned meals with fewer calories, sodium, and less saturated fat. When families prepare food together, parents or caregivers can also use the time to teach children about the ways their dietary selections can affect their health.

The Adolescent Diet

Teenagers’ dietary choices are influenced by their family’s economic status, the availability of food inside and outside the home, and established traditions. Studies have found links between the prevalence of family meals during adolescence and the establishment of healthy dietary behaviors by young adulthood. Yet, many of today’s teenagers make food selections on their own, which often means eating junk food or fast food on the go.

However, adolescents who regularly consume family meals or have done so in the past are more likely to eat breakfast and to eat more fruits and vegetables. Research has shown that adolescents who have regular meals with their parents are 42 percent less likely to drink alcohol, 50 percent less likely to smoke cigarettes, and 66 percent less likely to use marijuana. Regular family dinners also help protect teens from bulimia, anorexia, and diet pills. In addition, the frequency of family meals was inversely related to lower academic scores and incidents of depression or suicide.Mark Hyman, MD, “How Eating at Home Can Save Your Life,” Huffington Post.com, 9 January 2011. http://www.huffingtonpost.com/dr-mark-hyman/family-dinner-how _b_806114.html?

Sustainable Eating

As discussed at the beginning of this chapter, sustainable agricultural practices provide healthy, nutritious food for the consumers of today, while preserving natural resources for the consumers of tomorrow. Sustainability not only has economic and

environmental benefits, but also personal benefits, including reduced exposure to pesticides, antibiotics, and growth hormones. Sustainable eaters do all of the following:

- **Consume less processed food.** People who eat sustainably focus on whole foods that are high in nutritive value, rather than heavily processed foods with lots of additives.
- **Eat more home-cooked meals.** Sustainable eaters go out to restaurants less often, and when they do, they dine at establishments that provide dishes made from whole-food ingredients.
- **Consume a plant-based diet.** Research has shown that a plant-based diet, focused on whole grains, vegetables, fruits, and legumes, greatly reduces the risk of heart disease.
- **Buy organic food products.** Organically produced foods have been cultivated or raised without synthetic pesticides, antibiotics, or genetic engineering. Certified organic foods can be identified by the USDA's stamp.
- **Buy locally grown foods.** Buying locally benefits the environment by reducing the fossil fuels needed to transport food from faraway places. Also, farmers keep eighty to ninety cents for every dollar spent at a farmer's market.

Disease Prevention and Management

Eating fresh, healthy foods not only stimulates your taste buds, but also can improve your quality of life and help you to live longer. As discussed, food fuels your body and helps you to maintain a healthy weight. Nutrition also contributes to longevity and plays an important role in preventing a number of diseases and disorders, from obesity to cardiovascular disease. Some dietary changes can also help to manage certain chronic conditions, including high blood pressure and diabetes. A doctor or a nutritionist can provide guidance to determine the dietary changes needed to ensure and maintain your health.

Heart Health

According to the WHO, cardiovascular disease is the leading cause of death on the planet.World Health Organization. "The Top 10 Causes of Death." Accessed http://www.who.int/mediacentre/factsheets/fs310/en/. However, a healthy diet can go a long way toward preventing a number of conditions that contribute to cardiovascular malfunction, including high levels of blood cholesterol and narrowed arteries. As discussed in this text, it is extremely helpful to reduce the intake of trans fat, saturated fat, and sodium. This can considerably lower the risk of cardiovascular disease, or manage further incidents and artery blockages in current heart patients. It is also beneficial to eat a diet high in fiber and to include more omega-3 fatty acids, such as the kind found in mackerel, salmon, and other oily fish.

High Blood Pressure

Blood pressure is the force of blood pumping through the arteries. When pressure levels become too high, it results in a condition known as hypertension, which is asymptomatic but can lead to a number of other problems, including heart attacks, heart failure, kidney failure, and strokes. For people with high blood pressure, it can be beneficial to follow the same recommendations as those for heart patients. First of all, it is crucial to reduce the intake of sodium to prevent pressure levels from continuing to rise. It can also be helpful to increase potassium intake. However, patients should check with a doctor or dietitian first, especially if there are kidney disease concerns.

Tools for Change

The Dietary Approaches to Stop Hypertension, or DASH diet, is highly recommended to lower blood pressure. This program promotes an increased intake of potassium and calcium by emphasizing fruits, vegetables, whole grains, low-fat dairy products, and limited amounts of lean meat. The DASH diet also decreases the intake of saturated fat and sugar. Studies have shown that blood-pressure patients on the DASH diet were able to reduce their diastolic pressure levels (the lower measurement, which is taken between beats when the heart is relaxed) by up to 5 mmHg regardless of age, gender, or ethnicity. You can learn more about the DASH diet at http://dashdiet.org/.

Diabetes

The rising rates of diabetes have triggered a health crisis in the United States and around the world. In diabetics, the levels of blood glucose, or blood sugar, are too high because of the body's inability to produce insulin or to use it effectively. There are two types of this disease. Although the causes of Type 1 diabetes are not completely understood, it is known that obesity and genetics are major factors for Type 2.

Nutrition plays a role in lowering the risk of Type 2 diabetes or managing either form of the disease. However, it is a myth that there is one diabetes diet that every patient should follow. Instead, diabetics should keep track of the foods they consume that contain carbohydrates to manage and control blood-glucose levels. Also, a dietitian can help patients create a specific meal plan that fits their preferences, lifestyle, and health goals.

The Crisis of Obesity

Excessive weight gain has become an epidemic. According to the National Institutes of Health, over two-thirds of American adults are overweight, and one in three is obese. Obesity in particular puts people at risk for a host of complications, including Type 2 diabetes, heart disease, high cholesterol, hypertension, osteoarthritis, and some forms of cancer. The more overweight a person is, the greater his or her risk of developing life-threatening complications. There is no single cause of obesity and no single way to treat it. However, a healthy, nutritious diet is generally the first step, including consuming more fruits and vegetables, whole grains, and lean meats and dairy products.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Overweight and Obesity Statistics." *NIH Publication No. 04-4158.* Updated February 2010. win.niddk.nih.gov/publications/PDFs/stat904z.pdf.

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Kidney Disease

Chronic kidney failure is the gradual loss of kidney function and can cause dangerous levels of fluid and waste to build up in the body. Nutrition is very important in managing end-stage renal disease, and a patient with this condition should discuss a meal plan with a dietitian and physician. Certain macro- and micronutrients will need to be monitored closely, including protein, potassium, sodium, and phosphorus. Kidney patients must also keep track of their caloric intake and dietitians may recommend consuming more fast-releasing carbohydrates and low-saturated fats to boost the number of calories consumed each day.

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Cancer

Certain cancers are linked to being overweight or obese. Additionally, some foods are related to either an increased or decreased risk for certain cancers. Foods linked to decreased cancer risk include whole grains, high-fiber foods, fruits, and vegetables. Foods linked to increased cancer risk include processed meats and excess alcohol.

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Digestive Disorders

Digestive disorders can include constipation, heartburn or gastroesophageal reflux disease, inflammatory bowel disease, including Crohn's and ulcerative colitis, and irritable bowel syndrome. These disorders should be addressed with a physician. However, for many of them, diet can play an important role in prevention and management. For example, getting enough fiber and fluids in your diet and being active can help to alleviate constipation.

Key Takeaways

More and more consumers are weighing nutritional considerations as they choose which foods to purchase and prepare for their families. Studies have shown that family meals and home-cooked food not only benefit a person's health, but also their overall well-being. Family meals lead to the consumption of healthy food, tighter familial bonds, improved communication, and the teaching of table manners to young children. Diet plays a key role in the prevention and management of many chronic conditions or diseases, such as hypertension and diabetes.

Discussion Starter

1. What would you recommend to help people who are struggling with diabetes? What tips would you provide? What lifestyle changes might help? Use the dietary guidelines at the Mayo Clinic's website to help provide specific suggestions.

http://www.mayoclinic.com/health/diabetes-diet/DA00027.

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7.12: Diet Trends and Health

Learning Objectives

- Identify and describe the nutritional pros and cons of diets and food trends.
- Discuss the role of dietary supplements and the importance of using food as your primary nutritional source.

In the past, health was regarded merely as the absence of illness. However, a growing understanding of the complexity and potential of the human condition has prompted a new way of thinking about health. Today, we focus on the idea of wellness, which involves a great deal more than just not being sick. Wellness is a state of optimal well-being that enables an individual to maximize their potential. This concept includes a host of dimensions—physical, mental, emotional, social, environmental, and spiritual—which affect one's quality of life.University of Illinois at Urbana-Champaign, McKinley Health Center. "What Is Wellness?" © 2011 The Board of Trustees of the University of Illinois at Urbana-Champaign. www.mckinley.illinois.edu/Units/Health_Ed/wellness.htm. Striving for wellness begins with an examination of dietary choices.

Dietary Food Trends

Hundreds of years ago, when food was less accessible and daily life required much more physical activity, people worried less about obesity and more about simply getting enough to eat. In today's industrialized nations, conveniences have solved some problems and introduced new ones, including the hand-in-hand obesity and diabetes epidemics. Fad diets gained popularity as more North Americans struggled with excess pounds. However, new evidence-based approaches that emphasize more holistic measures are on the rise. These new dietary trends encourage those seeking to lose weight to eat healthy, whole foods first, while adopting a more active lifestyle. These sound practices put dietary choices in the context of wellness and a healthier approach to life.

Functional Foods

Many people seek out foods that provide the greatest health benefits. This trend is giving rise to the idea of functional foods, which not only help meet basic nutritional needs but also are reported to fight illness and aging. According to the Academy of Nutrition and Dietetics (AND), formerly known as the The Academy of Nutrition and Dietetics, functional foods may reduce the risk of disease or promote optimal health. The AND recognizes four types of functional foods.The Academy of Nutrition and Dietetics. "Functional Foods." *J Am Diet Assoc* 109, no. 4 (April 2009): 735–46. www.eatright.org/About/Content.aspx?id=8354. They are: conventional foods, modified foods, medical foods, and special dietary use foods.

The first group, **conventional foods**, represents the simplest form of functional foods. They are whole foods that have not been modified. Examples include whole fruits and vegetables (which are abundant in phytochemicals and antioxidants), yogurt and kefir (which contain natural probiotic bacteria that can help maintain digestive system health), and dark chocolate (which contains antioxidants).

Modified foods have been fortified, enriched, or enhanced with additional nutrients or bioactive compounds. Foods are modified using biotechnology to improve their nutritional value and health attributes. Examples of modified foods include calcium-fortified orange juice, breads enriched with B vitamins, iodized salt, cereals fortified with vitamins and minerals, margarine enhanced with plant sterols, and energy drinks that have been enriched with herbs (ginseng or guarana) or amino acids (taurine). It is important to consider that the health claims of some modified foods may be debatable, or entirely fraudulent. Check with a health professional regarding the effects of modified foods on your health.

Medical foods are designed for enteric administration under the guidance of a medical professional. (During enteric administration, food is treated so that it goes through the stomach undigested. Instead, the food is broken down in the intestines only.) Medical foods are created to meet very specific nutritional requirements. Examples of medical foods include liquid formulas for people with kidney disease, liver disease, diabetes, or other health issues. Medical food is also given to comatose patients through a gastronomy tube because they cannot eat by mouth.

Special dietary use foods do not have to be administered under a doctor's care and can be found in a variety of stores. Similar to medical foods, they address special dietary needs and meet the nutritional requirements of certain health conditions. For example, a bottled oral supplement administered under medical supervision is a medical food, but it becomes a special dietary use food when it

is sold to retail customers. Examples of special dietary use foods include gluten-free foods, lactose-free dairy products, and formulas and shakes that promote weight loss.

Popular Diets

The concept of functional foods represents initiatives aimed at addressing health problems. Certain diet plans take this concept one step further, by striving to prevent or treat specific conditions. For example, it is widely understood that people with diabetes need to follow a particular diet. Although some of these diet plans may be nutritionally sound, use caution because some diets may be fads or be so extreme that they actually *cause* health problems.Web MD. "Alternative Diet Programs: Topic Overview." Last modified June 30, 2009. http://www.webmd.com/diet/tc/alternative-diet-programs-topic-overview. Before experimenting with a diet, discuss your plans with your doctor or a registered dietitian. Throughout this section, we will discuss some of the more popular diets. Some fall under the category of fad diets, while others are backed by scientific evidence. Those that fall into the latter category provide a good foundation to build a solid regimen for optimal health.

The DASH Diet

The Dietary Approaches to Stop Hypertension, or DASH diet, focuses on reducing sodium intake to either 2,300 milligrams per day (as recommended by the *Dietary Guidelines for Americans*) or 1,500 milligrams per day. The DASH diet is an evidence-based eating plan that can help reduce high blood pressure. This plan may also decrease the risk of heart attack, stroke, diabetes, osteoporosis, and certain cancers.DASH Diet Oregon. "DASH Diet Eating Plan." © 2011 Nutrition Education Services/Oregon Dairy Council. http://www.dashdietoregon.org/. DASH tips to lower sodium include:

- Using spices instead of salt to add flavor
- Reading sodium content on processed or canned food labels, and choosing low-sodium options
- Removing some sodium from canned foods (such as beans) by rinsing the product before consumption
- Avoiding salt when cooking

DASH dieters eat lots of whole grains and high-fiber fruits and vegetables, and moderate amounts of low-fat dairy products, lean meats, and heart-healthy fish. In addition, DASH limits the use of saturated fats to less than 7 percent of total calories, and restricts the consumption of sweets and alcohol. The DASH diet also calls for consuming less added sugar and drinking fewer sugar-sweetened drinks. It replaces red meat with fish and legumes and calls for increased calcium, magnesium, potassium, and fiber. Also, even though some people on the DASH diet may find it lowers their HDL (good) cholesterol along with their LDL (bad) cholesterol, it still has a positive cumulative effect on heart health.DASH Diet Oregon. "DASH Diet Eating Plan." © 2011 Nutrition Education Services/Oregon Dairy Council. http://www.dashdietoregon.org/.

The Gluten-Free Diet

The gluten-free diet helps people whose bodies cannot tolerate **gluten**, a protein found in wheat, barley, and rye. One of the most important ways to treat this condition is to avoid the problematic foods, which is not easy. Although following a gluten-free diet is challenging, it is prescribed for patients with gluten intolerance and celiac disease, an autoimmune disorder with a genetic link. People who have celiac disease cannot consume gluten products without damaging their intestinal lining. Eating a gluten-free diet means finding replacements for bread, cereal, pasta, and more. It also means emphasizing fresh fruits, vegetables, and other foods without gluten. However, it is important to note that the gluten-free trend has become something of a fad even for those without a gluten intolerance. Celiac disease is a relatively rare condition found in only 1 percent of the population. Therefore, a gluten-free diet should be followed only with a physician's recommendation.

Low-Carb Diets

Low-carb diets, which include the Atkins Diet and the South Beach Diet, focus on limiting carbohydrates—such as grains, fruit, and starchy vegetables—to promote weight loss. The theory behind the low-carb diet is that insulin prevents the breakdown of fat by allowing sugar in the form of blood glucose to be used for energy. Proponents of this approach believe that because limiting carbs generally lowers insulin levels, it would then cause the body to burn stored fat instead. They believe this method not only brings about weight loss, but also reduces the risk factors for a number of conditions. However, some studies have shown that

people who followed certain low-carb diet plans for two years lost an average of nearly 9 pounds, which is similar to the amount of weight lost on higher carbohydrate diets.The Mayo Clinic. “Low-Carb Diet: Can It Help You Lose Weight?” Accessed December 21, 2011. http://www.mayoclinic.com/health/low-carb-diet/NU00279.

The benefits of this kind of diet include an emphasis on whole, unprocessed foods and a de-emphasis of refined carbohydrates, such as white flour, white bread, and white sugar. However, there are a number of downsides. Typically, the first two weeks allow for only 20 grams of carbs per day, which can be dangerously low. In addition, dieters using the low-carb approach tend to consume twice as many saturated fats as people on a diet high in healthy carbohydrates. Low-carb diets are also associated with a higher energy intake, and the notion that “calories don’t count,” which is prevalent in this kind of diet, is not supported by scientific evidence.Steele, V. “Health and Nutritional Effects of Popular Diets.” Kellogg Nutrition Symposium, The Team of Registered Dietitians & Nutrition Professionals at Kellogg Canada Inc. Insert to *Canadian Journal of Dietetic Practice and Research* 64, no. 3 (Fall 2003).

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The Macrobiotic Diet

The macrobiotic diet is part of a health and wellness regimen based in Eastern philosophy. It combines certain tenets of Zen Buddhism with a vegetarian diet and supports a balance of the oppositional forces *yin* and *yang*. Foods are paired based on their so-called yin or yang characteristics. Yin foods are thought to be sweet, cold, and passive, while yang foods are considered to be salty, hot, and aggressive.

Whole grains make up about 50 percent of the calories consumed and are believed to have the best balance of yin and yang. Raw and cooked vegetables comprise about 30 percent of the diet and include kale, cabbage, collards, bok choy, and broccoli on a daily basis, along with mushrooms and celery a few times a week. Bean or vegetable-based soups and broths can make up 5 to 10 percent of daily caloric intake. Additionally, the diet allows small amounts of fish and seafood several times a week, along with a few servings of nuts. The macrobiotic diet prohibits certain foods, such as chocolate, tropical fruits, and animal products, because they are believed to fall on the far end of the yin-yang spectrum, which would make it difficult to achieve a Zen-like balance.

The macrobiotic diet focuses on foods that are low in saturated fats and high in fiber, which can help to lower the risk of cardiovascular disease. Proponents of this diet also believe that it may protect against cancer. However, many nutritionists and healthcare providers express concerns, particularly if the diet is followed strictly. Extreme macrobiotic eating can be low in protein, low in calories, and pose a risk for starvation. In addition, the diet is also very low in essential vitamins and minerals.Zelman, K.M. “Macrobiotic Diet.” Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/macrobiotic-diet.

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The Mediterranean Diet

The traditional Mediterranean diet incorporates many elements of the dietary choices of people living in Greece and southern Italy. The Mediterranean diet focuses on small portions of nutritionally-sound food. This diet features food from plant sources, including vegetables, fruits, whole grains, beans, nuts, seeds, breads and potatoes, and olive oil. It also restricts the consumption of processed foods and recommends eating locally grown foods rich in micronutrients and antioxidants. Other aspects of this eating plan include consuming fish and poultry at least twice per week, eating red meat only a few times per month, having up to seven eggs per week, and drinking red wine in moderation and with meals. Unlike most diets, the Mediterranean diet does not cut fat consumption across the board. Instead, it incorporates low-fat cheese and dairy products, and it substitutes olive oil, canola oil, and other healthy oils for butter and margarine.

More than fifty years of nutritional and epidemiological research has shown that people who follow the Mediterranean diet have some of the lowest rates of chronic disease and the highest rates of longevity among the populations of the world. Studies have shown that the Mediterranean diet also helps to decrease excess body weight, blood pressure, blood fats, and blood sugar and insulin levels significantly.Kovacs, J. S. “Popular Diets of the World: The Mediterranean Diet.” Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/the-mediterranean-diet.

Tools for Change

For six years, researchers from the University of Bordeaux in France followed the dietary habits of more than seven thousand individuals age sixty-five and over. Participants who described greater consumption of extra-virgin olive oil reportedly lowered their risk of suffering a stroke by 41 percent. The study controlled for stroke risk factors, such as smoking, alcohol intake, high

blood pressure, and a sedentary lifestyle. To increase the amount of olive oil in your diet, try spreading olive oil instead of butter on your toast, making your own salad dressing using olive oil, vinegar or lemon juice, and herbs, cooking with olive oil exclusively, or simply adding a dose of it to your favorite meal.Holohan, E. “More Olive Oil in Diet Could Cut Stroke Risk: Study.” HealthFinder.gov, US Department of Health and Human Services. © 2011 Health Day. healthfinder.gov/news/newsstory.aspx?docID=653917.

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The Raw Food Diet

The raw food diet is followed by those who avoid cooking as much as possible in order to take advantage of the full nutrient content of foods. The principle behind **raw foodism** is that plant foods in their natural state are the most wholesome for the body. The raw food diet is not a weight-loss plan, it is a lifestyle choice. People who practice raw foodism eat only uncooked and nonprocessed foods, emphasizing whole fruits and vegetables. Staples of the raw food diet include whole grains, beans, dried fruits, seeds and nuts, seaweed, sprouts, and unprocessed produce. As a result, food preparation mostly involves peeling, chopping, blending, straining, and dehydrating fruits and vegetables.

The positive aspects of this eating method include consuming foods that are high in fiber and nutrients, and low in calories and saturated fat. However, the raw food diet offers little in the way of protein, dairy, or fats, which can cause deficiencies of the vitamins A, D, E, and K. In addition, not all foods are healthier uncooked, such as spinach and tomatoes. Also, cooking eliminates potentially harmful microorganisms that can cause foodborne illnesses. Therefore, people who primarily eat raw foods should thoroughly clean all fruit and vegetables before eating them. Poultry and other meats should *always* be cooked before eating.Web MD. “Raw Food Diet.” Accessed December 21, 2011. www.webmd.com/diet/guide/raw-food-diet.

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Vegetarian and Vegan Diets

Vegetarian and vegan diets have been followed for thousands of years for different reasons, including as part of a spiritual practice, to show respect for living things, for health reasons, or because of environmental concerns. For many people, being a vegetarian is a logical outgrowth of “thinking green.” When a food system is heavily focused on meat production there are deforestation issues, overgrazing of land and pasturage, and animal abuses. By avoiding animal flesh, vegetarians hope to look after their own health and that of the planet at the same time. Broadly speaking, vegetarians eat beans, grains, and fruits and vegetables, and do not eat red meat, poultry, seafood, or any other animal flesh. Some vegetarians, known as lactovegetarians, will eat dairy products. Others, known as lacto-ovo vegetarians, will eat dairy products and eggs. A vegan diet is the most restrictive vegetarian diet—vegans do not eat dairy, eggs, or other animal products, and some do not eat honey.

Vegetarian diets have a number of benefits. Well-balanced eating plans can lower the risk of a number of chronic conditions, including heart disease, diabetes, and obesity. They also help to promote sustainable agriculture. However, if a vegetarian does not vary his or her food choices, the diet may be insufficient in calcium, iron, omega-3 fatty acids, zinc, and vitamin B_{12}. Also, if people who follow these diets do not plan out their meals, they may gravitate toward foods high in fats.

Table 16.11.1: The Pros and Cons of Seven Popular Diets

Diet	Pros	Cons
DASH Diet	• Recommended by the National Heart, Lung, and Blood Institute, the American Heart Association, and many physicians • Helps to lower blood pressure and cholesterol • Reduces risk of heart disease and stroke • Reduces risk of certain cancers • Reduces diabetes risk	• There are very few negative factors associated with the DASH diet

Diet	Pros	Cons
Gluten-Free Diet	• Reduces the symptoms of gluten intolerance, such as chronic diarrhea, cramping, constipation, and bloating • Promotes healing of the small intestines for people with celiac disease, preventing malnutrition • May support weight loss • May be beneficial for other autoimmune diseases, such as Parkinson's disease, rheumatoid arthritis, and multiple sclerosis • May be helpful for Types 1 and 2 diabetes and anemia	• Risk of folate and iron deficiencies • Special gluten-free products can be hard to find and expensive • Requires constant vigilance and careful food label reading, since gluten is found in many products
Low-Carb Diet	• Restricts refined carbohydrates, such as white flour and white sugar • May temporarily improve blood sugar or blood cholesterol levels	• Not entirely evidence-based • Results in higher fat and protein consumption
Macrobiotic Diet	• Low in saturated fats and high in fiber • Emphasizes whole foods and de-emphasizes processed foods • Rich in phytoestrogens, which may reduce the risk of estrogen-related cancers	• Not entirely evidence-based • Lacks certain vitamins and minerals; supplements are often required • Can result in a very low caloric intake • Lack of energy may result from inadequate protein
Mediterranean Diet	• A reduced risk of cardiovascular disease and mortality • A lower risk of cancer • De-emphasizes processed foods and emphasizes whole foods and healthy fats • Lower sodium intake, due to fewer processed foods • Emphasis on monosaturated fats leads to lower cholesterol • Highlighting fruits and vegetables raises consumption of antioxidants	• Does not specify daily serving amounts • Potential for high fat and high calorie intake as nuts and oils are calorie-dense foods • Drinking one to two glasses of wine per day may not be healthy for those with certain conditions
Raw Food Diet	• Emphasizes whole foods • Focuses on nutritionally-rich foods • High in fiber	• Not entirely evidence-based • Very restrictive and limits protein and healthy fat intake • Could encourage the development of foodborne illness • Extremely difficult to follow • Can cause deficiencies in essential vitamins

Diet	Pros	Cons
Vegetarianism and Veganism	• May reduce cancer risk • May reduce heart disease risk • May reduce obesity risk • May help prevent Type 2 diabetes • Helps with weight reduction and weight maintenance	• Guidelines regarding fat and nutrient consumption must be followed • Requires vigilance to watch out for hidden animal products • Requires negotiating meals and holidays with meat-eating friends and family

Food Supplements and Food Replacements

Current trends also include the use of supplementation to promote health and wellness. Vitamins, minerals, herbal remedies, and supplements of all kinds constitute big business and many of their advertising claims suggest that optimal health and eternal youth are just a pill away. The main types of dietary supplements are macronutrients (amino acids, proteins, essential fatty acids), micronutrients (vitamins and minerals that promote healthy body functions), probiotics (beneficial bacteria such as the kind found in the intestines), and herbal supplements, which often target a specific body part, such as bones.



Figure Runaway argument for \eatSpaces?: .1: Multivitamins contain multiple micronutrients, such as vitamins and dietary minerals. Are dietary supplements really necessary to achieve optimal health? from Rageross (via Wikipedia)

Some public health officials recommend a daily multivitamin due to the poor diet of most North Americans. The US Preventive Task Force also recommends a level of folate intake which can be easier to achieve with a supplement. In addition, the following people may benefit from taking daily vitamin and mineral supplements:

- women who are pregnant or breast-feeding
- premenopausal women who may need extra calcium and iron
- older adults
- people with health issues that affect their ability to eat
- vegetarians, vegans, and others avoiding certain food groupsWatson, S. “How to Evaluate Vitamins and Supplements.” Web MD. Accessed December 21, 2011. http://www.webmd.com/vitamins-and-supplements/lifestyle-guide -11/how-to-evaluate-vitamins-supplements.

However, before you begin using dietary supplementation, consider that the word *supplement* denotes something added. Vitamins, minerals, and other assorted remedies should be considered as extras. They are add-ons—not replacements—for a healthy diet. As food naturally contains nutrients in its proper package, remember that food should always be your primary source of nutrients. When considering taking supplements, it is important to recognize possible drawbacks that are specific to each kind:

Micronutrient Supplements. Some vitamins and minerals are toxic at high doses. Therefore, it is vital to adhere to the Tolerable Upper Intake Levels (UL) so as not to consume too much of any vitamin. For example, too much vitamin A is toxic to the liver. Symptoms of vitamin A toxicity can include tinnitus (ringing in the ears), blurred vision, hair loss, and skin rash. Too much niacin can cause a peptic ulcer, hyperglycemia, dizziness, and gout.

Herbal Supplements. Some herbs cause side effects, such as heart palpitations and high blood pressure, and must be taken very carefully. Also, some herbs have contraindications with certain medicines. For example, Valerian and St. John's Wort negatively interact with certain prescription medications, most notably antidepressants. Additionally, there is a real risk of overdosing on herbs because they do not come with warning labels or package inserts.

Amino Acid Supplements. Certain amino acid supplements, which are taken by bodybuilders among others, can increase the risk of consuming too much protein. An occasional amino acid drink in the place of a meal is not a problem. However, problems may arise if you add the supplement to your existing diet. Most Americans receive two to three times the amount of protein required on a daily basis from their existing diets—taking amino acid supplements just adds to the excess.Web MD. "Choosing a Vitamin and Mineral Supplement—Topic Overview." Last revised May 4, 2011. http://www.webmd.com/food-recipes/tc/choosing-a-vitamin -and-mineral-supplement-topic-overview.

Supplement Claims and Restrictions

The Food and Drug Administration (FDA) regulates supplements, but it treats them like food rather than pharmaceuticals. Dietary supplements must meet the FDA's Good Manufacturing Standards, but are not required to meet the standards for drugs, although some companies do so voluntarily. Also, although supplement manufacturers are allowed to say a particular ingredient may reduce the risk of a disease or disorder, or that it might specifically target certain body systems, these claims are not approved by the FDA. This is why labels that make structural and functional claims are required to carry a disclaimer saying the product is not intended "to diagnose, treat, cure, or prevent any disease." In addition, in the United States, supplements are taken off the market only after the FDA has proven that they are hazardous.Watson, S. "How to Evaluate Vitamins and Supplements." Web MD. Accessed December 21, 2011. http://www.webmd.com/vitamins-and-supplements/lifestyle-guide -11/how-to-evaluate-vitamins-supplements.

Before Taking Supplements

The phrase *caveat emptor* means "buyer beware," and it is important to keep the term in mind when considering supplementation. Just because a product is "natural" that does not mean it can't be harmful or dangerous, particularly if used inappropriately. The following are helpful questions to explore before deciding to take a supplement:

- Does the scientific community understand how this supplement works and are all its effects well known?
- Is there proof that the supplement actually performs in the manner that it claims?
- Does this supplement interact with food or medication?
- Is taking this supplement necessary for my health?
- Is the supplement affordable?
- Is the supplement safe and free from contaminants?

Lastly, please remember that a supplement is only as good as the diet that accompanies it. We cannot overstate the importance of eating a healthy, well-balanced diet designed to provide all of the necessary nutrients. Food contains many more beneficial substances, such as phytochemicals and fiber, that promote good health and cannot be duplicated with a pill or a regimen of supplements. Therefore, vitamins and other dietary supplements should never be a substitute for food. Nutrients should always be derived from food first.

Key Takeaways

Attitudes toward food change over time, so it is important to ground dietary choices in fact, not fashion. Popular, evidence-based diets, such as the Mediterranean diet, the DASH diet, vegetarianism, and the gluten-free diet offer different approaches to promoting health, and each has its own benefits and risks. It is important to weigh the pros and cons of dietary supplementation. There are risks of overdosing and risks of contraindications with certain medications. Although supplements can be helpful, it is important to remember—food first!

Discussion Starter

1. Discuss the Mediterranean diet. What foods do you already consume that are recommended by this diet? What changes could you make to follow the diet more closely? How can you modify any concerns so that this diet will work for you?

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7.13: Threats to Health

Learning Objectives

- Discuss the roles of nutrition and lifestyle choices in the prevention and management of chronic disease.

Chronic Diseases

Chronic diseases are ongoing, life-threatening, and life-altering health challenges. They are the leading cause of death worldwide. Chronic conditions are increasing in frequency. They cause significant physical and emotional suffering and are an impediment to economic growth and vitality. It is important, now more than ever, to understand the different risk factors for chronic disease and to learn how to prevent their development.



Figure 16.12.1*: Obesity is a risk factor for a number of conditions, including arthritis and certain cancers. A "super obese" male with a BMI of 53 kg/m^2: weight 182 kg (400 lb), height 185 cm (6 ft 1 in). Image is public domain.*

The Risk Factors of Chronic Disease

A **risk factor** is a signal that your chances for acquiring a chronic disease may be increased. You might liken a risk factor to the flags that lifeguards sometimes set up at beaches. When you see these flags, you know immediately that swimming within the marked areas could be hazardous, and that if you choose to swim within these parameters anyway, you are doing so at your own risk. But, if you heed the warnings, you are taking the necessary step to protect your safety and health. Similarly, risk factors are warning signs that coincide with the development and progression of disease. However, risk factors are not a 100-percent guarantee that a person will develop a chronic disease, only that the conditions are right. For example, if a person gets sick with the flu, we can say with certainty that the illness was caused by a virus. However, we cannot say that a sedentary lifestyle caused the onset of cardiovascular disease in a patient, because a risk factor indicates a correlation, not a causation.

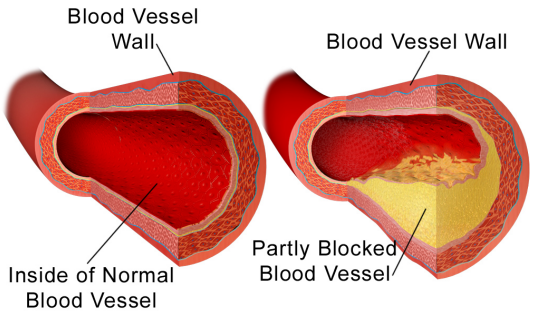
Chronic disease usually develops alongside a combination of the following risk factors: genetics, a prior disease such as obesity or hypertension, dietary and lifestyle choices, and environmental problems. Risk factors such as genetics and age cannot be changed. However, some risk factors can be altered to promote health and wellness (such as diet). For example, a person who continuously eats a diet high in sugars, saturated fats, and red meat is at risk for becoming obese and developing Type 2 diabetes, cardiovascular disease, or several other conditions. Making more healthy dietary choices can greatly reduce that risk. Being a woman over age sixty-five is a risk factor for developing osteoporosis, but that cannot be changed. Also, people without a genetic predisposition for a particular chronic illness can still develop it. Not having a genetic predipostion for a chronic disease is not a guarantee of immunity.

Identifying Your Risk Factors

To estimate your own risk factors for developing certain chronic diseases, search through your family’s medical history. What diseases do you note showing up among close blood relatives? This may be of concern to you. At your next physical, pay attention to your blood tests and ask the doctor if any results are out of normal range. It is also helpful to note your vital signs, particularly your blood pressure and resting heart rate. In addition, you may wish to keep a food diary to make a note of the dietary choices that you make on a regular basis and be aware of foods that are high in saturated fat, among other unhealthy options. As a general rule, it is important to look for risk factors that you can modify.to promote your health. For example, if you discover that your grandmother, aunt, and uncle all suffered from high blood pressure, then you may decide to avoid a high sodium diet. Identifying your risk factors can arm you with the information you need to help ward off disease.

Cardiovascular Disease

Throughout the remainder of this section, we will examine some of the more prevalent chronic diseases, their risk factors, and the choices that can help to discourage their development or progression. Let's begin with cardiovascular disease. According to the Centers for Disease Control and Prevention (CDC), heart disease is the leading cause of death in the United States.Centers for Disease Control and Prevention. "Leading Causes of Death." Last updated September 6, 2011. http://www.cdc.gov/nchs/fastats/lcod.htm. The disease generally starts with atherosclerosis, or a hardening of the arteries, a chronic condition so common that most people show signs of it by the time they turn thirty. Arteries start to narrow and harden when fats accumulate along their inner walls and form plaques. A plaque is made of fat, cholesterol, calcium, and other substances found in blood.



Normal and Partly Blocked Blood Vessel

Figure Runaway argument for \eatSpaces?: .2: Illustration comparing a normal blood vessel and partially blocked vessel due to atherosclerotic plaque build-up. Plaque formation along arterial walls impedes blood flow and can create a thrombus, or stationary blood clot. from BruceBlaus (via Wikipedia). For a video of the process click here.

Plaque formation causes arteries to narrow and harden, which elevates blood pressure because the vessels can't expand effectively to accommodate blood pulses. Higher blood pressure strains the heart and causes more damage. Arterial walls can become so weakened due to high blood pressure that they balloon and form what is known as an aneurysm. If the aneurysm bursts, it becomes a life-threatening event. The plaques themselves can also rupture due to a spike in blood pressure or a tremor along an arterial wall, and the body responds to this perceived injury by forming blood clots. These clots are serious health threats, whether they are stationary (a thrombus) or moving (an embolus). A stable clot can slowly kill off surrounding tissue, or grow so big that it blocks blood circulation and causes thrombosis. When a moving clot becomes stuck in an artery too small for its passage, it cuts off blood flow and causes cell death. This is referred to as an embolism. Blood clots in heart and brain arteries can cause heart attacks or strokes.

Table 16.12.1: The Risk Factors for Cardiovascular Disease

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases for men at forty-five, and for women at fifty-five. • **Sex.** Men have a higher risk than women, though the risk for women steeply rises after menopause. • **Family history.** The more family members who have heart disease, the greater the risk.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of atherosclerosis. • **Obesity.** Excess weight worsens other risk factors. • **Diabetes.** This condition is associated with an increased risk of heart disease. Both types have certain risk factors in common, including obesity and high blood pressure. • **Physical inactivity.** Lack of exercise is associated with heart disease. • **Cholesterol levels.** High levels of blood cholesterol can increase the risk. A high level of low-density lipoprotein (LDL), or the "bad" cholesterol, is a common contributing factor. However, a low level of high-density lipoprotein (HDL), or "good" cholesterol, can also promote atherosclerosis.

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Steps to Reducing the Risk of Cardiovascular Disease

Diet and nutrition can play a significant role in reducing the risk of cardiovascular disease. It is helpful to lower sodium intake, increase consumption of dietary fiber, and limit consumption of saturated fat, which promotes plaque formation. In addition, it is important to replace refined starches and added sugar, which can boost triglycerides, with whole grains, fruits, and vegetables. Eating foods rich in omega-3 fatty acids, especially fish, using alcohol in moderation, and opting for low or no-fat dairy products can all help reduce your cardiovascular disease risk. Emphasizing vegetable-based sources of protein, such as beans and legumes, can be beneficial, as well as consuming more soy products. It is also important to maintain a healthy weight, manage cholesterol levels, and avoid smoking or chewing tobacco.

Hypertension

Chronic high blood pressure, also known as hypertension, is a significant health hazard affecting one out of three adults in the United States.Centers for Disease Control and Prevention. “High Blood Pressure Facts.” Last updated March 21, 2011. www.cdc.gov/bloodpressure/facts.htm. This chronic condition is a major cause of heart attacks and strokes, yet it has no symptoms until blood pressure reaches very high levels, which is why it is known as “the silent killer.” The only way to find out if you have high blood pressure is to get an accurate reading of your resting blood pressure rate, which is best done by a medical professional and should be monitored regularly.

High blood pressure is such an important factor in cardiovascular disease, that keeping it within a healthy range is vitally important. As explained previosuly, blood pressure readings consist of two numbers. The top number measures **systolic** pressure (when the heart contracts) and the bottom number measures **diastolic** pressure (when the heart is at rest). The key blood pressure numbers to keep in mind are:

- **Ideal.** 120 over 80 or below
- **Prehypertension.** Higher than 120 over 80 and lower than 139 over 89
- **Hypertension.** Greater than 139 over 89

Table 16.12.2: The Risk Factors for Hypertension

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** After fifty-five, the risk of developing high blood pressure is 90 percent. • **Race.** African-Americans are more likely to develop hypertension, manifest it at a younger age, and have higher blood pressure readings. • **Family history.** There is a strong genetic component to high blood pressure, and an individual’s risk goes up along with the number of family members who have hypertension.	• **Weight.** Roughly 60 percent of people with hypertension are obese. • **Sodium consumption.** The more salt in a person’s diet, the more likely they are to have high blood pressure. • **Alcohol.** Drinking more than two drinks per day for men and one drink for women increases the likelihood of hypertension. • **Diet.** In addition to salt and alcohol consumption, other dietary factors increase chances of developing hypertension.

Steps to Reducing the Risk of High Blood Pressure

Although it is not possible to change one’s age or genetics, there are actions that people can take to decrease their risk of hypertension. Techniques to reduce blood pressure include becoming physically active, maintaining a healthy weight, reducing sodium intake below 2,400 milligrams per day (or below 1,500 milligrams if you are in a high-risk group or already have been diagnosed with hypertension), using alcohol moderately, and following the DASH diet, which was outlined in Section 15.1. Additionally, vitamin C, calcium, and potassium have all been shown to promote healthy blood pressure. It is also vital to monitor your blood pressure levels on a regular basis. Prompt intervention when readings rise above the ideal level (120 over 80) can save lives, which is why everyone should know the status of their blood pressure.

Cancer

More than one hundred diseases are classified as different forms of cancer, all of them characterized by the uncontrolled growth of abnormal cells. Cancer is triggered by mutations in a cell’s genetic material. The cause of these changes may be inherited, or it may

result from exposure to carcinogens, which are agents that can cause cancer. Carcinogens include chemicals, viruses, certain medical treatments such as radiation, pollution, or other substances and exposures that are known or suspected to cause cancer.American Cancer Society. “Known and Probable Human Carcinogens.” Last medical review June 29, 2011. http://www.cancer.org/Cancer/CancerCauses/OtherCarcinogens/GeneralInformationaboutCarcinogens/known-and-probable -human-carcinogens. The National Institutes of Health has classified fifty-four different compounds as known cancer-causing agents in humans.Brett Israel, “How Many Cancers Are Caused by the Environment?” *Scientific American*, 21 May 2010. http://www.scientificamerican.com/article.cfm?id=how-many -cancers-are-caused-by-the-environment.

Under normal conditions, a healthy cell will either repair any damage that has been done or self destruct so that no future cells will be affected. Cells become cancerous when their DNA is damaged, but they do not self-destruct or stop reproducing as normal cells would. As these abnormal cells continue their rapid growth, in most cancers they coalesce in a mass called a tumor. Cancer cells can overwhelm healthy cells and interfere with the healthy functioning of the body. They can also invade other organs and spread throughout the body in a process known as metastasis. Scientists and the medical community are giving considerable attention to the early stages of cancer, from the moment a healthy cell is exposed to a carcinogen to the point where cells with damaged DNA are replicating out of control. Intervention at any of these early stages could prove to be quite beneficial, because it is thought that most cancers are the result of lifestyle choices and environmental exposure.

The risk factors for different cancers can vary. For example, exposure to ultraviolet radiation from the sun and from tanning beds is a risk factor for skin cancer, while exposure to asbestos is a risk factor for mesothelioma cancer. Table 15.4.3 shows some common risk factors for a number of different types of cancer.

Table 16.12.3: The Risk Factors for Cancer

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Most cancers occur in people over the age of sixty-five. However, people of all ages, including children, can get cancer. • **Family history.** Certain types of cancer have a genetic link. However, environmental factors may also play a part.	• **Tobacco.** Smoking or chewing tobacco greatly increases the risk for certain cancers, including cancer of the lungs, bladder, cervix, kidneys, mouth, and pancreas. • **Alcohol.** Drinking alcohol is linked to cancers of the mouth, throat, esophagus, and breast, as well as to cancers of the neck and head. • **Obesity.** Linked to cancers of the colon, uterus, pancreas, esophagus, kidney, and breast. • **Cooking techniques.** Grilling, smoking, and preparing meat at high temperatures forms carcinogens. • **Red meat.** The risk of colon cancer seems to increase with the consumption of red meat and processed meat. • **Cured meats.** According to a recent study, there is a mild risk of pancreatic cancer with the consumption of cured meats, such as sausage, pepperoni, bacon, ham, smoked turkey, salami, and hot dogs. • **Physical inactivity.** Linked to colon, breast, and other cancers. • **Exposure to chemicals.** People who have jobs that expose them to chemicals on a regular basis, such as construction workers and painters, have an increased risk of cancer. • **Viruses or bacteria.** Certain viruses or bacteria may increase the risk of developing cancer. For example, human papillomaviruses, which are sexually transmitted, are the primary cause of cervical cancer.

Steps to Reducing the Risk of Cancer

According to the American Cancer Society, half of all American men and one-third of American women will be diagnosed with some form of cancer in their lifetime.American Cancer Society. “What Is Cancer?” Last medical review March 19, 2010. http://www.cancer.org/Cancer/CancerBasics/what-is-cancer. Although cancer is one of the leading causes of death worldwide,

ongoing research and innovations in treatment have improved the outlook for cancer patients to the point where millions now survive or live with cancer, making it a chronic disease.

The American Institute for Cancer Research (AICR) has published guidelines for preventing cancer and staying healthy. They include several dietary and lifestyle choices, such as participating in physical activity for thirty minutes per day or more, and maintaining a healthy weight. In addition, AICR recommends consuming a plant-based diet.American Institute for Cancer Research. "Guidelines for Cancer Prevention." No. E93-GL. © November 2007. http://preventcancer.aicr.org/site/DocServer/Guidelines_Brochure.pdf?docID=3561. Several epidemiological studies have found a link between eating plenty of fruits and vegetables and a low incidence of certain cancers. Fruits and vegetables containing a wide variety of nutrients and phytochemicals may either prevent or reduce the oxidative damage to cell structures. Cruciferous vegetables, such as cauliflower, broccoli, and Brussels sprouts, may also reduce the risk of certain cancers, such as endometrial, esophageal, and others. Also, studies have shown that the more fiber you have in your diet, the lower your risk of colon cancer.

Supplementation may also be helpful to a limited degree. Vitamin D and antioxidants have been linked to lowering the risk of some cancers (however taking an iron supplement may promote others). But, obtaining vital nutrients from food first is the best way to help prevent or manage cancer. In addition, regular and vigorous exercise can lower the risk of breast and colon cancers, among others. Also, wear sunblock, stay in the shade, and avoid the midday sun to protect yourself from skin cancer, which is one of the most common kinds of cancer.Mayo Clinic. "Cancer Prevention: 7 Steps to Reduce Your Risk." September 21, 2010. Accessed December 21, 2011. http://www.mayoclinic.com/health/cancer -prevention/CA00024.

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Diabetes

The World Health Organization reports that more than 346 million people around the world have diabetes and they predict that deaths due to the consquences of diabetes will double from 2005 to 2030.World Health Organization. "Diabetes." *Fact Sheet*, no. 312. August 2011. http://www.who.int/mediacentre/factsheets/fs312/en/. **Diabetes mellitus** is a metabolic disorder that results when the pancreas does not produce enough insulin to meet its needs or the body does not effectively utilize the insulin that it does produce. Insulin is the hormone that regulates blood glucose levels. The most common complication is hyperglycemia (elevated blood sugar), which gradually leads to damage in many of the body's systems, most notably the eyes, kidneys, nerves, and heart and blood vessels.

There are three kinds of diabetes: Type 1, Type 2, and gestational. Formerly known as juvenile or childhood-onset diabetes, Type 1 diabetes is an autoimmune condition in which the pancreas does not produce insulin. Type 1 diabetes is not preventable, and it's cause is unknown. Symptoms include excessive urination, thirst, persistant hunger, weight loss, vision problems, and fatigue.

Formerly known as adult-onset diabetes, Type 2 diabetes results when the pancreas produces enough insulin initially, but the body is unable to use the hormone properly (insulin resistance). Until recently, this disease was only found in adults. However, it is now found among children, too. More than 90 percent of diabetics have Type 2.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Diabetes Overview." *NIH Publication No. 09–3873* (November 2008). diabetes.niddk.nih.gov/dm/pubs/overview/. Major contributing factors to the development of Type 2 diabetes include excessive body weight and physical inactivity. The symptoms for Type 2 diabetes are similar to Type 1, but are much less noticeable. As a result, Type 2 diabetes may remain undiagnosed for several years after the onset, generally after complications have already manifested.

About 3 to 8 percent of pregnant women develop gestational diabetes during the latter stages of pregnancy. This condition is caused by a shortage of insulin or by pregnancy hormones. Gestational diabetes has symptoms similar to Type 2 diabetes, and some women may not experience any symptoms at all. In general, gestational diabetes fades away after the birth of the baby. However, women who have had gestational diabetes are at a greater risk of developing Type 2 diabetes within five to ten years. Also, infants born of mothers who suffer from this condition are at an increased risk of developing Type 2 diabetes as they grow older.National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Diabetes Overview." *NIH Publication No. 09–3873* (November 2008). diabetes.niddk.nih.gov/dm/pubs/overview/.

Table 16.12.4: The Risk Factors for Diabetes

Unmodifiable Risk Factors	Modifiable Risk Factors

Unmodifiable Risk Factors	Modifiable Risk Factors
• **Age.** Risk increases after age forty-five • **Medical history.** Diabetes during a previous pregnancy or recently giving birth to an infant who weighs more than 9 pounds. • **Family history.** A history of diabetes among one or more close relatives. • **Race and ethnicity.** Individuals from specific ethnic groups may have an increased risk for developing diabetes, including African Americans, Hispanic Americans, Asian Americans, and Native Americans. • **Viruses.** Exposure to: Epstein-Barr, Coxsackie, mumps, or cytomegalo viruses may trigger Type 1 diabetes.	• **Cigarette smoking.** Nicotine constricts blood vessels, and carbon monoxide damages their inner lining, which increases the risk of Type 2 diabetes. • **Obesity.** Excess body weight, especially around the waist, is a major contributing factor to Type 2 diabetes. • **Physical inactivity.** Lack of exercise is strongly associated with diabetes. • **High blood pressure.** Greater than or equal to 140/90 mmHg. • **Cholesterol levels.** HDL cholesterol under 35 mg/dL. • **Blood sugar.** Impaired glucose tolerance. • **Blood fats.** Elevated triglycerides (250 mg/dL or more).

Steps to Reducing the Risk of Diabetes

Unfortunately, Type 1 diabetes is almost impossible to prevent, although some clinical research suggests that breastfeeding an infant for at least three months may decrease the child's risk of developing this condition. However, people who are at risk for Type 2 or gestational diabetes can take steps to avoid the disease. For example, it is crucial to achieve and maintain a healthy body weight through regular physical activity. If you are at risk, strive for at least thirty minutes of moderate to intense exercise at least three times per week. Proper nutrition is also vital, and it is important to restrict sugary snacks, beverages, and desserts, and to limit the intake of trans fats and saturated fats. In addition, those who are at risk should consume whole grains, legumes, fruits, and vegetables, along with two servings of nonfried fish per week.

For people over age forty-five, it is important to have a glucose test every three years. Regular testing should begin at a younger age, and be performed frequently if you have any risk factors for developing Type 2 diabetes. In order to assess your health status, the following is recommended:

- Early diagnosis through blood testing
- Blood pressure measurement
- Blood lipid measurement

Food: The Best Medicine

As mentioned in Chapter 1, poor dietary choices and a sedentary lifestyle account for about 300–600 thousand deaths every year according to the US Department of Health and Human Services. That number is thirteen times higher than the deaths due to gun violence.Nutrition Policy, Center for Science in the Public Interest. "Why Good Nutrition Is Important." Accessed December 21, 2011. http://www.cspinet.org/nutritionpolicy/nutrition_policy.html. The typical North American diet is too high in saturated fat, sodium, and sugar, and too low in fiber in the form of whole fruits, vegetables, and whole grains to keep people healthy. With so many threats to optimal health it is vital to address those factors that are under your control, namely dietary and lifestyle choices. A diet that supplies your body with the needed energy and nutrients daily will result in efficient body functioning and in protection from disease. Making sound nutritional choices can also provide support for individuals undergoing treatment for short-term or chronic conditions. Finding a balance between nutritional needs with concerns about drug interactions can hasten recovery, improve quality of life, and minimize the side effects from treatment protocols.

Key Takeaways

Chronic diseases such as cardiovascular disease, high blood pressure, cancer, and diabetes are major public health threats, and major causes of mortality. Knowing the modifiable risk factors (such as diet, level of physical activity, and cigarette smoking) for certain diseases can help you to adapt your lifestyle to protect them. By following a healthy diet, becoming active, and making other sound lifestyle choices, individuals can reduce their risk of developing chronic diseases, or better manage their condition to prevent further complications.

Discussion Starter

1. Assess your risk for developing one of the four chronic diseases discussed in this section. Which risk factors can be modified? Which risk factors can't be modified? What can you do to lessen the chance that you will develop the disease?

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7.14: Careers in Nutrition

Learning Objectives

- List some of the jobs available to students who are interested in a career in food and nutrition.

If you are considering a career in nutrition, it is important to understand the opportunities that may be available to you. Both dietitians and nutritionists provide nutrion-related services to people in the private and public sectors. A dietitian is a healthcare professional who has registered credentials and can provide nutritional care in the areas of health and wellness for both individuals and groups. A nutritionist is an unregistered professional who may have the credentials of a dietitian, or may have acquired the knowledge via other avenues. People in both professions work to apply nutritional science, using evidence-based best practices, to help people nourish their bodies and improve their lives.

Becoming a registered dietitian requires a Bachelor's or Master's degree in dietetics, including courses in biology, chemistry, biochemistry, microbiology, anatomy and physiology, nutrition, and food-service management. Other suggested courses include economics, business, statistics, computer science, psychology, and sociology. In addition, people who pursue this path must complete a dietetic internship and pass a national exam. Also, some states have licensure that requires additional forms and documentation. To become a registered dietetic technician you must complete a dietetic technician program that involves supervised practice. Forty-seven states have licensure requirements for registered dietitians and nutritionists. A few remaining states do not have laws that regulate this profession.Bureau of Labor Statistics. "Dietitians and Nutritionists." *Occupational Outlook Handbook, 2010-11 Edition.* Last modified April 7, 2010. www.bls.gov/oco/ocos077.htm. Go to www.cdrnet.org/certifications/licensure/index.cfm to learn more.

Working in Nutrition

Dietitians and nutritionists plan food and nutrition programs, promote healthy eating habits, and recommend dietary modifications. For example, a dietitian might teach a patient with hypertension how to follow the DASH diet and reduce their sodium intake. Nutrition-related careers can be extremely varied. Some individuals work in the government, while others are solely in the private sector. Some jobs in nutrition focus on working with athletes, while others provide guidance to patients with long-term, life-threatening diseases. But no matter the circumstance or the clientele, working in the field of diet and nutrition focuses on helping people improve their dietary habits by translating nutritional science into food choices.

In the public sector, careers in nutrition span from government work to community outreach. Nutritionists and dietitians who work for the government may become involved with federal food programs, federal agencies, communication campaigns, or creating and analyzing public policy. On the local level, clinical careers include working in hospitals and nursing-care facilities. This requires creating meal plans and providing nutritional guidance to help patients restore their health or manage chronic conditions. Clinical dietitians also confer with doctors and other health-care professionals to coordinate dietary recommendations with medical needs. Nutrition jobs in the community often involve working in public health clinics, cooperative extension offices, and HMOs to prevent disease and promote the health of the local community. Nutrition jobs in the nonprofit world involve antihunger organizations, public health organizations, and activist groups.

Nutritionists and dietitians can also find work in the private sector. Increased public awareness of food, diet, and nutrition has led to employment opportunities in advertising, marketing, and food manufacturing. Dietitians working in these areas analyze foods, prepare marketing materials, or report on issues such as the impact of vitamins and herbal supplements. Consultant careers can include working in wellness programs, supermarkets, physicians' offices, gyms, and weight-loss clinics. Consultants in private practice perform nutrition screenings for clients and use their findings to provide guidance on diet-related issues, such as weight reduction. Nutrition careers in the corporate world include designing wellness strategies and nutrition components for companies, working as representatives for food or supplement companies, designing marketing and educational campaigns, and becoming lobbyists. Others in the private sector work in food-service management at health-care facilities or at company and school cafeterias. Sustainable agricultural practices are also providing interesting private sector careers on farms and in food systems. There are employment opportunities in farm management, marketing and sales, compliance, finance, and land surveying and appraisal.

Working toward Tomorrow

Whether you pursue nutrition as a career or simply work to improve your own dietary choices, what you have learned in this course can provide a solid foundation for the future. Remember, your ability to wake up, to think clearly, communicate, hope, dream, go to school, gain knowledge, and earn a living are totally dependent upon one factor—your health. Good health allows you to function normally and work hard to pursue your goals. Yet, achieving optimal health cannot be underestimated. It is a complex process, involving multiple dimensions of wellness, along with your physical or medical reality. The knowledge you have now acquired is also key. However, it is not enough to pass this nutrition class with good grades. Nutrition knowledge must be applied to make a difference in your life, throughout your life.

Throughout this textbook, we have focused on the different aspects of nutritional science, which helps to optimize health and prevent disease. Scientific evidence provides the basis for dietary guidelines and recommendations. In addition, researchers in the field of nutrition work to advance our knowledge of food production and distribution. Nutritional science also examines the ill effects of malnutrition and food insecurity. The findings that are uncovered today will influence not only what we eat, but how we grow it, distribute it, prepare it, and even enjoy it tomorrow.



Video 16.18.1: *Farms of the Future. This video examines the philosophy and science behind vertical farming. Could it provide our nutrients in the future (click to see video)?*

Summary and Key Takeaway

There are many paths that one can take to become a professional in the field of nutrition, including working as a nutritionist or becoming a registered dietitian. Some confuse the terms "dietitian" and "nutritionist," and this tends to be erroneous. A nutritionist is a person who advises on matters of food and nutrition impacts on health. In contrast, A dietitian is an expert in the relationship between human nutrition and the regulation of diet; a dietitian alters their patient's nutrition based upon their medical condition and individual needs.

Discussion Starter

1. Compare and contrast nutrition-related careers in the public and private sectors. Discuss which area would most interest you and the reasons why.

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8: Antioxidant Nutrients

In Chapter 8, nutrients important as antioxidants are explored, starting with an explanation of what oxidation and antioxidants are, then looking at vitamins E, C, and A, selenium, and phytochemicals.

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8.1: Chapter Introduction

Big Idea

Eating foods such as fruits, vegetables, herbs, and spices that are high in antioxidants can help prevent cell damage and promote health.



Figure 8.1.1: Nutmeg, which is obtained from the seed of the evergreen tree, *Myristica fragrans*, was once a highly coveted spice. IMage used with permission (public domain).

Government trickery and greed are a big part of the history of the woody, bittersweet nutmeg people sprinkle in their eggnog and add to their pumpkin pie. Arabs originally controlled the lucrative nutmeg trade. Run Island, part of the Banda archipelago in the Maluku province of Indonesia, and (for a while) the sole source of nutmeg, remained a well-kept secret under their control. Then, in 1521, the Portuguese conquered the southern region of Malay in Indonesia and discovered the island.

Control of this nutmeg source switched hands rapidly from this point on. Although the Portuguese claimed ownership for a moment, the Spaniards were quick to take over. In the seventeenth century, the Dutch East India Company invaded the Band Islands. They then ran plantation estates on Run Island and actively patrolled the sea in war vessels to discourage the stealing of seeds from *Myristica fragrans*. They went so far as to track the movement of pigeons and other animals that might unwittingly transport the seeds elsewhere, and they burned any trees found off of Run Island.

The battles over Run Island had one important motivation: money. Trade was lucrative in the seventeenth century because nutmeg was valued as a curative for stomach ailments, as an aphrodisiac, and as a healer of the liver. The spice even had a reputation for curing the plague, which might have worked—wearing a clove of it around the neck may have deterred fleas and other disease carriers. Buyers were also well aware of nutmeg's hallucinogenic properties and used it in high doses as a psychoactive drug. Its price was astronomically high and kept so by the Dutch, who burned their own nutmeg warehouses down to assure the laws of supply and demand did not lower the spice's value.

During the Napoleonic wars, while the Dutch were battling the French, the British slipped onto Run Island, stole *Myristica fragras* seeds, and successfully grew the tree on plantations on the island of Grenada. Today, Grenada, also known as the "Isle of Spice," produces about one-third of the world's supply, which is why its flag boasts a clove of nutmeg.

Our ancestors were probably right to value nutmeg for its curative properties. While it does not actually cure disease outright, nutmeg contains a variety of antioxidants, including phenolic compounds, lignans, and eugenol. Foods rich in antioxidants have been touted as preventative and curative, and some believe they delay certain aspects of the aging process. While we are no longer fighting over nutmeg's production and sale, we are waging a fierce debate about the lack of scientific proof of these believed benefits.

The "antioxidant hypothesis"—the educated guess that antioxidant chemicals protect against chronic disease—has existed for decades. Despite thousands of studies conducted on the health benefits of particular antioxidants, there is little evidence supporting the idea that they singularly prevent disease, reduce the effects of aging, or promote health. It is the *combination* of antioxidants, phytochemicals, and nutrient-rich foods that achieve these end goals.

Nutmeg has been shown in animal and laboratory studies to act as an antimicrobial, antifungal, and anti-inflammatory agent. It has protected against liver damage and stimulated male sexual activity in rats. However, none of these effects have been scientifically shown to occur in humans. On the other hand, nutmeg has proven effective as a psychoactive drug when taken in high doses.

In this chapter, you will learn there is no miracle food or supplement. The debate over the nutmeg's effectiveness as an antioxidant —and over the effects of antioxidants in general—is proof of this. You will also learn that plant chemicals can affect the body in

many different ways, depending on the type of chemical and the dosage. Different antioxidants are believed to have different functions, and those functions are sometimes interdependent or dependent on the amount of nutrient-rich foods you eat.

You Decide

Will you increase your intake of antioxidant- and nutrient-rich foods to improve health and reduce the risk of chronic disease? Why and how?

“Shall I not have intelligence with the earth? Am I not partly leaves and vegetable mold myself?” - Henry David Thoreau (July 12, 1817–May 6, 1862)

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8.2: Generation of Free Radicals in the Body

Learning Objectives

- Describe how free radicals are generated in the body.
- Explain oxidative stress and what diseases it is associated with.

In mainstream advertising, you may have heard that antioxidants can extend your life by preventing disease and slowing the aging process. But what are antioxidants? And how do they work in the body? Is there any truth to the marketers' claims? Are there better sources than supplements for antioxidants? After reading this chapter you will be able to answer these questions, and your new knowledge will assist you in making dietary decisions to optimize your health.

Keep in mind as you read there is no scientific evidence that antioxidants *singularly* provide bodily benefits, but there is evidence that certain benefits are achieved by ingesting antioxidants as part of a balanced, healthy, nutrient-rich diet. This is to say antioxidants may go a long way toward preventing damage, but other nutrients are necessary to repair damage and sustain health. No one chemical acts alone!

The Atom

Before we can talk about the nutritional value of antioxidants we must review a few chemistry basics, starting with the atom. Cells are the basic building blocks of life, but atoms are the basic building blocks of all matter, living and non-living.

The structural elements of an atom are protons (positively charged), neutrons (no charge), and electrons (negatively charged). Protons and neutrons are contained in the dense nucleus of the atom; the nucleus thus has a positive charge. Because opposites attract, electrons are attracted to this nucleus and move around it in the electron cloud.

Electrons contain energy, and this energy is stored within the charge and movement of electrons and the bonds atoms make with one another. However, this energy is not always stable, depending on the number of electrons within an atom.

Atoms are more stable when their electrons orbit in pairs. An atom with an odd number of electrons must have an unpaired electron. In most cases, these unpaired electrons are used to create chemical bonds. A chemical bond is an attractive force between atoms and contains potential energy. By bonding, electrons find pairs and chemicals become part of a molecule.

Bond formation and bond breaking are chemical reactions that involve the movement of electrons between atoms. These chemical reactions occur continuously in the body and many of them will be discussed in more detail later.

Previous, we reviewed how glucose breaks down into water and carbon dioxide as part of cellular respiration. The energy released by breaking those bonds is used to form molecules of adenosine triphosphate (ATP). Recall how during this process electrons are extracted from glucose in a stepwise manner and transferred to other molecules. Occasionally electrons "escape" and, instead of completing the cellular respiration cycle, are transferred to an oxygen molecule. Oxygen (a molecule with two atoms) with one unpaired electron is known as superoxide (Figure 8.1).

Atoms and molecules such as superoxide that have unpaired electrons are called free radicals; those containing oxygen are more specifically referred to as reactive oxygen species. The unpaired electron in free radicals destabilizes them, making them highly reactive. Other reactive oxygen species include hydrogen peroxide and the hydroxyl radical.



Figure 8.2.1: Superoxide: A molecule with one unpaired electron, which makes it a free radical. Source: Wikipedia. "Superoxide." Last modified November 2, 2012. (CC-BY-SA 3.0; DoSiDo).

The reactivity of free radicals is what poses a threat to macromolecules such as DNA, RNA, proteins, and fatty acids. Free radicals can cause chain reactions that ultimately damage cells. For example, a superoxide molecule may react with a fatty acid and steal one of its electrons. The fatty acid then becomes a free radical that can react with another fatty acid nearby. As this chain reaction continues, the permeability and fluidity of cell membranes changes, proteins in cell membranes experience decreased activity, and receptor proteins undergo changes in structure that either alter or stop their function. If receptor proteins designed to react to insulin levels undergo a structural change it can negatively affect glucose uptake.

Our bodies required oxygen to survive and oxidation is the process by which oxygen takes electrons from a material. This process can be beneficial, such as in making energy, or harmful, for example, free radicals that change the structure of a molecule. Free radicals are highly reactive molecules that can react with other molecules and cause damage; rusting is an example.

Free radicals occur naturally in our body (endogenous) during many different metabolic processes. Here are several examples. Aerobic metabolism, discussed in the chapter on energy metabolism, uses oxygen to burn substrate (glucose, fatty acids, and amino acids). The process of detoxifying drugs can generate free radicals. Finally, one way our immune system fights invaders is to produce free radicals.

Our environment also exposes us to free radicals. Examples of exogenous sources are cigarette smoke, air pollution, alcohol and polyunsaturated fatty acids.

Free radical reactions can continue unchecked unless stopped by a defense mechanism.

The Body's Defense

Free radical development is unavoidable, but human bodies have adapted by setting up and maintaining defense mechanisms that reduce their impact. The body's two major defense systems are free radical detoxifying enzymes and antioxidant chemicals. Free radical detoxifying enzyme systems are responsible for protecting the insides of cells from free radical damage. An antioxidant is any molecule that can block free radicals from stealing electrons; antioxidants act both inside and outside of cells.

Antioxidants sequester free radicals to make them less damaging and fruits, vegetables, herbs, and spices are high in antioxidants and thus help prevent cell damage and promote health. Vitamin C, vitamin E, and carotenoids are natural antioxidants present in fruits and vegetables. Also, there are several enzymes involved in detoxifying that require the essential minerals selenium, copper, and zinc.

Free Radical Detoxifying Enzymes

The three major enzyme systems and the chemical reactions they catalyze are:

1. **Superoxide Dismutases (SOD).** These enzymes have either a manganese, copper, or zinc cofactor, which is essential for their free radical detoxifying activity. During SOD-mediated enzymatic catalysis, two superoxides are converted into hydrogen peroxide and oxygen. Hydrogen peroxide (H_2O_2) is still considered a reactive oxygen species, but it is markedly less reactive than a superoxide. SOD enzymes are one of the fastest enzymes known, and they are also inducible, meaning that the higher their exposure to superoxides the greater their number and detoxifying activity.
2. **Catalase.** This enzyme contains iron as a cofactor and converts hydrogen peroxide to water and oxygen, thereby finishing the detoxification reaction started by SOD. In cells, catalase enzymes are found in high numbers and continuously patrol for hydrogen peroxide molecules. Catalase is highly efficient and is capable of destroying millions of hydrogen peroxide molecules per second.
3. **Glutathione Peroxidases.** The majority of enzymes within this family are dependent on the micronutrient selenium. Similar to catalase, these enzymes convert hydrogen peroxide to water and oxygen.

Antioxidant Chemicals

Antioxidants are broadly classified as either hydrophilic (water soluble) or hydrophobic (lipid soluble) chemicals, and this classification determines where they act in the body. Hydrophilic antioxidants act in the cytosol of cells or in extracellular fluids such as blood; hydrophobic antioxidants are largely responsible for protecting cell membranes from free radical damage.

The body can synthesize some antioxidants, but others must be obtained from the diet.

Antioxidant Chemicals the Body Synthesizes

There are two antioxidant chemicals that the body synthesizes. They are:

1. **Glutathione.** This molecule is composed of three amino acids and is found in high concentrations in cells. The cysteine amino acid of glutathione contains a sulfur group that can donate an electron to a free radical, thereby stabilizing it. After glutathione has lost its electron, it is regenerated enzymatically so that it can perform its antioxidant function once again.
2. **Uric Acid.** This molecule is a metabolic intermediate in the breakdown of nucleotides such as adenine, which is found in DNA and RNA, among other macromolecules. It circulates at high concentrations in the blood and disables circulating free radicals. However, uric acid is a good example of the adage “it’s the dose that makes the poison” because high concentrations in the blood can cause gout, a painful joint disorder.

Antioxidant Chemicals Obtained from the Diet

There are many different antioxidants in food, including selenium, which is one of the major antioxidants. However, the antioxidants you may be the most familiar with are vitamins. The “big three” vitamin antioxidants are vitamins E, A, and C, although it may be that they are called the “big three” only because they are the most studied.

Table 8.2.1: Some Antioxidants Obtained from Diet and Their Related Functions

Antioxidant	Functions Attributed to Antioxidant Capacity
Vitamin A	Protects cellular membranes, prevents glutathione depletion, maintains free radical detoxifying enzyme systems, reduces inflammation
Vitamin E	Protects cellular membranes, prevents glutathione depletion
Vitamin C	Protects DNA, RNA, proteins, and lipids, aids in regenerating vitamin E
Carotenoids	Free radical scavengers
Lipoic acid	Free radical scavenger, aids in regeneration of vitamins C and E
Phenolic acids	Free radical scavengers, protect cellular membranes
Selenium	Cofactor of free radical detoxifying enzymes, maintains glutathione levels, aids in regeneration of vitamins C and E

The Body’s Offense

While our bodies have acquired multiple defenses against free radicals, we also use free radicals to support its functions. For example, the immune system uses the cell-damaging properties of free radicals to kill pathogens. First, immune cells engulf an invader (such as a bacterium), then they expose it to free radicals such as hydrogen peroxide, which destroys its membrane. The invader is thus neutralized.

Scientific studies also suggest hydrogen peroxide acts as a signaling molecule that calls immune cells to injury sites, meaning free radicals may aid with tissue repair when you get cut.

Free radicals are necessary for many other bodily functions as well. The thyroid gland synthesizes its own hydrogen peroxide, which is required for the production of thyroid hormone. Reactive oxygen species and reactive nitrogen species, which are free radicals containing nitrogen, have been found to interact with proteins in cells to produce signaling molecules. The free radical nitric oxide has been found to help dilate blood vessels and act as a chemical messenger in the brain.

By acting as signaling molecules, free radicals are involved in the control of their own synthesis, stress responses, regulation of cell growth and death, and metabolism.

Sources of Free Radicals in the Environment

The body creates free radicals through the normal processes of metabolism. When the amount of free radicals exceeds the body’s ability to eliminate or neutralize them, an oxidative imbalance occurs.

Substances and energy sources from the environment can add to or accelerate the production of free radicals within the body. Exposure to excessive sunlight, ozone, smoke, heavy metals, ionizing radiation, asbestos, and other toxic chemicals increase the number of free radicals in the body. They do so by being free radicals themselves or by adding energy that provokes electrons to move between atoms. Excessive exposure to environmental sources of free radicals can contribute to disease by overwhelming the free radical detoxifying systems and those processes involved in repairing oxidative damage.

Video 8.2.1

Free Radical Formation (click to see video)

Oxidative Stress

Oxidative stress refers to an imbalance in any cell, tissue, or organ between a number of free radicals and the capabilities of the detoxifying and repair systems. Sustained oxidative damage results only under conditions of oxidative stress—when the detoxifying and repair systems are insufficient. Free radical-induced damage, when left unrepaired, destroys lipids, proteins, RNA, and DNA, and can contribute to disease. Oxidative stress has been implicated as a contributing factor to cancer, atherosclerosis (hardening of arteries), arthritis, diabetes, kidney disease, Alzheimer’s disease, Parkinson’s disease, schizophrenia, bipolar disorder, emphysema, and cataracts.

Aging is a process that is genetically determined but modulated by factors in the environment. In the process of aging, tissue function declines. The idea that oxidative stress is the primary contributor to age-related tissue decline has been around for decades, and it is true that tissues accumulate free radical-induced damage as we age. Recent scientific evidence slightly modifies this theory by suggesting oxidative stress is not the initial trigger for the age-related decline of tissues; it is suggested that the true culprit is progressive dysfunction of metabolic processes, which leads to increases in free radical production, thus influencing the stress response of tissues as they age.

Video 8.2.2

Free Radicals or Oxidative Stress Will Age Our Bodies' Cells (click to see video)

Oxidative stress occurs when there is an imbalance between free radical production and their detoxification. Sustained oxidative tissue damage that can contribute to disease occurs only when free radical detoxification systems and repair systems are overwhelmed.

Key Takeaways

- Free radicals, unstable molecules with unpaired electrons, are an unavoidable byproduct of cellular metabolism.
- Free radicals can steal electrons from lipids, proteins, RNA, and DNA, causing them damage.
- The body has defenses against free radicals—free radical detoxifying enzymes and antioxidant chemicals.
- The body can synthesize some antioxidant molecules, but many are obtained from the diet.
- The body sometimes uses free radicals for beneficial functions such as killing pathogens and regulating cell growth and death.
- Oxidative stress is an imbalance between free radical production and detoxification and repair systems. It also plays an integral role in the development of many chronic diseases and in age-related decline of tissues.
- Excessive sunlight, ozone, smoke, heavy metals, radiation, asbestos, and other toxic chemicals increase the amount of free radicals in the body and can accelerate the progression of diseases in which oxidative stress is a contributing cause.

Discussion Starter

1. What are some ways you can prevent exposure to environmental factors that increase free radical production in your body?

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8.3: Antioxidant Micronutrients

Learning Objectives

1. List the antioxidant nutrients.
2. Give examples of the best food sources of antioxidant nutrients.
3. Name some phytochemicals and their health benefits as backed by scientific evidence.

The market is flooded with advertisements for "super antioxidant" supplements teeming with molecules that block free radical production, stimulate the immune system, prevent cancer, and reduce the signs of aging. Based on the antioxidant-supplement industry's success, the general public appears to believe these health claims. However, these claims are not backed by scientific evidence; rather, there is some evidence suggesting supplements can actually cause harm.

While scientists have found evidence supporting the consumption of antioxidant-rich foods as a method of reducing the risk of chronic disease, there is no "miracle cure;" no pill or supplement alone can provide the same benefits as a healthy diet. Remember, it is the combination of antioxidants and other nutrients in healthy foods that is beneficial.

In this section, we will review how particular antioxidants function in the body, learn how they work together to protect the body against free radicals, and explore the best nutrient-rich dietary sources of antioxidants.

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Antioxidant Vitamins

One dietary source of antioxidants is vitamins. In our discussion of antioxidant vitamins, we will focus on vitamins C, E, and A.

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Vitamin C Functions and Health Benefits

Vitamin C, also commonly called ascorbic acid, is a water-soluble micronutrient essential in the diet for humans, although most other mammals can readily synthesize it. Vitamin C's ability to easily donate electrons makes it a highly effective antioxidant. It is effective in scavenging reactive oxygen species, reactive nitrogen species, and many other free radicals. It protects lipids both by disabling free radicals and by aiding in the regeneration of vitamin E.

In addition to its role as an antioxidant, vitamin C is a required part of several enzymes involved in the synthesis of collagen, signaling molecules in the brain, some hormones, and amino acids. Vitamin C levels in the body are affected by the amount in the diet, which influences how much is absorbed and how much the kidney allows to be excreted, such that the higher the intake, the more vitamin C is excreted. Vitamin C is not stored in any significant amount in the body, but once it has reduced a free radical, it is very effectively regenerated and therefore it can exist in the body as a functioning antioxidant for many weeks.

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Other Functions

Vitamin C has several other important functions. It is a co-factor in the formation of collagen. Collagen is a fibrous structural protein found in skin, scars, blood vessels, tendons, ligaments, bone, and teeth. Another function, vitamin C assists in the absorption of iron.

Deficiency signs and symptoms

The classic condition associated with vitamin C deficiency is scurvy. You only need about 10 mg/day of ascorbic acid to prevent scurvy and it takes about one month to appear. The signs and symptoms of scurvy include skin disorders such as rough, dry, scaly skin, bleeding gums, degeneration of muscles, painful joints, weakness, depression, and increased susceptibility to infections. These are associated with the physiological changes in collagen. In children, growth is impeded. People who smoke, experience physical stress and are alcoholics at a greater risk of developing a vitamin C deficiency and may need extra vitamin C. Scurvy is prevented by having an adequate Intake of fruits and vegetables rich in vitamin C.

Cardiovascular Disease

Vitamin C's ability to prevent disease has been debated for many years. Overall, higher dietary intakes of vitamin C (via food intake, not supplements), are linked to decreased disease risk. A review of multiple studies published in the April 2009 issue of the *Archives of Internal Medicine* concludes there is moderate scientific evidence supporting the idea that higher dietary vitamin C intakes are correlated with reduced cardiovascular disease risk, but there is insufficient evidence to conclude that taking vitamin C supplements influences cardiovascular disease risk.Mente, A., et al. "A Systematic Review of the Evidence Supporting a Causal Link between Dietary Factors and Coronary Heart Disease." *Arch Intern Med* 169, no.7 (2009): 659–69. http://archinte.ama-assn.org/cgi/content/full/169/7/659.

Vitamin C levels in the body have been shown to correlate well with fruit and vegetable intake, and higher plasma vitamin C levels are linked to reduced risk of some chronic diseases. In a study involving over twenty thousand participants, people with the highest levels of circulating vitamin C had a 42 percent decreased risk for having a stroke.Myint, P.K. et al. "Plasma Vitamin C Concentrations Predict Risk of Incident Stroke Over 10 Y[ears] in 20,649 Participants of the European Prospective Investigation into Cancer, Norfolk Prospective Population Study." *Am J Clin Nutr* 87, no.1 (2008): 64–69. http://www.ajcn.org/content/87/1/64.long.

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Cancer

There is some evidence that a higher vitamin C intake is linked to a reduced risk of cancers of the mouth, throat, esophagus, stomach, colon, and lung, but not all studies confirm this is true. As with the studies on cardiovascular disease, the reduced risk of cancer is the result of eating foods rich in vitamin C, such as fruits and vegetables, not from taking vitamin C supplements. In these studies, the specific protective effects of vitamin C cannot be separated from the many other beneficial chemicals in fruits and vegetables.

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Immunity

Vitamin C does have several roles in the immune system, and many people increase vitamin C intake either from diet or supplements when they have a cold. Many others take vitamin C supplements routinely to prevent colds. Contrary to this popular practice, however, there is no good scientific evidence that vitamin C prevents a cold. A review of more than fifty years of studies published in 2004 in the *Cochrane Database of Systematic Reviews* concludes that taking vitamin C routinely does not prevent colds in most people, but it does slightly reduce cold severity and duration. Moreover, taking megadoses (up to 4 grams per day) at the onset of a cold provides no benefits.Douglas, R.M. et al. "Vitamin C for Preventing and Treating the Common Cold." *Cochrane Database of Systematic Reviews* 4 (2004): CD000980. http://www.ncbi.nlm.nih.gov/pubmed/15495002?dopt=Abstract.

Gout is a disease caused by elevated circulating levels of uric acid and is characterized by recurrent attacks of tender, hot, and painful joints. There is some evidence that a higher intake of vitamin C reduces the risk of gout.

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Dietary Reference Intakes for Vitamin C

The RDAs and ULs for different age groups for vitamin C are listed in Table 8.3.1. They are considered adequate to prevent scurvy. Vitamin C's effectiveness as a free radical scavenger motivated the Institute of Medicine (IOM) to increase the RDA for smokers by 35 milligrams, as tobacco smoke is an environmental and behavioral contributor to free radicals in the body.

Table 8.3.1: Dietary Reference Intakes for Vitamin C

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	40*	–
Infants (7–12 months)	50*	–
Children (1–3 years)	15	400
Children (4–8 years)	25	650
Children (9–13 years)	45	1200
Adolescents (14–18 years)	75 (males), 65 (females)	1800
Adults (> 19 years)	90 (males), 75 (females)	2000
*denotes Adequate Intake		

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin C.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminC-QuickFacts/.

Heat, iron, copper, and oxygen can destroy vitamin C in foods.

High doses of vitamin C have been reported to cause numerous problems, but the only consistently shown side effects are gastrointestinal upset and diarrhea. To prevent these discomforts the IOM has set a UL for adults at 2,000 milligrams per day (greater than twenty times the RDA). Greater than 4000 grams per day may cause health problems including nausea, abdominal cramps, diarrhea, interference with medications like anti-clotting drugs, act as a pro-oxidant, and give a false positive/negative urine analysis for diabetes detection.

At very high doses in combination with iron, vitamin C has sometimes been found to increase oxidative stress, reaffirming that getting your antioxidants from foods is better than getting them from supplements, as that helps regulate your intake levels. There is some evidence that taking vitamin C supplements at high doses increases the likelihood of developing kidney stones, however, this effect is most often observed in people that already have multiple risk factors for kidney stones.

Discontinuing your intake of high doses of vitamin C can cause rebound scurvy because enzyme levels for vitamin C are elevated. It is best to taper down a high dose instead of stopping immediately.

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Dietary Sources of Vitamin C

Citrus fruits are great sources of vitamin C and so are many vegetables. In fact, British sailors in the past were often referred to as “limeys” as they carried sacks of limes onto ships to prevent scurvy. Vitamin C is not found in significant amounts in animal-based foods like meat and dairy, and grains and legumes.

Because vitamin C is water-soluble, it leeches away from foods considerably during cooking, freezing, thawing, and canning. Up to 50 percent of vitamin C can be boiled away. Therefore, to maximize vitamin C intake from foods, you should eat fruits and vegetables raw or lightly steamed. For the vitamin C content of various foods, see Table 8.3.2.

Table 8.3.2: Vitamin C Content of Various Foods

Food	Serving	Vitamin C (mg)
Orange juice	6 oz.	62–93
Grapefruit juice	6 oz.	62–70
Orange	1 medium	70
Grapefruit	½ medium	38
Strawberries	1 c.	85
Tomato	1 medium	16
Sweet red pepper	½ c. raw	95
Broccoli	½ c. cooked	51
Asparagus	1 c. cooked	20
Romaine lettuce	2 c.	27
Kale	1 c. boiled	53
Cauliflower	1 c. boiled	55
Potato	1 medium, baked	17

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin C.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminC-HealthProfessional/.

Vitamin E Functions and Health Benefits

Vitamin E is actually eight chemically similar substances, of which alpha-tocopherol appears to be the most potent antioxidant. Alpha-tocopherol and vitamin E’s other constituents (tocotrienols) are fat-soluble and primarily responsible for protecting cell membranes against lipid destruction caused by free radicals.

After alpha-tocopherol interacts with a free radical it is no longer capable of acting as an antioxidant unless it is enzymatically regenerated. Vitamin C helps to regenerate some of the alpha-tocopherol, but the remainder is eliminated from the body. Therefore, to maintain vitamin E levels, you ingest it as part of your diet.

In addition to its antioxidant functions, vitamin E, mainly as alpha-tocopherol, can change the functions of proteins in cells, plays a role in the operations of the immune system, enhances the dilation of blood vessels, and inhibits blood clot formation. Despite vitamin E’s numerous beneficial functions when taken in recommended amounts, large studies do not support the idea that taking higher doses of this vitamin will increase its power to prevent or reduce disease risk.Goodman, M., Bostlick RM, Kucuk O, Jones DP. 2011. Clinical trials of antioxidants as cancer prevention agents: past, present, and future. Free Radic Biol Med. 51(5): 1068–84.· McGinley C, Shafat A. Donnelly AE. 2009. Does antioxidant vitamin supplementation protect against muscle damage? Sports Med. 39(12): 1011–32.

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Deficiency signs and symptoms

Inadequate intake of vitamin E can cause erythrocyte hemolysis or fragile red blood cells, hemolytic anemia, and/or neuromuscular dysfunction involving the spinal cord and retina. Groups at risk of developing a deficiency are premature infants because they lack fat stores, people eating very little food, individuals with fat malabsorption (e.g. cystic fibrosis), people who consume large amounts of polyunsaturated fatty acids, and people who smoke or live in a smoggy area.

Cardiovascular Disease

Recall from Chapter 4 that low-density lipoproteins (LDLs) transport cholesterol and other lipids from the liver to the rest of the body. LDLs are often referred to as "bad cholesterol," as an elevation in their levels in the blood is a risk factor for cardiovascular disease. Oxidation of the lipids and proteins in LDLs causes them to stick to the walls of arteries and this contributes to the development of fatty streaks and, eventually, plaque, which hardens the arteries. Hardening of the arteries, called atherosclerosis can lead to a heart attack.

Vitamin E reduces the oxidation of LDLs, and it was therefore hypothesized that vitamin E supplements would protect against atherosclerosis. However, large clinical trials have not consistently found evidence to support this hypothesis. In fact, in the "Women's Angiographic Vitamin and Estrogen Study," postmenopausal women who took 400 international units (264 milligrams) of vitamin E and 500 milligrams of vitamin C twice per day had higher death rates from all causes.Waters, D.D. et al. "Effects of Hormone Replacement Therapy and Antioxidant Vitamin Supplements on Coronary Atherosclerosis in Postmenopausal Women: A Randomized Controlled Trial." *JAMA* 288, no. 19 (2002): 2432–40. doi: 10.1001/jama.288.19.2432

Other studies have not confirmed the association between increased vitamin E intake from supplements and increased mortality. There is more consistent evidence from observational studies that a higher intake of vitamin E from foods is linked to a decreased risk of dying from a heart attack.

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Cancer

The large clinical trials that evaluated whether there was a link between vitamin E and cardiovascular disease risk also looked at cancer risk. These trials, called the HOPE-TOO Trial and Women's Health Study, did not find that vitamin E at doses of 400 international units (264 milligrams) per day or 600 international units (396 milligrams) every other day reduced the risk of developing any form of cancer.HOPE and HOPE-TOO Trial Investigators. "Effects of Long-Term Vitamin E Supplementation on Cardiovascular Events and Cancer." *JAMA* 293 (2005):1338–47. http://jama.ama-assn.org/content/293/11/1338.long.· Lee, I-M., et al. "Vitamin E in the Primary Prevention of Cardiovascular Disease and Cancer: The Women's Health Study." *JAMA* 294 (2005): 56–65. http://jama.ama-assn.org/content/294/1/56.long.

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Eye Conditions

Oxidative stress plays a role in the age-related loss of vision, called macular degeneration. Age-related macular degeneration (AMD) primarily occurs in people over age fifty and is the progressive loss of central vision resulting from damage to the center of the retina, referred to as the macula. There are two forms of AMD, dry and wet, with wet being the more severe form.

In the dry form, deposits form in the macula; the deposits may or may not directly impair vision, at least in the early stages of the disease. In the wet form, abnormal blood vessel growth in the macula causes vision loss. Clinical trials evaluating the effects of vitamin E supplements on AMD and cataracts (clouding of the lens of an eye) did not consistently observe a decreased risk for either. However, scientists do believe vitamin E in combination with other antioxidants such as zinc and copper may slow the progression of macular degeneration in people with early-stage disease.

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Dementia

The brain's high glucose consumption makes it more vulnerable than other organs to oxidative stress. Oxidative stress has been implicated as a major contributing factor to dementia and Alzheimer's disease. Some studies suggest vitamin E supplements delay the progression of Alzheimer's disease and cognitive decline, but again, not all of the studies confirm the relationship. A recent study with over five thousand participants published in the July 2010 issue of the *Archives of Neurology* demonstrated that people with the highest intakes of dietary vitamin E were 25 percent less likely to develop dementia than those with the lowest intakes of vitamin E.Devore, E. E. et al. "Dietary Antioxidants and Long-Term Risk of Dementia." *Arch Neurol* 67, no.7 (2010): 819–25. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923546/?tool=pubmed. More studies are needed to better assess the dose and dietary requirements of vitamin E and, for that matter, whether other antioxidants lower the risk of dementia, a disease that not only devastates the mind, but also puts a substantial burden on loved ones, caretakers, and society in general.

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Dietary Reference Intakes for Vitamin E

The Recommended Dietary Allowances (RDAs) and Tolerable Upper Intake Levels (ULs) for different age groups for vitamin E are given in Table 8.3.3 "Dietary Reference Intakes for Vitamin E". The RDAs are based on scientific evidence that these levels of vitamin E in the diet prevent conditions associated with vitamin E deficiency, which is rare (signs and symptoms of such conditions are not always evident) but is primarily the result of nerve degeneration. People with malabsorption disorders, such as Crohn's disease or cystic fibrosis, and babies born prematurely, are at higher risk for vitamin E deficiency. High doses interfere with vitamin K and enhance anti-blood clotting medications.

Fat in the diet is required for vitamin E absorption as it is packaged into lipid-rich chylomicrons in intestinal cells and transported to the liver. The liver stores some of the vitamin E or packages it into lipoproteins, which deliver it to cells.

Table 8.3.3: Dietary Reference Intakes for Vitamin E

Age Group	RDA Males and Females mg/day	UL
Infants (0–6 months)	4*	–
Infants (7–12 months)	5*	–
Children (1–3 years)	6	200
Children (4–8 years)	7	300
Children (9–13 years)	11	600
Adolescents (14–18 years)	15	800
Adults (> 19 years)	15	1,000
*denotes Adequate Intake		

Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin E." Last modified October 11, 2011. http://ods.od.nih.gov/factsheets/VitaminE-QuickFacts/.

Vitamin E supplements often contain more than 400 international units, which is almost twenty times the RDA. The UL for vitamin E is set at 1,500 international units for adults. There is some evidence that taking vitamin E supplements at high doses has negative effects on health. As mentioned, vitamin E inhibits blood clotting and a few clinical trials have found that people taking vitamin E supplements have an increased risk of stroke. In contrast to vitamin E from supplements, there is no evidence that consuming foods containing vitamin E compromises health.

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Dietary Sources of Vitamin E

Vitamin E is found in many foods, especially those higher in fat, such as nuts and oils. Some spices, such as paprika and red chili pepper, and herbs, such as oregano, basil, cumin, and thyme, also contain vitamin E. (Keep in mind spices and herbs are commonly used in small amounts in cooking and therefore are a lesser source of dietary vitamin E.) See Table 8.3 for a list of foods and their vitamin E contents.

> *To increase your dietary intake of vitamin E from plant-based foods try a spinach salad with tomatoes and sunflower seeds, and add a dressing made with sunflower oil, oregano, and basil.*

Table 8.3.4: Vitamin E Content of Various Foods

Food	Vitamin E (mg)	Percent Daily Value
Wheat-germ oil (1 Tbsp.)	20.3	100
Sunflower seeds (1 oz.)	7.4	37
Almonds (1 oz.)	6.8	34
Sunflower oil (1 Tbsp.)	5.6	28
Safflower oil (1 Tbsp.)	4.6	23
Hazelnuts (1 oz.)	4.3	22
Peanut butter (2 Tbsp.)	2.9	15
Peanuts (1 oz.)	2.2	11
Corn oil (1 Tbsp.)	1.9	10
Kiwi (1 medium)	1.1	6
Tomato (1 medium)	0.7	4
Spinach (1 c. raw)	0.6	3

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin E.” Last reviewed October 11, 2011. http://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/.

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Vitamin A Functions and Health Benefits

Vitamin A is a generic term for a group of similar compounds called retinoids. Retinol is the form of vitamin A found in animal-derived foods, and it is converted in the body to the biologically active forms of vitamin A: retinal and retinoic acid (thus retinol is sometimes referred to as “preformed vitamin A”). About 10 percent of plant-derived carotenoids, including beta-carotene, can be converted in the body to retinoids and are another source of functional vitamin A. The retinoids are aptly named as their most notable function is in the retina of the eye where they aid in vision, particularly in seeing under low-light conditions. This is why night blindness is the most definitive sign of vitamin A deficiency.

Like vitamin E, vitamin A is fat-soluble and is packaged into chylomicrons in small intestine mucosal cells, and then transported to the liver. The liver stores and exports vitamin A as needed; it is released into the blood bound to a retinol-binding protein, which transports it to cells.

Beta-carotene is not considered a vitamin but is split by an intestinal enzyme to form retinol. It is brightly colored green, yellow, orange and/or red. It acts as an antioxidant.

Vitamin A has several important functions in the body, including maintaining vision and a healthy immune system. Many of vitamin A’s functions in the body are similar to the functions of hormones (for example, vitamin A can interact with DNA, causing a change in protein function). Vitamin A assists in maintaining healthy skin and the linings and coverings of tissues; it also regulates growth and development. As an antioxidant, vitamin A protects cellular membranes, helps in maintaining glutathione levels, and influences the amount and activity of enzymes that detoxify free radicals.

Deficiency signs and symptoms

A deficiency of vitamin A can 1-2 years to manifest since it fat soluble and stored in the body. Signs and symptoms include night blindness, xerophthalmia which can progress to total blindness, an irreversible condition, keratinization, and exacerbate infectious diseases. Keratin is a protein that is secreted from epithelial cells. Without adequate intake of vitamin, A keratin accumulates in lumps in hair follicles and skin becomes dry, scaly and rough. In the gastrointestinal tract, the cells do not form properly and malabsorption of nutrients can occur. A lack of vitamin A is correlated with the severity of measles. Groups at risk of developing a vitamin A deficiency include infants and children in developing countries, people who eat very little fat and individuals with fat malabsorption as seen with Cystic fibrosis and AIDS.

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Vision

Retinol that is circulating in the blood is taken up by cells in the retina, where it is converted to retinal and is used as part of the pigment rhodopsin, which is involved in the eye’s ability to see under low light conditions. A deficiency in vitamin A thus results in less rhodopsin and a decrease in the detection of low-level light, a condition referred to as night blindness.

Insufficient intake of dietary vitamin A over time can also cause complete vision loss. In fact, vitamin A deficiency is the number one cause of preventable blindness worldwide. Vitamin A not only supports the vision function of eyes but also maintains the coverings and linings of the eyes. Vitamin A deficiency can lead to the dysfunction of the linings and coverings of the eye, causing dryness of the eyes, a condition called xerophthalmia. This condition can progress, causing ulceration of the cornea and eventually blindness.

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Immunity

The common occurrence of advanced xerophthalmia in children who died from infectious diseases led scientists to hypothesize that supplementing vitamin A in the diet for children with xerophthalmia might reduce disease-related mortality. In Asia in the late 1980s, targeted populations of children were administered vitamin A supplements, and the death rates from measles and diarrhea declined by up to 50 percent. Vitamin A supplementation in these deficient populations did not reduce the number of children who contracted these diseases, but it did decrease the severity of the diseases so that they were no longer fatal. Soon after the results of these studies were communicated to the rest of the world, the World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) commenced worldwide campaigns against vitamin A deficiency. UNICEF estimates that the distribution of over half a billion vitamin A capsules prevents 350,000 childhood deaths annually.Sommer, A. “Vitamin A Deficiency and Clinical Disease: A Historical Overview.” *J Nutr* 138 (2008):1835–39. http://jn.nutrition.org/content/138/10/1835.long.

In the twenty-first century, science has demonstrated that vitamin A greatly affects the immune system. What we are still lacking are clinical trials investigating the proper doses of vitamin A required to help ward off infectious disease and how large of an effect vitamin A supplementation has on populations that are not deficient in this vitamin. This brings up one of our common themes in this text—micronutrient deficiencies may contribute to the development, progression, and severity of a disease, but this does not mean that an increased intake of these micronutrients will solely prevent or cure disease. The effect, as usual, is cumulative and depends on the diet as a whole, among other things.

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Growth and Development

Vitamin A acts similarly to some hormones in that it is able to change the amount of proteins in cells by interacting with DNA. This is the primary way that vitamin A affects growth and development. Vitamin A deficiency in children is linked to growth retardation; however, vitamin A deficiency is often accompanied by protein malnutrition and iron deficiency, thereby confounding the investigation of vitamin A’s specific effects on growth and development.

In the fetal stages of life, vitamin A is important for limb, heart, eye, and ear development and in both deficiency and excess, vitamin A causes birth defects. Furthermore, both males and females require vitamin A in the diet to effectively reproduce.

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Cancer

Vitamin A's role in regulating cell growth and death, especially in tissues that line and cover organs, suggests it may be effective in treating certain cancers of the lung, neck, and liver. It has been shown in some observational studies that vitamin A-deficient populations have a higher risk for some cancers. However, vitamin A supplements have actually been found to increase the risk of lung cancer in people who are at high risk for the disease (i.e., smokers, ex-smokers, workers exposed to asbestos). The Beta-Carotene and Retinol Efficacy Trial (CARET) involving over eighteen thousand participants who were at high risk for lung cancer found that people who took supplements containing very high doses of vitamin A (25,000 international units) and beta-carotene had a 28 percent higher incidence of lung cancer midway through the study, which was consequently stopped.Goodman, G.E. et al. "The Beta-Carotene and Retinol Efficacy Trial: Incidence of Lung Cancer and Cardiovascular Disease Mortality During 6-year Follow-up after Stopping Beta-Carotene and Retinol Supplements." *J Natl Cancer Inst* 96, no. 23 (2004): 1743–50. http://jnci.oxfordjournals.org/content/96/23/1743.long.

Vitamin A supplementation is a relatively common practice in treating some types of cancer patients and is thought to improve the effectiveness of some anti-cancer drugs, but many oncologists (physicians who treat cancer patients) do not recommend this practice as vitamin A may actually inhibit the actions of some anticancer drugs.

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Vitamin A Toxicity

Vitamin A toxicity, or hypervitaminosis A, is rare. Typically it requires you to ingest ten times the RDA of preformed vitamin A in the form of supplements (it would be hard to consume such high levels from a regular diet) for a substantial amount of time, although some people may be more susceptible to vitamin A toxicity at lower doses. The signs and symptoms of vitamin A toxicity include dry, itchy skin, loss of appetite, swelling of the brain, joint pain and birth defects. In severe cases, vitamin A toxicity may cause permanent liver damage, coma, and death.

Some acne medications, like Accutane, are a derivative of vitamin A; in other words, they are made from vitamin A but are chemically different. Physicians prescribing these drugs will monitor vitamin A levels closely to avoid toxicity. Eating dietary vitamin A is not beneficial for acne.

Vitamin A is essential during pregnancy, but doses above 3,000 micrograms per day (10,000 international units) have been linked to an increased incidence of birth defects. Pregnant women should check the amount of vitamin A contained in any prenatal or pregnancy multivitamin she is taking to assure the amount is below the UL.

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Dietary Reference Intakes for Vitamin A

There is more than one source of vitamin A in the diet. There is preformed vitamin A, which is abundant in many animal-derived foods, and there are carotenoids, which are found in high concentrations in vibrantly colored fruits and vegetables and some oils.

Some carotenoids are converted to retinol in the body by intestinal cells and liver cells. However, only minuscule amounts of certain carotenoids are converted to retinol, meaning fruits and vegetables are not necessarily good sources of vitamin A. Beta-carotene dissolved in oil is more readily converted to retinol; one-half of a microgram of beta-carotene is converted to retinol. Overall, the carotenoids do not have the same biological potency of preformed vitamin A, but as you will soon find out, they have other attributes that influence health, most notably their antioxidant activity.

The RDA for vitamin A includes all sources of vitamin A. The amount of vitamin A obtained from carotenoids—the retinol activity equivalent (RAE)—can be calculated. For example, 12 micrograms of fruit- or vegetable-based beta-carotene will yield 1 microgram of retinol, as mentioned.

The RDA for vitamin A is considered sufficient to support growth and development, reproduction, vision, and immune system function while maintaining adequate stores (good for four months) in the liver.

Table 8.3.5: Dietary Reference Intakes for Vitamin A

Age Group	RDA Males and Females mcg/day	UL
Infants (0–6 months)	400*	600
Infants (7–12 months)	500*	600
Children (1–3 years)	300	600
Children (4–8 years)	400	900
Children (9–13 years)	600	1,700
Adolescents (14–18 years)	Males: 900	2,800
	Females: 700	
Adults (> 19 years)	Males: 900	3,000
	Females: 700	
*denotes Adequate Intake		

Source: Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin A." Last reviewed September 5, 2012. http://ods.od.nih.gov/factsheets/VitaminA-QuickFacts/.

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Dietary Sources of Vitamin A

Preformed vitamin A is found only in foods from animals, with the liver being the richest source because that's where vitamin A is stored (see Table 8.3.6). Fortified milk and milk products, eggs, butter and fish liver oils are also good sources of vitamin A. The dietary sources of carotenoids will be given in the following text.

Table 8.3.6: Vitamin A Content of Various Foods

Food	Serving	Vitamin A (IU)	Percent Daily Value
Beef liver	3 oz.	27,185	545
Chicken liver	3 oz.	12,325	245
Milk, skim	1 c.	500	10
Milk, whole	1 c.	249	5
Cheddar cheese	1 oz.	284	6

Source: Source: National Institutes of Health, Office of Dietary Supplements. "Dietary Supplement Fact Sheet: Vitamin A." Last reviewed July 25, 2012. http://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/.

Phytochemicals

Phytochemicals are chemicals in plants that may provide some health benefit; they are not nutrients. Carotenoids are one type of phytochemical. Phytochemicals also include indoles, lignans, phytoestrogens, stanols, saponins, terpenes, flavonoids, carotenoids, anthocyanidins, phenolic acids, and much more. They are found not only in fruits and vegetables, but also in grains, seeds, nuts, and legumes. They are present to give the plant color, flavor, odor, and protection.

Many phytochemicals act as antioxidants, but they have several other functions, such as mimicking hormones, altering the absorption of cholesterol, inhibiting inflammatory responses, and blocking the actions of certain enzymes.

Phytochemicals are present in small amounts in the food supply, and although thousands have been and are currently being scientifically studied, their health benefits remain largely unknown. It is not known if they are essential; no deficiency syndromes have been found. Also, largely unknown is their potential for toxicity, which could be substantial if taken in large amounts in the form of supplements. Moreover, phytochemicals often act in conjunction with each other and with micronutrients. Thus, supplementing with only a few may impair the functions of other phytochemicals or micronutrients. As with the antioxidant vitamins, it is the mixture and variety of phytochemicals in foods that are linked to health benefits.

Carotenoids Function and Health Benefits

Carotenoids are pigments synthesized by plants that give them their yellow, orange, and red color. Over six hundred carotenoids have been identified and, with just a few exceptions, all are found in the plant kingdom. There are two classes of carotenoids—the xanthophylls, which contain oxygen, and the carotenes, which do not.

In plants, carotenoids absorb light for use in photosynthesis and act as antioxidants. Beta-carotene, alpha-carotene, gamma-carotene, and beta-cryptoxanthin are converted to some extent to retinol in the body. The other carotenoids, such as lycopene, are not. Many biological actions of carotenoids are attributed to their antioxidant activity, but they likely act by other mechanisms, too.

Beta-carotene from foods is not toxic but may turn skin yellow or orange.

Eye Conditions

Lutein, found in green leafy vegetables, and zeaxanthin, found in peppers, corn, and saffron, act as antioxidants in the retina of the eye and protect it from ultraviolet light damage. Diets high in these carotenoids are associated with a decreased risk of AMD, and there is good evidence that supplements containing these carotenoids also provide vision benefits. A review published in the August 2010 issue of *Current Medical Research and Opinion* concludes that supplementation with lutein and zeaxanthin reduces the incidence of AMD and cataracts.Barker II, F. M. “Dietary Supplementation: Effects on Visual Performance and Occurrence of AMD and Cataracts.” *Curr Med Res Opin* 26, no. 8 (2010): 2011–23. http://informahealthcare.com/doi/abs/10.1185/03007995.2010.494549.

The data that supports that beta-carotene supplementation may delay the progression of AMD is more convincing when beta-carotene is taken in combination with other micronutrients. The Age-Related Eye Disease Study found that a supplement containing 500 milligrams of vitamin C, 400 international units of vitamin E, 15 milligrams of beta-carotene, 80 milligrams of zinc oxide, and 2 milligrams of copper as cupric oxide reduced the risk of progressing to advanced stages of AMD by 25 percent.Age-Related Eye Disease Study Research Group. “A Randomized, Placebo-Controlled, Clinical Trial of High-Dose Supplementation with Vitamins C and E, Beta-Carotene, and Zinc for Age-Related Macular Degeneration and Vision Loss.” *Arch Ophthalmol* 119, no. 10 (2001): 1417–36. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1462955/. This study did not find that the formulated supplement significantly prevented the onset of disease, only that it delayed its progression specifically in people with intermediate or advanced stage AMD. Studies are ongoing to determine if other antioxidant combinations actually protect against developing AMD at all.

Cardiovascular Disease

While some studies do associate a decreased risk for atherosclerosis with higher dietary intake of carotenoids, others do not. There is a large number of studies that show total carotenoid intake is associated with improvement in blood vessel function. A smaller number of studies show that intake of specific carotenoids, such as lycopene and alpha-carotene, are also associated with improved blood vessel function. The main problems associated with linking carotenoids to a decrease in cardiovascular disease risk, or any other disease for that matter, are that they are present in foods containing many other beneficial plant chemicals, and trials evaluating the effects of specific carotenoids in the form of supplements provide inconsistent and sometimes contradictory results.

Cancer

A higher intake of some carotenoids, but not others, is linked to decreased risks for some cancers. A review of two large studies (> 120,000 men and women) published in the October 2000 issue of *The American Journal of Clinical Nutrition* reports that there is no significant association between beta-carotene intake and lung cancer risk, but men and women with the highest intakes of total carotenoids had a more than 30 percent risk reduction for developing lung cancer.Michaud, D.S. et al. “Intake of Specific Carotenoids and Risk of Lung Cancer in 2 Prospective US Cohorts.” *Am J Clin Nutr* 72, no. 4 (2000): 990–97. http://www.ajcn.org/content/72/4/990.long. Other large studies conducted in Europe have confirmed the inverse relationship of total dietary carotenoid intake with lung cancer risk. There is some evidence that diets rich in lycopene, which is present in high concentrations in tomatoes, is linked to decreased prostate cancer risk, but it is not known if it is lycopene specifically or some other component in tomatoes that protects against prostate cancer.

Carotenoid Bioavailability and Dietary Sources

Carotenoids are not absorbed as well as vitamin A, but similar to vitamin A, they do require fat in the meal for absorption. In intestinal cells, carotenoids are packaged into the lipid-containing chylomicrons inside small intestine mucosal cells and then transported to the liver. In the liver, carotenoids are repackaged into lipoproteins, which transport them to cells.

In contrast to most micronutrients, carotenoid availability is actually increased by the cooking process because cooking, along with chopping and homogenizing, releases carotenoids from the plant matrix. Thus, eating a can of tomatoes provides more lycopene than eating a raw tomato. However, overcooking transforms some of the carotenoids into inactive products, and in general, it is best to chop and lightly steam vegetables containing carotenoids to maximize their availability from foods. Cooking carotenoid-containing foods in oil also enhance the bioavailability of carotenoids. In the United States, the most consumed carotenoids are alpha-carotene, beta-carotene, beta-cryptoxanthin, lycopene, lutein, and zeaxanthin. See Table 8.3.7 and Note 8.18 for the carotenoid content of various foods.

Table 8.3.7: Alpha- and Beta-Carotene Content of Various Foods

Food	Serving	Beta-carotene (mg)	Alpha-carotene (mg)
Pumpkin, canned	1c.	17.00	11.70
Carrot juice	1c.	22.00	10.20
Carrots, cooked	1c.	13.00	5.90
Carrots, raw	1 medium	5.10	2.10
Winter squash, baked	1c.	5.70	1.40
Collards, cooked	1c.	11.60	0.20
Tomato	1 medium	0.55	0.10

Food	Serving	Beta-carotene (mg)	Alpha-carotene (mg)
Tangerine	1 medium	0.13	0.09
Peas, cooked	1c.	1.20	0.09

Source: US Department of Agriculture, Agricultural Research Service. 2010. *USDA National Nutrient Database for Standard Reference*, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl.

Interactive 8.3.1

Visit the USDA website and find out more about the carotenoid content of various foods.

http://www.ars.usda.gov/Services/docs.htm?docid=20958

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Three Other Phytochemicals and Their Potential Health Benefits

Three classes of phytochemicals (other than carotenoids) are flavonoids, organosulfur compounds, and lignans. Their potential health benefits are discussed below.

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Flavonoids

Flavonoids are a large class of chemicals including anthocyanidins (found in red, blue, and purple berries), flavanols (found in teas, chocolate, berries, apples, yellow onions, kale, and broccoli), and isoflavones (found in soy products). Flavonoids are very effective free radical scavengers, and there is some evidence that higher intakes of flavonoid-rich foods and/or beverages reduce the risk of cardiovascular disease, but this has not been consistently observed. Although flavonoids have been shown to reduce the incidence of some tumors in animals, similar studies in humans have been inconclusive.

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Organosulfur Compounds

These compounds are predominantly found in garlic, but can also be found in onions and leeks. It's suspected that the higher intake of garlic is the aspect of the Mediterranean diet that contributes to a decreased risk of cardiovascular disease. Animal and laboratory studies suggest the organosulfur compounds in garlic reduce cholesterol, are anti-inflammatory, stimulate the synthesis of glutathione, and cause the death of cancer cells. There is some evidence in humans that garlic reduces cholesterol, but more recent studies did not confirm that the effect was significant or sustained. A higher intake of garlic likely inhibits blood clot formation in humans.

Observational studies suggest diets high in organosulfur compounds decrease the risk of gastric and colorectal cancer. For other cancers, the data is less consistent.

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Lignans

Lignans are a group of chemical compounds obtained from many food sources, including grains, nuts, seeds, fruits, and vegetables, and especially flax seed. Some lignans are also called phytoestrogens as they can mimic or inhibit some of the actions of the hormone estrogen in the body.

The antiestrogenic effect of some lignans suggests they may be helpful in treating hormone-dependent cancers, such as breast and ovarian cancers. However, studies are few and conflicting on whether eating foods high in lignans reduces breast or ovarian cancer.

In regard to cardiovascular disease risk, diets rich in whole grains are protective, but it remains unclear whether it is the lignans in whole grains that are responsible for the reduced risk. Whole grains contain many other beneficial phytochemicals, micronutrients, and fiber.

Interactive 8.3.2

To discover more about phytochemicals, visit the website for the Micronutrient Information Center of the Linus Pauling Institute at Oregon State University.

http://lpi.oregonstate.edu/infocenter/phytochemicals.html

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Other Dietary Sources of Beneficial Phytochemicals

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Herbs and Spices

These are the aromatic parts of plants, such as the leaves, seeds, pods, and berries. They are an additional dietary source of phytochemicals, and many have exceptional antioxidant capacity.

Throughout the ages, people have used spices and herbs not only for adding flavor to foods but also as medicines. Curcumin, the principal component of turmeric, has been used for over two thousand years in India to treat a variety of ailments. As of 2011, over seventy clinical trials are investigating the health benefits of curcumin, which may include reducing cancer risk and delaying the progression of Alzheimer's disease.

You learned in the beginning of this chapter that nutmeg comes from the dried seed kernel of *Myristica fragrans* and has been used as an antimicrobial, antifungal, and anti-inflammatory agent, and as a pain reliever. In high doses, nutmeg acts similar to a psychoactive drug in that it causes euphoria, delusions, and hallucinations. According to a study conducted on over 3,100 foods, beverages, spices, herbs, and supplements, the spices and herbs were the dietary sources most rich in antioxidants (see Note 8.20 "Interactive 8.3").

Interactive 8.3.3

Read the article, "The Total Antioxidant Content of More than 3,100 Foods, Beverages, Spices, Herbs, and Supplements Used Worldwide," published in the January 2010 issue of the *Nutrition Journal*. It is a useful source to find dietary sources of antioxidants.

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2841576/?tool=pubmed

Tools for Change

Add some spice, flavor, and decoration to your food along with beneficial antioxidants and phytochemicals. Embracing cuisine rich in spices and herbs further enhances the health benefits of eating a diet rich in fruit and vegetables. Think spices are too hot for your palate? As little as half a teaspoon of cinnamon has been shown in scientific studies to provide health benefits, such as improving glucose homeostasis in people with Type 2 diabetes. Over fifteen clinical trials are now evaluating the effectiveness of cinnamon as an adjunct treatment for Type 2 diabetes and/or cardiovascular disease.

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Tea

Tea is an aromatic beverage made from the dried parts of plants steeped in hot water. Its health benefits have been known for years, and as with coffee, the benefits are not just physiological, but also mental and social. In folklore, teas are considered curatives of stomachache, diarrhea, and even the plague. In *The Book of Tea*, Okakura Kakuzo asserts that consuming a cup of tea provides "the adoration of the beautiful among the sordid facts of everyday existence."Okakura Kakuzo. *The Book of Tea*. (Berlin, Germany: Dover Publications, 1964).

Teas can contain more than seven hundred different phytochemicals. Some of them may be beneficial and others may not be, as some reduce the dietary absorption of some micronutrients. The health claims of drinking tea—black, green, or red—number at least in the hundreds but remain mostly scientifically unsupported. There are a great number of studies showing that drinking tea is at least linked to a decreased risk of heart disease, cancer, and diabetes, but the exact phyotchemicals eliciting these health benefits are under intense scrutiny. Moreover, people who consume more tea are likely to drink fewer soft drinks and therefore, based on a "replacement theory," have a reduced likelihood of having a chronic disease.

Antioxidant Minerals

In addition to the antioxidant vitamins and phytochemicals, several minerals have antioxidant function, including selenium, manganese, iron, copper, and zinc.

Selenium Functions and Health Benefits

Selenium is a trace mineral because we need it in ultra small amounts, but it packs a powerful punch. Around twenty-five, known proteins require selenium to function. Some are enzymes involved in detoxifying free radicals and include glutathione peroxidases and thioredoxin reductase. As an integral functioning part of these enzymes, selenium aids in the regeneration of glutathione and oxidized vitamin C. Selenium as part of glutathione peroxidase also protects lipids from free radicals, and, in doing so, spares vitamin E. This is just one example of how antioxidants work together to protect the body against free radical-induced damage.

Other functions of selenium-containing proteins include protecting endothelial cells that line tissues, converting the inactive thyroid hormone to the active form in cells, and mediating inflammatory and immune system responses.

Observational studies have demonstrated that selenium deficiency is linked to an increased risk of cancer. A review of forty-nine observational studies published in the May 2011 issue of the *Cochrane Database of Systematic Reviews* concludes that higher selenium exposure reduces overall cancer incidence by about 34 percent in men and 10 percent in women, but notes these studies had several limitations, including data quality, bias, and large differences among different studies.Dennert, G. et al. "Selenium for Preventing Cancer." *Cochrane Database of Systematic Reviews* 5 (2011): CD005195. http://www.ncbi.nlm.nih.gov/pubmed/21563143. Additionally, this review states that there is no convincing evidence from six clinical trials that selenium supplements reduce cancer risk.

Because of its role as a lipid protector, selenium has been suspected to prevent cardiovascular disease. In some observational studies, low levels of selenium are associated with a decreased risk of cardiovascular disease. However, other studies have not always confirmed this association and clinical trials are lacking.

Deficiency signs and symptoms

A deficiency of selenium predisposes an individual to the virus that causes Keshan's disease, a degenerative heart disease. As well, inadequate selenium intake can cause Kashin-Beck disease, a form of arthritis. People at risk of developing these deficiencies are ones who eat food grown in areas where the soil levels of selenium are low, for example, Keshan, China.

Dietary Reference Intakes for Selenium

The IOM has set the RDAs for selenium based on the amount required to maximize the activity of glutathione peroxidases found in blood plasma. The RDAs for different age groups are listed in Table 8.9.

Table 8.3.8: Dietary Reference Intakes for Selenium

Age Group	RDA Males and Females mcg/day	UL
Infants (0–6 months)	15*	45
Infants (7–12 months)	20*	65
Children (1–3 years)	20	90
Children (4–8 years)	30	150
Children (9–13 years)	40	280
Adolescents (14–18 years)	55	400
Adults (> 19 years)	55	400
*denotes Adequate Intake		

Selenium at doses several thousand times the RDA can cause acute toxicity, and when ingested in gram quantities can be fatal. Chronic exposure to foods grown in soils containing high levels of selenium (significantly above the UL) can cause brittle hair and nails, gastrointestinal discomfort, skin rashes, halitosis (garlic breath), fatigue, and irritability. The IOM has set the UL for selenium for adults at 400 micrograms per day.

Dietary Sources of Selenium

Organ meats, muscle meats, and seafood have the highest selenium content. Plants do not require selenium, so the selenium content in fruits and vegetables is usually low. Animals fed grains from selenium-rich soils do contain some selenium. Grains and some nuts contain selenium when grown in selenium-containing soils. See Table 8.3.9 for the selenium content of various foods.

Table 8.3.9: *Selenium Contents of Various Foods*

Food	Serving	mcg
Brazil nuts	1 oz.	544.0
Shrimp	3 oz.	34.0
Crab meat	3 oz.	41.0
Ricotta cheese	1 c.	41.0
Salmon	3 oz.	40.0
Pork	3 oz.	35.0
Ground beef	3 oz.	18.0
Round steak	3 oz.	28.5
Beef liver	3 oz.	28.0
Chicken	3 oz.	13.0
Whole-wheat bread	2 slices	23.0

Food	Serving	mcg
Couscous	1 c.	43.0
Barley, cooked	1 c.	13.5
Milk, low-fat	1 c.	8.0
Walnuts, black	1 oz.	5.0

Source: US Department of Agriculture, Agricultural Research Service. 2010. *USDA National Nutrient Database for Standard Reference*, Release 23. http://www.ars.usda.gov/ba/bhnrc/ndl.

Manganese, Iron, Copper, and Zinc: Functions and Health Benefits

As with selenium, manganese, iron, copper, and zinc are essential cofactors for enzymes involved in detoxifying free radicals. In the proper doses, they allow for optimal detoxification of free radicals. In excess and when not bound to proteins, manganese, iron, and copper actually accelerate the production of free radicals. This is an attribute of all antioxidants in general, although the effect is greater for certain antioxidants.

Antioxidants can become pro-oxidants when the conditions are altered. Recall from Section 8.2 of this chapter that oxidative stress results from an imbalance in free radicals with their detoxifying and repair systems. Another factor that can cause oxidative stress is a high level of antioxidants, as some will revert to acting as pro-oxidants.

Key Takeaways

- Health claims of antioxidant supplements are not backed by scientific evidence and there is some evidence suggesting they cause harm.
- Consuming antioxidant-rich foods is scientifically supported to reduce the risk of chronic diseases.
- Antioxidants have specific functions, and they can act in concert with each other to protect against free radicals.
- Some antioxidants are involved in the regeneration of other antioxidants.
- Many phytochemicals act as antioxidants, but they perform several other functions as well.
- Dietary antioxidants and phytochemicals in the proper doses are beneficial to health but can cause harm in excess.

Discussion Starters

1. In regard to doses, discuss why it is better to obtain antioxidants from the diet and not from supplements. When might supplements be advantageous?
2. With more scientific evidence in hand, debate whether or not the supplement industry requires more regulation.

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8.4: The Whole Nutrient Package versus Disease

Learning Objectives

- List some of the health-related conditions that might be mitigated by eating antioxidant- and phytochemical-rich foods regularly.
- Explain the importance of eating a variety of fruits, vegetables, nuts, legumes, teas, and grains to obtain antioxidants and phytochemicals.



Figure 8.4.1: Forget the antioxidant-pill hype and get all of the health benefits of antioxidants and phytochemicals by eating a variety of fruits and vegetables. © Thinkstock

A healthy diet incorporating seven or more servings of fruits and vegetables has been shown in many scientific studies to reduce cardiovascular disease and overall deaths attributable to cancer. The WHO states that insufficient fruit and vegetable intake is linked to approximately 14 percent of gastrointestinal cancer deaths, about 11 percent of heart attack deaths, and 9 percent of stroke deaths globally.World Health Organization. “Global Strategies on Diet, Physical Activity, and Health.” Accessed September 30, 2011. http://www.who.int/dietphysicalactivity/fruit/en/index.html. The WHO estimates that, overall, 2.7 million deaths could be avoided annually by increasing fruit and vegetable intake. These preventable deaths place an economic, social, and mental burden on society. This is why, in 2003, the WHO and the Food and Agricultural Organization of the United Nations launched a campaign to promote fruit and vegetable intake worldwide.

In the last section, we reviewed the health benefits of particular antioxidants and phytochemicals obtained from fruits and vegetables and discovered that naturally incorporating them into the diet rather than taking supplements is best. Here we will consider the scientific evidence that diets rich in antioxidants actually lower chronic disease risk.

Antioxidant Variety in Food Provides Health Benefits

Not only has the several-billion-dollar supplement industry inundated us with FDA-unapproved health claims, but science is continuously advancing and providing us with a multitude of promising health benefits from particular fruits, vegetables, teas, herbs, and spices. For instance, blueberries protect against cardiovascular disease, an apple or pear a day reduces stroke risk by over 52 percent, eating more carrots significantly reduces the risk of bladder cancer, drinking tea reduces cholesterol and helps glucose homeostasis, and cinnamon blocks infection and reduces the risk of some cancers. However, recall that science also tells us that no one nutrient alone is shown to provide these effects.

What micronutrient and phytochemical sources are best at protecting against chronic disease? All of them, together. Just as there is no wonder supplement or drug, there is no superior fruit, vegetable, spice, herb, or tea that protects against all diseases. A review in the July–August 2010 issue of *Oxidative Medicine and Cellular Longevity* concludes that the plant-food benefits to health are attributed to two main factors—that nutrients and phytochemicals are present at low concentrations in general, and that the complex mixtures of nutrients and phytochemicals provide additive and synergistic effects.Bouayed, J. and T. Bohn. “Exogenous Antioxidants—Double-Edged Swords in Cellular Redox State: Health Beneficial Effects at Physiologic Doses versus Deleterious Effects at High Doses.” *Oxidative Medicine and Cellular Longevity* 3, no. 4 (2010): 228–37. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2952083/?tool=pubmed. In short, don’t overdo it with supplements and make sure you incorporate a wide variety of nutrients in your diet.

Eating a variety of fruits and vegetables rich in antioxidants and phytochemicals promotes health. Consider these diets:

- **Mediterranean diet.** Fresh fruit and vegetables are abundant in this diet, and the cultural identity of the diet involves multiple herbs and spices. Moreover, olive oil is the main source of fat. Fish and poultry are consumed in low amounts and red meat is consumed in very low amounts. An analysis of twelve studies involving over one million subjects published in the September 2008 issue of the *British Medical Journal* reports that people who followed the Mediterranean diet had a 9 percent decrease in overall deaths, a 9 percent decrease in cardiovascular death, a 6 percent decrease in cancer deaths, and a 13 percent reduced incidence of Parkinson's disease and Alzheimer's disease.Sofi, F. et al. "Adherence to Mediterranean Diet and Health Status: Meta-Analysis." *Br Med J* 337 (2008): a1344. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2533524/. The authors of this study concluded that the Mediterranean diet is useful as a primary prevention against some major chronic diseases.
- **Dietary Approaches to Stop Hypertension (DASH diet).** Recall from Chapter 11 that the DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. Results from a follow-up study published in the December 2009 issue of the *Journal of Human Hypertension* suggest the low-sodium DASH diet reduces oxidative stress, which may have contributed to the improved blood vessel function observed in salt-sensitive people (between 10 to 20 percent of the population).Al-Solaiman, Y. et al. "Low-Sodium DASH Reduces Oxidative Stress and Improves Vascular Function in Salt-Sensitive Humans." *J Hum Hypertens* 12 (2009): 826–35. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2783838/?tool=pubmed.
- **Diets high in fruits and vegetables.** An analysis of The Nurses' Health Study and the Health Professionals' Follow-up Study reported that for every increased serving of fruits or vegetables per day, especially green leafy vegetables and vitamin C-rich fruits, there was a 4 percent lower risk for heart disease.Joshipura, K.J. et al. "The Effect of Fruit and Vegetable Intake on Risk for Coronary Heart Disease." *Ann Intern Med* 134, no. 12 (2001): 1106–14. http://www.ncbi.nlm.nih.gov/pubmed/11412050.

Americans Typically Eat Fewer than the Recommended Servings of Fruits and Vegetables

An article in the January 2009 issue of the *Medscape Journal of Medicine* reports that fewer than one in ten Americans consumes the recommended amount of fruits and vegetables, which is between five and thirteen servings per day.Kimmons, J. et al. "Fruit and Vegetable Intake among Adolescents and Adults in the United States: Percentage Meeting Individualized Recommendations." *Medscape Journal of Medicine* 11, no. 1 (2009): 26. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2654704/?tool=pubmed. According to this study, the largest single contributor to fruit intake was orange juice, and potatoes were the dominant vegetable.

The USDA recommends that you fill half your plate with fruits and vegetables. The number of servings of fruits and vegetables that a person should consume every day is dependent on age, sex, and level of physical activity. For example, a forty-year-old male who exercises for sixty minutes per day should consume 2 cups of fruit and 3½ cups of vegetables, while a fifteen-year-old female who exercises for thirty minutes per day should consume 1½ cups of fruit and 2½ cups of vegetables. (One cup of a fruit or vegetable is equal to one banana, one small apple, twelve baby carrots, one orange, or one large sweet potato.) To find out the amount of fruits and vegetables the Centers for Disease Control and Prevention (CDC) recommends, see the Interactive 8.4.1.

Interactive 8.4.1

The CDC provides a fruit- and vegetable-intake calculator.

www.fruitsandveggiesmatter.gov/form.html

Improving Fruit and Vegetable Intake at Home and in Your Community

Eating more fruits and vegetables can make you think better, too. According to a study published in 2009 in the *Journal of Alzheimer's Disease*, no matter your age, eating more fruits and vegetables improves your brain function.Polidori, M.C. et al. "High Fruit and Vegetable Intake Is Positively Correlated with Antioxidant Status and Cognitive Performance in Healthy Subjects." *Journal of Alzheimer's Disease* 17, no. 4 (2009): 921–7. http://www.ncbi.nlm.nih.gov/pubmed/19542607. Check out "Interactive 8.4.2" for thirteen fun ways to increase your fruit and vegetable intake.

Interactive 8.4.2

Visit the University of Nebraska-Lincoln's website to discover thirteen fun ways to increase your fruit and vegetable intake. http://food.unl.edu/web/fnh/freezer-bags

For individually based strategies on how to stretch your fruit and vegetable budget see "Interactive 8.4.3".

Interactive 8.4.3

The Department of Health and Human Services provides “30 Ways in 30 Days to Stretch Your Fruit and Vegetable Budget.” www.fruitsandveggiesmatter.gov/downloads/Stretch_FV_Budget.pdf

Tools for Change

Accept the challenge of optimizing your fruit and vegetable intake. Make it easier on your wallet by choosing five of the thirty ways ("Interactive 8.4.2) to stretch your fruit and vegetable budget, and implement them in the next seven days.

The CDC has developed seven strategies to increase American’s intake of fruits and vegetables.Centers for Disease Control and Prevention. “The CDC Guide to Fruit and Vegetable Strategies to Increase Access, Availability, and Consumption.” March 2010. www.cdph.ca.gov/SiteCollectionDocuments/StratstoIncreaseFruitVegConsumption.pdf.

1. Support local and state governments in the implementation of a Food Policy Council, which develops policies and programs that increase the availability of affordable fruits and vegetables.
2. In the food system, increase the availability and affordability of high-quality fruits and vegetables in underserved populations.
3. Promote farm-to-where-you-are programs, which is the delivery of regionally grown farm produce to community institutions, farmers markets, and individuals.
4. Encourage worksites, medical centers, universities, and other community and business establishments to serve more fruits and vegetables in cafeterias and onsite eateries.
5. Support schools in developing healthy food messages to students by incorporating activities such as gardening into curricula.
6. Encourage the development and support of community and home gardens.
7. Have emergency food programs, including food banks and food rescue programs, increase their supply of fruits and vegetables.

The seven strategies developed by the CDC are based on the idea that improving access to and availability of fruits and vegetables will lead to an increase in their consumption.

Key Takeaways

- Antioxidants and phytochemicals from fruits and vegetables are thought to reduce disease risk.
- Antioxidants and phytochemicals may be beneficial in low doses but not in high doses.
- Eat a variety of foods rich in micronutrient antioxidants and phytochemicals to promote health.
- Fewer than one in ten Americans consume the recommended amount of fruits and vegetables, which is between five and thirteen servings per day.
- National and international campaigns aim to increase the intake of fruits and vegetables worldwide.

Discussion Starters

1. Discuss the various strategies you use, or plan to use, to increase the quantity of fruits and vegetables in your diet. Learn other interesting and fun ways to do so from your peers.
2. Share with your classmates your favorite spices, how you use them, and where you buy them.

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8.E: Exercises

It's Your Turn

1. Use the fruit- and vegetable-intake calculator provided by the CDC to determine the amount of fruit and vegetables recommended for your diet, and then plan a menu for a day that incorporates the recommended amount of fruits and vegetables. www.fruitsandveggiesmatter.gov/form.html
2. The next time you're at the grocery store, record the number, color, and names of the fruits and vegetables available. Draw a table of them, sorted by color. Write a brief statement on whether you have access to an affordable variety of fruits and vegetables.
3. Visit the website "Nutrition-and-You" and choose three herbs and/or spices to write a brief summary on, including the plant they come from, their potential health benefits, and how they are used in foods. http://www.nutrition-and-you.com/healthy_spices.html

Apply It

1. Visit the Oldways website at http://www.oldwayspt.org/mediterranean-diet-pyramid and construct a pyramid of the Mediterranean diet.

Expand Your Knowledge

1. Read the article, "Antioxidant Content of Whole-Grain Breakfast Cereals, Fruits, and Vegetables" in the *Journal of the American College of Nutrition* (http://www.jacn.org/content/19/suppl_3/312S.long) and summarize in a paragraph the unique phytochemical profile and antioxidant capacity of whole grains.
2. Find out how much fruit and vegetables cost by reviewing this document published by the USDA (www.ers.usda.gov/Publications/EIB71/EIB71.pdf), and make a chart of the costs of your favorite fruits and vegetables.

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9: Nutrients and Bone Metabolism

In this chapter, we delve into nutrients important for bone health. First, we explore the structure and function of bones, and then calcium, vitamin D, phosphorus, magnesium, fluoride, and vitamin K. A look at osteoporosis and at supplements rounds out this chapter.

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9.1: Chapter Introduction

Note: Big Idea

Build peak bone mass during youth to preserve bone mass during aging.

Milk has been and will continue to be a key component in the diets of millions of people. During the agrarian age, people drank milk from the animals they raised. At the dawn of the twentieth century, nutritional science appeared on the scene and quickly acknowledged milk's importance as a part of a balanced diet. For over one hundred years, several US government nutrition programs have highlighted milk's value. How does milk get from a cow to your doorstep?

In the early nineteenth century, raw milk was distributed in carelessly washed metal pails and was, at times, still warm from the cow when it reached its destination. If you got up too late to fetch your milk you received little of the coagulated cream on top. This distribution method did not suffice for the widespread delivery of fresh milk to the masses living in cities, thus milk and its preparation methods had to be changed in several ways. Consuming raw milk can be a potential health hazard as harmful bacteria such as Salmonella, E. coli, and Listeria may be present, all of which are known as culprits for many foodborne illnesses. Pasteurization, homogenization, fortification, and eventually packaging in plastic containers were developed to address distribution and food-safety issues.

In 1863, Louis Pasteur invented pasteurization. Pasteurization involves heating the milk to a high temperature (greater than 161 degrees Fahrenheit) for a short time (less than 20 seconds) and is an effective method of killing 99.999 percent of bacteria, molds, and yeast. Pasteurization was a welcome technology as it extended the shelf life of milk by about two to three weeks and destroyed infectious bacteria, such as those that caused diphtheria, typhoid fever, tuberculosis, and scarlet fever, thereby making milk safe to drink. Unfortunately, pasteurization also destroys vitamins, enzymes, and some beneficial bacteria. Milk may also be microfiltered, a process that pushes milk forcefully through ceramic filters that remove bacteria. Milk is homogenized so that it does not separate into butterfat globules and milk fluid. During homogenization, milk is emulsified under intense pressure as it is pumped through narrow tubes. Fat globules are broken into smaller ones and they do not recoagulate. The homogenization process, however, does not have a negative effect on the milk's nutritional value or effectiveness.



Figure 9.1.1: Milk: An ever-changing product of the dairy industry. © Shutterstock

The dairy industry has gone through many changes to increase milk production, quality, and distribution. As a result of pasteurization and to meet the health needs of the American population, a public-policy decision was made in 1933 to fortify milk with vitamin D to prevent childhood bone disease. More recently, changes include expanding the number of cows per herd, increasing milk production per cow by over six-fold, improving dairy cow nutrition and herd management practices, and advancing technologies that increase storage time and decrease bacterial contamination. How did milk production increase six-fold per cow? Most cows are Holsteins, bred with optimum genetics for producing milk. They are provided with the best nutrition, a dietary pattern taken from many scientific studies that provides optimal nutrients specifically for cows to make milk. Some people are concerned about the changes that were brought about by controversial methods, such as injecting dairy cows with bovine growth hormone. This increases milk production by about 15 percent but also increases the risk of udder infection in the cows. As a result, antibiotics are widely used in the dairy industry. There is evidence linking widespread antibiotic use with the increase in the resistance of bacteria. This practice also decreases the effectiveness of antibiotics in humans.

Note: You Decide

How will you ensure that you are building strong bones and will be able to avoid detrimental bone loss in old age?

It is estimated that every three seconds around the globe, an osteoporotic fracture occurs. Over two hundred million women worldwide suffer from this disease.Kanis, J. A. *WHO Technical Report*, (University of Sheffield, United Kingdom, 2007): 66. Statistics also show that one in three women and one in five men over sixty will experience an osteoporotic fracture.European Foundation for Osteoporosis and National Osteoporosis Foundation. “Who Are Candidates for Prevention and Treatment for Osteoporosis?” *Osteoporos Int* 7, no. 1 (1997):Melton 3rd, L. J. et al. “Perspective. How Many Women Have Osteoporosis?” *J Bone Miner Res* 7 (1992): 1005.Kanis, J. A. et al. “Long-Term Risk of Osteoporotic Fracture.” *Malmo Osteoporos Int* 11 (2000): 669. How can you prepare yourself and fortify your bones against this disease? Milk is a ready and convenient source of calcium and vitamin D, but one glass of milk per day is not sufficient to provide adequate intake of these nutrients and many people have an allergy or intolerance to dairy products. Other good sources of calcium and vitamin D are soybeans, parsley, kale, salmon, broccoli, eggs, tuna, beans, and fortified products such as soymilk, rice milk, and almond milk. As you read this chapter you will learn the importance of building and preserving healthy bones through proper diet and exercise. Whatever you decide, know that your bone health will be affected by your dietary and lifestyle choices for years to come.

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9.2: Bone Structure and Function

Learning Objectives

- Explain the process of bone remodeling and explain why bones are living tissues.

Your bones are stronger than reinforced concrete. Bone tissue is a composite of fibrous collagen strands that resemble the steel rebar in concrete and a hardened mineralized matrix that contains large amounts of calcium, just like concrete. But this is where the similarities end. Bone outperforms reinforced concrete by several orders of magnitude in compression and tension strength tests. Why? The microarchitecture of bone is complex and built to withstand extreme forces. Moreover, bone is a living tissue that is continuously breaking down and forming new bone to adapt to mechanical stresses.



Video Link 9.2.1*: The Human Body: Bone Strength. This video is a dramatic demonstration of bone strength. (https://www.youtube.com/watch?v=FlATeMqTH2g).*

Why Is the Skeletal System Important?

The human skeleton consists of 206 bones and other connective tissues called ligaments, tendons, and cartilage. Ligaments connect bones to other bones, tendons connect bones to muscles, and cartilage provides bones with more flexibility and acts as a cushion in the joints between bones. The skeleton's many bones and connective tissues allow for multiple types of **movement** such as typing and running. The skeleton provides **structural support** and **protection** for all the other organ systems in the body. The skull, or cranium, is like a helmet and protects the eyes, ears, and brain. The ribs form a cage that surrounds and protects the lungs and heart. In addition to aiding in movement, protecting organs, and providing structural support, **red** and **white blood cells** and **platelets** are synthesized in bone marrow. Another vital function of bones is that they act as a **storage depot** for minerals such as calcium, phosphorous, and magnesium. Although bone tissue may look inactive at first glance, at the microscopic level you will find that bones are continuously breaking down and reforming. Bones also contain a complex network of canals, blood vessels, and nerves that allow for nutrient transport and communication with other organ systems.

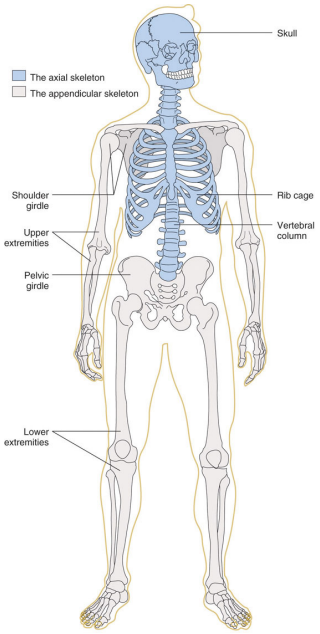


Figure 9.2.1: The human skeleton contains 206 bones. It is divided into two main parts, the axial and appendicular. © Networkgraphics

Bone Anatomy and Structure

To optimize bone health through nutrition, it is important to understand bone anatomy. The skeleton is composed of two main parts, the axial and the appendicular parts. The axial skeleton consists of the skull, vertebral column, and rib cage, and is composed of eighty bones. The appendicular skeleton consists of the shoulder girdle, pelvic girdle, and upper and lower extremities and is composed of 126 bones. Bones are also categorized by size and shape. There are four types of bone: long bones, short bones, flat bones, and irregular bones. The longest bone in your body is the femur (or "thigh" bone), which extends from your hip to your knee. It is a long bone and functions to support your weight as you stand, walk, or run. Your wrist is composed of eight irregular-shaped bones, which allows for the intricate movements of your hands. Your twelve ribs on each side of your body are curved flat bones that protect your heart and lungs. Thus, the bones' different sizes and shapes allow for their different functions.

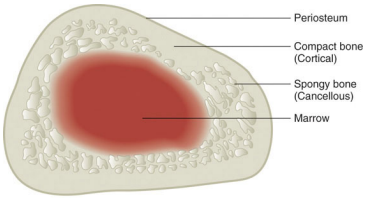


Figure 9.2.2: The Arrangement of Bone Tissues. Bone is composed of organized living tissues. © Networkgraphics

Bones are composed of approximately 65 percent inorganic material known as mineralized matrix. This mineralized matrix consists of mostly crystallized hydroxyapatite. The bone's hard crystal matrix of bone tissue gives it its rigid structure. Ninety-nine percent of all calcium in the body in bone and teeth. The other 35 percent of bone is organic material, most of which is the fibrous protein, collagen. The collagen fibers are networked throughout bone tissue and provide it with flexibility and strength. The bones' inorganic and organic materials are structured into two different tissue types. There is spongy bone, also called trabecular or cancellous bone, and compact bone also called cortical bone (Figure 9.2.1). The two tissue types differ in their microarchitecture and porosity. Trabecular bone is 50 to 90 percent porous and appears as a lattice-like structure under the microscope. It is found at the ends of long bones, in the cores of vertebrae, and in the pelvis. Trabecular bone tissue makes up about 20 percent of the adult skeleton. The denser cortical bone is about 10 percent porous and it looks like many concentric circles, similar to the rings in a tree trunk, sandwiched together (Figure 9.2.2). Cortical bone tissue makes up approximately 80 percent of the adult skeleton. It surrounds all trabecular tissue and is the only bone tissue in the shafts of long bones.

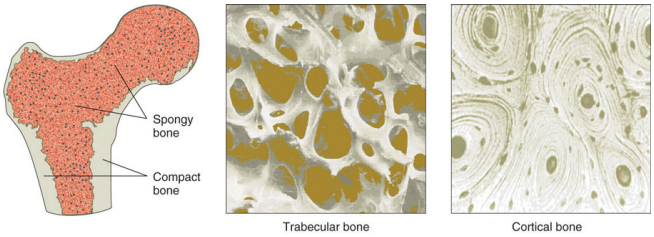


Figure 9.2.3: The two basic tissue types of bones are trabecular and cortical. Trabecular (spongy) and cortical (compact) bone tissues differ in their microarchitecture and porosity. © Networkgraphics

Bone tissue is arranged in an organized manner. A thin membrane, called the periosteum, surrounds the bone. It contains connective tissue with many blood vessels and nerves. Lying below the periosteum is the cortical bone. In some bones, the cortical bone surrounds the less-dense trabecular bone and the bone marrow lies within the trabecular bone, but not all bones contain trabecular tissue or marrow.

Bone Tissues and Cells, Modeling and Remodeling

Bone tissue contains many different cell types that constantly resize and reshape bones throughout growth and adulthood. Bone tissue cells include osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. The osteoprogenitor cells are cells that have not matured yet. Once they are stimulated, some will become osteoblasts, the bone builders, and others will become osteoclasts, the cells that break bone down. Osteocytes are the most abundant cells in bone tissue. Osteocytes are star-shaped cells that are networked throughout the bone via their long cytoplasmic arms that allow for the exchange of nutrients and other factors from bones to the blood and lymph.

Bone Modeling and Remodeling

During infancy, childhood, and adolescence, bones are continuously growing and changing shape through two processes called growth (or ossification) and modeling. In fact, in the first year of life, almost 100 percent of the bone tissue in the skeleton is replaced. In the process of modeling, bone tissue is dismantled at one site and built up at a different site. Between 35 and 45 years of life, bone formation equals bone breakdown; the mineral density of the bones is greatest in our late twenties. After 45 years, our bones stop growing and modeling but continue to go through a process of bone remodeling. In the process of remodeling, bone tissue is degraded and built up at the same location. About 10 percent of bone tissue is remodeled each year in adults. As observed in Video 9.2.1, bones adapt their structure to the forces acting upon them, even in adulthood. This phenomenon is called **Wolff's law**, which states that bones will develop a structure that is best able to resist the forces acting upon them. This is why exercising, especially when it involves weight-bearing activities, increases bone strength.



***Video 9.2.1**: Bone Modification. This video on bone remodeling demonstrates a bone's adaptability to mechanical stresses (click to see video).*

The first step in bone remodeling is osteocyte activation (see Figure 9.2.3). Osteocytes detect changes in mechanical forces, calcium homeostasis, or hormone levels. In the second step, osteoclasts are recruited to the site of the degradation. Osteoclasts are large cells with a highly irregular ruffled membrane. These cells fuse tightly to the bone and secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone

tissue matrix. This process is called bone resorption and resembles pit excavation. Our bodies excavate pits in our bone tissue because bones act as storehouses for calcium and other minerals. Bones supply these minerals to other body tissues as the demand arises. Bone tissue also remodels when it breaks so that it can repair itself. Moreover, if you decide to train to run a marathon your bones will restructure themselves by remodeling to better able sustain the forces of their new function.

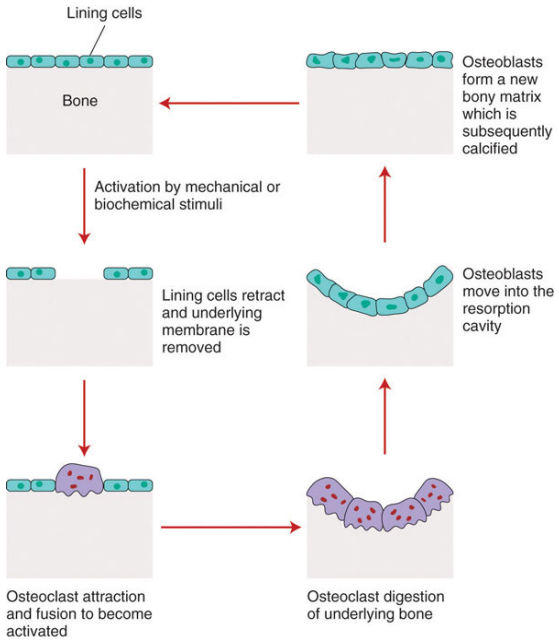


Figure 9.2.4*: Bone remodeling occurs in four steps: activation, osteoclast resorption, surface preparation, and building new bone tissue. © Networkgraphics*

After a certain amount of bone is excavated, the osteoclasts begin to die and bone resorption stops. In the third step of bone remodeling, the site is prepared for building. In this stage, sugars and proteins accumulate along the bone's surface, forming a cement line which acts to form a strong bond between the old bone and the new bone that will be made. These first three steps take approximately two to three weeks to complete. In the last step of bone remodeling, osteoblasts lay down new osteoid tissue that fills up the cavities that were excavated during the resorption process. Osteoid is bone matrix tissue that is composed of proteins such as collagen and is not mineralized yet. To make collagen, vitamin C is required. A symptom of vitamin C deficiency (known as scurvy) is bone pain, which is caused by diminished bone remodeling. After the osteoid tissue is built up, the bone tissue begins to mineralize. The last step of bone remodeling continues for months, and for a much longer time afterward the mineralized bone is continuously packed in a more dense fashion.

After menopause, breakdown is much greater than formation. This process can be slowed with the use of hormone replacement therapy.

Thus, we can say that bone is a living tissue that continually adapts itself to mechanical stress through the process of remodeling. For bone tissue to remodel certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K are required.

Key Takeaways

The skeletal system aids in movement, provides support for and protects organs, synthesizes platelets and red and white blood cells, and serves as a storage depot for minerals, such as calcium. The skeleton is composed of connective tissues including bones, cartilage, tendons, and ligaments.Bones are made up of a periosteum that surrounds compact bone, which in turn surrounds trabecular bone. Bone marrow resides within the trabecular bone. Bone tissue cells are osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes. Bone is a living tissue that adapts to mechanical stress via the remodeling process. Bone remodeling is a multifaceted process involving four steps: osteocyte activation, osteoclast-mediated bone resorption, surface preparation, and osteoblast-mediated bone building. The bone remodeling process requires certain nutrients such as calcium, phosphorus, magnesium, fluoride, vitamin D, and vitamin K.

Discussion Starters

1. Analyze the shape of some of your bones. Recognize the varying structure of different bones that allows for the performance of multiple functions. With a classmate, compare the shape of hand bones (that allow for fine articulated movements) to the shape of foot bones and toe bones (that allow more awkward movement). If you designed a bone system to grasp a doorknob or hang upside down, what would it look like? For inspiration, go to the web and look at bat bones, monkey bones, and human bones.
2. Why do you think it hurts when you hit your funny bone? Why are there no bones to protect the nerves?

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9.3: Bone Mineral Density is an Indicator of Bone Health

Learning Objectives

- Identify the tests used to measure bone mass.

Bone mineral density (BMD) is a measurement of the amount of calcified tissue in grams per centimeter squared of bone tissue. BMD can be thought of as the total amount of bone mass in a defined area. When BMD is high, bone strength will be great. Similar to measuring blood pressure to predict the risk of stroke, a BMD measurement can help predict the risk of bone fracture. The most common tool used to measure BMD is called dual energy X-ray absorptiometry (DEXA). During this procedure, a person lies on their back and a DEXA scanner passes two X-ray beams through their body (Figure 9.3.1). The amount of X-ray energy that passes through the bone is measured for both beams. The total amount of the X-ray energy that passes through a person varies depending on their bone thickness. Using this information and a defined area of bone, the amount of calcified tissue in grams per unit area (cm^2) is calculated.

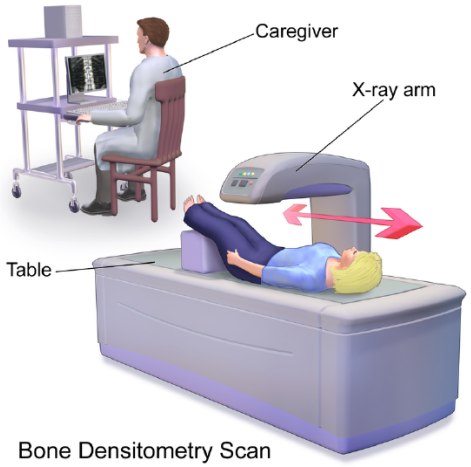
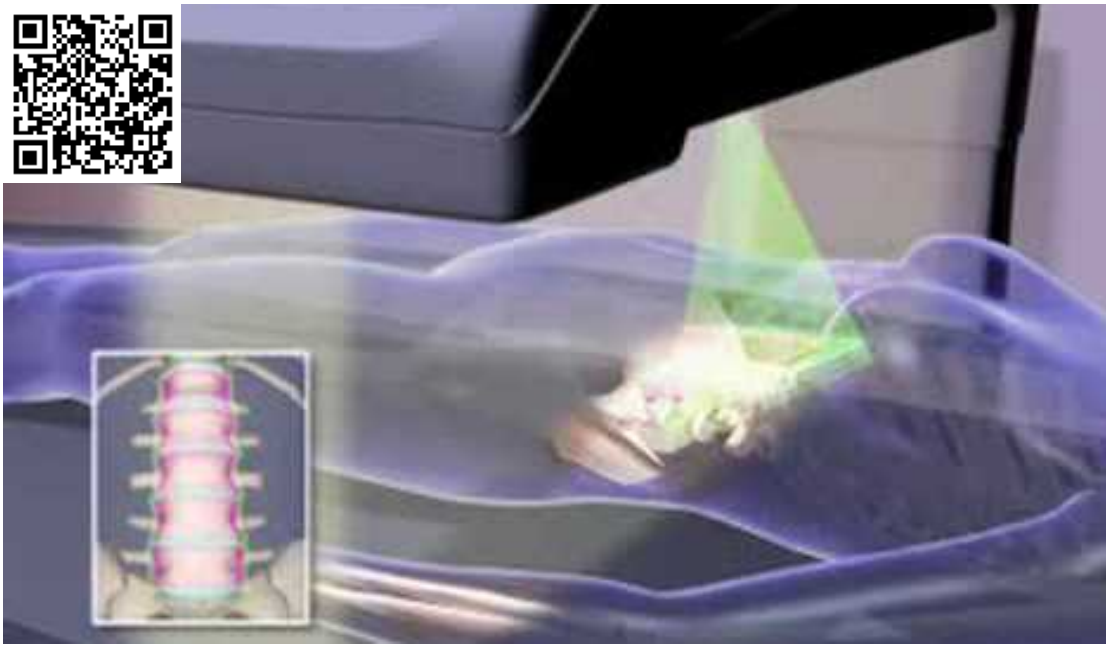


Figure 9.3.1: Bone Densitometry Scan. This image was donated by Blausen Medical. "Blausen gallery 2014". Wikiversity Journal of Medicine. DOI:10.15347/wjm/2014.010. ISSN 20018762.

Most often the DEXA scan focuses on measuring BMD in the hip and the spine. These measurements are then used as indicators of overall bone strength and health. DEXA is the cheapest and most accurate way to measure BMD. It also uses the lowest dose of radiation. Other methods of measuring BMD include quantitative computed tomography (QCT) and radiographic absorptiometry. People at risk for developing bone disease are advised to have a DEXA scan. We will discuss the many risk factors linked to an increased incidence of osteoporosis and the steps a person can take to prevent the disease from developing.



Video9.3.1: *DEXA—Dual Energy X-Ray Absorptiometry (click to see video).*

Key Takeaways

Bone-mineral density is a measurement of calcified bone tissue and positively correlates with overall bone health. DEXA is a clinical tool used to assess BMD.

Discussion Starter

1. Evaluate the animation below that discusses the technology of the DEXA procedure. Form a hypothesis on why doctors recommend this procedure for women over age fifty. Discuss your findings.

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9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D

Learning Objectives

- List the four primary functions of calcium in the human body.
- Identify the Dietary Reference Intake for calcium.

Calcium

Calcium is a major mineral nutrient that is a cation with two positive charges. When bound to anionic compounds like carbonate, it is water soluble. The most abundant mineral in the body is calcium, and greater than 99 percent of it is stored in bone tissue. Although only 1 percent of the calcium in the human body is found in the blood and soft tissues, it is here that it performs the most critical functions. Blood calcium levels are rigorously controlled so that if blood levels drop the body will rapidly respond by stimulating bone resorption, thereby releasing stored calcium into the blood. (This is discussed in further detail shortly.) Thus, bone tissue sacrifices its stored calcium to maintain blood calcium levels. This is why bone health is dependent on the intake of dietary calcium and also why blood levels of calcium do not always correspond to dietary intake. A fall in blood calcium is not due to diet but abnormal regulatory control of blood levels.

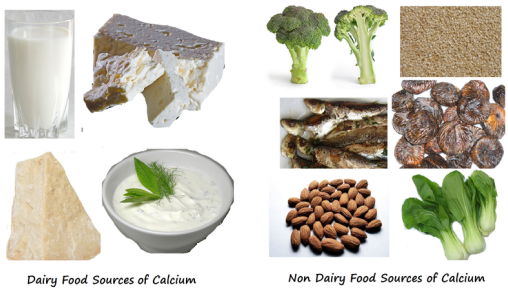


Figure 9.4.1: Calcium is an important mineral for multiple body functions. It is important to consume calcium-rich foods to sustain proper dietary intake of calcium. (CC BY-SA 4.0;'Brookepinsent)

Calcium's Functional Roles

Calcium plays a role in a number of different functions in the body:

- **Bone and tooth formation.** The most well-known calcium function is to build and strengthen bones and teeth. Recall that when bone tissue first forms during the modeling or remodeling process, it is unhardened, protein-rich osteoid tissue. In the osteoblast-directed process of bone mineralization, calcium phosphates (salts) are deposited on the protein matrix. The calcium salts gradually crystallize into hydroxyapatite, which typically makes up about 65 percent of bone tissue. When your diet is calcium deficient, the mineral content of bone decreases (becomes less dense) causing it to become brittle and weak. Thus, increased calcium intake helps to increase the mineralized content of bone tissue. Greater mineralized bone tissue corresponds to a greater BMD, and to greater bone strength. The varying arrangements of the calcium-rich hydroxyapatite crystals on bone tissue's protein matrix contribute to bone's differing mechanical properties. In tooth enamel, hydroxyapatite crystals are densely packed, making it the most mineralized tissue (more than 95 percent) in the human body. Tooth enamel's densely packed crystal architecture provides it with its incredible strength and durability. The mineralized bone tissue in human teeth is so incredibly strong that back molars can withstand bite forces exceeding four hundred pounds of pressure.
- **Nerve impulse transmission.** Calcium facilitates electrical impulse transmission from one nerve cell to another. Calcium binds to vesicles that contain neurotransmitters, causing a release into the neural synapses (junction between nerve cells). This allows the flow of ions in and out of nerve cells. If calcium is lacking, nerve-cell function will fail (see Note 9.30 "Interactive 9.1").
- **Muscle contraction.** The flow of calcium ions along the muscle cell's surface and the influx of calcium into the muscle cell are critical for muscle contraction. If calcium levels fall below a crucial range, the muscles can't relax after contracting. The muscles become stiff, and involuntary twitching may ensue in a condition known as tetany.
- **Clotting factors.** When a blood vessel is injured and bleeding starts, it must be stopped or death may result. Clotting factors and platelets are continuously circulating in the blood in case of such an emergency. When an injury occurs, the damaged tissue releases specific factors that activate the circulating clotting factors and platelets. Some of the clotting factors require calcium for activation. If clotting factors weren't activated blood clots would not form.

In addition to calcium's four primary functions calcium has several other minor functions that are also critical for maintaining normal physiology. For example, without calcium, the hormone insulin could not be released from cells in the pancreas and glycogen could not be broken down in muscle cells and used to provide energy for muscle contraction. Calcium is also important for vascular control and blood pressure.

-

Maintaining Calcium Levels

Because calcium performs such vital functions in the body, blood calcium level is closely regulated by the hormones parathyroid hormone (PTH), calcitriol, and calcitonin. Calcitriol is the active hormone produced from vitamin D. Parathyroid hormone and calcitriol act in a concert to increase calcium levels in the blood, while calcitonin does the opposite and decreases blood calcium levels. These hormones maintain calcium levels in the blood in a range between 9 and 11 milligrams per deciliter.

-

Parathyroid Hormone

Four parathyroid glands, each the size of a grain of rice, can be found in the neck on the sides of the thyroid gland. PTH increases blood calcium levels via three different mechanisms (Figure 9.4). First, PTH stimulates the release of calcium stored in the bone. Second, PTH acts on kidney cells to increase calcium reabsorption and decrease its excretion in the urine. Third, PTH stimulates enzymes in the kidney that activate vitamin D to calcitriol. Calcitriol acts on intestinal cells and increases dietary calcium absorption. Thus, stored calcium is released, more calcium is absorbed from the diet, and less calcium is excreted, all of which increase calcium levels in the blood.

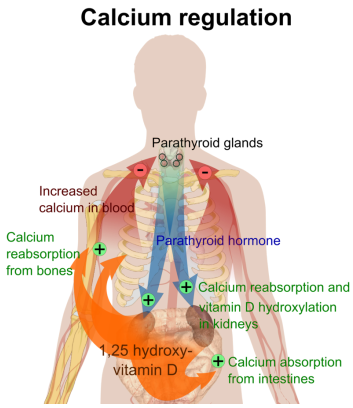


Figure 9.4.2: This is a typical negative feedback loop in which low calcium levels in the blood stimulate PTH release. PTH increases the movement of calcium from the bones, kidneys, and intestine to the blood with the help of activated vitamin D. The now higher calcium levels in the blood shut off further PTH release. (CC-BY-SA 3.0; Mikael Häggström).

Calcitriol (1,25 Hydroxy-Vitamin D)

Calcitriol functions as a second hand to PTH. It not only increases calcium release from bone tissue but also it increases the absorption of calcium in the small intestine and increases calcium reabsorption by the kidneys. Neither hormone will work unless accompanied by the other. Vitamin D regulates PTH secretion and PTH regulates vitamin D activation to calcitriol. Adequate levels of vitamin D allow for a balance of the calcium between what is released by bone tissue and what is incorporated into bone tissue so that bone health is not compromised. Calcitriol and PTH function together to maintain calcium homeostasis.

Calcitonin

Calcitonin is a hormone secreted by certain cells in the thyroid gland in response to high calcium levels in the blood. In comparison to PTH and calcitriol, calcitonin plays a small role in regulating calcium levels on a day-to-day basis. This is because as calcium levels rise in the blood, calcium feedback inhibits PTH release and effectively shuts off the actions of PTH and calcitriol. This route of feedback inhibition helps prevent calcium's further accumulation in the blood. At higher nonphysiological concentrations, calcitonin lowers blood calcium levels by increasing calcium excretion in the urine, preventing further absorption of calcium in the gut and by directly inhibiting bone resorption.

Other Health Benefits of Calcium in the Body

Besides forming and maintaining strong bones and teeth, calcium has been shown to have other health benefits for the body, including:

- **Cancer.** The National Cancer Institute reports that there is enough scientific evidence to conclude that higher intakes of calcium decrease colon cancer risk and may suppress the growth of polyps that often precipitate cancer. Although higher calcium consumption protects against colon cancer, some studies have looked at the relationship between calcium and prostate cancer and found higher intakes may increase the risk for prostate cancer; however, the data is inconsistent and more studies are needed to confirm any negative association.
- **Blood pressure.** Multiple studies provide clear evidence that higher calcium consumption reduces blood pressure. A review of twenty-three observational studies concluded that for every 100 milligrams of calcium consumed daily, systolic blood pressure is reduced 0.34 millimeters of mercury (mmHg) and diastolic blood pressure is decreased by 0.15 mmHg.Birkett, N. J. "Comments on a Meta-Analysis of the Relation between Dietary Calcium Intake and Blood Pressure." *Am J Epidemiol* 148, no. 3 (1998): 223–28. http://aje.oxfordjournals.org/content/148/3/223.long. There is emerging evidence that higher calcium intakes prevent against other risk factors for cardiovascular disease, such as high cholesterol and obesity, but the scientific evidence is weak or inconclusive.
- **Kidney stones.** Another health benefit of a high-calcium diet is that it blocks kidney stone formation. Calcium inhibits the absorption of oxalate, a chemical in plants such as parsley and spinach, which is associated with an increased risk of developing kidney stones. Calcium's protective effects on kidney stone formation occur only when you obtain calcium from dietary sources. Calcium supplements may actually increase the risk for kidney stones in susceptible people.

Deficiency Signs and Symptoms

Children who do not eat enough calcium and vitamin D may experience rickets. In adults, osteomalacia, osteopenia, and osteoporosis are progressed when calcium intakes are inadequate. People at risk of developing these diseases include individuals who lack enough money to eat the right foods, children, pregnant women, elderly, people with a low milk intake and post menopausal women.

Calcium Needs, Sources, and Bioavailability

Dietary Reference Intake for Calcium

The recommended dietary allowances (RDA) for calcium are listed in Table 9.4.1. The RDA is elevated to 1,300 milligrams per day during adolescence because this is the life stage of accelerated bone growth. Studies have shown that a higher intake of calcium during puberty increases the total amount of bone tissue that accumulates in a person. For women above age fifty and men older than seventy-one, the RDAs are also a bit higher for several reasons including that as we age, calcium absorption in the gut decreases, vitamin D_3 activation is reduced, and maintaining adequate blood levels of calcium is important to prevent an acceleration of bone tissue loss (especially during menopause). Currently, the dietary intake of calcium for females above age nine is, on average, below the RDA for calcium. The Institute of Medicine (IOM) recommends that people do not consume over 2,500 milligrams per day of calcium as it may cause adverse effects in some people.

Calcium needs are also increased during lactation, kidney or liver failure, aging, and a diet high in phosphate. Consuming too much calcium has been associated with constipation, urinary stone formation, kidney dysfunction, and/or interference of other mineral absorption such as non-heme iron.

Table 9.4.1: Dietary Reference Intakes for Calcium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	200*	–
Infants (6–12 months)	260*	–
Children (1–3 years)	700	2,500

* denotes Adequate Intake

Age Group	RDA (mg/day)	UL (mg/day)
Children (4–8 years)	1,000	2,500
Children (9–13 years)	1,300	2,500
Adolescents (14–18 years)	1,300	2,500
Adults (19–50 years)	1,000	2,500
Adult females (50–71 years)	1,200	2,500
Adults, male & female (> 71 years)	1,200	2,500
* denotes Adequate Intake		

Source: Ross, A. C. et al. “The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know.” J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. US National Library of Medicine. http://www.ncbi.nlm.nih.gov/pubmed/21118827.



Figure 9.4.3: Incorporate tofu, an excellent source of calcium, into your diet. Tofu kabobs make a delicious meal. © Shutterstock

In the typical American diet, calcium is obtained mostly from dairy products, primarily cheese. A slice of cheddar or Swiss cheese contains just over 200 milligrams of calcium. One cup of nonfat milk contains approximately 300 milligrams of calcium, which is about a third of the RDA for calcium for most adults. Foods fortified with calcium such as cereals, soy milk, and orange juice also provide one-third or greater of the calcium RDA. Although the typical American diet relies mostly on dairy products for obtaining calcium, there are many other good nondairy sources of calcium (see Section 9.4 and Table 9.4.2). A food’s calcium content can be calculated from the percent daily value (percent DV) displayed on the Nutrition Facts panel (Figure 9.4.4). Since the RDA for calcium used to calculate the daily value (DV) is 1,000 milligrams, you multiply the percent DV by ten to arrive at the calcium content in milligrams for a serving of a particular food. It is important to note that most processed foods offer a poor source for this vital mineral as the refinement process strips away the nutrients in the food.

Tools for Change

If you need to increase calcium intake, are a vegan, or have a food allergy to dairy products, it is helpful to know that there are several plant-based foods that are high in calcium. Broccoli, kale, mustard greens, and Brussel sprouts are excellent sources. One cup of these cooked vegetables provides between 100 and 180 milligrams of calcium. To increase the calcium content in your lunch and add some texture to your food, chop up some kale and put it on your sandwich or in your soup. For a list of nondairy sources that are high in calcium, see Table 9.4.2 "Nondairy Dietary Sources of Calcium". Additionally, you can find the calcium content for thousands of foods by visiting the USDA National Nutrient Database (http://www.nal.usda.gov/fnic/foodcomp/search/). When obtaining your calcium from a vegan diet, it is important to know that some plant-based foods significantly impair the absorption of calcium. These include spinach, Swiss chard, rhubarb, beets, cashews, and peanuts. With careful planning and good selections, you can ensure that you are getting enough calcium in your diet even if you do not drink milk or consume other dairy products.

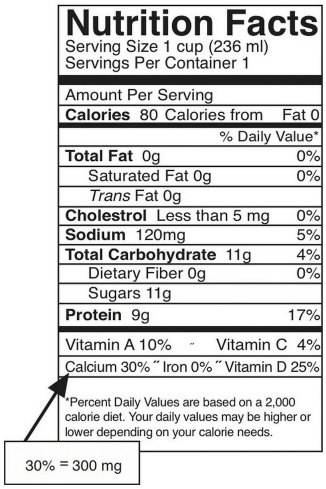


Figure 9.4.4: How to Calculate Calcium in Milligrams from the Nutrition Facts Panel

The percent DV of calcium is given on the Nutrition Facts panel. To convert this to milligrams (mg), multiply this number by ten. This is the amount of calcium in milligrams in one serving. This can be done this easily ONLY for calcium and not for other nutrients because the DV for calcium, based on the RDA for adults between the ages of nineteen and fifty, is equal to 1,000 milligrams.

Table 9.4.2: Nondairy Dietary Sources of Calcium

Food, Standard Amount	Calcium (mg)	Calories

Food, Standard Amount	Calcium (mg)	Calories
Fortified ready-to-eat cereals (various), 1 oz.	236–1043	88–106
Soy beverage, calcium fortified, 1 c.	368	98
Sardines, Atlantic, in oil, drained, 3 oz.	325	177
Tofu, firm, prepared with nigarib, ½ c.	253	88
Pink salmon, canned, with bone, 3 oz.	181	118
Collards, cooked from frozen, ½ c.	178	31
Molasses, blackstrap, 1 Tbsp.	172	47
Soybeans, green, cooked, ½ c.	130	127
Turnip greens, cooked from frozen, ½ c.	124	24
Ocean perch, Atlantic, cooked, 3 oz.	116	103
Oatmeal, plain and flavored, instant, fortified, 1 packet prepared	99–110	97–157
Cowpeas, cooked, ½ c.	106	80
White beans, canned, ½ c.	96	153
Kale, cooked from frozen, ½ c.	90	20
Okra, cooked from frozen, ½ c.	88	26
Soybeans, mature, cooked, ½ c.	88	149
Blue crab, canned, 3 oz.	86	84
Beet greens, cooked from fresh, ½ c.	82	19
Pak-choi, Chinese cabbage, cooked from fresh, ½ c.	79	10
Clams, canned, 3 oz.	78	126
Dandelion greens, cooked from fresh, ½ c.	74	17
Rainbow trout, farmed, cooked, 3 oz.	73	144

Source: US Department of Agriculture. Appendix B-4, "Nondairy Food Sources of Calcium." *2005 Dietary Guidelines for Americans*. Updated July 9, 2008. www.health.gov/dietaryguidelines/dga2005/document/html/appendixb.htm.

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Calcium Bioavailability

Bioavailability refers to the amount of a particular nutrient in foods that is actually absorbed in the intestine and not eliminated in the urine or feces. Simply put, the bioavailability of calcium is the amount that is on hand to perform its biological functions. In the small intestine, calcium absorption primarily takes place in the duodenum (first section of the small intestine) when intakes are low, but calcium is also absorbed passively in the jejunum and ileum (second and third sections of the small intestine), especially when intakes are higher. The body doesn't completely absorb all the calcium in food. About 30 percent of calcium is absorbed from milk and other dairy products. Interestingly, the calcium in some vegetables such as kale, Brussel sprouts, and bok choy, is better absorbed by the body than are dairy products. The body absorbs approximately 50 percent of calcium from these plant-based sources.

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Factors that Increase Calcium Bioavailability

Stomach acid releases calcium from foods and ionizes it to Ca^{++}. Calcium must be in its ionized form to be absorbed in the small intestine. The greatest positive influence on calcium absorption comes from having an adequate intake of vitamin D. People deficient in vitamin D absorb less than 15 percent of calcium from the foods they eat. The hormone estrogen is another factor that enhances calcium bioavailability. Thus, as a woman ages and goes through menopause, during which estrogen levels fall, the amount of calcium absorbed decreases and the risk for bone disease increases. Some fibers, such as inulin, found in jicama, onions, and garlic, also promote calcium intestinal uptake.

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Factors that Decrease Calcium Bioavailability

Chemicals that bind to calcium decrease its bioavailability. These negative effectors of calcium absorption include the oxalates in certain plants, the tannins in tea, phytates in nuts, seeds, and grains, and some fibers. Oxalates are found in high concentrations in spinach, parsley, cocoa, and beets. In general, the calcium bioavailability is inversely correlated to the oxalate content in foods. High-fiber, low-fat diets also decrease the amount of calcium absorbed, an effect likely related to how fiber and fat influence the amount of time food stays in the gut. Anything that causes diarrhea, including sicknesses, medications, and certain symptoms related to old age, decreases the transit time of calcium in the gut and therefore decreases calcium absorption. As we get older, stomach acidity sometimes decreases, diarrhea occurs more often, kidney function is impaired, and vitamin D absorption and activation is compromised, all of which contribute to a decrease in calcium bioavailability.

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Vitamin D

Vitamin D refers to a group of fat-soluble vitamins derived from cholesterol. Vitamins D_2 and D_3 are the only ones known to have biological actions in the human body. Although vitamin D_3 is called a vitamin, the body can actually synthesize vitamin D_3. When exposed to sunlight, a cholesterol precursor in the skin is transformed into vitamin D_3. However, this is not the bioactive form of vitamin D. It first must be acted upon by enzymes in the liver and then transported to the kidney where vitamin D_3 is finally transformed into the active hormone, calcitriol (1,25-dihydroxy vitamin D_3) (Figure 9.7).

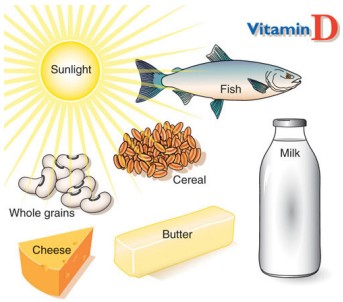


Figure 9.4.5: *Vitamin D Food Sources. © Networkgraphics*

The skin synthesizes vitamin D when exposed to sunlight. In fact, for most people, more than 90 percent of their vitamin D_3 comes from the casual exposure to the UVB rays in sunlight. For example, healthy light skinned individuals can make sufficient vitamin D to meet the body's need with about 15 minutes of sun exposure on their face, arms and hands two to three times per week. Anything that reduces your exposure to the sun's UVB rays decreases the amount of vitamin D_3 your skin synthesizes. That would include long winters, your home's altitude, whether you are wearing sunscreen, and the color of your skin (including tanned skin). Do you ever wonder about an increased risk for skin cancer by spending too much time in the sun? Do not fret. Less than thirty minutes of sun exposure to the arms and legs will increase blood levels of vitamin D_3 more than orally taking 10,000 IU (250 micrograms) of vitamin D_3. However, it important to remember that the skin production of vitamin D_3 is a regulated process, so too much sun does cause vitamin D toxicity.

Interactive 9.4.1 Vitamin D Production in the Body

Visit the University of North Carolina Gillings School of Global Public Health website to review the activation of vitamin D to calcitriol. www.unc.edu/tlim/nutr240/?6

A person's vitamin D status is determined by measuring 25-hydroxy vitamin D_3 levels in the blood serum because it reflects both the vitamin D obtained from production in the skin and that from dietary sources. Measuring the active hormone, calcitriol, does not accurately reflect one's vitamin D status because of its short half-life (six to twelve hours). The vast majority of nutrition experts consider a concentration of 25-hydroxy vitamin D_3 in the blood serum less than 20 nanograms per milliliter as an indicator of vitamin D deficiency. The IOM states that serum levels above 20 nanograms per milliliter are sufficient to maintain bone health in healthy individuals. Both nutrition experts and health advocates currently are debating what the optimal levels of vitamin D_3 should be to take full advantage of all of its health benefits. Some advocates propose that serum levels of vitamin D_3 above 40 nonograms per milliliter are optimal. To determine whether higher levels of vitamin D_3 provide advantages in fighting diseases such as cancer, a large clinical trial called VITAL (Vitamin D and Omega-3 Trial) has been initiated at Brigham and Women's Hospital and Harvard Medical School in Boston, Massachusetts. To remain updated on this trial, visit their website at http://www.vitalstudy.org/index.html.

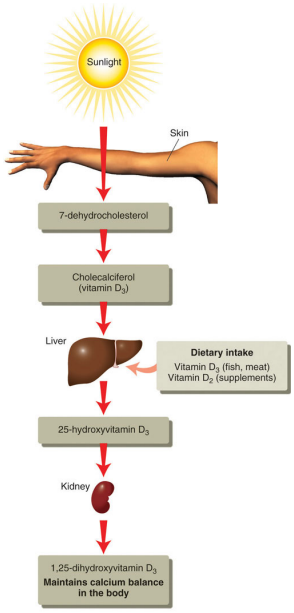


Figure 9.4.6: The Activation of Vitamin D to Calcitriol. © Networkgraphics

Vitamin D's Functional Role

As previously discussed, activated vitamin D_3 (calcitriol) regulates blood calcium levels in concert with parathyroid hormone. In the absence of an adequate intake of vitamin D, less than 15 percent of calcium is absorbed from foods or supplements. The effects of calcitriol on calcium homeostasis are critical for bone health. Vitamin D is important for bone metabolism, enhancing calcium absorption from the intestinal tract and reabsorption of calcium in the kidney.

A deficiency of vitamin D in children causes the bone disease nutritional rickets. Rickets is very common among children in developing countries and is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture. In adults, vitamin D deficiency causes a similar disease called osteomalacia, which is characterized by low BMD. Osteomalacia has the same symptoms and consequences as osteoporosis and often coexists with osteoporosis. Vitamin D deficiency is common, especially in the elderly population, dark-skinned populations, and in the many people who live in the northern latitudes where sunlight exposure is much decreased during the long winter season. Other groups at risk are people with fat malabsorption, people with kidney or liver failure, and people with low milk consumption or non-fortified milk consumption.malabsorption, people with kidney or liver failure, and people with low milk consumption or non-fortified milk consumption.

Observational studies have shown that people with low levels of vitamin D in their blood have lower BMD and an increased incidence of osteoporosis. In contrast, diets with high intakes of salmon, which contains a large amount of vitamin D, are linked with better bone health. A review of twelve clinical trials, published in the May 2005 issue of the *Journal of the American*

Medical Association, concluded that oral vitamin D supplements at doses of 700–800 international units per day, with or without coadministration of calcium supplements, reduced the incidence of hip fracture by 26 percent and other nonvertebral fractures by 23 percent."Fracture Prevention with Vitamin D Supplementation: A Meta-Analysis of Randomized Controlled Trials." *JAMA* 293, no. 18 (2005): 2257–64. http://jama.ama-assn.org/content/293/18/2257.long. A reduction in fracture risk was not observed when people took vitamin D supplements at doses of 400 international units.

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Vitamin D Needs and Sources

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Dietary Reference Intake for Vitamin D

The Institute of Medicine RDAs for vitamin D for different age groups is listed in Table 9.4.3 "Dietary Reference Intakes for Vitamin D". For adults, the RDA is 600 international units, which is equivalent to 15 micrograms of vitamin D. The National Osteoporosis Foundation recommends slightly higher levels and that adults under age fifty get between 400 and 800 international units of vitamin D every day, and adults fifty and older get between 800 and 1,000 international units of vitamin D every day. According to the IOM, the tolerable upper intake level (UL) for vitamin D is 4,000 international units per day. Toxicity from excess vitamin D is rare, but certain diseases such as hyperparathyroidism, lymphoma, and tuberculosis make people more sensitive to the increases in calcium caused by high intakes of vitamin D.

Table 9.4.3: Dietary Reference Intakes for Vitamin D

Age Group	RDA (mcg/day)	UL (mcg/day)
Infant (0–6 months)	10*	25
Infants (6–12 months)	10*	25
Children (1–3 years)	15	50
Children (4–8 years)	15	50
Children (9–13 years)	15	50
Adolescents (14–18 years)	15	50
Adults (19–71 years)	15	50
Adults (> 71 years)	20	50
* denotes Adequate Intake		

Source: Ross, A. C. et al. "The 2011 Report on Dietary Reference Intakes for Calcium and Vitamin D from the Institute of Medicine: What Clinicians Need to Know." J Clin Endocrinol Metab 96, no. 1 (2011): 53–8. http://www.ncbi.nlm.nih.gov/pubmed/21118827.

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Vitamin D Bioavailability

There are few food sources of vitamin D. Oily fish, such as salmon, is one of the best. The amount of vitamin D obtained from one 3-ounce piece of salmon is greater than the recommended intake for one day. Many foods, including dairy products (milk, margarine, butter), orange juice, and cereals are now fortified with vitamin D. Most vitamin-D-fortified foods contain about 25 percent of the RDA for vitamin D per serving, but check the label. Many people are deficient in vitamin D as a result of the few dietary sources for this vitamin. Other less abundant vitamin D containing foods are egg yolk, veal, and beef.

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Other Health Benefits of Vitamin D in the Body

Many other health benefits have been linked to higher intakes of vitamin D, from decreased cardiovascular disease to the prevention of infection. Furthermore, evidence from laboratory studies conducted in cells, tissues, and animals suggest vitamin D prevents the growth of certain cancers, blocks inflammatory pathways, reverses atherosclerosis, increases insulin secretion, and blocks viral and bacterial infection and many other things. Vitamin D deficiency has been linked to an increased risk for autoimmune diseases. (Autoimmune diseases are those that result from an abnormal immune response targeted against the body's own tissues.) An increased prevalence of the autoimmune diseases, rheumatoid arthritis, multiple sclerosis, and Type 1 diabetes has been observed in populations with inadequate vitamin D levels. Additionally, vitamin D deficiency is linked to an increased incidence of hypertension. Until the results come out from the VITAL study, the bulk of scientific evidence touting other health benefits of vitamin D is from laboratory and observational studies and requires confirmation in clinical intervention studies.

Key Takeaways

Calcium is the most abundant mineral in the body and has four primary functions: making bones strong and healthy, facilitating nerve-to-nerve communication, stimulating muscle contraction, and activating blood-clotting factors. Other benefits of calcium in the body include decreasing blood pressure and preventing colon cancer. Calcium blood-levels are rigorously controlled by three hormones: PTH, calcitriol, and calcitonin. The DRI for calcium intake for adults averages from 1,000–1,200 milligrams per day. Only some of the calcium in food is absorbed by the body. Vitamin D and estrogen enhance the bioavailability of calcium in the body. Alternately, diets high in oxalates, some types of fiber, and diets low in fat decrease the bioavailability of calcium in the body. Vitamin D is essential for maintaining calcium levels in the body. Once activated to calcitriol, it acts in concert with PTH to keep blood levels of calcium constant, especially by enhancing its intestinal absorption. High levels of vitamin D in the blood promote bone health.

Discussion Starters

1. Talk about some of the vital functions of calcium and vitamin D in the body. Why are these nutrients so important to health? What can you do to increase these vitamins in your diet?
2. Watch the video below. List the pros and cons of consuming both raw and pasteurized milk. Develop an informed opinion based upon the history of milk and the scientific evidence about both types of milk consumption.

   Raw Milk

   (click to see video)

9.4: Micronutrients Essential for Bone Health- Calcium and Vitamin D is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

9.5: Other Essential Micronutrients for Bone Health

Learning Objectives

- Identify additional nutrients that are vital in maintaining bone health and state their primary role.
- Identify food sources for each nutrient.

Bone tissue is greater than 70 percent inorganic material and as such, minerals are important for maintaining skeletal health. In addition to calcium, other minerals critical for bone health are phosphorus, magnesium, and fluoride. Vitamin K is also important to bone health. But that is not all—iron, copper, zinc, and vitamin C are also essential for the synthesis of collagen. Consuming too much or too little vitamin A affects bone health too, as it plays a role in osteoclast and osteoblast activities. The fact that there are many bone-friendly nutrients provides us with one more reason why it is better to eat a diet rich in many nutrients than taking one particular supplement. In Table 9.5.1, notice the important nutrients for bone health and good food sources for each.

Table 9.5.1: Micronutrients and Bone Health

Micronutrient	Functional Role in Bone Health	Food Sources
Calcium	• Component of mineralized bone • Provides structure and microarchitecture	collards, mustard greens, kale, turnips, broccoli, beans, black molasses, and fortified juices, cereals, and milk.
Phosphorus	• Component of mineralized bone • Provides structure and microarchitecture	non-genetically-modified soy, legumes, whole grains, dairy, nuts, and seeds
Magnesium	• Component of mineralized bone • Provides structure and microarchitecture	whole grains and legumes, almonds, cashews, hazelnuts, beets, collards, and kelp
Fluoride	• Component of mineralized bone • Provides structure and microarchitecture • Stimulates new bone growth	fluoridated water, foods prepared in fluoridated water, seafood (because the ocean contains natural sodium flouride)
Vitamin D	• Critical for maintaining calcium levels • Aids the absorption of calcium, promotes bone health	salmon, mackerel, tuna, sardines, mushrooms, cod liver oil, egg yolks, and fortified milk, yogurt, and cheese
Vitamin K	• Stimulates bone remodeling	kale, spinach, turnip, and other dark leafy vegetables
Boron	• May enhance calcium absorption and estrogen metabolism	avocado, nuts, peanut butter, green and orange vegetables, grapes, and raisins
Iron	• Helps enzymes and regulators function properly so the body can form optimal bone structure for bone strength	red meat, egg yolks, dark leafy vegetables, dried fruit, iron-fortified foods, beans, lentils, chick peas, liver, and artichoke
Vitamin C	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	citrus fruits, tomatoes and tomato juice, potatoes, Brussel sprouts, cauliflower, broccoli, strawberries, cabbage, and spinach
Zinc	• Helps enzymes and regulators to function properly so the body can form optimal bone structure for bone strength	oysters, wheat germ, pumpkin seeds, squash, watermelon seeds, beans, sesame seeds, tahini, beef, lamb

Phosphorus's Functional Role

Phosphorus is the second most abundant mineral in the human body. Eighty-five percent of it is housed in the skeleton. In addition to serving as a primary mineral in the skeleton, phosphorus in the form of phosphate is a component of the backbones of RNA and DNA, the cellular energy storing molecule, adenosine triphosphate (ATP), and phospholipids. Because phosphorus is present with calcium in mineralized bone, it is somewhat regulated in parallel with calcium. PTH and calcitriol stimulate bone resorption, increasing not only blood levels of calcium but also blood phosphate levels. However, in contrast to the effect of PTH on calcium reabsorption by the kidney, PTH stimulates the renal excretion of phosphate so that it does not accumulate to toxic levels. It is usually found as phosphate or phosphorous salt.

Deficiency signs and symptoms include muscle weakness, loss of appetite (anorexia) and bone pain. A deficiency is rare but more apt to be found in preterm infants, elderly individuals, excess alcohol intake and postmenopausal women.

Dietary Reference Intake and Food Sources for Phosphorus

In comparison to calcium, most Americans are not at risk for having a phosphate deficiency. Phosphate is present in many foods popular in the American diet including meat, fish, dairy products, processed foods, and beverages. Phosphate is added to many foods because it acts as an emulsifying agent, prevents clumping, improves texture and taste, and extends shelf-life. The average intake of phosphorus in US adults ranges between 1,000 and 1,500 milligrams per day, well above the RDA of 700 milligrams per day. The UL set for phosphorous is 4,000 milligrams per day for adults and 3,000 milligrams per day for people over age seventy.

Table 9.5.2: Dietary Reference Intakes for Phosphorus

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	100*	–
Infants (6–12 months)	275*	–
Children (1–3 years)	460	3,000
Children (4–8 years)	500	3,000
Children (9–13 years)	1,250	4,000
Adolescents (14–18 years)	1,250	4,000
Adults (19–70 years)	700	4,000
Adults (> 70 years)	700	3,000
* denotes Adequate Intake		

Table 9.5.3: Calcium and Phosphorus Contents in 100 Grams of Certain Foods

Foods	Calcium (mg)	Phosphorus (mg)
Dairy Products		
Buttermilk	116	89
Milk, nonfat	123	101

Foods	Calcium (mg)	Phosphorus (mg)
Milk, whole	207	158
Yogurt, low-fat	199	157
Yogurt, whole milk	121	95
Cottage cheese, low-fat	69	151
Swiss cheese	791	567
Meats		
Beef, round steak	7	199
Chicken	15	216
Crab	59	175
Oysters	62	159
Legumes/Nuts		
Macadamia nuts	85	188
Soybeans	145	158
Lentils	19	180
Lima beans	21	74
Vegetables		
Broccoli	47	66
Carrots	27	44
Lettuce, iceberg	19	20
Parsley	140	60
Cereals/Grains		
Barley	32	309
Wheat flour, white	15	108
Oat bran	10	119
Rice, brown	10	77
Rice, white	19	55
Processed Foods		
American cheese	712	923
Au gratin potatoes	83	95
Fish sticks	26	182
Fast food hamburger	46	97
Chocolate cake mix	150	270
Chocolate wafer cookies	31	32
Granola bar	105	230
Carbonated Beverages		
Cola	2	11
Clear soda	2	0

Source: Adapted from US Department of Agriculture National Nutrient Database. Last modified November 1, 2012. http://www.nal.usda.gov/fnic/foodcomp/search/.

Magnesium's Functional Role

Magnesium is another major mineral and our bodies contain approximately 25 grams. Approximately 60 percent of magnesium in the human body is stored in the skeleton, making up about 1 percent of mineralized bone tissue. Magnesium is not an integral part of the hydroxyapatite crystal, but it does reside on the surface of the crystal and helps crystal formation to maximize bone structure. Observational studies link magnesium deficiency with an increased risk for osteoporosis. A magnesium-deficient diet is associated with decreased levels of parathyroid hormone and the activation of vitamin D, which may lead to an impairment of bone remodeling. A study in nine hundred elderly women and men did show that higher dietary intakes of magnesium correlated to an increased BMD in the hip.Tucker, K. L. et al. "Potassium, Magnesium, and Fruit and Vegetable Intakes Are Associated with Greater Bone Mineral Density in Elderly Men and Women." *Am J Clin Nutr* 69, no. 4 (1999): 727–36. Only a few clinical trials have evaluated the effects of magnesium supplements on bone health and their results suggest some modest benefits on BMD.

In addition to participating in bone maintenance, magnesium has several other functions in the body. In every reaction involving the cellular energy molecule, ATP, magnesium is a required cofactor. More than three hundred enzymatic reactions require magnesium. Magnesium plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids, and is essential for nerve conduction, muscle contraction, and blood clotting. Another health benefit of magnesium is that it may decrease blood pressure.

Dietary Reference Intake and Food Sources for Magnesium

The RDAs for magnesium for adults between ages nineteen and thirty are 400 milligrams per day for males and 310 milligrams per day for females. For adults above age thirty, the RDA increases slightly to 420 milligrams per day for males and 320 milligrams for females.



Figure 9.5.1: For optimal magnesium intake, try consuming whole-grain breads and cereals. (Public domain; Peggy Greb, USDA ARS)

Table 9.5.4: Dietary Reference Intakes for Magnesium

Age Group	RDA (mg/day)	UL (mg/day)
Infants (0–6 months)	30*	–
Infants (6–12 months)	75*	–
Children (1–3 years)	80	65
Children (4–8 years)	130	110
Children (9–13 years)	240	350
Adolescents (14–18 years)	410	350
Adults (19–30 years)	400	350
Adults (> 30 years)	420	350

* denotes Adequate Intake Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Magnesium.” Last reviewed July 13, 2009. http://ods.od.nih.gov/factsheets/Magnesium-HealthProfessional/.

Magnesium is part of the green pigment, chlorophyll, which is vital for photosynthesis in plants; therefore green leafy vegetables are a good dietary source of magnesium. Magnesium is also found in high concentrations in fish, dairy products, meats, whole grains, and nuts. Additionally chocolate, coffee, and hard water contain a good amount of magnesium. Most people in America do not fulfill the RDA for magnesium in their diets. Typically, Western diets lean toward a low fish intake and the unbalanced consumption of refined grains versus whole grains.

A deficiency in magnesium causes hypomagnesemia or low levels of magnesium in the blood which is often accompanied by a low blood calcium and potassium levels. Hypomagnesium is associated with long-term use of protein inhibitor drugs commonly used to treat GERD. Muscle cramps, spasms, nausea, weakness, irritability, and confusion are also symptoms of a magnesium deficiency. Groups at risk for developing a magnesium deficiency are individuals with renal disease, chronic diarrhea, chronic alcohol abuse and elderly people.

A high intake of magnesium is not toxic but pharmacological doses beyond the upper limit can cause diarrhea, nausea, abdominal cramps, pH imbalances, massive dehydration, cardiac arrest, and death. The excessive use of antacids can cause hypermagnesemia that affects kidney functions and impairs nerve, muscle and heart function.

Fluoride’s Functional Role

Fluoride is a water soluble anion. It is known mostly as the mineral that combats tooth decay and is bound to fluoro-hydroxyapatite. It assists in tooth and bone development and maintenance. Fluoride combats tooth decay via three mechanisms:

1. Blocking acid formation by bacteria
2. Preventing demineralization of teeth
3. Enhancing remineralization of destroyed enamel

Fluoride was first added to drinking water in 1945 in Grand Rapids, Michigan; now over 60 percent of the US population consumes fluoridated drinking water. The Centers for Disease Control and Prevention (CDC) has reported that fluoridation of water prevents, on average, 27 percent of cavities in children and between 20 and 40 percent of cavities in adults. The CDC considers water fluoridation one of the ten great public health achievements of the twentieth century.Centers for Disease Control. “10 Great Public Health Achievements in the 20th Century.” *Morbidity and Mortality Weekly Report* 48, no. 12 (April 2, 1999): 241–43. www.cdc.gov/about/history/tengpha.htm. The optimal fluoride concentration in water to prevent tooth decay ranges between 0.7–1.2 milligrams per liter. Exposure to fluoride at three to five times this concentration before the growth of permanent teeth can cause fluorosis, which is the mottling and discoloring of the teeth. Inadequate intake of fluoride has been linked to dental caries with poor mouth hygiene. People who drink water that is not fluoridated or use toothpaste with no fluoridation, are at a greater risk of developing the signs of a fluoride deficiency. Excess amounts of fluoride are toxic and cause fluorosis.

Fluoride’s benefits to mineralized tissues of the teeth are well substantiated, but the effects of fluoride on bone are not as well known. Fluoride is currently being researched as a potential treatment for osteoporosis. The data are inconsistent on whether consuming fluoridated water reduces the incidence of osteoporosis and fracture risk. Fluoride does stimulate osteoblast bone building activity, and fluoride therapy in patients with osteoporosis has been shown to increase BMD. In general, it appears that at low doses, fluoride treatment increases BMD in people with osteoporosis and is more effective in increasing bone quality when the intakes of calcium and vitamin D are adequate. The Food and Drug Administration has not approved fluoride for the treatment of osteoporosis mainly because its benefits are not sufficiently known and it has several side effects including frequent stomach upset and joint pain. The doses of fluoride used to treat osteoporosis are much greater than that in fluoridated water.

Dietary Reference Intake and Food Sources for Fluoride

The IOM has given Adequate Intakes (AI) for fluoride but has not yet developed RDAs. The AIs are based on the doses of fluoride shown to reduce the incidence of cavities, but not cause dental fluorosis. From infancy to adolescence, the AIs for fluoride increase from 0.01 milligrams per day for ages less than six months to 2 milligrams per day for those between the ages of fourteen and eighteen. In adulthood, the AI for males is 4 milligrams per day and for females is 3 milligrams per day. The UL for young children is set at 1.3 and 2.2 milligrams per day for girls and boys, respectively. For adults, the UL is set at 10 milligrams per day. Greater than 70 percent of a person’s fluoride comes from drinking fluoridated water when they live in a community that fluoridates the drinking water. Other beverages with a high amount of fluoride include teas and grape juice. Solid foods do not contain a large amount of fluoride. Fluoride content in foods depends on whether it was grown in soils and water that contained fluoride or cooked with fluoridated water. Canned meats and fish that contain bones do contain some fluoride.

Table 9.5.5: Dietary Reference Intakes for Fluoride

Age Group	AI (mg/day)	UL (mg/day)
Infants (0–6 months)	0.01	0.7
Infants (6–12 months)	0.50	0.9
Children (1–3 years)	0.70	1.3

Age Group	AI (mg/day)	UL (mg/day)
Children (4–8 years)	1.00	2.2
Children (9–13 years)	2.00	10.0
Adolescents (14–18 years)	3.00	10.0
Adult Males (> 19 years)	4.00	10.0
Adult Females (> 19 years)	3.00	10.0

Source: Institute of Medicine. *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride.* January 1, 1997. www.iom.edu/Reports/1997/Dietary-Reference-Intakes-for-Calcium-Phosphorus-Magnesium-Vitamin-D-and-Fluoride.aspx.

Vitamin K's Functional Role

Vitamin K refers to a group of fat-soluble vitamins that are similar in chemical structure. They act as coenzymes and have long been known to play an essential role in blood coagulation. Without vitamin K, blood would not clot. Vitamin K is also required for maintaining bone health. It modifies the protein osteocalcin, which is involved in the bone remodeling process. All the functions of osteocalcin and the other vitamin K-dependent proteins in bone tissue are not well understood and are under intense study. Some studies do show that people who have diets low in vitamin K also have an increased risk of bone fractures.

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Dietary Reference Intake and Food Sources for Vitamin K

The AI of vitamin K for adult females is 75 micrograms per day, and for males, it is 120 micrograms per day. A UL for vitamin K has not been set. Vitamin K is present in many foods. It is found in highest concentrations in green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce. Additionally, vitamin K can be synthesized via bacteria in the large intestine. The exact amount of vitamin K synthesized by bacteria that is actually absorbed in the lower intestine is not known, but likely contributes less than 10 percent of the recommended intake. Newborns have low vitamin K stores and it takes time for the sterile newborn gut to acquire the good bacteria it needs to produce vitamin K. So, it has become a routine practice to inject newborns with a single intramuscular dose of vitamin K. This practice has basically eliminated vitamin K-dependent bleeding disorders in babies.

Table 9.5.6: Dietary Reference Intakes for Vitamin K

Age Group	RDA (mcg/day)
Infants (0–6 months)	2.0*
Infants (6–12 months)	2.5*
Children (1–3 years)	30
Children (4–8 years)	55
Children (9–13 years)	60
Adolescents (14–18 years)	75
Adult Males (> 19 years)	120
Adult Females (> 19 years)	90

* denotes Adequate Intake. Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Summary

Phosphorous is a primary mineral component of bone, is regulated in parallel with calcium, and in high amounts is detrimental to bone health. Magnesium helps keep bones strong. A deficiency in magnesium can compromise bone health. Fluoride combats tooth decay and benefits teeth and bones when present in the diet at the recommended intake. Vitamin K is a coenzyme that participates in the modification of proteins that act in bone tissues and promotes normal blood clotting.

Discussion Starters

1. Discuss and plan a dinner menu that specifically contains bone-friendly foods. What are you going to serve? Be sure to include enough bone-friendly foods for the different types of vegetarians.
2. Discuss some of the functional roles that magnesium, phosphorous, fluoride, and vitamin K serve in the body. In the midst of a busy schedule, how can you ensure you are eating the right amount of foods to provide an adequate supply of these nutrients?

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9.6: Osteoporosis

Learning Objectives

- Describe osteoporosis, including its notable characteristics

There are several factors that lead to loss of bone quality during aging, including a reduction in hormone levels, decreased calcium absorption, and increased muscle deterioration. It is comparable to being charged with the task of maintaining and repairing the structure of your home without having all of the necessary materials to do so. However, you will learn that there are many ways to maximize your bone health at any age.

Osteoporosis is the excessive loss of bone over time. It leads to decreased bone strength and an increased susceptibility to bone fracture. The Office of the Surgeon General (OSG) reports that approximately ten million Americans over age fifty are living with osteoporosis, and an additional thirty-four million have osteopenia, which is lower-than-normal bone mineral density.Office of the Surgeon General. “Bone Health and Osteoporosis: A Report of the Surgeon General.” October 2004. www.surgeongeneral.gov/library/bonehealth/chapter_1.html. Osteoporosis is a debilitating disease that markedly increases the risks of suffering from bone fractures. A fracture in the hip causes the most serious consequences—and approximately 20 percent of senior citizens who have one will die in the year after the injury. Osteoporosis affects more women than men, but men are also at risk for developing osteoporosis, especially after the age of seventy. These statistics may appear grim, but many organizations—including the National Osteoporosis Foundation and the OSG—are disseminating information to the public and to healthcare professionals on ways to prevent the disease, while at the same time, science is advancing in the prevention and treatment of this disease.International Osteoporosis Foundation. “Facts and Statistics about Osteoporosis and Its Impact.” © 2012 International Osteoporosis Foundation. Accessed http://www.iofbonehealth.org/facts-and-statistics.html.

As previously discussed, bones grow and mineralize predominately during infancy, childhood, and puberty. During this time, bone growth exceeds bone loss. By age twenty, bone growth is fairly complete and only a small amount (about 10 percent) of bone mass accumulates in the third decade of life. By age thirty, bone mass is at its greatest in both men and women and then gradually declines after age forty. Bone mass refers to the total weight of bone tissue in the human body. The greatest quantity of bone tissue a person develops during his or her lifetime is called peak bone mass. The decline in bone mass after age forty occurs because bone loss is greater than bone growth. On a cellular level, this means that the osteoclast-mediated bone degradation exceeds that of the bone building activity of osteoblasts. The increased bone degradation decreases the mineral content of bone tissue leading to a decrease in bone strength and increased fracture risk.

Osteoporosis is referred to as a silent disease, much like high blood pressure, because symptoms are rarely exhibited. A person with osteoporosis may not know he has the disease until he experiences a bone break or fracture. Detection and treatment of osteoporosis, before the occurrence of a fracture, can significantly improve the quality of life. To detect osteopenia or osteoporosis, BMD must be measured by the DEXA procedure. The results of a BMD scan are most often reported as T-scores. A T-score compares a person’s BMD to an averaged BMD of a healthy thirty-year-old population of the same sex. According to the World Health Organization, a T-score of −1.0 or above indicates normal BMD. A person with a T-score between −1.0 and −2.5 has a low BMD, which is a condition referred to as osteopenia. A person with a T-score of −2.5 or below is diagnosed with osteoporosis. National Osteoporosis Foundation. “Having A Bone Density Test.” © 2011. www.nof.org/node/42 This classification of T-scores is based on studies of white postmenopausal women and does not apply to premenopausal women, nonwhite postmenopausal women, or men.

Osteoporosis is categorized into two types that differ by the age of onset and what type of bone tissue is most severely deteriorated. Type 1 osteoporosis, also called postmenopausal osteoporosis, most often develops in women between the ages of fifty and seventy. Between the ages of forty-five and fifty, women go through menopause and their ovaries stop producing estrogen. Because estrogen plays a role in maintaining bone mass, its rapid decline during menopause accelerates bone loss. This occurs mainly as a result of increased osteoclast activity. The trabecular tissue is more severely affected because it contains more osteoclasts cells than cortical tissue. Type 1 osteoporosis is commonly characterized by wrist and spine fractures. Type 2 osteoporosis is also called senile osteoporosis and typically occurs after the age of seventy. It affects women twice as much as men and is most often associated with hip and spine fractures. In Type 2 osteoporosis, both the trabecular and cortical bone tissues are significantly affected. Not everybody develops osteoporosis as they age. Other factors, which will be discussed in Section 9.6 of this chapter, also contribute to the risk or likelihood of developing the disease.

During the course of both types of osteoporosis, BMD decreases and the bone tissue microarchitecture is compromised. Excessive bone resorption in the trabecular tissue increases the size of the holes in the lattice-like structure making it more porous and weaker. A disproportionate amount of resorption of the strong cortical bone causes it to become thinner. The deterioration of one or both types of bone tissue causes bones to weaken and, consequently, become more susceptible to fractures. The American Academy of Orthopaedic Surgeons reports that one in two women and one in five men older than sixty-five will experience a bone fracture caused by osteoporosis.American Academy of Orthopaedic Surgeons. “Osteoporosis.” © 1995–2012. Last reviewed August 2009. orthoinfo.aaos.org/topic.cfm?topic=a00232.

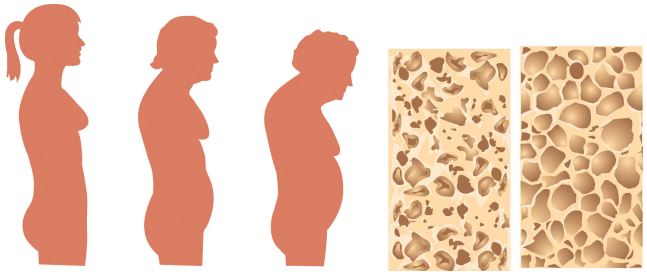


Figure 9.6.1: Osteoporosis in vertebrae. Osteoporosis is characterized by a gradual weakening of the bones, which leads to poor skeletal formation. © Shutterstock

When the vertebral bone tissue is weakened, it can cause the spine to curve (Figure 9.6.1). The increase in spine curvature not only causes pain but also decreases a person's height. Curvature of the upper spine produces what is called Dowager's hump, also known as kyphosis. Severe upper-spine deformity can compress the chest cavity and cause difficulty breathing. It may also cause abdominal pain and loss of appetite because of the increased pressure on the abdomen.



Video 9.6.1: *Osteoporosis Defined. See this 3D medical animation about osteoporosis (click to see video).*

Key Takeaways

Bone mineral density (BMD) is an indicator of bone quality and correlates with bone strength. Excessive bone loss can lead to the development of osteopenia and eventually osteoporosis. Osteoporosis affects women more than men but is a debilitating disease for either sex. Osteoporosis is often a silent disease that doesn't manifest itself until a fracture is sustained.

Discussion Starters

1. Discuss how bone microarchitecture is changed in people with osteoporosis. How do these structural changes increase the risk of having a bone fracture?
2. Go back to Section 9.2 and review that bone is a living tissue that adapts to changes in mechanical forces. How might weight training help prevent a fracture in someone with osteoporosis?

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9.7: Risk Factors for Osteoporosis

Learning Objectives

- Discuss risk factors for osteoporosis.



Figure 9.7.1: *Certain risk factors for developing osteoporosis are biological, such as being Caucasian or Asian and being over age forty. Other factors are related to lifestyle choices such as smoking. © Shutterstock*

A risk factor is defined as a variable that is linked to an increased probability of developing a disease or adverse outcome. Recall that advanced age and being female increase the likelihood of developing osteoporosis. These factors present risks that should signal doctors and individuals to focus more attention on bone health, especially when the risk factors exist in combination. This is because not all risk factors for osteoporosis are out of your control. Risk factors such as age, gender, and race are biological risk factors and are based on genetics that cannot be changed. By contrast, there are other risk factors that can be modified, such as physical activity, alcohol intake, and diet. The changeable risk factors for osteoporosis provide a mechanism to improve bone health even though some people may be genetically predisposed to the disease.

Non-modifiable Risk Factors

Age, Sex, Body Type, and Heredity

As noted previously, after age forty, bone mass declines due to bone breakdown exceeding bone building (osteoblasts decrease). Therefore, any person over the age of forty has an increased probability of developing osteoporosis in comparison to a younger person. As noted, starting out with more bone (a high peak bone mass) enables you to lose more bone during the aging process and not develop osteoporosis. Females, on average, have a lower peak bone mass in comparison to males and therefore can sustain less bone tissue loss than males before developing a low BMD. Similarly, people with small frames are also at higher risk for osteoporosis. Being of advanced age, being a woman, and having a small frame are all biological risk factors for osteoporosis. Other biological risk factors that are linked to an increased likelihood of developing osteoporosis are having low estrogen levels, or another endocrine disorder such as hyperthyroidism, having a family member with osteoporosis, and being Caucasian or Asian. Caucasians have the highest risk of fractures while Asians have an intermediate risk and African Americans the lowest risk. Risk is correlated with bone density with Caucasians having the lowest bone mineral density and African Americans the highest.

Estrogen Level

Estrogen is the primary female reproductive hormone and it stimulates osteoblast-mediated bone building and reduces osteoclast activity. Any condition in which estrogen levels are reduced throughout a woman's life decreases BMD and increases the risk for osteoporosis. By far the most profound effect on estrogen occurs during female menopause. Around the age of forty-five or fifty, women stop producing estrogen. The rapid decline in estrogen levels that occurs during menopause speeds up the bone resorptive process, and as a result, the loss of bone tissue in menopausal women lasts for a period of five to ten years. Up to 3 percent of bone tissue is lost annually during menopause and therefore potentially 30 percent of peak bone mass can vanish during this time, leading to a substantial increase in the risk of developing osteoporosis in postmenopausal women.

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Medications

Some medications, most notably glucocorticoids (used to treat inflammatory disorders such as rheumatoid arthritis and asthma), are associated with an increased risk for osteoporosis. A side effect of glucocorticoids is that they stimulate bone resorption and decrease bone building. Other medications linked to an increased risk for osteoporosis are certain anticancer drugs, some antidiabetic drugs, and blood thinners.

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Other Diseases

Diseases that predispose people to osteoporosis include those that disrupt nutrient absorption and retention, such as anorexia nervosa, chronic kidney disease, and Crohn's disease; diseases that influence bone remodeling such as hyperthyroidism and diabetes; and diseases that are characterized by chronic inflammatory responses such as cancer, chronic obstructive pulmonary disease, and rheumatoid arthritis.

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Modifiable Risk Factors

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Physical Inactivity

Bone is a living tissue, like muscle, that reacts to exercise by gaining strength. Physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly. Recall that mechanical stress increases bone remodeling and leads to increased bone strength and quality. Weight-bearing exercise puts mechanical stress on bones and therefore increases bone quality. The stimulation of new bone growth occurs when a person participates in weight-bearing or resistance activities that force the body to work against gravity. Research has shown that this is an excellent way to activate osteoblasts to build more new bone. Conversely, physical inactivity lowers peak bone mass, decreases BMD at all ages, and is linked to an increase in fracture risk, especially in the elderly. Even in the elderly, weight bearing exercise can increase bone mass.



Figure 9.7.2: Dancing is a form of weight-bearing activity that forces the body to move against gravity and therefore stimulates new bone growth. San Francisco Sunday Streets: Valencia. (CC-BY-2.0; David McSpadden)

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Being Underweight

Being underweight significantly increases the risk for developing osteoporosis. This is because people who are underweight often also have a smaller frame size and therefore have a lower peak bone mass. Maintaining a normal, healthy weight is important and acts as a form of weight-bearing exercise for the skeletal system as a person moves about. Additionally, inadequate nutrition negatively impacts peak bone mass and BMD. The most striking relationship between being underweight and bone health is seen in people with the psychiatric illness anorexia nervosa. Anorexia nervosa is strongly correlated with low peak bone mass and a low BMD. In fact, more than 50 percent of men and women who have this illness develop osteoporosis and sometimes it occurs very early in life.Mehler, P. S. and K. Weiner. “The Risk of Osteoporosis in Anorexia Nervosa.” Reprinted from *Eating Disorders Recovery Today* 1, no. 5 (Summer 2003). © 2003 Gurze Books. www.eatingdisordersreview.com/nl/nl_edt_1_5_2.html Women with anorexia nervosa are especially at risk because they not only have inadequate nutrition and low body weight, but also the illness is also associated with estrogen deficiency.

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Smoking, Alcohol, and Caffeine

Cigarette smoking has long been connected to a decrease in BMD and an increased risk of osteoporosis and fractures. However, because people who smoke are more likely to be physically inactive and have poor diets, it is difficult to determine whether smoking itself causes osteoporosis. What is more, smoking is linked to earlier menopause and therefore the increased risk for developing osteoporosis among female smokers may also be attributed, at least in part, to having stopped estrogen production at an earlier age. A review of several studies, published in the *British Medical Journal* in 1997, reports that in postmenopausal women who smoked, BMD was decreased an additional 2 percent for every ten-year increase in age and that these women had a substantial increase in the incidence of hip fractures.Law, M. R., and A.K. Hackshaw. “A Meta-Analysis of Cigarette Smoking, Bone Mineral Density and Risk of Hip Fracture: Recognition of a Major Effect.” *Br Med J* 315, no. 7112 (October 4, 1997): 841–6. http://www.ncbi.nlm.nih.gov/pubmed/9353503.

Alcohol intake’s effect on bone health is less clear. In some studies, excessive alcohol consumption was found to be a risk factor for developing osteoporosis, but the results of other studies suggest consuming two drinks per day is actually associated with an increase in BMD and a decreased risk for developing osteoporosis. The International Osteoporosis Foundation states that consuming more than two alcoholic drinks per day is a risk factor for developing osteoporosis and sustaining a hip fracture in both men and women.International Osteoporosis Foundation. “New IOF Report Shows Smoking, Alcohol, Being Underweight, and Poor Nutrition Harm our Bones.” Accessed October 2011. http://www.iofbonehealth.org/news/news-detail.html?newsID=193. Moreover, excessive alcohol intake during adolescence and young adulthood have a more profound effect on BMD and osteoporosis risk than drinking too much alcohol later in life.

Some studies have found that similar to alcohol intake, excessive caffeine consumption has been correlated to decreased BMD, but in other studies, moderate caffeine consumption actually improves BMD. Overall, the evidence that caffeine consumption poses a risk for developing osteoporosis is scant, especially when calcium intake is sufficient. Some evidence suggests that carbonated soft drinks negatively affect BMD and increase fracture risk. Their effects, if any, on bone health are not attributed to caffeine content or carbonation. It is probable that any effects of the excessive consumption of soft drinks, caffeinated or not, on bone health can be attributed to the displacement of milk as a dietary source of calcium.

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Nutrition

Ensuring adequate nutrition is a key component in maintaining bone health. Having low dietary intakes of calcium and vitamin D are strong risk factors for developing osteoporosis. Another key nutrient for bone health is protein. Remember that the protein collagen comprises almost one-third of bone tissue. A diet inadequate in protein is a risk factor for osteoporosis. Multiple large observational studies have shown that diets high in protein increase BMD and reduce fracture risk and that diets low in protein correlate to decreased BMD and increased fracture risk. There has been some debate over whether diets super high in animal protein decrease bone quality by stimulating bone resorption and increasing calcium excretion in the urine. A review in the May 2008 issue of the *American Journal of Clinical Nutrition* concludes that there is more evidence that diets adequate in protein play a role in maximizing bone health and there is little consistent evidence that suggests high protein diets negatively affect bone health when calcium intake is adequate.Heaney, R. P. and D.K. Layman. “Amount and Type of Protein Influences Bone Health.” *Am J Clin Nutr* 87, no. 5 (2008): 1567S–70S. http://www.ajcn.org/content/87/5/1567S.long

Key Takeaways

Non-modifiable risk factors for osteoporosis include: being female, being over age fifty, having a small frame, having an endocrine disorder, having a family member with the disease, and being Caucasian or Asian. The risk factors for osteoporosis that can be changed are smoking, alcohol intake, physical inactivity, and poor nutrition. Dietary inadequacy, certain medications, and diseases increase the risk for developing osteoporosis.

Discussion Starter

1. Discuss why it is important for a person with more than one biological risk factor for osteoporosis to begin to manage their lifestyle early on to prevent the development of the disease.

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9.8: Osteoporosis Prevention and Treatment

Learning Objectives

- Explain why it is important to build peak bone mass when you are young.
- Identify the tests used to measure bone mass.

Although the symptoms of osteoporosis do not occur until old age, osteoporosis is referred to as a childhood disease with old-age consequences. Thus, preventing osteoporosis in old age begins with building strong bones when you are growing. Remember, the more bone mass a person has to start with, the greater the loss a person can withstand without developing osteopenia or osteoporosis. Growing and maintaining healthy bones requires good nutrition, adequate intake of minerals and vitamins that are involved in maintaining bone health, and weight-bearing exercise.



Figure 9.8.1: An exercise group engages in a weight-bearing activity, which is a primary way to prevent osteoporosis. © Shutterstock

Primary Prevention

Actions taken to avoid developing a disease before it starts are considered primary prevention. Primary prevention of osteoporosis begins early on in life. About one-half of mineralized bone is built during puberty and the requirements for calcium intake are higher at this time than at other times in life. Unfortunately, calcium intake in boys and girls during adolescence is usually below the recommended intake of 1,300 milligrams per day. To combat inadequate nutrition and physical inactivity in adolescents, the US Department of Health and Human Services launched the Best Bones Forever!™ campaign in 2009.US Department of Health and Human Services. *Best Bones Forever!* Last updated September 2009. www.bestbonesforever.gov/index.cfm This campaign is focused on promoting bone health, especially in girls, and reducing the incidence of osteoporosis in women.

Interactive 9.8.1 Visit the Best Bones Forever!™ website.

www.bestbonesforever.gov/index.cfm

An article in the October 2008 issue of *Food and Nutrition Research* concluded that there is extensive evidence that when girls and boys exercise they increase their peak bone mass and build a stronger skeleton. The greatest benefits to bone health were observed when exercise was combined with good nutrition.Karlsson, M. K., A. Nordqvist, and C. Karlsson. “Physical Activity Increases Bone Mass during Growth.” *Food and Nutrition Research* 52 (Published online October 1, 2008). doi: 10.3402/fnr.v52i0.1871 Because there is such a strong correlation between peak bone mass and a decreased risk of developing osteoporosis, the main thrust of organizations that promote bone health, such as the National Osteoporosis Foundation, is to provide information on how to increase skeletal health early on in life, particularly during the time period of peak bone growth, which is puberty.

Primary prevention extends throughout life, and people with one or more risk factors for osteoporosis should have their BMD measured. The National Osteoporosis Foundation recommends the following groups of people get BMD screening:

- Women who are sixty-five or older
- Men who are seventy or older
- Women and men who break a bone after age fifty

- Women going through menopause with other risk factors
- Men fifty to sixty-nine years of age with risk factors National Osteoporosis Foundation. “National Osteoporosis Foundation on Bone Mineral Density Testing.” www.nof.org/node/501

Primary Prevention Tactics

Nutrition: Eat Right for Your Bones

Eating a balanced diet throughout life is helpful in preventing the onset of osteoporosis and deleterious fractures in old age. There is ample scientific evidence to suggest that low intakes of calcium and vitamin D in adulthood are linked to an increased risk for developing osteoporosis. Therefore, it is essential to make sure your diet contains adequate levels of these nutrients. The roles of calcium and vitamin D in maintaining bone health are discussed in detail elsewhere in this chapter (Chapter 9.4). A high phosphorus intake coupled with a low calcium intake may contribute bone loss. It is better if your diet contains the appropriate amount of calcium, phosphorus, and protein.

Physical Activity: Use It or Lose It

Mechanical stress is one of the activation signals for bone remodeling and can increase bone strength. Exercises that apply forces to the bone increase BMD. The most helpful are weight-bearing exercises such as strength training with weights, and aerobic weight-bearing activities, such as walking, running, and stair climbing. Certain aerobic exercises such as biking and swimming do not build bones, although they are very good for cardiovascular fitness. The importance of weight-bearing exercise to bone health is seen most clearly in astronauts. Investigators who analyzed the BMD of astronauts found that typically it decreases by 1.8 percent every month in space. That means during a six-month stay at a space station an astronaut may lose greater than 10 percent of their bone mass. The lack of gravity, which tugs on the bones of people on Earth every day, is what causes bone mass loss in astronauts. NASA imposes a rigorous workout to prevent and to restore the loss of bone mass in astronauts. While in space, astronauts exercise two-and-a-half hours each day on a treadmill and use a resistance-exercise device where they pull rubber band-like cords attached to pulleys. Then, when they return to Earth astronauts undergo weeks of rehabilitation to rebuild both bone and muscle tissue.

Video 9.8.1: Exercise Helps Keep Astronauts Healthy in Space

This video from NASA explains the importance of exercise in maintaining the health of astronauts in space. (click to see video)

Fall Prevention

Reducing the number of falls a person has decreases the likelihood of sustaining a fracture. Fairly simple modifications to a person’s environment, such as installing nightlights, railings on stairs, bars to hold onto in showers, and removing cords and throw rugs in walking paths can significantly reduce the likelihood of falling. Importantly, people at risk should have their vision and balance checked frequently.

Secondary Prevention

A person who has undergone a DEXA scan and been diagnosed with osteopenia or osteoporosis has multiple strategies available to reduce the chances of breaking a bone. These types of treatment strategies are referred to as secondary prevention. The OSG reports that the primary goals in the prevention and treatment of osteoporosis are to maintain bone health by preventing its loss and by actually building new bone.Office of the Surgeon General. “Bone Health and Osteoporosis: A Report of the Surgeon General.” October 2004 www.surgeongeneral.gov/library/bonehealth/chapter_9.html To accomplish these goals, the OSG recommends a pyramid approach. The base of the pyramid focuses on balancing nutrition, increasing physical activity, and preventing falls (primary prevention tactics). The second step in the pyramid is to determine if any underlying disorders or diseases are causing osteoporosis and to treat them. The third step is pharmacotherapy and involves administering medications. The second and third steps in the pyramid are secondary prevention tactics.

Secondary Prevention Tactics

We have noted that certain medications and diseases either cause or aggravate osteoporosis. Treating diseases such as hyperparathyroidism or discontinuing the use of or lowering the dose of medications such as prednisone, substantially reduces the risk of further deterioration of bone tissue and fracture. (In Section 9.3 of this chapter, you learned the mechanics of how the parathyroid hormone regulates calcium homeostasis.) When parathyroid hormone is present at continuously high levels in the blood, it causes a marked elevation in calcium levels. It raises blood calcium levels by increasing osteoclast activity, thereby increasing bone breakdown and bone loss. Hyperparathyroidism is treated by the surgical removal of the parathyroid gland tumor. Chronic kidney disease and vitamin D deficiency can also cause an increase in parathyroid hormone levels. When the increase in parathyroid hormone is the result of disorders in other organs, the condition is referred to as secondary hyperparathyroidism.

Treating diseases such as chronic kidney disease and Crohn's disease, which are associated with decreased activation of vitamin D, increased calcium excretion, or malabsorption, is important in people who have not developed osteoporosis yet in order to arrest further losses in BMD. If these types of conditions exist simultaneously with osteoporosis, it is recommended that both disorders be treated to prevent further bone deterioration.

Key Takeaways

Osteoporosis is a childhood disease with old age consequences. Primary prevention of osteoporosis begins early in life with proper diet and exercise. The strategies of secondary prevention that focus on treating osteoporosis aim to arrest further bone loss and reduce fracture risk. Osteoporosis prevention and treatment involves a three-tiered approach that incorporates lifestyle modifications, the assessment, and treatment of underlying causes of the disease, and pharmacotherapy.

Discussion Starters

1. Do you or any of your classmates have children? What could a parent of a teenager do to help their child achieve a high peak bone mass?
2. Discuss the tactics you might employ at your age to maximize your bone health and minimize your risk for developing osteoporosis.

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9.9: Deficiency, Supplementation, and Choices

Learning Objectives

- List the groups most at risk for calcium inadequacy and explain why they are at risk.
- Understand the benefits and risks of calcium supplementation.



Figure 9.9.1: Calcium inadequacy is most prevalent in adolescent girls and the elderly. Proper dietary intake of calcium is critical for proper bone health. © Shutterstock

Despite the wealth of evidence supporting the many health benefits of calcium (particularly bone health), the average American diet falls short of achieving the recommended dietary intakes of calcium. In fact, in females older than nine years of age, the average daily intake of calcium is only about 70 percent of the recommended intake. Here we will take a closer look at particular groups of people who may require extra calcium intake.

- **Adolescent teens.** A calcium-deficient diet is common in teenage girls as their dairy consumption often considerably drops during adolescence.
- **Amenorrheic women and the "female athlete triad."** Amenorrhea refers to the absence of a menstrual cycle. Women who fail to menstruate suffer from reduced estrogen levels, which can disrupt and have a negative impact on the calcium balance in their bodies. The "female athlete triad" is a combination of three conditions characterized by amenorrhea, disrupted eating patterns, and osteoporosis. Exercise-induced amenorrhea and anorexia nervosa-related amenorrhea can decrease bone mass.Drinkwater, B., B. Bruemner, and C. Chesnut. "Menstrual History As a Determinant of Current Bone Density in Young Athletes." *JAMA* 263, no. 4 (1990): 545–8. http://www.ncbi.nlm.nih.gov/pubmed/2294327?dopt=Abstract;Marcus, R. et al. "Menstrual Function and Bone Mass in Elite Women Distance Runners: Endocrine and Metabolic Features." *Ann Intern Med* 102, no. 2 (1985):158–63. http://www.ncbi.nlm.nih.gov/pubmed/3966752?dopt=Abstract In female athletes, as well as active women in the military, low BMD, menstrual irregularities, and individual dietary habits together with a history of previous stress issues, are related to an increased susceptibility to future stress fractures.Nattiv, A. "Stress Fractures and Bone Health in Track and Field Athletes." *J Sci Med Sport* 3, no. 3 (2000): 268–79. http://www.ncbi.nlm.nih.gov/pubmed/11101266?dopt=Abstract.;Johnson, A.O., et al. "Correlation of Lactose Maldigestion, Lactose Intolerance, and Milk Intolerance." *Am J Clin Nutr* 57, no. 3 (1993): 399–401. http://www.ncbi.nlm.nih.gov/pubmed/8438774?dopt=Abstract.
- **The elderly.** As people age, calcium bioavailability is reduced, the kidneys lose their capacity to convert vitamin D to its most active form, the kidneys are no longer efficient in retaining calcium, the skin is less effective at synthesizing vitamin D, there are changes in overall dietary patterns, and older people tend to get less exposure to sunlight. Thus the risk for calcium inadequacy is great.International Osteoporosis Foundation. "Calcium and Vitamin D in the Elderly." © 2012. http://www.iofbonehealth.org/patients-public/about-osteoporosis/prevention /nutrition/calcium-and-vitamin-d-in-the-elderly.html.
- **Postmenopausal women.** Estrogen enhances calcium absorption. The decline in this hormone during and after menopause puts postmenopausal women especially at risk for calcium deficiency. Decreases in estrogen production are responsible for an increase in bone resorption and a decrease in calcium absorption. During the first years of menopause, annual decreases in bone mass range from 3–5 percent. After age sixty-five, decreases are typically less than 1 percent.Daniels, C. E. "Estrogen Therapy for Osteoporosis Prevention in Postmenopausal Women." *National Institute of Health: Pharmacy Update* (March/April 2001).

- **Lactose-intolerant people.** Groups of people, such as those who are lactose intolerant, or who adhere to diets that avoid dairy products, may not have an adequate calcium intake.
- **Vegans.** Vegans typically absorb reduced amounts of calcium because their diets favor plant-based foods that contain oxalates and phytates.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Calcium and Vitamin D.* (Washington, DC: National Academy Press, 2010). In addition, because vegans avoid dairy products, their overall consumption of calcium-rich foods may be less.

If you are lactose intolerant, have a milk allergy, are a vegan, or you simply do not like dairy products, remember that there are many plant-based foods that have a good amount of calcium (see "Tools for Change" in Section 9.4 and Table 9.4.2 "Nondairy Dietary Sources of Calcium") and there are also some low-lactose and lactose-free dairy products on the market.

Calcium Supplements: Which One to Buy?

As discussed earlier, most people need 1,200 to 1,300 mg of calcium per day and should keep the amount under 2.5 grams per day to avoid kidney stones and an iron deficiency. Many people choose to fulfill their daily calcium requirements by taking calcium supplements. Synthetic calcium supplements are sold primarily as calcium carbonate, calcium chloride, calcium gluconate, calcium citrate, calcium lactate, and calcium phosphate, with elemental calcium contents of about 200 milligrams per pill. It is important to look for the amount of calcium, not the total weight because some calcium supplements contain chelators. There is no relationship between the cost of the supplement and the quality and availability of the calcium. Natural sources of calcium are oyster shells, dolomite (limestone) and bone meal.

Calcium carbonate requires an acidic environment in the stomach to be used effectively. Although this is not a problem for most people, it may be for those on medication to reduce stomach acid production or for the elderly who may have a reduced ability to secrete acid in the stomach. For these people, calcium citrate may be a better choice. Otherwise, calcium carbonate is the cheapest. The body is capable of absorbing approximately 30 percent of the calcium from these forms.



Figure 9.9.2: Getting informed about the risks and benefits of calcium supplementation is important. (Public domain; This image was released by the National Cancer Institute, an agency part of the National Institutes of Health, with the ID 7512)

Beware of Lead

There is public health concern about the lead content of some brands of calcium supplements, as supplements derived from natural sources such as oyster shell, bone meal, and dolomite (a type of rock containing calcium magnesium carbonate) are known to contain high amounts of lead. In one study conducted on twenty-two brands of calcium supplements, it was proven that eight of the brands exceeded the acceptable limit for lead content. This was found to be the case in supplements derived from oyster shell and refined calcium carbonate. The same study also found that brands claiming to be lead-free did, in fact, show very low lead levels. Because lead levels in supplements are not disclosed on labels, it is important to know that products not derived from oyster shell or other natural substances are generally low in lead content (oyster shells, dolomite and bone meal may be high in heavy metals). In addition, it was also found that one brand did not disintegrate as is necessary for absorption, and one brand contained only 77 percent of the stated calcium content.Ross, E. A., N. J. Szabo, and I. R. Tebbett. “Lead Content of Calcium Supplements.” *JAMA* 2000 Sep 20; 284 (2000): 1425–33.

Diet, Supplements, and Chelated Supplements

In general, calcium supplements perform to a lesser degree than dietary sources of calcium in providing many of the health benefits linked to higher calcium intake. This is partly attributed to the fact that dietary sources of calcium supply additional nutrients with health-promoting activities. It is reported that chelated forms of calcium supplements are easier to absorb as the chelation process protects the calcium from oxalates and phytates that may bind with the calcium in the intestines. However, these are more expensive supplements and only increase calcium absorption up to 10 percent. In people with low dietary intakes of calcium, calcium supplements have a negligible benefit on bone health in the absence of a vitamin D supplement. However, when calcium supplements are taken along with vitamin D, there are many benefits to bone health: peak bone mass is increased in early adulthood, BMD is maintained throughout adulthood, the risk of developing osteoporosis is reduced, and the incidence of fractures is decreased in those who already had osteoporosis. Calcium and vitamin D pills do not have to be taken at the same time for effectiveness. But remember that vitamin D has to be activated and in the bloodstream to promote calcium absorption. Thus, it is important to maintain an adequate intake of vitamin D.

The Calcium Debate

A recent study published in the *British Medical Journal* reported that people who take calcium supplements at doses equal to or greater than 500 milligrams per day in the absence of a vitamin D supplement had a 30 percent greater risk for having a heart attack.Bolland, M. J. et al. “Effect of Calcium Supplements on Risk of Myocardial Infarction and Cardiovascular Events: Meta-Analysis.” *Br Med J* 341, no. c3691 (July 29, 2010). Does this mean that calcium supplements are bad for you? If you look more closely at the study, you will find that 5.8 percent of people (143 people) who took calcium supplements had a heart attack, but so did 5.5 percent of the people (111) people who took the placebo. While this is one study, several other large studies have not shown that calcium supplementation increases the risk for cardiovascular disease. While the debate over this continues in the realm of science, we should focus on the things we do know:

1. There is overwhelming evidence that diets sufficient in calcium prevent osteoporosis and cardiovascular disease.
2. People with risk factors for osteoporosis are advised to take calcium supplements if they are unable to get enough calcium in their diet. The National Osteoporosis Foundation advises that adults age fifty and above consume 1,200 milligrams of calcium per day. This includes calcium both from dietary sources and supplements.
3. Consuming more calcium than is recommended is not better for your health and can prove to be detrimental. Consuming too much calcium at any one time, be it from diet or supplements, impairs not only the absorption of calcium itself but also the absorption of other essential minerals, such as iron and zinc. Since the GI tract can only handle about 500 milligrams of calcium at one time, it is recommended to have split doses of calcium supplements rather than taking a few all at once to get the RDA of calcium.

Other Choices that Affect Bone Health

Too Much Soda

There are many proponents of low-phosphate diets for bone health. Scientific studies do provide evidence that diets consisting of a high intake of processed foods and cola beverages compromise bone health as well as increase the prevalence of obesity. Overall, however, the data is inconsistent to show whether it is the phosphate content that is the culprit. The mechanism by which diets high in phosphate could cause a decrease in bone health is the following: a high dietary intake of phosphate leads to an increase in blood phosphate levels. High levels of phosphate in the blood stimulate the release of parathyroid hormone (PTH), which in turn stimulates bone resorption and calcium is lost from the bone. When calcium intake is adequate, it shuts off PTH release, but when calcium intake is inadequate and phosphate intake is high, bone health suffers. How much it suffers is under a considerable amount of debate in the scientific literature. It is a good idea to eat foods that are good sources of both calcium and phosphorus. Table 9.5.3 "Calcium and Phosphorus Contents in 100 Grams of Certain Foods" shows the calcium and phosphorus contents in certain foods.

Tools for Change

While the scientific community debates the effects of phosphate, we do know that carbonated cola beverages have negative effects on bone health. A study published in the *Archives of Pediatrics and Adolescent Medicine* reports that teenage girls who were

physically active and drank carbonated cola beverages were five times more likely to break a bone than physically active girls who did not drink carbonated beverages.Wyshak, G. “Teenaged Girls, Carbonated Beverage Consumption, and Bone Fractures.” *Arch Pediatr Adolesc Med* 154 (2000): 610–13. http://archpedi.ama-assn.org/cgi/content/full/154/6/610?ijkey=d457e7f399850f63fdb8ee9ff3c3a61afcf3e352 The Beverage Guidance Panel, headed by Dr. Barry Popkin from the University of North Carolina, Chapel Hill, recommends drinking not more than one 8-ounce carbonated soft drink per day. A bone-healthy diet is one that does not replace milk and high calcium snacks with carbonated soft drinks and processed foods.



Figure 9.9.3: To decrease cola consumption try replacing sugary processed cola drinks with a nice cold glass of your favorite herbal tea. (CC-BY-SA 3.0l; 663highland).

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A Lactose-Free Diet

Evidence has been uncovered recently indicating that lactose-free diets result in decreased calcium absorption because dietary lactose has been shown to actually enhance calcium absorption. Thus, lactose intolerance (and lactose-free diets) may predispose one to inadequate bone mineralization, an issue now correlated to many other disorders involving pediatric patients. Researchers are still working to clarify the effects of lactose-free diets in youth on long-term bone mineral content and the risks of osteoporosis and bone fractures with aging. Calcium homeostasis is also affected by protein intake, vitamin D status (Holick, MF. Ann Epidemiol. 2009 Feb;19(2):73–8. Epub 2008 Mar 10.NIH Public Access: “Vitamin D Status: Measurements, Interpretations, and Clinical Application.” http://www.ncbi.nlm.nih.gov/pubmed/18329892), salt intake, and genetic and other factors, making long-term studies critical in determining the risks of each or all of these to bone health. Recent studies also indicate that in the future, genetic testing may be appropriate for spotting people who may be at a higher risk of lactase deficiency and subsequent decreased BMD. This may enable early intervention through dietary modification or supplementation.Heyman, M. B., MD, MPH. “Lactose Intolerance in Infants, Children, and Adolescents.” *Pediatrics* 118, no. 3 (September 1, 2006): 1279–86. doi: 10.1542/peds.2006-1721.

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Bone Health: A Firm Foundation

In your effort to maintain proper bone health, and prevent and treat osteoporosis, you will need to eat a balanced diet of foods that contain not only calcium and vitamin D, but also the other important bone-building nutrients. You will also need to employ physical exercise habits to encourage bone activity, such as remodeling. By consuming foods rich in bone-building materials on a daily basis, you can reduce your need for supplementation. However, if you cannot get the required amounts of calcium you need through diet alone, there are inexpensive, safe, and effective calcium supplements to choose from. As with anything you choose to consume or with any activity that you choose to undertake, supplementation, diet, and exercise should be uniquely tailored to your circumstances.

Key Takeaways

The groups of people who are most at risk for calcium inadequacy are adolescent teens, amenorrheic women, the female triad athlete, the elderly, lactose-intolerant people, those with milk allergies, and vegans. When taking calcium supplements, be sure to monitor vitamin D intake to ensure that the proper benefits are achieved. Split doses are more effective since the gastrointestinal tract can only absorb up to 500 milligrams at one time. There is need for caution when choosing different brands of calcium supplements. Oyster shell and other naturally derived brands tend to contain unusually high concentrations of lead. Other brands do not contain the stated amount of calcium as advertised. The best sources of calcium come from the diet. If you are considered at risk for inadequate calcium intake, then proper supplementation along with a good diet can produce positive results on bone health.

Discussion Starters

1. Discuss the argument for and against calcium supplementation. Defend your personal view with scientific facts.
2. Visit the websites below and come up with your own opinion on whether carbonated cola beverages increase the risk of developing osteoporosis. Discuss with your classmates what evidence is lacking. What do you and your classmates think about the position of The Coca-Cola Company Beverage Institute? Do they make a good argument? Can you counter it with better scientific evidence?

   http://www.medpagetoday.com/Endocrinology/Osteoporosis/4247

   http://www.jacn.org/content/20/4/271.full

   http://www.beverageinstitute.org/en_US/pages/expert-beverages-and-bone-health-harmful-helpful-or-no-effect.html

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9.E: Nutrients Important for Bone Health (Exercises)

It's Your Turn

1. Watch the following video on the DEXA technology. Then compose a hypothetical list of osteoporosis risk factors for a woman over the age of fifty and provide a recommendation on when she should start having her BMD monitored.

   DEXA—Dual Energy X-Ray Absorptiometry

   (click to see video)
2. Summarize in a written discussion why it is critical to achieve a high peak bone mass early in young adulthood to reduce the risk of developing osteoporosis later in life. Provide a graph of the bone-life cycle in men and women.

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CHAPTER OVERVIEW

10: Nutrients Involved in Hematopoietic System

In this chapter 10, we look at the nutrients important in energy metabolism and blood health, by first looking at blood and at metabolism, and then discussing the B vitamins, vitamin K, magnesium, iron, zinc, and other micronutrients. We also explore iron-deficient anemia and iron toxicity.

10.1: Chapter Introduction

10.2: Blood's Function in the Body and in Metabolism Support

10.3: Vitamins Important for Metabolism and for Blood Function and Renewal

10.4: Minerals Important for Blood Function and Renewal

10.5: Iron-Deficiency Anemia

10.E: Exercises

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10.1: Chapter Introduction

Big Idea

Micronutrients come from many sources and some may surprise you; get them in the right amounts to support metabolism and blood health.

Video 10.1.1

How to Get Iron into Your Diet

(click to see video)

View this video for simple steps you can take to obtain and maintain healthy iron levels in your body.



Figure 10.1.1: Mmm, cornbread cooked in a cast iron skillet—the smell and taste of cooking on the range. Can this also be an iron-friendly meal? © Shutterstock

In a small town in the Appalachian Mountains, Joseph Lodge founded Lodge Iron Cookware in 1896. Today it is still a family-run business that provides Americans with pioneer-style iron cookware. Iron cookware was and still is, prized for its heat retention, even heating, and durability. In fact, many pans sold one hundred years ago are still in use today. Unbeknownst to the American pioneers, the cookware also leaches iron, an essential mineral, into foods as they are cooked in cast-iron hardware.

Iron has several vital functions in the body. Primarily it is the oxygen carrier of the protein hemoglobin, which is found in red blood cells. Oxygen is essential for cellular metabolism. A reduction in the oxygen-carrying capacity of red blood cells hampers the synthesis of energy and consequently cell function. Additionally, iron is required for energy production and enzymatic synthesis of RNA and DNA. Therefore cells that are rapidly dividing are acutely sensitive to an iron deficiency. Since red blood cells are under a constant state of renewal in the body, low iron levels impede their synthesis, eventually causing anemia. A person with anemia experiences fatigue, shortness of breath, dizziness, muscle weakness, and pale skin. In infants and children, iron-deficiency anemia can impair growth, motor control, mental functioning, behavior, and performance in school. Iron deficiency is the number one nutritional deficiency in the world, and even in America, it affects 10 percent of women of childbearing age and many infants, children, and adolescents.

Dietary sources of iron include red meats, poultry, leafy green vegetables, prunes, raisins, egg yolks, lentils, oysters, clams, artichokes, and enriched cereal grains. While there are many food sources of iron, only a small fraction of dietary iron is absorbed. One method of increasing dietary intake of iron is cooking foods in an iron skillet. Acidic foods high in moisture content, such as tomatoes, absorb more iron during cooking than nonacidic foods. For example, cooking spaghetti sauce in iron cookware can increase the iron content ten-fold. How much iron leaches into food is also dependent on cooking times; the longer food is in the pan the more iron is absorbed into the food. Stirring food more often increases contact time and thus more iron is absorbed from the cookware. The utility of iron cookware in increasing dietary intake of iron has prompted some international public health organizations to distribute iron cookware to high-risk populations in developing countries as a strategy to reduce the prevalence of iron-deficiency anemia worldwide.

You Decide

What are the different ways to build iron storehouses in your body without taking a pill?

In this chapter, we will discuss the importance of blood and its vital role in support of metabolism and pull together what we have learned about macronutrient metabolism. You will also learn the important roles micronutrients have in metabolism and how they support blood function and renewal. We will also consider food sources of these valuable nutrients. Read the facts, then decide the best way to supplement your diet with iron friendly eating and cooking.

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10.2: Blood's Function in the Body and in Metabolism Support

Learning Objectives

- List each component of blood and its major role.

You know you cannot live without blood, and that your heart pumps your blood over a vast network of veins and arteries within your body, carrying oxygen to your cells. However, beyond these basic facts, what do you know about your blood?

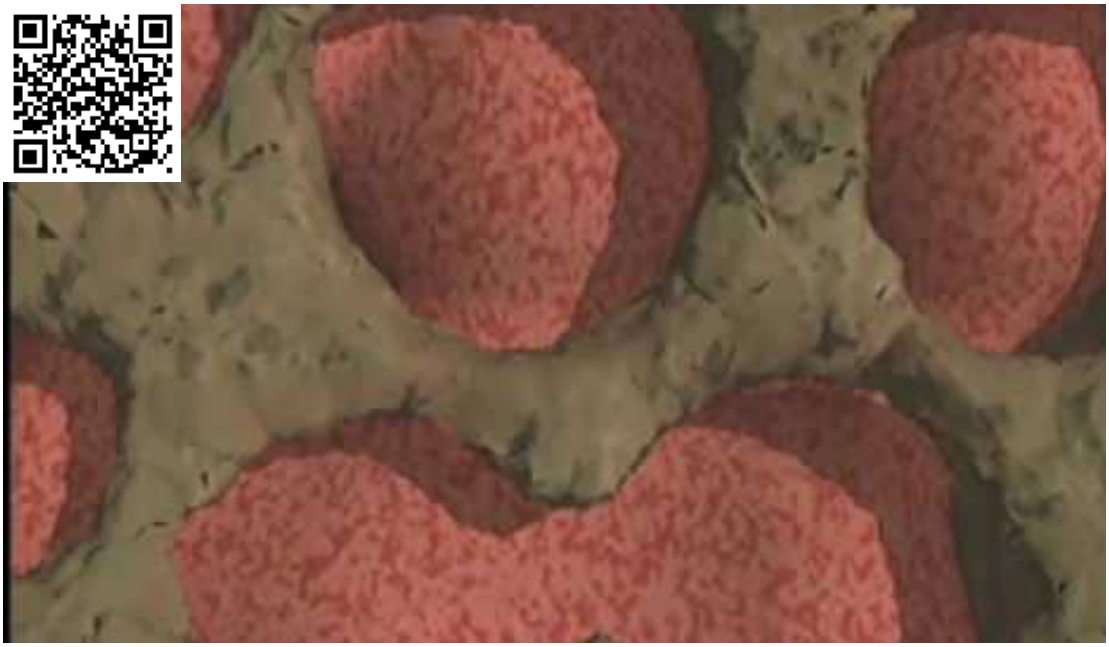
Blood is a connective tissue of the circulatory system, transporting absorbed nutrients to cells like O_2, glucose, and amino acids, and waste products from cells like CO_2 and urea. It supports cellular metabolism by transporting synthesized macromolecules and waste products. Additionally, it transports molecules, such as hormones, allowing for communication between organs. The volume of blood coursing throughout an adult human body is about 5 liters (1.3 gallons) and accounts for approximately 8 percent of human body weight.

What Makes Up Blood and How Do These Substances Support Blood Function?

Blood is about 78 percent water and 22 percent solids by volume. The liquid part of blood is called plasma and it is mostly water (95 percent), but also contains proteins such as albumin and lipoproteins, ions, glucose, amino acids, lipids, vitamins, minerals, waste products like ammonia and urea, gases, enzymes, and hormones. You learned in Chapter 5 that the protein albumin is found in high concentrations in the blood. Albumin helps maintain the fluid balance between blood and tissues, as well as helping to maintain a constant blood pH. In Chapter 11 you will learn that the water component of blood is essential for its actions as a transport vehicle and that the electrolytes carried in blood maintain fluid balance and a constant pH. Furthermore, the high water content of blood helps maintain body temperature, and the constant flow of blood distributes heat throughout the body. Blood is exceptionally good at temperature control, so much so that the many small blood vessels in your nose are capable of warming frigid air to body temperature before it reaches the lungs.

The cellular components of blood include red blood cells, white blood cells, and platelets. Red blood cells are the most numerous of the components. Each drop of blood contains millions of them. Red blood cells are red because they each contain approximately 270 million hemoglobin proteins, which contain the mineral iron, which when bound to oxygen turns red. The most vital duty of red blood cells is to transport oxygen from the lungs to all cells in the body so that they can make energy via aerobic metabolism. The white blood cells that circulate in blood are part of the immune system and they survey the entire body looking for foreign invaders to destroy. They make up about 1 percent of blood volume. Platelets are fragments of cells that are always circulating in the blood in case of an emergency. When blood vessels are injured platelets rush to the site of injury to plug the wound. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow. Red blood cells live for about 120 days, white blood cells live anywhere from eighteen hours to one year, or even longer, and platelets have a lifespan of about ten days.

Bone marrow is the place where many blood cells develop prior to entering the circulatory system.



***Video 10.2.1**: What Is Blood? Watch this brief animation on the importance of blood components (click to see video).*

Nutrients In

Once absorbed from the small intestine, all nutrients require transport to cells in need of their support. Additionally, molecules manufactured in other cells sometimes require delivery to other organ systems. Blood is the conduit and blood vessels are the highways that support nutrient and molecule transport to all cells. Water-soluble molecules, such as some vitamins, minerals, sugars, and many proteins, move independently in blood. Fat-soluble vitamins, triglycerides, cholesterol, and other lipids are packaged into lipoproteins that allow for transport in the watery milieu of blood. Many proteins, drugs, and hormones are dependent on transport carriers, primarily albumin. In addition to transporting all of these molecules, blood must transfer the oxygen breathed in by the lungs to all cells in the body. As discussed, the iron-containing hemoglobin molecule in red blood cells accomplishes this.

-

Wastes Out

In the metabolism of macronutrients to energy, cells produce the waste products carbon dioxide and water. As blood travels through smaller and smaller vessels, the rate of blood flow is dramatically reduced allowing for the efficient exchange of nutrients and oxygen for cellular waste products. The kidneys remove any excess water in the blood, and blood delivers the carbon dioxide to the lungs where it is exhaled. Also, the liver produces the waste product urea from the breakdown of amino acids and detoxifies many harmful substances, all of which require transport in the blood to the kidneys for excretion.

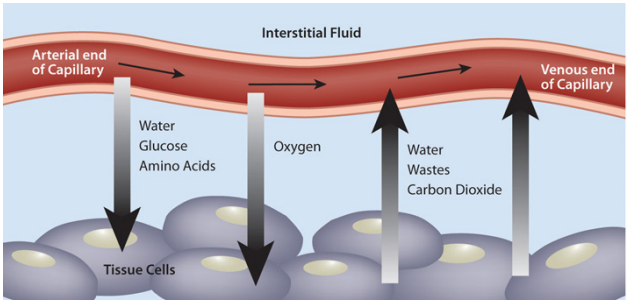


Figure 10.2.2: The Capillary Exchange: Nutrients In and Wastes Out

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All for One, One for All

We are not going to talk about the three musketeers, but we will talk about the way our bodies function and work harmoniously to sustain life. The eleven organ systems in the body completely depend on each other for continued survival as a complex organism. Blood allows for transport of nutrients, wastes, water, and heat, and is also a conduit of communication between organ systems. Blood's importance to the rest of the body is aptly presented in its role in glucose delivery, especially to the brain. The brain metabolizes, on average, 6 grams of glucose per hour. In order to avert confusion, coma, and death, glucose must be readily available to the brain at all times. To accomplish this task, cells in the pancreas sense glucose levels in the blood. If glucose levels are low, the hormone glucagon is released into the blood and is transported to the liver where it communicates the signal to ramp-up glycogen breakdown and glucose synthesis. The liver does just that, and glucose is released into the blood, which transports it to the brain. Concurrently, blood transports oxygen to support the metabolism of glucose to energy in the brain. Healthy blood conducts its duties rapidly, avoiding hypoglycemic coma and death. This is just one example of the body's survival mechanisms exemplifying life's mantra, "All for one, one for all."

-

What Makes Blood Healthy?

Maintaining healthy blood, including its continuous renewal, is essential to support its vast array of vital functions. Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes. As with all other tissues, blood needs macro- and micronutrients to optimally function. In the bone marrow, where blood cells are made, amino acids are required to build the massive amount of hemoglobin packed within every red blood cell, along with all other enzymes and cellular organelles contained in each blood cell. Red blood cells, similar to the brain, use only glucose as fuel, and it must be in constant supply to support red-blood-cell metabolism. As with all other cells, the cells in the blood are surrounded by a plasma membrane, which is composed primarily of lipids. Blood health is also acutely sensitive to deficiencies in some vitamins and minerals more than others, a topic that will be explored in this chapter.

-

What Can Blood Tests Tell You About Your Health?

Since blood is the conduit of metabolic products and wastes, measuring the components of blood, and particular substances in the blood can reveal not only the health of blood, but also the health of other organ systems. In standard blood tests performed during an annual physical, the typical blood tests conducted can tell your physician about the functioning of a particular organ or about disease risk.

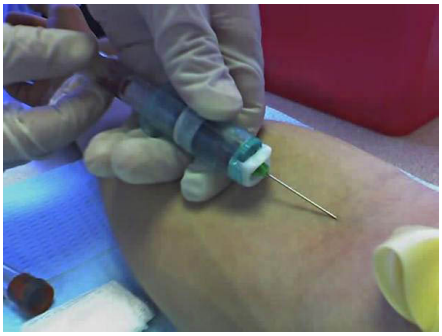


Figure 10.2.3: Blood tests are helpful tools in diagnosing disease and provide much information on overall health.Venipuncture using a vacutainer. from Wikipedia.

A biomarker is defined as a measurable molecule or trait that is connected with a specific disease or health condition. The concentrations of biomarkers in blood are indicative of disease risk. Some biomarkers are cholesterol, triglycerides, glucose, and prostate-specific antigen. The results of a blood test give the concentrations of substances in a person's blood and display the normal ranges for a certain population group. Many factors, such as physical activity level, diet, alcohol intake, and medicine intake can influence a person's blood test levels and cause them to fall outside the normal range, so results of blood tests outside the "normal" range are not always indicative of health problems. The assessment of multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status. See Table 10.1 for a partial list of substances measured in a typical blood test. This table notes only a few of the things that their levels tell us about health.

Table 10.1.1: Blood Tests

Substance Measured	Indicates
Red-blood-cell count	Oxygen-carrying capacity
Hematocrit (red-blood-cell volume)	Anemia risk
White-blood-cell count	Presence of infection
Platelet count	Bleeding disorders, atherosclerosis risk
pH	Metabolic, kidney, respiratory abnormalities
Albumin	Liver, kidney, and Crohn's disease, dehydration
Bilirubin	Liver-function abnormality
Oxygen/Carbon Dioxide	Respiratory or metabolic abnormality
Hemoglobin	Oxygen-carrying capacity
Iron	Anemia risk
Magnesium	Magnesium deficiency
Electrolytes (calcium, chloride, magnesium, potassium)	Many illnesses (kidney, metabolic, etc.)
Cholesterol	Cardiovascular disease risk
Triglycerides	Cardiovascular disease risk
Glucose	Diabetes risk
Hormones	Many illnesses (diabetes, reproductive abnormalities)

Source: National Heart Lung and Blood Institute. "Types of Blood Tests." January 6, 2012. http://www.nhlbi.nih.gov/health/health-topics/topics/bdt/types.html.

Interactive 10.1.1

Visit the websites of the National Heart, Lung, and Blood Institute and Lab Tests Online to find out more on what to expect on blood tests and how to interpret results.

http://www.nhlbi.nih.gov/health/dci/Diseases/bdt/bdt_whatdo.html

http://labtestsonline.org/

Key Takeaways

- Blood is a connective tissue of the circulatory system and the fluid in the body that transports absorbed nutrients to cells and waste products from cells.
- The fluid part of blood, plasma, makes up the largest amount of blood volume and contains proteins, ions, glucose, lipids, vitamins, minerals, waste products, gases, enzymes, and hormones. The cellular components of blood include red blood cells, white blood cells, and platelets. Blood is under a constant state of renewal and is synthesized from stem cells residing in bone marrow.
- As blood travels through smaller and smaller vessels the rate of blood flow is dramatically reduced, allowing for the efficient exchange of nutrients and oxygen for cellular waste products.
- Blood is healthy when it contains the appropriate amount of water and cellular components, and proper concentrations of dissolved substances, such as albumin and electrolytes.
- The assessment of multiple blood parameters aid in the diagnosis of disease risk and are indicative of overall health status.

Discussion Starters

1. Why does the heart pump blood at a faster rate during exercise?
2. Come up with an estimate on how often it is safe to donate blood. Get the facts on donating blood by visiting the website of the Red Cross.

   http://www.redcrossblood.org/donating-blood/eligibility-requirements

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10.3: Vitamins Important for Metabolism and for Blood Function and Renewal

Learning Objectives

- Summarize the role of the B vitamins in blood functions.
- Explain how Vitamin K supports a life-saving function of blood.

In addition to being essential for metabolism, many vitamins and minerals are required for blood renewal and function. At insufficient levels in the diet, these vitamins and minerals impair the health of blood and consequently the delivery of nutrients in and wastes out, amongst its many other functions. In this section, we will focus on the vitamins that take part in metabolism and blood function and renewal.

Vitamins: Functions in Blood

Folate (pteroylglutamic acid)

- Folate is a water-soluble vitamin and its primary form is tetrahydrofolate (THF). It is a required coenzyme for the synthesis of the amino acid methionine, and for making RNA and DNA. Therefore, rapidly dividing cells are most affected by folate deficiency. Red blood cells, white blood cells, and platelets are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic, also called megaloblastic, anemia. Macrocytic and megaloblastic mean “big cell,” and anemia refers to fewer red blood cells or red blood cells containing less hemoglobin. Macrocytic anemia is characterized by larger immature red blood cells and fewer mature red blood cells. It is caused by red blood cells being unable to produce DNA and RNA fast enough—cells grow but do not divide, making them large in size.

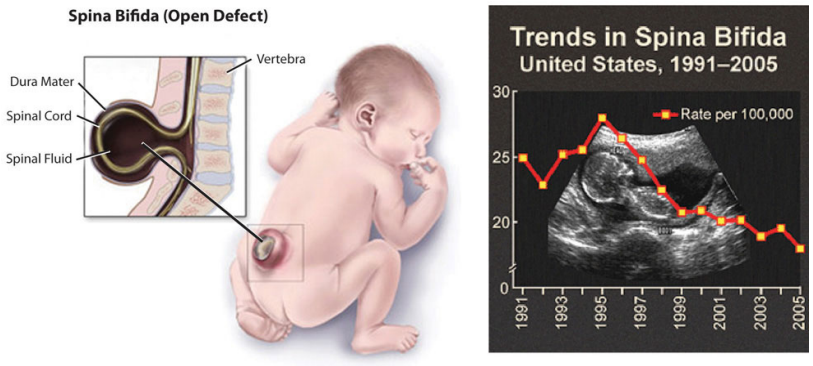


Figure 10.3.1: Spina bifida is a neural-tube defect that can have severe health consequences.

Folate is especially essential for the growth and specialization of cells of the central nervous system. Children whose mothers were folate-deficient during pregnancy have a higher risk of neural-tube birth defects. Folate deficiency is causally linked to the development of spina bifida, a neural tube defect that occurs when the spine does not completely enclose the spinal cord, and anencephalopathy (no brain). Spina bifida can lead to many physical and mental disabilities (Figure 10.3.1). Observational studies show that the prevalence of neural-tube defects was decreased after the fortification of enriched cereal grain products with folate in 1996 in the United States (and 1998 in Canada) compared to before grain products were fortified with folate (Figure 10.4.3). Additionally, results of clinical trials have demonstrated that neural-tube defects are significantly decreased in the offspring of mothers who began taking folate supplements one month prior to becoming pregnant and throughout the pregnancy. In response to the scientific evidence, the Food and Nutrition Board of the Institute of Medicine (IOM) raised the RDA for folate to 600 micrograms per day for pregnant women. Some were concerned that higher folate intakes may cause colon cancer, however scientific studies refute this hypothesis.

A deficiency in folate can manifest with a variety of different symptoms including mental confusion, headache, glossitis (smooth, red tongue), weakness, fatigue, dyspnea (shortness of breath), and elevated blood levels of homocysteine. Smokers, individuals who consume large amounts of alcohol, oral contraceptive users, pregnant women, infants fed goats' milk, cancer patients receiving some type of chemotherapy, antibiotic users, and chronic consumers of aspirin and antacids are at risk of developing a folate deficiency. Folate can mask a vitamin B_{12} deficiency.

See Table 10.3.1 for a list of foods rich in folate. Folate is easily destroyed by heat and air, so one should be careful when cooking folate-rich foods. Fresh is best.

Cobalamin (B_{12})

Vitamin B12 or cobalamin is water-soluble and the biggest vitamin by weight and size. Cobalamin contains cobalt, making it the only vitamin that contains a metal ion. Cobalamin is an essential part of coenzymes. It is necessary for the maintenance of nerve cells, energy metabolism, hormone production, fat and protein catabolism, for folate coenzyme function (removes methyl group), and for hemoglobin synthesis. An enzyme requiring cobalamin is needed by a folate-dependent enzyme to synthesize DNA. Thus, a deficiency in cobalamin has similar consequences to health as folate deficiency. In children and adults cobalamin deficiency causes macrocytic anemia, and in babies born to cobalamin-deficient mothers, there is an increased risk of neural tube defects.

In order for the human body to absorb cobalamin, the stomach, pancreas, and small intestine must be functioning properly. Cells in the stomach secrete a protein called intrinsic factor that is necessary for cobalamin absorption, which occurs in the small intestine (illeum). Impairment of secretion of this protein either caused by an autoimmune disease or by chronic inflammation of the stomach (such as that occurring in some people with H.pylori infection), can lead to the disease pernicious anemia, a type of macrocytic anemia. Vitamin B_{12} malabsorption is most common in the elderly, who may have impaired functioning of digestive organs, a normal consequence of aging. Only a small amount of vitamin B_{12} is absorbed passively without the intrinsic factor complex. Pernicious anemia is treated with large oral doses of vitamin B_{12} or by putting the vitamin under the tongue, where it is absorbed into the bloodstream without passing through the intestine. In patients that do not respond to oral or sublingual treatment, vitamin B_{12} is given by injection.

People with stomach dysfunction, vegans and people with bariatric surgery or ileum problems are at risk of developing a vitamin B_{12} deficiency. It can take up to 20 years for the deficiency to manifest if your dietary intake is inadequate but only 3 to 7 years if you are missing intrinsic factor. Dietary folate can disguise a vitamin B_{12} deficiency until irreversible neurological problems develop.

A summary of the prominent functions of the folate and vitamin B_{12} their deficiency syndromes is given in Table 10.3.1.

Table 10.3.1: Vitamin Functions in Blood, and Deficiency Syndromes

B Vitamin	Function	Deficiency: Signs and Symptoms
Folate	Coenzyme; amino acid synthesis, RNA, DNA, and red blood cell synthesis	Diarrhea, mouth sores, confusion, anemia, neural tube defects
B_{12} (cobalamin)	Coenzyme; fat and protein catabolism, folate function, red-blood-cell synthesis	Muscle weakness, sore tongue, anemia, nerve damage, neural tube defects

Interactive 10.3.1

The USDA has an interactive database of nutrient contents in food. To view reports of single nutrients simply click on the one you are interested in and view the report. http://www.ars.usda.gov/Services/docs.htm?docid=20958

Dietary Sources Rich in Folate and Vitamin B_{12}

To assist you in getting all the folate you need to support blood cell synthesis look over Table 10.3.2 for good dietary sources of these micronutrients. Fifty to ninety percent of folate in foods can be destroyed by food processing and preparation, unltraviolet light, and oxidation.

Vitamin B_{12} is produced by the bacteria in your gut and you can find it in fermented foods, nutritional yeast, and soil contaminants. Foods tend to be a secondary source of vitamin B_{12} with gut microbes being the primary source. A list of foods considered good sources of vitamin B_{12} are shown in Table 10.3.3.

Table 10.3.2: Dietary Sources of Folate

Food	Micrograms per Serving	Percent Daily Value
Liver	185 (3 oz.)	45
Calf liver	650 (3 oz.)	160

Food	Micrograms per Serving	Percent Daily Value
Fortified breakfast cereals	400 (¾ c.)	100
Spinach	100 (½ c., boiled)	25
Northern beans	100 (½ c., boiled)	25
Asparagus	85 (4 spears, boiled)	20
Vegetarian baked beans	60 (1 c.)	15
Broccoli	45 (2 spears)	10
Avocado	45 (½ c.)	10
Bread (enriched)	25 (1 slice)	6

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Folate.” Last reviewed April 15, 2009. http://ods.od.nih.gov/factsheets/Folate-HealthProfessional/.

Table 10.3.3: Dietary Sources of Vitamins B_{12}

Food	Micrograms per Serving	Percent Daily Value
Liver	48 (1 slice)	800
Clams	34.2 (3 oz.)	570
Organic calf liver	31 (3 oz.)	520
Fortified breakfast cereals	6.0 (1 serving)	100
Trout (wild)	5.4 (3 oz.)	90
Trout (farmed)	3.5 (3 oz.)	58
Salmon (sockeye)	4.8 (3 oz.)	80
Cheeseburger	2.1	35
Yogurt (plain)	1.4 (1 c.)	23
Beef (top sirloin)	1.4 (3 oz.)	23
Milk	0.9 (1 c.)	15
Egg	0.6 (1 large)	10

Source: National Institutes of Health, Office of Dietary Supplements. “Dietary Supplement Fact Sheet: Vitamin B_{12}.” Last reviewed June 24, 2011. http://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/.

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Vitamin K: Functions in Blood

Vitamin K is a fat-soluble vitamin that is critical for the formation of the blood clotting factors, thrombin, and fibrin. Blood-clotting proteins are continuously circulating in the blood. Upon injury to a blood vessel, platelets stick to the wound forming a plug. The clotting factors circulating close by responding in a series of protein-protein interactions resulting in the formation of the fibrous protein, fibrin, which reinforces the platelet plug (Video 10.3.2) for an animation of the blood-clotting cascade of events). Vitamin K is also needed for the formation of the bone matrix proteins osteocalcin and matrix Gla.



Video 10.3.1: *How Does Blood Clot? This video gives a brief description of the blood-clotting process (click to see video).*

A deficiency in vitamin K causes bleeding disorders. It is relatively rare, but people who have liver or pancreatic disease, celiac disease, or malabsorption conditions are at higher risk for vitamin K deficiency. Signs and symptoms include nosebleeds, easy bruising, broken blood vessels, bleeding gums, and heavy menstrual bleeding in women. The function of the anticoagulant drug warfarin is impaired by excess vitamin K intake from supplements. Calcium additionally plays a role in activation of blood-clotting proteins as discussed in the previous chapter. Vitamin K also plays a role in bone mineralization and a deficiency in this vitamin prevents bone mineralization. People who have fat malabsorption, some infants at birth, and people taking a large amount of non-absorbable antibiotics for a long time are at risk of developing a deficiency.

The rat poison, Warfarin, blocks blood clotting by inhibiting vitamin K. It is used to treat strokes and heart attacks. If one's vitamin K intake is high, this reduces the effectiveness of these drugs. Fluorescent light and sunlight destroy vitamin K.

Dietary Reference Intakes and Sources of Vitamin K

The RDA for vitamin K for adult males is 120 mcg/day and for adult females is 90 mcg/day. Vitamin K is present in many foods and most highly concentrated in green leafy vegetables. See Table 10.3.4 for a list of dietary sources of vitamin K. Bacteria in our large intestine synthesize vitamin K.

Table 10.3.4: Dietary Sources of Vitamin K

Food	Micrograms per Serving	Percent Daily Value
Broccoli (½ c.)	160.0	133
Asparagus (4 spears)	34.0	28
Cabbage (½ c.)	56.0	47
Spinach (½ c.)	27.0	23
Green peas (½ c.)	16.0	13
Cheese (1 oz.)	10.0	8
Ham (3 oz.)	13.0	11
Ground beef (3 oz.)	6.0	5
Bread	1.1	<1
Orange	1.3	1

Key Takeaways

- The water-soluble B vitamins are involved as coenzymes in the breakdown of nutrients and in the building of macromolecules, such as protein, RNA, and DNA.

- B-vitamin deficiencies are relatively rare especially in developed countries; although the health consequences can be severe as with folate deficiency during pregnancy and the increased risk of neural-tube defects in offspring.
- Vitamin K is necessary for blood clotting.

Discussion Starters

1. Discuss how the actions of B vitamins are interdependent; meaning the level of one affects the function of another.
2. Have a classroom debate on whether it is prudent for the federal government to regulate claims on micronutrient supplements, such as those containing B vitamins.

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10.4: Minerals Important for Blood Function and Renewal

Learning Objectives

- List the primary function of each of the minerals involved in metabolism.
- Summarize the roles of minerals important in blood function and renewal.

In a well-balanced diet, minerals are plentiful, and herbs are power-packed with minerals. Eat more plants, spice up your food, and drink herbal teas to obtain optimum mineral nutrition.



Iron

- Iron is a trace mineral that we need small quantities every day. It is slightly water soluble and is a cation that exists in two states, +2 (ferrous) or +3 (ferric). Red blood cells contain the oxygen carrier protein hemoglobin. It is composed of four globular peptides, each containing a heme complex. In the center of each heme, lies iron (Figure 10.4.2). Eighty percent of the body's iron is bound to hemoglobin. In the muscle, iron is part of the oxygen-binding protein, myoglobin. Iron is a key component of hundreds of metabolic enzymes. Many of the proteins of the electron transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

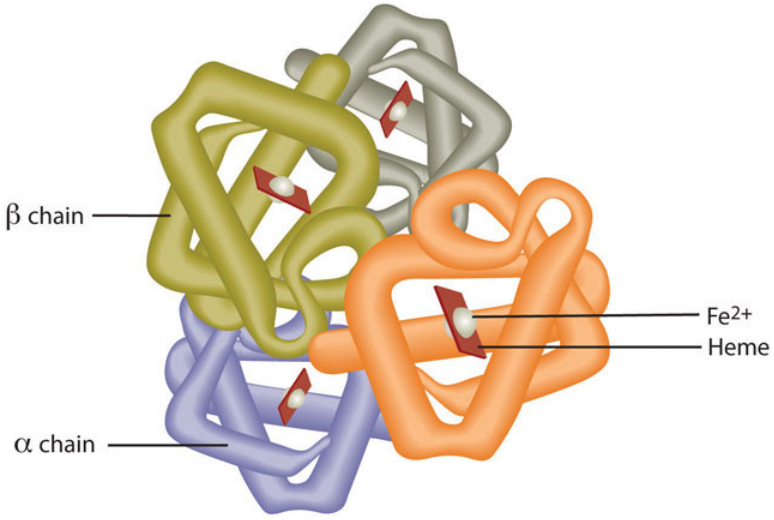


Figure 10.4.1: Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

The iron in hemoglobin binds to oxygen in the capillaries of the lungs and transports it to cells where the oxygen is released (see "Video 10.5.1"). If iron levels are low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with

chronic blood loss or low intake. Only 2-35% of the iron in your diet is absorbed. Once absorbed, the iron may be incorporated into hemoglobin or myoglobin to transport oxygen, or incorporated into other proteins, or stored in the liver, bone marrow or spleen. Ferritin is the molecule that stores iron in mucosal cells. When the iron is needed it is released from the ferritin and transported by transferrin to other cells for use. Once in the body, it is difficult to excrete iron but some iron will be lost when mucosal cells of the gut are shedded, a process that occurs about every 3-5 days.

Erythrocytes or RBCs circulate for about 120 days and then they are removed. When blood cells are decommissioned, the liver and spleen degrade the red blood cell and transferrin or recycles the iron back to the liver the bone marrow where red blood cells are made. The heme component is recycled into bile. Hepcidin, a hormone produced by the liver, regulates iron balance by inhibiting its release. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources. Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.



Video 10.4.1***:*** *Oxygen Transport. Watch this video to view how hemoglobin in red blood cells transports oxygen to all cells in the body.*

Dietary iron comes in two forms, as heme iron or as nonheme iron. The bioavailability of iron is highly dependent on dietary sources and the form of iron. In animal-based foods, about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the *American Journal of Clinical Nutrition* reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent and that from vegetarian diets range between 5 and 12 percent.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. Vegans are at higher risk for iron deficiency, but careful meal planning does prevent its development. Iron deficiency is the most common of all micronutrient deficiencies and will be explored in depth in Section 10.5.

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Zinc

Zinc is a trace mineral that is a cation and cofactor for over two hundred enzymes in the human body that play a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. It is important for wound healing, transport of vitamin A, taste perception, growth and development, and cofactor in genetic material and protein (zinc fingers).

As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world’s population has a zinc-deficient diet.Prasad, Ananda. “Zinc deficiency.” BMJ 2003 February 22; 326(7386): 409–410. doi: 10.1136/bmj.326.7386.409. Accessed October 2, 2011. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1125304/?tool=pmcentrez.

This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, taste changes, loss of appetite, impaired vision, impaired immune function, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia. People at risk of developing a zinc deficiency are people consuming excess iron, copper and/or dietary fiber, people that lack financial access to a nutrient adequate diet, the elderly, pregnant women and children. Zinc is rich in foods high in protein.

Copper

- Copper is a trace mineral that is cation and exists in the +1 or +2 state. Like iron, copper assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport, and hemoglobin synthesis. The other important function of copper is an antioxidant, which was also discussed in Chapter 8.

Symptoms of mild to moderate copper deficiency are rare. More severe copper deficiency can cause anemia from the lack of iron mobilization in the body for red blood cell synthesis. Other signs and symptoms include growth retardation in children and neurological problems because copper is a cofactor for an enzyme that synthesizes myelin, which surrounds many nerves. Groups at risk of developing a copper deficiency are people who consume too much zinc.

Menke's disease is a genetic disorder that causes a copper deficiency. The onset occurs typically during infancy and is characterized by sparse, kinky hair; failure to gain weight and grow at the expected rate (failure to thrive); and deterioration of the nervous system. Often these children do not live past age 3. Early treatment with copper may improve the prognosis in some affected individuals.

Individuals with the rare inherited disease, Wilson's disease, accumulate copper in the liver and brain. Excess copper intake

Table 10.4.1: Mineral Functions in Metabolism and Blood and Deficiency Syndrome

Mineral	Function	Deficiency: Signs and Symptoms
Trace		
Iron	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate
Zinc	Assists in energy production, protein, RNA and DNA synthesis; required for hemoglobin synthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss
Copper	Assists in energy production, iron metabolism, cofactor for enzymes	Anemia: fatigue, paleness, faster heart rate

Dietary Reference Intakes for Minerals and Dietary Sources

The RDA set by the IOM for minerals involved in metabolism are listed for adults in Table 10.4.2 "Dietary Reference Intakes and Food Sources for Minerals Important for Metabolism". The table also lists dietary sources for these micronutrients. The mineral content of foods is greatly affected by the soil from which it grew, and thus geographic location is the primary determinant of the mineral content of foods. For instance, iodine comes mostly from seawater so the greater the distance from the sea the lesser the iodine content in the soil.

Table 10.4.2: Dietary Reference Intakes and Food Sources for Minerals Important for Blood Formation

Mineral	RDA (mg/day)	Food Sources
Trace		
Iron	8 (males)	Heme sources: Animal products such as
* denotes Adequate Intake, **for ages 31–50 only		

Mineral	RDA (mg/day)	Food Sources
	18 (females)	meat, fish, and poultry Non-heme sources: fortified breakfast cereals, beans (tofu), spinach, peas, dried fruit, whole grains
Zinc	11 (males)	Red meat, poultry, seafood, fortified breakfast cereals, beans, nuts, whole grains
	8 (females)	
Copper	0.900 (males)	Whole grains, liver, legumes, seeds, cocoa, water if copper pipes
	0.900 (females)	
* denotes Adequate Intake, **for ages 31–50 only		

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Bioavailability

Minerals are not as efficiently absorbed as most vitamins and so the bioavailability of minerals can be very low. Plant-based foods often contain factors, such as oxalate and phytate, that bind to minerals and inhibit their absorption. In general, minerals are better absorbed from animal-based foods. In most cases, if dietary intake of a particular mineral is increased, absorption will decrease. Some minerals influence the absorption of others. For instance, excess zinc in the diet can impair iron and copper absorption. Conversely, certain vitamins enhance mineral absorption. For example, vitamin C boosts iron absorption, and vitamin D boosts calcium and magnesium absorption. As is the case with vitamins, certain gastrointestinal disorders and diseases, such as Crohn's disease and kidney disease, as well as the aging process, impair mineral absorption, putting people with malabsorption conditions and the elderly at higher risk for mineral deficiencies.

Key Takeaways

- Minerals cannot be broken down to release energy.
- Minerals are cofactors for hundreds of enzymes involved in metabolism.
- Iron especially, but also copper and zinc are critical for blood function and renewal.
- Minerals are not as efficiently absorbed as most vitamins and bioavailability can be very low.

Discussion Starters

1. Discuss why "more is not always better," especially how this saying pertains to micronutrient intake.
2. Look up the chemical structure of phytate and explain how it inhibits the absorption of positively charged minerals.

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10.5: Iron-Deficiency Anemia

Learning Objectives

- Discuss why iron-deficiency anemia is the most prevalent nutritional deficiency worldwide, its impacts on human health, and possible solutions to combat it.

Iron-Deficiency Anemia: Signs, Symptoms, and Treatment

Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. Regardless of the cause (be it from low dietary intake of iron or via excessive blood loss), iron-deficiency anemia has the following signs and symptoms, which are linked to the essential functions of iron in energy metabolism and blood health:

- Fatigue
- Weakness
- Pale skin
- Shortness of breath
- Dizziness
- Swollen, sore tongue
- Abnormal heart rate

- Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. There are three stages of iron deficiency. The first stage is iron depletion in which iron stores become low, and ferritin levels are reduced. Usually, there are no accompanying signs or symptoms that iron levels are being depleted. In the second stage, iron deficiency erythropoiesis, transferrin levels decrease resulting in reduced iron transport. Production time for heme is reduced. Feelings of a low energy level, reduced capacity to do physical work, slow cognitive function are signs that anemia is developing. In some rare instances, pica may occur which is the appetite for ice, clay, paste, and other non-food items. The last stage is iron deficiency anemia. It is characterized by a low hemoglobin concentration with small (microcytic), pale (hypochromic) RBCs. Symptoms include fatigue upon exertion, weakness, headaches, apathy, pallor, poor resistance to cold temperatures, low physical work capacity, and poor immune function.

Several different blood tests are needed to assess iron status. The clinician must decide if the anemia is the result of an iron deficiency or other nutrients such as folate or vitamin B_{12}. These include the following:

- Serum iron which is poor measure of iron status
- Serum ferritin which indicates storage status and is a good measure of early deficiency
- Transferrin which can provide clues on a progressing deficiency. Total iron-binding capacity and transferrin saturation may be measured
- Hematocrit which is not a good measure of iron status
- Hemoglobin which is late indicator of iron deficiency
- Erythrocyte protoporphyrin which measures the non-heme, non-complexed protoporphyrin in blood. Used to measure if blood has too little iron or too much lead.
- Mean cell volume (MCV) measures the average size of the RBC. Several anemias have smaller RBC.
- Mean corpuscular Hb concentration (MCHC)
- Liver and bone marrow biopsies - very invasive and rarely done to assess iron status.

Several different groups are at risk of developing anemia. Iron is lost through the gastrointestinal tract, urine, sweat or skin. If you have chronic changes in one of these systems, you could be at risk of developing an iron deficiency. Menstruating women and growing individuals such as infants, children, adolescents, and pregnant women have increased needs for iron that are not always met by their diet. A chronic anemia of exercise has been reported but the cause is unknown. It may be due to an increase in blood volume, damage to RBCs (foot-strike hemolysis), or sweat loss. People with excessive blood loss can develop anemia. Ulcers, wounds, surgery, infections and regular blood donation can contribute to excessive blood loss. Vegetarians require more iron than individuals who include animal products in their diet and must be careful to eat enough iron. Finally, people who live in developing countries are more likely to develop an iron deficiency.

Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron. Iron supplements have some adverse side effects including nausea, constipation, diarrhea, vomiting, and abdominal pain. Reducing the

dose at first and then gradually increasing to the full dose often minimizes the side effects of iron supplements.

See Table 10.5.1 for good dietary sources of iron. The absorption of iron changes with your body's need; it is higher if your iron stores are low. Even though your body can modulate iron absorption, less than 35% of what you eat is absorbed and ranges between 2 - 35%. Heme iron is more efficiently absorbed, 25%, than non-heme iron, 17%. There are several things you can do to improve non-heme iron absorption. Avoiding foods and beverages high in phytates and also tea (which contains tannic acid and polyphenols, both of which impair iron absorption), is important for people who have iron-deficiency anemia. Eating a dietary source of vitamin C at the same time as iron-containing foods improves absorption of nonheme iron in the gut. Additionally, unknown compounds that likely reside in muscle tissue of meat, poultry, and fish (MFP factor) increase iron absorption from both heme and nonheme sources. These factors have not been identified. See Table 10.6.2 for more enhancers and inhibitors for iron absorption.

Excess dietary calcium, zinc, phosphorus, and manganese can interfere with iron absorption. Antacids increase stomach pH which decreases iron absorption. Remember, acid converts the ferric state of iron to ferrous which improve water solubility and absorption.

Another way to increase iron intake is to cook using iron cookware but the amount of iron leached from the pan into your food depends on several factors. First, the acidity of the food; the more acidic the food, more iron will be released into the food. Second, the longer you leave the food to cook in iron cookware, more iron will be imparted to the food. White flour is fortified with iron which can contribute significant amounts of iron to one's diet if you eat a lot of foods made with fortified white flour. Otherwise, there are better iron sources.

Table 10.5.1: Dietary Sources of Iron

	Milligrams per serving	Percent RDA (males)	Percent RDA (females)
Oysters (3 oz.)	13.20	165	73
Beef liver (3 oz.)	7.50	94	42
Prune juice (½ c.)	5.20	65	29
Clams (2 oz.)	4.20	53	23
Walnuts (½ c.)	3.75	47	21
Chickpeas (½ c.)	3.00	38	19
Bran flakes (½ c.)	2.80	37	16
Pork roast (3 oz.)	2.70	34	15
Raisins (½ c.)	2.55	32	14
Roast beef (3 oz.)	1.80	23	10
Green peas (½ c.)	1.50	19	8
Peanuts (½ c.)	1.50	19	8
Green beans (½ c.)	1.00	13	6
Egg (1)	1.00	13	6

Source: University of Maryland Medical Center. “Iron.” © 2011 University of Maryland Medical Center (UMMC). All rights reserved. www.umm.edu/altmed/articles/iron-000309.htm#ixzz2BIykoCPs.

Table 10.5.2: Enhancers and Inhibitors of Iron Absorption

Enhancer	Inhibitor
Meat	Phosphate
Fish	Calcium

Enhancer	Inhibitor
Poultry	Tea
Seafood	Coffee
Stomach acid	Colas
	Soy protein
	High doses of minerals (antacids)
	Bran/fiber
	Phytates
	Oxalates
	Polyphenols

Iron Deficiency: A Worldwide Nutritional Health Problem

The Centers for Disease Control and Prevention reports that iron deficiency is the most common nutritional deficiency worldwide.Centers for Disease Control and Prevention. “Iron and Iron Deficiency.” Accessed October 2, 2011. www.cdc.gov/nutrition/everyone/basics/vitamins/iron.html. The WHO estimates that 80 percent of people are iron deficient and 30 percent of the world population has iron-deficiency anemia.The World Bank. “Anemia.” Accessed October 2, 2011. web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743 ~theSitePK:672263,00.html. The main causes of iron deficiency worldwide are parasitic worm infections in the gut causing excessive blood loss, and malaria, a parasitic disease causing the destruction of red blood cells. In the developed world, iron deficiency is more the result of dietary insufficiency and/or excessive blood loss occurring during menstruation or childbirth.

At-Risk Populations

Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes. Infants, children, and even teens require more iron because iron is essential for growth. In these populations, iron deficiency (and eventually iron-deficiency anemia) can also cause the following signs and symptoms: poor growth, failure to thrive, and poor performance in school, as well as mental, motor, and behavioral disorders. Women who experience heavy menstrual bleeding or who are pregnant require more iron in the diet. One more high-risk group is the elderly. Both elderly men and women have a high incidence of anemia and the most common causes are a dietary iron deficiency and/or a chronic disease such as ulcer, inflammatory diseases, and cancer. Additionally, those who have recently suffered from traumatic blood loss, frequently donate blood, or take excessive antacids for heartburn need more iron in their diet.

Iron Toxicity

The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity. In children, death has occurred from ingesting as little as 200 mg of iron and therefore it is critical to keep iron supplements out of children’s reach. The IOM has set tolerable upper intake levels of iron (Table 10.5.3 "Tolerable Upper Intake Levels of Iron"). Mostly a hereditary disease, hemochromatosis is the result of a genetic mutation that leads to abnormal iron metabolism and an accumulation of iron in certain tissues such as the liver, pancreas, and heart. The signs and symptoms of hemochromatosis are similar to those of iron overload in tissues caused by high dietary intake of iron or other nongenetic metabolic abnormalities but are often increased in severity.

Table 10.5.1: Tolerable Upper Intake Levels of Iron

Age	Males (mg/day)	Females (mg/day)	Pregnancy (mg/day)	Lactation (mg/day)

Age	Males (mg/day)	Females (mg/day)	Pregnancy (mg/day)	Lactation (mg/day)
7–12 months	40	40	N/A	N/A
1–13 years	40	40	N/A	N/A
14–18 years	45	45	45	45
19+ years	45	45	45	45

Source: Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc.* January 9, 2001. www.iom.edu/Reports/2001/Dietary-Reference-Intakes-for-Vitamin-A-Vitamin-K-Arsenic-Boron-Chromium-Copper-Iodine-Iron-Manganese-Molybdenum-Nickel-Silicon-Vanadium-and-Zinc.aspx.

Thalassemia is an inherited disorder that causes the hemoglobin molecule to be abnormally shaped. People of Asian, Chinese, Mediterranean or African descent have a greater risk of carrying the defective gene. People with this disease are anemic and need transfusions to stay alive. Often the excess iron will be stored in tissues causing an iron toxicity. They require chelation therapy to remove the excess iron.

There are a variety of other conditions that can lead to iron toxicity. Iron toxicity may look display symptoms similar to a deficiency, apathy, lethargy, and fatigue. Consuming more than 45 mg/day can lead to an overload and gastrointestinal distress, constipation, nausea, emesis, and diarrhea. Unchecked, this can lead to intestinal damage, liver damage and or failure. Hemosiderosis is excess storage of iron in the liver, heart, joints and other tissues. Excess iron from blood transfusions or unknown etiologies can cause iron to build up in these tissues. Males tend to experience more hemosiderosis than females. Iron supplements should be kept away from children and iron overload is one of the leading causes of accidental death of children.

-

Preventing Iron-Deficiency Anemia

In young children, iron-deficiency anemia can cause significant motor, mental, and behavior abnormalities that are long-lasting. In the United States, the high incidence of iron-deficiency anemia in infants and children was a major public-health problem prior to the early 1970s, but now the incidence has been greatly reduced. This achievement was accomplished by implementing the screening of infants for iron-deficiency anemia in the health sector as a common practice, advocating the fortification of infant formulas and cereals with iron, and distributing them in supplemental food programs, such as that within Women, Infants, and Children (WIC). Breastfeeding, iron supplementation, and delaying the introduction of cow's milk for at least the first twelve months of life were also encouraged. These practices were implemented across the socioeconomic spectrum and by the 1980s iron-deficiency anemia in infants had significantly declined. Other solutions had to be introduced in young children, who no longer were fed breast milk or fortified formulas and were consuming cow's milk. The following solutions were introduced to parents: provide a diet rich in sources of iron and vitamin C, limit cow's milk consumption to less than twenty-four ounces per day, and a multivitamin containing iron.



Figure 10.5.1: While supplementation may be necessary in acute situations, the best way to boost your iron intake is through good eating habits. Imag used with permission (Public Domain; This image was released by the National Cancer Institute, an agency part of the National Institutes of Health).

In the third world, iron-deficiency anemia remains a significant public-health challenge. The World Bank claims that a million deaths occur every year from anemia and that the majority of those occur in Africa and Southeast Asia. The World Bank states five key interventions to combat anemia:The World Bank. "Anemia." Accessed October 2, 2011. web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTHEALTHNUTRITIONANDPOPULATION/EXTPHAAG/0,,contentMDK:20588506~menuPK:1314803~pagePK:64229817~piPK:64229743 ~theSitePK:672263,00.html

- Provide at-risk groups with iron supplements.
- Fortify staple foods with iron and other micronutrients whose deficiencies are linked with anemia.
- Prevent the spread of malaria and treat the hundreds of millions with the disease.
- Provide insecticide-treated bed netting to prevent parasitic infections.
- Treat parasitic-worm infestations in high-risk populations.

Also, there is an ongoing investigation as to whether supplying iron cookware to at-risk populations is effective in preventing and treating iron-deficiency anemia.

Key Takeaways

- Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body, resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. It is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in iron.
- The main causes of iron deficiency worldwide are parasitic-worm infections in the gut (causing excessive blood loss), malaria, a parasitic disease causing the destruction of red blood cells, and insufficient iron in the diet.
- Infants, children, adolescents, and women are the populations most at risk worldwide for iron-deficiency anemia by all causes.
- In America in the past, iron-deficiency anemia was prevalent in infants and young children. After the introduction of infant screening, fortification of formulas and foods, and educating parents on providing an iron-rich diet, iron-deficiency anemia significantly declined in this country.
- In the third world, iron-deficiency anemia remains a significant public-health challenge. Solutions to reduce the prevalence of iron-deficiency anemia in the developing world include providing supplements to target populations, fortifying foods with iron and other blood-healthy micronutrients, preventing the spread of malaria, treating parasitic infections, and giving iron cookware to high-risk populations.
- The body excretes little iron and therefore the potential for accumulation in tissues and organs is considerable. Iron accumulation in certain tissues and organs can cause a host of health problems in children and adults, including extreme fatigue, arthritis, joint pain, and severe liver and heart toxicity.

Discussion Starters

1. Come up with a hypothesis or two on why it is vital that blood is continuously renewed.
2. Discuss the effectiveness and cost of some possible solutions for eliminating iron-deficiency anemia worldwide.

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10.E: Exercises

It's Your Turn

1. Make a chart of the vitamins and minerals important for metabolism and list their main functions.
2. List four functions of blood.
3. With regard to the functions of iron in metabolism and blood health, describe how low iron levels lead to the characteristic signs and symptoms of iron-deficiency anemia.

Apply It

1. Draw a flow chart of the stages of nutrient catabolism and point out where the B vitamins are required.
2. Summarize in a paragraph why a pregnant woman requires more iron in the diet and why it is important for newborn babies to be screened for iron deficiency.
3. Plan a daily menu that meets the RDA for iron and iron-absorption enhancers.

Expand Your Knowledge

1. Read "Sir Frederick Hopkins—Nobel Lecture" on the history of the discovery of vitamins and summarize in a paragraph or two the importance of continuing scientific investigation to define the functions of vitamins in order to improve the health of humans. http://www.nobelprize.org/nobel_prizes/medicine/laureates/1929/hopkins-lecture.html
2. Go to the USDA database (http://www.ars.usda.gov/Services/docs.htm?docid=20958) and prepare a list of the top ten food sources of vitamin B_6 and vitamin B_{12}.
3. Why would having too many red blood cells decrease the amount of oxygen delivered to cells? To help answer this question visit the website of the National Heart, Lung, and Blood Institute (http://www.nhlbi.nih.gov/health/dci/Diseases/poly/poly_all.html).

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CHAPTER OVERVIEW

11: Water, Electrolytes, Acid-Base Balance

In this Chapter, we look at the nutrients important to fluid and electrolyte balance, including water, sodium, chloride, and potassium. We also look at sports drinks, caffeinated beverages, and alcohol.

11.1: Chapter Introduction
11.2: Overview of Fluid and Electrolyte Balance
11.3: Water's Importance to Vitality
11.4: Regulation of Water Balance
11.5: Electrolytes Important for Fluid Balance
11.6: Consequences of Deficiency or Excess
11.7: Water Concerns
11.E: Water, Electrolytes, Acid-Base Balance (Exercises)

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11.1: Chapter Introduction

Video 11.1.1: Sport Safety: Dehydration

Dr. Casa, researcher and professor at the University of Connecticut, explains the importance of keeping hydrated during sports. (click to see video)

Maintaining the right level of water in your body is crucial to survival, as either too little or too much water in your body will result in less-than-optimal functioning. One mechanism to help ensure the body maintains water balance is thirst. Thirst is the result of your body's physiology telling your brain to initiate the thought to take a drink. Sensory proteins detect when your mouth is dry, your blood volume too low, or blood electrolyte concentrations too high and send signals to the brain stimulating the conscious feeling to drink.



Figure 11.1.1: John O'Brien The US Men's National team practices at SAS Soccer Park in Cary, NC on April 9, 2006 ahead of their international friendly against Jamaica. (CC-SA-BY 3.0; Jarrett Campbell)

In the summer of 1965, the assistant football coach of the University of Florida Gators requested scientists affiliated with the University study why the withering heat of Florida caused so many heat-related illnesses in football players and provide a solution to increase athletic performance and recovery post-training or game. The discovery was that inadequate replenishment of fluids, carbohydrates, and electrolytes were the reason for the "wilting" of their football players. Based on their research, the scientists concocted a drink for the football players containing water, carbohydrates, and electrolytes and called it "Gatorade." In the next football season, the Gators were nine and two and won the Orange Bowl. The Gators' success launched the sports-drink industry, which is now a multibillion-dollar industry that is still dominated by Gatorade.

The latest National Health and Nutrition Examination Survey, covering the period from 2005 to 2008, reports that about 50 percent of Americans consume sugary drinks daily.Ogden, C. et al. "Consumption of Sugar Drinks in the United States, 2005–2008." Centers for Disease Control and Prevention. *NCHS Data Brief*, no. 71 (August 2011). http://www.cdc.gov/nchs/data/databriefs/db71.htm. Excess consumption of sugary soft drinks has been scientifically proven to increase the risk for dental caries, obesity, Type 2 diabetes, and cardiovascular disease. In addition to sugary soft drinks, beverages containing added sugars include fruit drinks, sports drinks, energy drinks and sweetened bottled waters. Previously, we considered in detail the effects of sugary soft drinks on health. In this chapter, we will consider sports drinks. Sports drinks are designed to rehydrate the body after excessive fluid depletion. Electrolytes, in particular, promote normal rehydration to prevent fatigue during physical exertion. Are they a good choice for achieving the recommended fluid intake? Are they performance and endurance enhancers like they claim? Who should drink them?

Typically, eight ounces of a sports drink provides between fifty and eighty calories and 14 to 17 grams of carbohydrate, mostly in the form of simple sugars. Sodium and potassium are the most commonly included electrolytes in sports drinks, with the levels of these in sports drinks being highly variable. The American College of Sports Medicine says a sports drink should contain 125 milligrams of sodium per 8 ounces as it is helpful in replenishing some of the sodium lost in sweat and promotes fluid uptake in the small intestine, improving hydration.

In this chapter, we will consider the importance of maintaining fluid and electrolyte balance in the human body, the functions of water and electrolytes in the body, the consequences of getting too much or too little of water and electrolytes, the best dietary

sources of these nutrients, and healthier beverage choices. After reading this chapter you will know what to look for in sports drinks and will be able to select the best products to keep hydrated.

Video 11.1.1: Effects of Dehydration on Athletes

This video portrays the effects of hard-core training on the ability of an athlete's body to adapt to extremes. "We endorse thirst as the best scientifically supported method for you to use." Association of International Marathons and Distance Races. (click to see video)

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11.2: Overview of Fluid and Electrolyte Balance

Learning Objectives

- Define osmosis.

A human body is made up of mostly water. An adult consists of about 37 to 42 liters of water or about eighty pounds. Fortunately, humans have compartmentalized tissues; otherwise, we might just look like a water balloon! Newborns are approximately 70 percent water. Adult males typically are composed of about 60 percent water and females are about 55 percent water. (This gender difference reflects the differences in body-fat content since body fat is practically water-free. This also means that if a person gains weight in the form of fat the percentage of total body water content declines.) As we age total body water content also diminishes so that by the time we are in our eighties the percent of water in our bodies has decreased to around 45 percent. Does the loss in body water play a role in the aging process? Alas, no one knows. But, we do know that dehydration accelerates the aging process whereas keeping hydrated decreases headaches, muscle aches, and kidney stones. Additionally, a study conducted at the Fred Hutchinson Cancer Research Center in Seattle found that women who drank more than five glasses of water each day had a significantly decreased risk of developing colon cancer.Shannon J. E. et al. “Relationship of Food Groups and Water Intake to Colon Cancer Risk.” *Cancer Epidemiol Biomarkers Prev* 5, no. 7 (1996): 495–502. http://cebp.aacrjournals.org/content/5/7/495.long.

Fluid and Electrolyte Balance

Although water makes up the largest percentage of body volume, it is not actually pure water but rather a mixture of cells, proteins, glucose, lipoproteins, electrolytes, and other substances. **Electrolytes** are substances that, when dissolved in water, disassociate into charged ions. Positively charged electrolytes are called **cations** and negatively charged electrolytes are called **anions**. For example, in water sodium chloride (the chemical name for table salt) disassociates into sodium cations (Na^+) and chloride anions (Cl^-). **Solutes** refer to all dissolved substances in a fluid, which may be charged, such as sodium (Na^+), or uncharged, such as glucose. In the human body, water and solutes are distributed into two compartments: inside cells, called **intracellular**, and outside cells, called **extracellular** (about 40% of total body water). The extracellular water compartment is subdivided into the spaces between cells (interstitial) and intravascular or blood plasma and other bodily fluids (such as cerebrospinal fluid which surrounds and protects the brain and spinal cord). The composition of solutes differs between the fluid compartments. For instance, more protein is inside cells than outside and more chloride anions exist outside of cells than inside.

Osmoregulation

One of the essential homeostatic functions of the body is to maintain fluid balance and the differences in solute composition between cells and their surrounding environment. Osmoregulation is the control of fluid balance and composition in the body. The processes involved keep fluids from becoming too dilute or too concentrated. Fluid compartments are separated by selectively permeable membranes, which allow some things, such as water, to move through while other substances require special transport proteins, channels, and often energy. The movement of water between fluid compartments happens by osmosis, which is simply the movement of water through a selectively permeable membrane from an area where it is highly concentrated in an area where it is not so concentrated. Water is never transported actively; that is, it never takes energy for water to move between compartments. Although cells do not directly control water movement, they do control movement of electrolytes and other solutes and thus indirectly regulate water movement by controlling where there will be regions of high and low concentrations.

Video 11.2.1: Osmosis

This is a short animation of osmosis.(click to see video)

Cells maintain their water volume at a constant level, but the composition of solutes in a cell is in a continuous state of flux. This is because cells are bringing nutrients in, metabolizing them, and disposing of waste products. To maintain water balance a cell controls the movement of electrolytes to keep the total number of dissolved particles, called osmolality the same inside and outside (Figure 7.1). The total number of dissolved substances is the same inside and outside a cell, but the composition of the fluids differs

between compartments. For example, sodium exists in extracellular fluid at fourteen times the concentration as compared to that inside a cell.

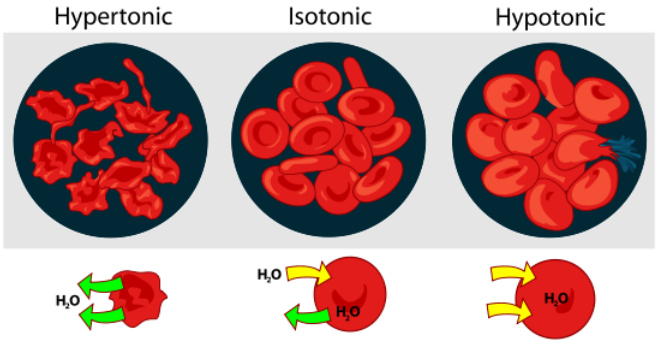


Figure 11.2.1: Cells maintain water volume by actively controlling electrolyte concentrations. Imaged used with permission (Public Domain; LadyofHats)

If a cell is placed in a solution that contains fewer dissolved particles (known as a hypotonic solution) than the cell itself, water moves into the more concentrated cell, causing it to swell (Figure 11.2.1). Alternatively, if a cell is placed in a solution that is more concentrated (known as a hypertonic solution) water moves from inside the cell to the outside, causing it to shrink. Cells keep their water volume constant by pumping electrolytes in and out in an effort to balance the concentrations of dissolved particles on either side of their membranes. When a solution contains an equal concentration of dissolved particles on either side of the membrane, it is known as an isotonic solution.

Key Takeaways

- A human body is mostly water.
- Movement of water is regulated by controlling the movement of electrolytes between fluid compartments.
- While water makes up the largest percentage of body volume it is not pure water but a mixture of water, cells, proteins, glucose, lipoproteins, electrolytes and other substances.
- In the human body water and solutes are distributed into two compartments; inside cells, called intracellular, and outside cells, called extracellular.
- One of the essential homeostatic functions, called osmoregulation of the body is to maintain fluid balance and the differences in composition between fluid compartments.
- The movement of water between fluid compartments happens by the process of osmosis.
- Water is never transported actively; that is, it never takes special proteins and energy for water to move between compartments, it simply flows from an area of high concentration to an area where its concentration is lower.
- Under normal circumstances, a cell maintains its water volume at a constant level, but the composition of solutes in a cell is in a continuous state of flux.
- To maintain water balance a cell controls the movement of electrolytes to keep the total number of dissolved particles the same inside and outside.

Discussion Starters

1. If the membrane surrounding a cell was permeable to sodium what would happen to the concentration of sodium inside and outside a cell?
2. Discuss why maintaining fluid homeostasis is a dynamic process.

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11.3: Water's Importance to Vitality

Learning Objectives

- Describe the four major functions of water in the human body

You get up in the morning, flush wastes down the toilet, take a shower, brush your teeth, drink, eat, drive, wash the grime from your windshield, get to work, and drink coffee. Next, to a fountain, you eat lunch and down it with a glass of water, you use the toilet, again and again, drive home, prepare dinner, etc. Add all the ways you use water every day and you still will not come close to the countless uses water has in the human body. Of all the nutrients, water is the most critical as its absence proves lethal within a few days. Organisms have adapted numerous mechanisms for water conservation. Water uses in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.



Figure 11.3.1: Water is the foundation of all life—the surface of the earth is 70 percent water; the volume of water in humans is about 60 percent. "The Blue Marble" is a famous photograph of the Earth taken on December 7, 1972, by the crew of the Apollo 17 spacecraft en route to the Moon at a distance of about 29,000 kilometers (18,000 statute miles). It shows Africa, Antarctica, and the Arabian Peninsula. (Public Domain; NASA)

Water As a Transportation Vehicle

Water is called the "universal solvent" because more substances dissolve in it than any other fluid. Molecules dissolve in water because of the hydrogen and oxygen molecules ability to loosely bond with other molecules. Molecules of water (H_2O) surround substances, suspending them in a sea of water molecules. The solvent action of water allows for substances to be more readily transported. A pile of undissolved salt would be difficult to move throughout tissues, as would a bubble of gas or a glob of fat. Water moves nutrients and transports waste for excretion in the urine, feces or breath. Blood, the primary transport fluid in the body is about 78 percent water. Dissolved substances in blood include proteins, lipoproteins, glucose, electrolytes, and metabolic waste products, such as carbon dioxide and urea, all of which are either dissolved in the watery surrounding of blood to be transported to cells to support basic functions or are removed from cells to prevent waste build-up and toxicity. Blood is not just the primary vehicle of transport in the body, but also as a fluid tissue blood structurally supports blood vessels that would collapse in its absence. Similarly, the brain is 75 percent water, with the water in the brain providing structure.

Water As a Medium for Chemical Reactions

Water is required for even the most basic chemical reactions. Previously, you learned that enzymes are proteins and proteins fold into their functional shape based on how their amino-acid sequences react with water. Once formed, enzymes must conduct their specific chemical reactions in a medium, which in all organisms is water. Water is an ideal medium for chemical reactions as it can

store a large amount of heat, is electrically neutral, and has a pH of 7.0, meaning it is not acidic or basic. Additionally, water is involved in many enzymatic reactions as an agent to break bonds or, by its removal from a molecule, to form bonds.

-

Water As a Lubricant/Shock Absorber

Many may view the slimy products of a sneeze as gross, but sneezing is essential for removing irritants and could not take place without water. Mucus, which is not only essential to discharge nasal irritants, but also required for breathing, transportation of nutrients along the gastrointestinal tract, and elimination of waste materials through the rectum is composed of more than 90 percent water. Mucus is a frontline defense against injury and foreign invaders. It protects tissues from irritants, entraps pathogens, and contains immune-system cells that destroy pathogens. Water is the main component of the lubricating fluid between joints and eases the movement of articulated bones.

The aqueous and vitreous humors, which are fluids that fill the extra space in the eyes and the cerebrospinal fluid surrounding the brain and spinal cord, are primarily water and buffer these organs against sudden changes in the environment. Watery fluids surrounding organs provide both chemical and mechanical protection. Just two weeks after fertilization water fills the amniotic sac in a pregnant woman providing a cushion of protection for the developing embryo.

-

Water As a Temperature Regulator

Another homeostatic function of the body, termed **thermoregulation,** is to balance heat gain with heat loss and body water plays an important role in accomplishing this. Human life is supported within a narrow range of temperature, with the temperature set point of the body being 98.6°F (37°C). Too low or too high of a temperature causes enzymes to stop functioning and metabolism is halted. At 82.4°F (28°C) muscle failure occurs and hypothermia sets in. At the opposite extreme of 111.2°F (44°C) the central nervous system fails and death results. Water is good at storing heat, an attribute referred to as **heat capacity** and thus helps maintain the temperature set point of the body despite changes in the surrounding environment. There are several mechanisms in place that move body water from place to place as a method to distribute heat in the body and equalize body temperature (Figure 7.2). The hypothalamus in the brain is the thermoregulatory center. The hypothalamus contains special protein sensors that detect blood temperature. The skin also contains temperature sensors that respond quickly to changes in immediate surroundings. In response to cold sensors in the skin, a neural signal is sent to the hypothalamus, which then sends a signal to smooth muscle tissue surrounding blood vessels causing them to constrict and reduce blood flow. This reduces heat loss to the environment. The hypothalamus also sends signals to muscles to erect hairs and shiver and to endocrine glands like the thyroid to secrete hormones capable of ramping up metabolism. These actions increase heat conservation and stimulate its production in the body in response to cooling temperatures.

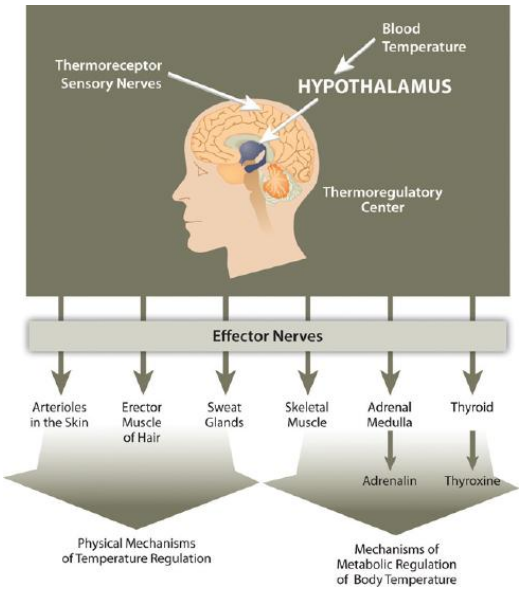


Figure 11.3.2: *Thermoregulation is the ability of an organism to maintain body temperature despite changing environmental temperatures.*

When body temperature rises, as what occurs during exercise, the hypothalamus detects an increase in blood temperature. In response, the hypothalamus sends a signal to the smooth muscle of blood vessels causing them to dilate so that more blood flows to the body's periphery. Once on the skin, extra heat exits the body via perspiration (sweat), which is 98 to 99 percent water. Water on the skin's surface evaporates, a process that takes energy and results in the loss of heat, thereby cooling the body. Perspiration is a process that intertwines temperature homeostasis with fluid and electrolyte homeostasis. Water and electrolytes lost in sweat need to be replenished in order to maintain fluid and electrolyte balance.

Key Takeaways

- Uses of water in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.
- Water has been termed the "universal solvent" because more substances dissolve in it than any other fluid. Water is essential to form enzymes and serves as a medium for chemical reactions. Water as a component of body fluids acts as a lubricant and shock absorber.
- Water is good at storing heat and buffers the body against extreme variations in temperature.
- There are several mechanisms that move body water from place to place as a method of heat distribution and temperature equalization.

Discussion Starters

1. Refer back to the discussion of lipids and discuss why lipids are coated with proteins, forming chylomicrons, prior to absorption.
2. Why do your fingers turn white in the cold?

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11.4: Regulation of Water Balance

Learning Objectives

- Discuss the physiological events that trigger the thirst mechanism.
- Describe two mechanisms by which the body controls urine output.

As you eat a bite of food, the salivary glands secrete saliva. As the food enters your stomach, gastric juice is secreted. As it enters the small intestine, pancreatic juice is secreted. Each of these fluids contains a great deal of water. How is that water replaced in these organs? What happens to the water now in the intestines? In a day there is an exchange of about 10 liters of water among the body's organs. The osmoregulation of this exchange involves complex communication between the brain, kidneys, and endocrine system. A homeostatic goal for a cell, a tissue, an organ, and an entire organism is to balance water output with water input.

Osmosis is the passage of solutions across a semi-permeable membrane. Water follows the ions in an attempt to equalize the ionic concentration in the compartments on both sides of the membrane. Osmotic pressure is the pressure excreted by particles in a solution to draw water across a membrane.

Regulation of Daily Water Input

Total water output per day averages 2.5 liters. This must be balanced with water input. Our tissues produce around 300 milliliters of water per day through metabolic processes. The remainder of water output must be balanced by drinking fluids and eating solid foods. The average fluid consumption per day is 1.5 liters, and water gained from solid foods approximates 700 milliliters.

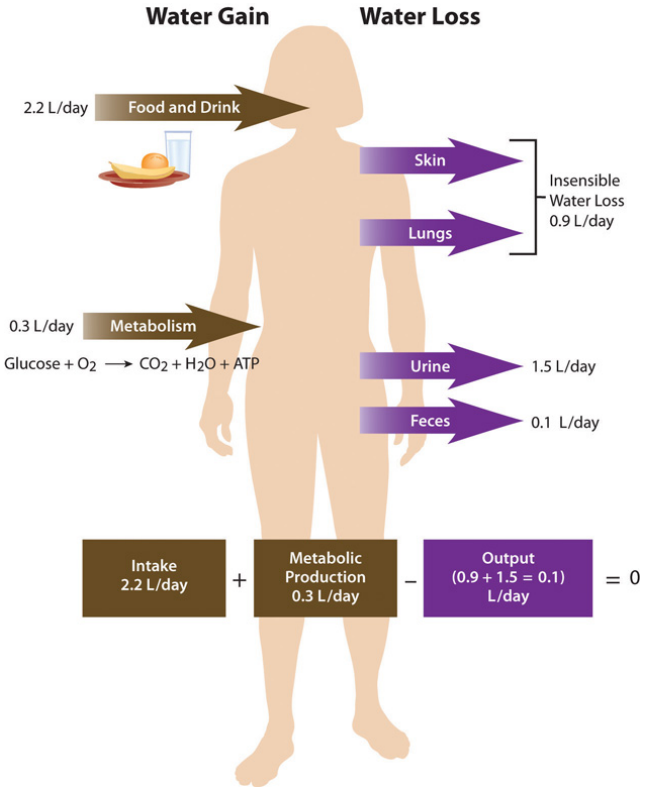


Figure 11.4.1: Daily Fluid Loss and Gain

Dietary Gain of Water

The Food and Nutrition Board of the Institute of Medicine (IOM) has set the Adequate Intake (AI) for water for adult males at 3.7 liters (15.6 cups) and at 2.7 liters (11 cups) for adult females.Institute of Medicine Panel on Dietary Reference Intakes for Electrolytes and Water. *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate*. (Washington, D.C.:

National Academies Press, 2005). http://www.nap.edu/openbook.php?record_id=10925&page=73. These intakes are higher than the average intake of 2.2 liters. It is important to note that the AI for water includes water from *all dietary sources*; that is, water coming from food as well as beverages. People are not expected to consume 15.6 or 11 cups of pure water per day. In America, approximately 20 percent of dietary water comes from solid foods. See Table 11.4.1 for the range of water contents for selected food items. Beverages include water, tea, coffee, sodas, and juices.

Table 11.4.1: Water Content in Foods

Percentage	Food Item
90–99	Nonfat milk, cantaloupe, strawberries, watermelon, lettuce, cabbage, celery, spinach, squash
80–89	Fruit juice, yogurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple
70–79	Bananas, avocados, cottage cheese, ricotta cheese, baked potato, shrimp
60–69	Pasta, legumes, salmon, chicken breast
50–59	Ground beef, hot dogs, steak, feta cheese
40–49	Pizza
30–39	Cheddar cheese, bagels, bread
20–29	Pepperoni, cake, biscuits
10–19	Butter, margarine, raisins
1–9	Walnuts, dry-roasted peanuts, crackers, cereals, pretzels, peanut butter
0	Oils, sugars

Source: US Department of Agriculture, Agricultural Research Service. 2010. *National Nutrient Database for Standard Reference*, Release 23. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl.

There is some debate over the amount of water required to maintain health because there is no consistent scientific evidence proving that drinking a particular amount of water improves health or reduces the risk of disease. In fact, kidney stone prevention seems to be the only premise for water consumption recommendations. You may be surprised to find out that the commonly held belief that people need to drink eight 8-ounce glasses of water per day isn't an official recommendation and isn't based on any scientific evidence! The amount of water/fluids a person should consume every day is actually variable and should be based on the climate a person lives in, as well as their age, physical activity level, and kidney function. No maximum for water intake has been set.

-

Thirst Mechanism: Why Do We Drink?

Thirst is an osmoregulatory mechanism to increase water input. The thirst mechanism is activated in response to changes in water volume in the blood but is even more sensitive to changes in blood osmolality. Blood osmolality is primarily driven by the concentration of sodium cations. The urge to drink results from a complex interplay of hormones and neuronal responses that coordinate to increase water input and contribute toward fluid balance and composition in the body. The "thirst center" is contained within the hypothalamus, a portion of the brain that lies just above the brain stem. In older people, the thirst mechanism is not as responsive and as we age there is a higher risk for dehydration. Thirst happens in the following sequence of physiological events:

1. Receptor proteins in the kidney, heart, and hypothalamus detect decreased fluid volume or increased sodium concentration in the blood.
2. Hormonal and neural messages are relayed to the brain's thirst center in the hypothalamus.
3. The hypothalamus sends neural signals to higher sensory areas in the cortex of the brain, stimulating the conscious thought to drink.

4. Fluids are consumed.
5. Receptors in the mouth and stomach detect mechanical movements involved with fluid ingestion.
6. Neural signals are sent to the brain and the thirst mechanism is shut off.

The physiological control of thirst is the backup mechanism to increase water input. Fluid intake is controlled primarily by conscious eating and drinking habits dependent on social and cultural influences. For example, you might have a habit of drinking a glass of orange juice and eating a bowl of cereal every morning before school or work. Most American adolescents have a daily habit of soft-drink consumption. Soft-drink consumption is influenced by demographics, access to soft drinks, social impacts, and personal behavior.

Regulation of Daily Water Output

As stated, daily water output averages 2.5 liters. There are two types of outputs. The first type is **insensible water loss**, meaning we are unaware of it. The body loses about 400 milliliters of its daily water output through exhalation. Another 500 milliliters is lost through our skin. The second type of output is **sensible water loss**, meaning we are aware of it. Urine accounts for about 1,500 milliliters of water output, and feces account for roughly 100 milliliters of water output. Regulating urine output is a primary function of the kidneys, and involves communication with the brain and endocrine system.

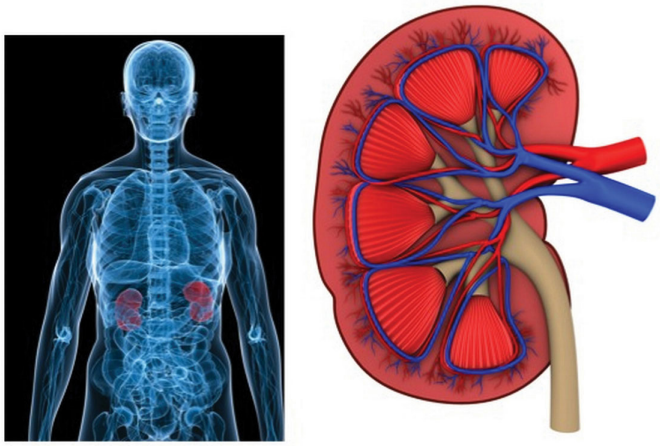


Figure 11.4.2: Kidneys. A primary function of the kidneys is to filter blood and remove wastes. They play a major role in fluid and electrolyte balance.© Thinkstock

The Kidneys Detect Blood Volume

The kidneys are two bean-shaped organs, each about the size of a fist and located on either side of the spine just below the rib cage (Figure 7.4). The kidneys filter about 190 liters of blood and produce (on average) 1.5 liters of urine per day. Urine is mostly water, but it also contains electrolytes and waste products, such as urea. The amount of water filtered from the blood and excreted as urine is dependent on the amount of water in, and the electrolyte composition of, blood.

Kidneys have protein sensors that detect blood volume from the pressure, or stretch, in the blood vessels of the kidneys. When blood volume is low, kidney cells detect decreased pressure and secrete the enzyme, renin. Renin travels in the blood and cleaves another protein into the active hormone, **angiotensin**. Angiotensin targets three different organs (the adrenal glands, the hypothalamus, and the muscle tissue surrounding the arteries) to rapidly restore blood volume and, consequently, pressure.

- First, angiotensin travels to the outer perimeter of the adrenal glands and stimulates the release of the hormone aldosterone. Aldosterone travels back to the kidneys and stimulates the sodium-potassium pump. As a result of the pump's work, the blood reabsorbs the sodium from the liquid that has already been filtered by the kidneys. Water follows sodium into the blood by osmosis, resulting in less water in the urine and restored fluid balance and composition of blood.
- Next, angiotensin travels to the hypothalamus where it stimulates the thirst mechanism and the release of antidiuretic hormone. Antidiuretic hormone travels back to the kidneys where it increases sodium and water reabsorption.
- Lastly, angiotensin targets smooth muscle tissue surrounding arteries, causing them to contract (narrow) the blood vessels, which assists in elevating blood pressure.

The Hypothalamus Detects Blood Osmolality

Osmoreceptors (specialized protein receptors) in the hypothalamus detect sodium concentration in the blood. In response to a high sodium level, the hypothalamus activates the thirst mechanism and concurrently stimulates the release of antidiuretic hormone. Thus, it is not only kidneys that stimulate antidiuretic- hormone release, but also the hypothalamus. This dual control of antidiuretic hormone release allows for the body to respond to both decreased blood volume and increased blood osmolality.

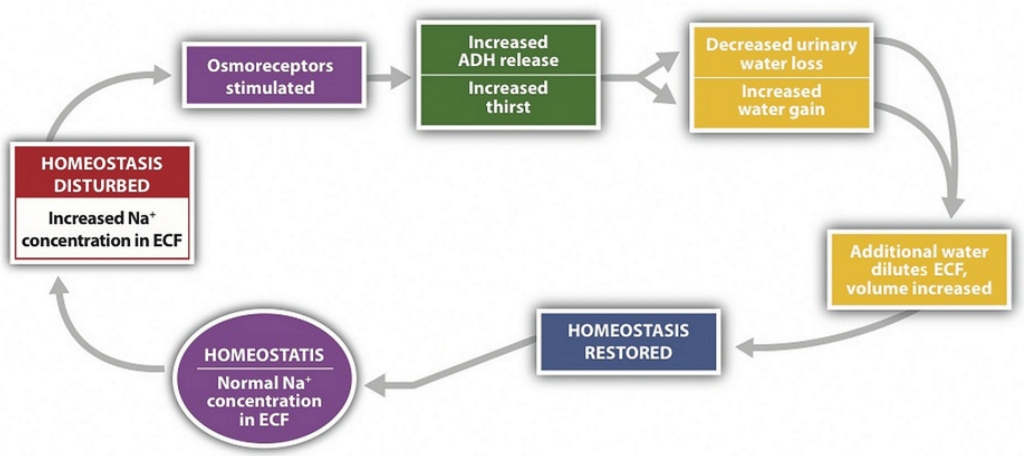


Figure 11.4.3: Sodium and fluid balance are intertwined.

The Adrenal Glands Detect Blood Osmolality

Cells in the adrenal glands sense when sodium levels are low, and when potassium levels are high, in the blood. In response to either stimulus, they release aldosterone. Therefore, aldosterone is released in response to angiotensin stimulation and is also controlled by blood electrolyte concentrations. In either case, aldosterone communicates the same message, which is to increase sodium reabsorption and consequently water reabsorption. In exchange, potassium is excreted.

The mechanisms involved in regulating water input and output are intertwined with those controlling electrolyte balance. In a healthy individual, this multilevel coordinated control of fluid and electrolyte levels in the body ensures homeostasis. However, in a person with heart failure, the crosstalk between organs can have dire consequences. Heart failure results in a decrease in blood output from the heart, which lowers blood pressure. In response to the lower blood pressure, the kidneys release renin leading to the release of antidiuretic hormone. Antidiuretic hormone acts on the kidneys and increases water reabsorption, thereby increasing blood volume and pressure. This makes the heart work harder and exacerbates the heart condition. To block this response, people with heart failure are treated with drugs that block the kidneys' compensatory response. Diuretics are drugs that act either by inhibiting the actions of antidiuretic hormone or by promoting sodium excretion in the urine. This increases water output and blood pressure is reduced. Diuretics, along with other drugs, are useful in treating heart failure and in decreasing blood pressure in people with hypertension.

Key Takeaways

- A homeostatic goal for a cell, tissue, organ, and entire organism is to balance water output with water input. The amount of water a person should consume every day is variable and should be based on the climate a person lives in, as well as their age, physical activity level, and kidney function.
- Thirst results from a complex interaction of hormones and neuronal responses that coordinate to achieve fluid balance and composition in the body. Thirst is triggered by either a decrease in blood volume or an increase in blood osmolality.
- Other mechanisms by which body water balance is maintained are aimed at controlling the water volume of urine. The amount of water filtered from the blood and excreted as urine is dependent upon the amount of water in blood and the electrolyte composition of blood.
- The regulation of water output involves complex communication between the kidneys, hypothalamus, and endocrine glands.

Discussion Starters

1. Why do people urinate more often when it is cold outside?
2. Discuss the signs you first detect when you are thirsty.

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11.5: Electrolytes Important for Fluid Balance

Learning Objectives

- Explain the role of the electrolytes sodium, potassium, and chloride in fluid balance.

Cells are about 75 percent water and blood plasma is about 95 percent water. Why then, does the water not flow from blood plasma to cells? The maintenance of the unequal volumes of water between fluid compartments is achieved by balancing the force of water (hydrostatic pressure) against the force of all dissolved substances. Concentration means the amount of particles in a set volume of water. (Recall that individual solutes can differ in concentration between the intracellular and extracellular fluids, but the total concentration of all dissolved substances is equal.)

The force driving the water movement through the selectively permeable membrane is the higher solute concentration on the one side. Solutes at different concentrations on either side of a selectively permeable membrane exert a force, called osmotic pressure. The higher concentration of solutes on one side compared to the other of the U-tube exerts osmotic pressure, pulling the water to a higher volume on the side of the U-tube containing more dissolved particles. When the osmotic pressure is equal to the pressure of the water on the selectively permeable membrane, net water movement stops (though it still diffuses back and forth at an equal rate).

One equation exemplifying equal concentrations but different volumes is the following

5 grams of glucose in 1 liter = 10 grams of glucose in 2 liters (5g/L = 5g/L)

The differences in concentrations of particular substances provide concentration gradients that cells can use to perform work. A concentration gradient is a form of potential energy, like water above a dam. When water falls through a dam the potential energy is changed to moving energy (kinetic), that in turn is captured by turbines. Similarly, when an electrolyte at a higher concentration in the extracellular fluid is transported into a cell with lower concentration, the potential energy is harnessed and used to perform work.

Cells are constantly transporting nutrients in and waste out. How is the concentration of solutes maintained if they are in a state of flux? This is where electrolytes come into play. The cell (or more specifically the numerous sodium-potassium pumps in its membrane) continuously pumps sodium ions out to establish a chemical gradient. The transport protein, called the sodium-glucose symporter, uses the sodium gradient to power glucose movement into the cell. Sodium and glucose both move into the cell. Water passively follows the sodium. To restore balance, the sodium-potassium pump transfers sodium back to the extracellular fluid and water follows. Every cycle of the sodium-potassium pump involves the movement of three sodium ions out of a cell, in exchange for two potassium ions into a cell. To maintain charge neutrality on the outside of cells every sodium cation is followed by a chloride anion. Every cycle of the pump costs one molecule of ATP (adenosine triphosphate). The constant work of the sodium-potassium pump maintains the solute equilibrium and consequently, water distribution between intracellular and extracellular fluids.

The unequal movement of the positively charged sodium and potassium ions makes intracellular fluid more negatively charged than the extracellular fluid. This charge gradient is another source of energy that a cell uses to perform work. You will soon learn that this charge gradient and the sodium-potassium pump are also essential for nerve conduction and muscle contraction. The many functions of the sodium-potassium pump in the body account for approximately a quarter of total resting energy expenditure.

Interactive

View this animation of the sodium-potassium pump maintaining fluid balance in cells.

http://nutrition.jbpub.com/resources/animations.cfm?id=27&debug=0

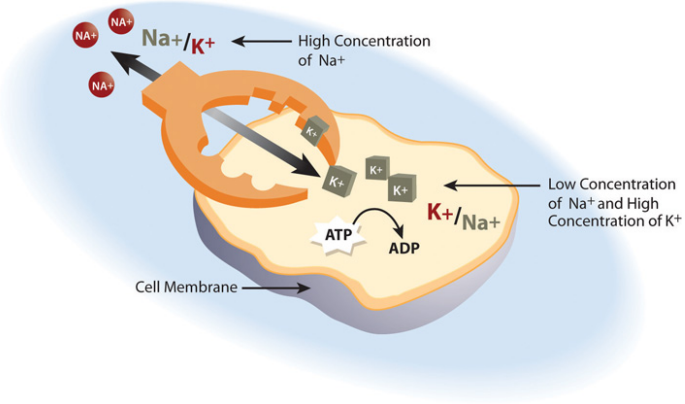


Figure 11.5.1: The sodium-potassium pump is the primary mechanism for cells to maintain water balance between themselves and their surrounding environment.

Sodium

Sodium is a major extracellular cation that is water soluble and vital not only for maintaining fluid balance but also for many other essential functions. In contrast to many minerals, sodium absorption in the small intestine is extremely efficient and in a healthy individual, 90-95% is excreted by the kidneys, the remainder in the feces and sweat. Very little sodium is required in the diet (about 200 milligrams) because the kidneys actively reabsorb sodium. Kidney reabsorption of sodium is hormonally controlled, allowing for a relatively constant sodium concentration in the blood.

Other Functions of Sodium in the Body

The second notable function of sodium is in nerve impulse transmission. Nerve impulse transmission results from the transport of sodium cations into a nerve cell, which creates a charge difference (or voltage) between the nerve cell and its extracellular environment. Similar to how a current moves along a wire, a sodium current moves along a nerve cell. Stimulating a muscle contraction also involves the movement of sodium ions as well as other ion movements. For a muscle to contract, a nerve impulse travels to a muscle. The movement of the sodium current in the nerve communicates to the muscle by releasing the neurotransmitter, acetylcholine. Acetylcholine signals sodium channels in the muscle to open and sodium rushes in, creating another current that travels along the muscle eventually culminating in contraction. In both the nerve cell and the muscle cell, the sodium that went in during a stimulus now has to be moved out by the sodium-potassium pump.

Sodium is essential for nutrient absorption in the small intestine and also for nutrient reabsorption in the kidney. Amino acids, glucose, and water must make their way from the small intestine to the blood. To do so they pass through intestinal cells on their way to the blood. The transport of nutrients through intestinal cells is facilitated by the sodium-potassium pump, which by moving sodium out of the cell, creates a higher sodium concentration outside of the cell (requiring ATP).

Sodium Imbalances

Sweating is a homeostatic mechanism for maintaining body temperature, which influences fluid and electrolyte balance. Sweat is mostly water but also contains some electrolytes, mostly sodium and chloride. Under normal environmental conditions (i.e., not hot, humid days) water and sodium loss through sweat are negligible but is highly variable among individuals. It is estimated that sixty minutes of high-intensity physical activity, like playing a game of tennis, can produce approximately one liter of sweat; however, the amount of sweat produced is highly dependent on environmental conditions. A liter of sweat typically contains between 1 and 2 grams of sodium and therefore exercising for multiple hours can result in a high amount of sodium loss in some people. Additionally, hard labor can produce substantial sodium loss through sweat. In either case, the lost sodium is easily replaced in the next snack or meal.

In athletes, **hyponatremia**, or a low blood-sodium level, is not so much the result of excessive sodium loss in sweat, but rather drinking too much water. The excess water dilutes the sodium concentration in blood. Illnesses causing vomiting, sweating, and diarrhea may also cause hyponatremia. The symptoms of hyponatremia, also called water intoxication since it is often the root

cause, include nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death. The physiological events that occur in water intoxication are the following:

1. Excessive sodium loss and/or water intake.
2. Sodium levels fall in blood and in the fluid between cells.
3. Water moves to where solutes are more concentrated (i.e. into cells).
4. Cells swell.
5. Symptoms, including nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death result.



Figure 11.5.2: Pictured is Serena Williams, one of the greatest female tennis players of all time. Only in the extreme does a person lose too much sodium through sweat. © Shutterstock

Hyponatremia in endurance athletes (such as marathon runners) can be avoided by drinking the correct amount of water, which is about 1 cup every twenty minutes during the event. Sports drinks are better at restoring fluid and blood-glucose levels than replacing electrolytes. During an endurance event, you would be better off drinking water and eating an energy bar that contains sugars, proteins, and electrolytes. The American College of Sports Medicine suggests if you are exercising for longer than one hour you eat one high carbohydrate (25–40 grams) per hour of exercise along with ample water.Convertino, V. A. et al. “American College of Sports Medicine Position Stand. Exercise and Fluid Replacement.” US National Library of Medicine, National Institutes of Health. *Medicine and Science in Sports and Exercise* 28, no. 1 (January 1996): i–vii. http://www.ncbi.nlm.nih.gov/pubmed/9303999. Watch out for the fat content, as sometimes energy bars contain a hefty dose. If you’re not exercising over an hour at high intensity, you can skip the sports drinks, but not the water. For those who do not exercise or do so at low to moderate intensity, sports drinks are another source of extra calories, sugar, and salt.

Other people at risk of hyponatremia are people on a very low sodium diet due to special diets. These types of diets are used to treat kidney disease, hypertension, and heart disease. Excessive vomiting, for example, bulimia nervosa, or excessive diarrhea can also cause a loss of sodium resulting in hyponatremia.

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Needs and Dietary Sources of Sodium

The IOM has set an AI level for sodium for healthy adults between the ages of nineteen and fifty at 1.5 grams (1,500 milligrams). (See Table 11.5.1 "Dietary Reference Intakes for Sodium".) Table salt is approximately 40 percent sodium and 60 percent chloride. One teaspoon of salt contains approximately 2300 mg sodium. As a reference point, only ⅔ teaspoon of salt is needed in the diet to meet the AI for sodium. The AI takes into account the amount of sodium lost in sweat during recommended physical activity levels and additionally provides for the sufficient intake of other nutrients, such as chloride, meaning that to get all the other nutrients in our diet, we have to allow for a higher intake of sodium. The Tolerable Upper Intake Level (UL) for sodium is 2.3 grams per day for adults. (Just over 1 teaspoon of salt contains the 2.3 grams of sodium recommended). The UL is considered appropriate for healthy individuals but not those with hypertension (high blood pressure). The IOM estimates that greater than 95 percent of men and 75 percent of women in America consume salt in excess of the UL. Many scientific studies demonstrate that reducing salt

intake prevents hypertension, is helpful in reducing blood pressure after hypertension is diagnosed, and reduces the risk for cardiovascular disease. The IOM recommends that people over fifty, African Americans, diabetics, and those with chronic kidney disease should consume no more than 1.5 grams of sodium per day. The American Heart Association (AHA) states that all Americans, not just those listed, should consume less than 1.5 grams of sodium per day to prevent cardiovascular disease. The AHA recommends this because millions of people have risk factors for hypertension and there is scientific evidence supporting that lower-sodium diets are preventive against hypertension.

Table 11.5.1: Dietary Reference Intakes for Sodium

Age Group	Adequate Intake (mg/day)	Tolerable Upper Intake Level (mg/day)
Infants (0–6 months)	120	ND
Infants (6–12 months)	370	ND
Children (1–3 years)	1,000	1,500
Children (4–8 years)	1,200	1,900
Children (9–13 years)	1,500	2,200
Adolescents (14–18 years)	1,500	2,300
Adults (19–50 years)	1,500	2,300
Adults (50–70 years)	1,300	2,300
Adults (> 70 years)	1,200	2,300
ND = not determined		

Source: Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Food Sources for Sodium

Most sodium in the typical American diet comes from processed and prepared foods. Manufacturers add salt to foods to improve texture and flavor, and also as a preservative. The amount of salt in similar food products varies widely. Some foods, such as meat, poultry, and dairy foods, contain naturally-occurring sodium. For example, one cup of low-fat milk contains 107 milligrams of sodium. Naturally-occurring sodium accounts for less than 12 percent of dietary intake in a typical diet. Soft water replaced the calcium with sodium which contributes to the sodium content of one's diet. Soy sauce and monosodium glutamate are also sources of sodium. For the sodium contents of various foods see Table 11.5.2.

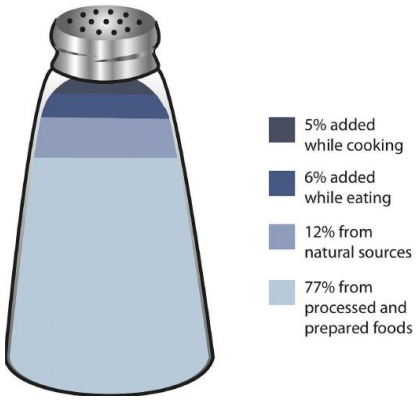


Figure 11.5.3: Dietary Sources of Sodium

Table 11.5.2: Sodium Contents of Selected Foods

Food Group	Serving Size	Sodium (mg)
Breads, all types	1 oz.	95–210

Food Group	Serving Size	Sodium (mg)
Rice Chex cereal	1 ¼ c.	292
Raisin Bran cereal	1 c.	362
Granola bar	1 bar	83
Frozen pizza, plain, cheese	4 oz.	450–1200
Frozen vegetables, all types	½ c.	2–160
Salad dressing, regular fat, all types	2 Tbsp.	110–505
Salsa	2 Tbsp.	150–240
Soup (tomato), reconstituted	8 oz.	700–1260
Tomato juice	8 oz. (~1 c.)	340–1040
Potato chips	1 oz. (28.4 g)	120–180
Tortilla chips	1 oz. (28.4 g)	105–160
Pretzels	1 oz. (28.4 g)	290–560
Potato	1 medium	1–5
Pork	3 oz.	59
Chicken	(½ breast)	69
Chicken fast food dinner		2243
Chicken noodle soup	1 c.	1107
Ham	3 oz.	1114
Dill pickle	1	928
Sweet pickle	1	128
Soy sauce	1 Tbsp.	1029
Corn on cob	1 ear	1
Canned corn	1 c.	384
Baked beans, canned	1 c.	856
Hot dog	1	639
Burger, fast-food	1	990
Catsup	1 Tbsp.	156
Steak	3 oz.	55
Canned tuna	3 oz.	384
Fresh tuna	3 oz.	50
Dry-roasted peanuts	1 c.	986
Cheddar cheese	1 oz.	176
American cheese	1 oz.	406
Tap water	8 oz.	12

Interactive

To find out the sodium content of other foods visit the USDA National Nutrient Database for Standard Reference, Release 17.

www.nal.usda.gov/fnic/foodcomp/Data/SR17/wtrank/sr17a307.pdf.

Sodium on the Nutrition Facts Panel

The Nutrition Facts panel displays the amount of sodium (in milligrams) per serving of the food in question (Figure 11.5.4). Food additives are often high in sodium, for example, monosodium glutamate (MSG) contains 12 percent sodium. Additionally, baking soda, baking powder, disodium phosphate, sodium alginate, and sodium nitrate or nitrite contain a significant proportion of sodium.



Nutrition Facts
Serving Size ½ cup (114g)
Servings Per Container 4

Amount Per Serving	
Calories 90	Calories from Fat 130
	% Daily Value*
Total Fat 3g	5%
Saturated Fat 0g	0%
Cholestrol 0 mg	0%
Sodium 300mg	13%
Total Carbohydrate 13g	4%
Dietary Fiber 3g	12%
Sugars 3g	
Protein 3g	

Vitamin A 80% • Vitamin C 60%
Calcium 4% • Iron 4%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholestrol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Nutrition Facts
8 servings per container
Serving size **2/3 cup (55g)**

Amount per serving
Calories **230**

	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Figure 11.5.4: Sodium levels in milligrams is a required listing on a nutrition facts panel. The old nutrition facts panel is shown on the left and the new nutrition facts panel is shown on the right. Notice, both still require sodium.

When you see a food's Nutrition Facts label, you can check the ingredients list to identify the source of the added sodium. Various claims about the sodium content in foods must be in accordance with Food and Drug Administration (FDA) regulations (Table 11.5.3).

Table 11.5.3: Food Packaging Claims Regarding Sodium

Claim	Meaning
"Light in Sodium" or "Low in Sodium"	Sodium is reduced by at least 50 percent
"No Salt Added" or "Unsalted"	No salt added during preparation and processing*
"Lightly Salted"	50 percent less sodium than that added to similar food
"Sodium Free" or "Salt Free"	Contains less than 5 mg sodium per serving
"Very Low Salt"	Contains less than 35 mg sodium per serving
"Low Salt"	Contains less than 140 mg sodium per serving

*Must also declare on package "This is not a sodium-free food" if food is not sodium-free. Source: US Food and Drug Administration. "Food Labeling Guide." Revised October 2009. Accessed October 2, 2011. www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/FoodLabelingNutrition/FoodLabelingGuide/ucm064911.htm.

Tools for Change

To decrease your sodium intake, become a salt-savvy shopper by reading the labels and ingredients lists of processed foods and choosing those lower in salt. Even better, stay away from processed foods and control the seasoning of your foods. Eating a diet with less salty foods diminishes salt cravings so you may need to try a lower sodium diet for a week or two before you will be satisfied with the less salty food.



Figure 11.5.5: Take control of your salt intake and prepare your own foods. Not enough time? A packaged dinner from your grocer's freezer rarely supplies you with leftovers, a time saver for the next meal, but does supply a large amount of salt. © Shutterstock

Salt Substitutes

For those with hypertension or those looking for a way to decrease salt use, using a salt substitute for food preparation is one option. However, many salt substitutes still contain sodium, just in lesser amounts than table salt. Also, remember that most salt in the diet is not from table-salt use, but from processed foods. Salt substitutes often replace the sodium with potassium. People with kidney disorders often have problems getting rid of excess potassium in the diet and are advised to avoid salt substitutes containing potassium. People with liver disorders should also avoid salt substitutes containing potassium because their treatment is often accompanied by potassium dysregulation. Table 11.5.4 displays the sodium and potassium amounts in some salt substitutes.

Table 11.5.4: Salt Substitutes

Product	Serving Size	Sodium (mg)	Potassium (mg)

Product	Serving Size	Sodium (mg)	Potassium (mg)
Salt	1 tsp.	2,300	0
Mrs. Dash	1 tsp.	0	40
Spike (Salt-Free)	1 tsp.	0	96
Veg-It	1 tsp.	<65	<65
Adolph's Sodium-Free Tenderizer	¼ tsp.	0	420
Accent Low-Sodium Seasoning	1 tsp.	600	0
Salt Sense	1 tsp.	1,560	0
Pleasoning Mini-Mini Salt	1 tsp.	440	0
Morton Lite Salt	1 tsp.	1,100	1,500
Estee Salt-It	1 tsp.	0	3,520
Morton Nature's Seasons	1 tsp.	1,300	2,800
Morton Salt Substitute	1 tsp.	0	2,730
No Salt	1 tsp.	5	2,500
Nu-Salt	1 tsp.	0	529

Source: University of Wisconsin Hospitals and Clinics Authority. "Health Facts for You: Guidelines for a Low Sodium Diet." March 2011. www.uhs.wisc.edu/health-topics/nutrition-fitness-and-heart-health/documents/Sodium.pdf.

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Alternative Seasonings

Table salt may seem an essential ingredient of good food, but there are others that provide alternative taste and zest to your foods. See Table 11.5.5 for an AHA list of alternative food seasonings.

Table 11.5.5: Salt Alternatives

Seasoning	Foods
Allspice	Lean ground meats, stews, tomatoes, peaches, applesauce, cranberry sauce, gravies, lean meat
Almond extract	Puddings, fruits
Caraway seeds	Lean meats, stews, soups, salads, breads, cabbage, asparagus, noodles
Chives	Salads, sauces, soups, lean-meat dishes, vegetables
Cider vinegar	Salads, vegetables, sauces
Cinnamon	Fruits, breads, pie crusts
Curry powder	Lean meats (especially lamb), veal, chicken, fish, tomatoes, tomato soup, mayonnaise,
Dill	fish sauces, soups, tomatoes, cabbages, carrots, cauliflower, green beans, cucumbers, potatoes, salads, macaroni, lamb
Garlic (not garlic salt)	Lean meats, fish, soups, salads, vegetables, tomatoes, potatoes
Ginger	Chicken, fruits

Seasoning	Foods
Lemon juice	Lean meats, fish, poultry, salads, vegetables
Mace	Hot breads, apples, fruit salads, carrots, cauliflower, squash, potatoes, veal, lamb
Mustard (dry)	lean ground meats, lean meats, chicken, fish, salads, asparagus, broccoli, Brussels sprouts, cabbage, mayonnaise, sauces
Nutmeg	Fruits, pie crust, lemonade, potatoes, chicken, fish, lean meatloaf, toast, veal, pudding
Onion powder	Lean meats, stews, vegetables, salads, soups
Paprika	Lean meats, fish, soups, salads, sauces, vegetables
Parsley	Lean meats, fish, soups, salads, sauces, vegetables
Peppermint extract	Puddings, fruits
Pimiento	Salads, vegetables, casserole dishes
Rosemary	Chicken, veal, lean meatloaf, lean beef, lean pork, sauces, stuffings, potatoes, peas, lima beans
Sage	Lean meats, stews, biscuits, tomatoes, green beans, fish, lima beans, onions, lean pork
Savory	Salads, lean pork, lean ground meats, soups, green beans, squash, tomatoes, lima beans, peas
Thyme	Lean meats (especially veal and lean pork), sauces, soups, onions, peas, tomatoes, salads
Turmeric	Lean meats, fish, sauces, rice

Source: American Heart Association. “Shaking the Salt Habit.” Updated June 6, 2012. http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Shaking-the-Salt-Habit_UCM_303241_Article.jsp.

Tools for Change

Do you think many alternative spices are too expensive? Spices are much cheaper in bulk, and many grocery stores and ethnic markets carry them in this way. For example, when purchased in bulk, cumin is, on average, only one dollar per ounce, a quantity that takes many meals to exhaust.

Chloride

Chloride is the primary anion in extracellular fluid. Chloride moves easily across membranes following the sodium and potassium gradients. In addition to passively following sodium and potassium, chloride has its own protein channels that reside in cell membranes. These protein channels are especially abundant in the gastrointestinal tract, pancreas, and lungs. Chloride is the major anion in sweat and vomit. It is the anion of stomach acid, HCl.

-

Chloride’s Role in Fluid Balance

Chloride aids in fluid balance mainly because it follows sodium in order to maintain charge neutrality. Chloride channels also play a role in regulating fluid secretion, such as pancreatic juice into the small intestine and the flow of water into mucus. Fluid secretion and mucus are important for many of life’s processes. Their importance is exemplified in the signs and symptoms of the genetic disease, cystic fibrosis.

Cystic Fibrosis

Cystic fibrosis, or CF, is one of the most prevalent inherited diseases in people of European descent. It is caused by a mutation in a protein that transports chloride ions out of the cell. CF's signs and symptoms include salty skin, poor digestion and absorption (leading to poor growth), sticky mucus accumulation in the lungs (causing increased susceptibility to respiratory infections), liver damage, and infertility.

When chloride channels do not transport chloride out of cells, the following signs and symptoms of CF become apparent:

1. **Salty skin.** Defective chloride channels in the sweat glands cause excess release of chloride, which sodium then follows into the sweat.
2. **Poor digestion and growth.** Defective chloride channels in the pancreas cause pancreatic juices to thicken. As a result of the thickening, the release of pancreatic juices is slowed and nutrient digestion is compromised.
3. **Respiratory infection.** Defective chloride channels in the lungs cause thickened mucus. The mucus then traps bacteria.
4. **Liver damage.** Defective chloride channels in the gall bladder cause thickened gallbladder secretions. The gallbladder ducts then become blocked, leading to liver damage.
5. **Infertility.** Defective chloride channels in male and female reproductive organs can result in impaired sperm transport and viscous mucus in the cervix, respectively.

Other Functions of Chloride

Chloride has several other functions in the body, most importantly in acid-base balance. Blood pH is maintained in a narrow range and the number of positively charged substances is equal to the number of negatively charged substances. Proteins, such as albumin, as well as bicarbonate ions and chloride ions, are negatively charged and aid in maintaining blood pH. Hydrochloric acid (a gastric acid composed of chlorine and hydrogen) aids in digestion and also prevents the growth of unwanted microbes in the stomach. Immune-system cells require chloride, and red blood cells use chloride anions to remove carbon dioxide from the body.

Chloride Imbalances

Low dietary intake of chloride and more often diarrhea can cause low blood levels of chloride. Symptoms typically are similar to those of hyponatremia and include weakness, nausea, and headache. Excess chloride in the blood is rare with no characteristic signs or symptoms.

Needs and Dietary Sources of Chloride

Most chloride in the diet comes from salt. (Salt is 60 percent chloride.) A teaspoon of salt equals 5.6 grams, with each teaspoon of salt containing 3.4 grams of chloride and 2.2 grams of sodium. The chloride AI for adults, set by the IOM, is 2.3 grams. Therefore just ⅔ teaspoon of table salt per day is sufficient for chloride as well as sodium. The AIs for other age groups are listed in Table 11.5.5.

Table 11.5.5: Adequate Intakes for Chloride

Age Group	g/day
Infants (0–6 months)	0.18
Infants (6–12 months)	0.57
Children (1–3 years)	1.50
Children (4–8 years)	1.90
Children (9–13 years)	2.30
Adolescents (14–18 years)	2.30
Adults (19–50 years)	2.30
Adults (51–70 years)	2.00
Adults (> 70 years)	1.80

Source: Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Other Dietary Sources of Chloride

Chloride has dietary sources other than table salt, namely as another form of salt—potassium chloride. Dietary sources of chloride are all foods containing sodium chloride, as well as tomatoes, lettuce, olives, celery, rye, whole-grain foods, and seafood. Although many salt substitutes are sodium-free, they may still contain chloride.

Bioavailability

In the small intestine, the elements of sodium chloride split into sodium cations and chloride anions. Chloride follows the sodium ion into intestinal cells passively, making chloride absorption quite efficient. When chloride exists as a potassium salt, it is also well absorbed. Other mineral salts, such as magnesium chloride, are not absorbed as well, but bioavailability still remains high.

Potassium

Potassium is a major water-soluble cation that is the most abundant positively charged ion inside of cells (intracellular). Most potassium is lost in the urine (80-90%) and the remainder is via the feces. Ninety percent of potassium exists in intracellular fluid, with about 10 percent in extracellular fluid, and only 1 percent in blood plasma. As with sodium, potassium levels in the blood are strictly regulated. The hormone aldosterone is what primarily controls potassium levels, but other hormones (such as insulin) also play a role. When potassium levels in the blood increase, the adrenal glands release aldosterone. The aldosterone acts on the collecting ducts of kidneys, where it stimulates an increase in the number of sodium-potassium pumps. Sodium is then reabsorbed and more potassium is excreted. Because potassium is required for maintaining sodium levels, and hence fluid balance, about 200 milligrams of potassium are lost from the body every day. So, potassium one of potassium's important functions is fluid and electrolyte balance.

Other Functions of Potassium in the Body

Nerve impulse involves not only sodium but also potassium. A nerve impulse moves along a nerve via the movement of sodium ions into the cell. To end the impulse, potassium ions rush out of the nerve cell, thereby decreasing the positive charge inside the nerve cell. This diminishes the stimulus. To restore the original concentrations of ions between the intracellular and extracellular fluid, the sodium-potassium pump transfers sodium ions out in exchange for potassium ions in. On completion of the restored ion concentrations, a nerve cell is now ready to receive the next impulse. Similarly, in muscle cells, potassium is involved in restoring the normal membrane potential and ending the muscle contraction. Potassium also is involved in protein synthesis, energy metabolism, and platelet function, and acts as a buffer in blood, playing a role in acid-base balance.

Imbalances of Potassium

Insufficient potassium levels in the body (**hypokalemia**) can be caused by a low dietary intake of potassium or by high sodium intakes, but more commonly it results from medications that increase water excretion, mainly diuretics. The signs and symptoms of hypokalemia are related to the functions of potassium in nerve cells and consequently skeletal and smooth muscle contraction. The signs and symptoms include muscle weakness and cramps, respiratory distress, and constipation. Severe potassium depletion can cause the heart to have abnormal contractions and can even be fatal. High levels of potassium in the blood, or **hyperkalemia**, is toxic and also affects the heart. It is a silent condition as it often displays no signs or symptoms. Extremely high levels of potassium in the blood disrupt the electrical impulses that stimulate the heart and can cause the heart to stop. Hyperkalemia is usually the result of kidney dysfunction.

Groups at risk of developing hypokalemia are individuals with renal and large intestine issues such as urine and diarrhea losses; people with uncontrolled diabetes which causes diabetic acidosis and urine losses; dehydration; prolonged diarrhea or emesis; and, certain drugs like diuretics, steroids or laxatives. These deficiencies are due to excessive loss and not a dietary deficiency.

Needs and Dietary Sources of Potassium

The IOM based their AIs for potassium on the levels associated with a decrease in blood pressure, a reduction in salt sensitivity, and a minimal risk of kidney stones. For adult male and females above the age of nineteen, the adequate intake for potassium is 4.7

grams per day. The AIs for other age groups are listed in Table 11.5.6.

Table 11.5.6: Adequate Intakes for Potassium

Age Group	g/day
Infants (0–6 months)	0.4
Infants (6–12 months)	0.7
Children (1–3 years)	3.0
Children (4–8 years)	3.8
Children (9–13 years)	4.5
Adolescents (14–18 years)	4.7
Adults (> 19 years)	4.7

Institute of Medicine. *Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate.* February 11, 2004. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx.

Food Sources for Potassium

Fruits and vegetables that contain high amounts of potassium are spinach, lettuce, broccoli, peas, tomatoes, potatoes, bananas, apples, and apricots. Whole grains and seeds, certain fish (such as salmon, cod, and flounder), and meats are also high in potassium. The Dietary Approaches to Stop Hypertension (DASH diet) emphasizes potassium-rich foods and will be discussed in greater detail in the next section.

Video 11.5.4: High Potassium Foods

This slideshow pictures foods high in potassium, with its percentage of the Recommended Daily Allowance.(click to see video)

Bioavailability

Greater than 90 percent of dietary potassium is absorbed in the small intestine. Although highly bioavailable, potassium is a very soluble mineral and easily lost during cooking and processing of foods. Fresh and frozen foods are better sources of potassium than canned.

Key Takeaways

- The maintenance of water volume between fluid compartments is achieved by keeping the concentration of all dissolved substances between the compartments the same.
- Individual solutes are at different concentrations between fluid compartments, providing a mechanism by which to control water movement.
- Sodium is the primary regulator of water balance and plays important roles in nerve transmission, muscle contraction, and nutrient absorption and reabsorption.
- Most sodium in the typical American diet comes from processed and prepared foods.
- Chloride aids in fluid balance by helping to maintain charge neutrality. Chloride channels also play a role in regulating fluid secretion, such as the flow of pancreatic juice into the small intestine and the flow of water into mucus.
- Potassium is the most abundant positively charged ion inside of cells, and similar to sodium, potassium levels in the blood are under strict regulatory control. Potassium is the exchanged cation for sodium and helps maintain fluid balance.

Discussion Starters

1. Why might high sodium intake cause depletion of potassium in the body?
2. Read the following article from *ScienceDaily* and discuss why salt is so prevalent in the diet.

   http://www.sciencedaily.com/releases/2009/03/090310152329.htm

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11.6: Consequences of Deficiency or Excess

Learning Objectives

- Summarize the following fluid and electrolyte imbalance disorders: dehydration, water intoxication, heat stroke, and hypertension.
- Describe the DASH diet and state its benefits.

As with all nutrients, having too much or too little water has health consequences. Excessive water intake can dilute the levels of critical electrolytes in the blood. Water intoxication is rare, however, when it does happen, it can be deadly. On the other hand, having too little water in the body is common. In fact, diarrhea-induced dehydration is the number-one cause of early-childhood death worldwide. In this section, we will discuss subtle changes in electrolytes that compromise health on a chronic basis.

High-Hydration Status: Water Intoxication/Hyponatremia

Water intoxication mainly affects athletes who over hydrate. Water intoxication is extremely rare, primarily because healthy kidneys are capable of excreting up to one liter of excess water per hour. Over hydration was unfortunately demonstrated in 2007 by Jennifer Strange, who drank six liters of water in three hours while competing in a “Hold Your Wee for a Wii” radio contest. Afterward, she complained of a headache, vomited, and died.

Low-Hydration Status: Dehydration

Dehydration refers to water loss from the body without adequate replacement. It can result from either water loss or electrolyte imbalance, or, most commonly, both. Dehydration can be caused by prolonged physical activity without adequate water intake, heat exposure, excessive weight loss, vomiting, diarrhea, blood loss, infectious diseases, malnutrition, electrolyte imbalances, and very high glucose levels. Physiologically, dehydration decreases blood volume. The water in cells moves into the blood to compensate for the low blood volume, and cells shrink. Signs and symptoms of dehydration include thirst, dizziness, fainting, headaches, lack of concentration, low blood pressure, fatigue, low (dark color urine) to no urine output, inability to regulate body temperature, weakness and lethargy, and, in extreme cases, loss of consciousness and death. Signs and symptoms are usually noticeable after about 2 percent of total body water is lost.

Caffeine and alcohol consumption can increase urinary output. If the output is not matched by input, then the person can become dehydrated.

Chronic dehydration is linked to higher incidences of some diseases. There is strong evidence that low-hydration status increases the risk for kidney stones and exercise-induced asthma. There is also some scientific evidence that chronic dehydration increases the risk for kidney disease, heart disease, and the development of hyperglycemia in people with diabetes. Older people often suffer from chronic dehydration as their thirst mechanism is no longer as sensitive as it used to be.



Figure 11.6.1: Older people need to guard against dehydration by taking steps to drink more, especially when exercising. © Shutterstock

Heat Stroke

Heat stroke is a life-threatening condition that occurs when the body temperature is greater than 105.1°F (40.6°C). It is the result of the body being unable to sufficiently cool itself by thermoregulatory mechanisms. Dehydration is a primary cause of heat stroke as there are not enough fluids in the body to maintain adequate sweat production, and cooling of the body is impaired. Signs and symptoms are dry skin (absence of sweating), dizziness, trouble breathing, rapid pulse, confusion, agitation, seizures, coma, and possibly death. Dehydration may be preceded by heat exhaustion, which is characterized by heavy sweating, rapid breathing, and fast pulse. The elderly, infants, and athletes are the most at risk for heat stroke.

Hypertension

Blood pressure is the force of moving blood against arterial walls. It is reported as the systolic pressure over the diastolic pressure, which is the greatest and least pressure on an artery that occurs with each heartbeat. The force of blood against an artery is measured with a device called a sphygmomanometer. The results are recorded in millimeters of mercury, or mmHg. A desirable blood pressure ranges between 90/60 and 120/80 mmHg. Hypertension is the scientific term for high blood pressure and defined as a sustained blood pressure of 140/90 mmHg or greater. Hypertension is a risk factor for cardiovascular disease, and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke. The Centers for Disease Control and Prevention (CDC) reported that in 2007–2008 approximately 33 percent of Americans were hypertensive.Centers for Disease Control and Prevention. “FastStats—Hypertension.” Accessed October 2, 2011. http://www.cdc.gov/nchs/fastats/hyprtens.htm. The percentage of people with hypertension increases to over 60 percent in people over the age of sixty.

Risk factors for hypertension include obesity, cardiovascular disease, age, heredity or genetics, race, BMI over 30, type 2 diabetes, and salt sensitivity. About 30-50% of people with hypertension are sensitive to salt.



Figure 11.6.2: *Blood pressure is measured with a cuff, also known as a sphygmomanometer, that measures blood pressure in millimeters of mercury, or mmHg. © Shutterstock*

There has been much debate about the role sodium plays in hypertension. In the latter 1980s and early 1990s the largest epidemiological study evaluating the relationship of dietary sodium intake with blood pressure, called INTERSALT, was completed and then went through further analyses.Intersalt Cooperative Research Group. “Intersalt: An International Study of Electrolyte Excretion and Blood Pressure. Results for 24 Hour Urinary Sodium and Potassium Excretion.” *BMJ* 297, no. 6644 (1988): 319–28. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1834069/.’ Elliott, P. et al. “Intersalt Revisited: Further Analyses of 24 Hour Sodium Excretion and Blood Pressure within and across Populations.” *BMJ* 312, no. 7041 (1996): 1249–53. http://www.ncbi.nlm.nih.gov/pubmed/8634612. More than ten thousand men and women from thirty-two countries participated in the study. The study concluded that a higher sodium intake is linked to an increase in blood pressure. A more recent study, involving over twelve thousand US citizens, concluded that a higher sodium-to-potassium intake is linked to higher cardiovascular mortality and all-causes mortality.Yang Q. et al. “Sodium and Potassium Intake and Mortality among US Adults: Prospective Data from the Third National Health and Nutrition Examination Survey.” *Arch Intern Med* 171, no. 13 (2011): 1183–91. doi:

10.1001/archinternmed.2011.257. The DASH-Sodium trial was a clinical trial which evaluated the effects of a specified eating plan with or without reduced sodium intake. The DASH diet is an eating plan that is low in saturated fat, cholesterol, and total fat. Fruits, vegetables, low-fat dairy foods, whole-grain foods, fish, poultry, and nuts are emphasized while red meats, sweets, and sugar-containing beverages are mostly avoided. (To find out more about the DASH eating plan see "Interactive 11.6.1. In this study, people on the low-sodium (1500 milligrams per day) DASH diet had mean systolic blood pressures that were 7.1 mmHg lower than people without hypertension not on the DASH diet. The effect on blood pressure was greatest in participants with hypertension at the beginning of the study who followed the DASH diet. Their systolic blood pressures were, on average, 11.5 mmHg lower than participants with hypertension on the control diet.Sacks, F. M. et al. “Effects on Blood Pressure of Reduced Dietary Sodium and the Dietary Approaches to Stop Hypertension (DASH) Diet.” *N Engl J Med* 344, no. 1 (2001): 3–10. http://www.ncbi.nlm.nih.gov/pubmed/11136953. Following the DASH diet not only reduces sodium intake, but also increases potassium, calcium, and magnesium intake. All of these electrolytes have a positive effect on blood pressure, although the mechanisms by which they reduce blood pressure are largely unknown.

While some other large studies have demonstrated little or no significant relationship between sodium intake and blood pressure, the weight of scientific evidence demonstrating low-sodium diets as effective preventative and treatment measures against hypertension led the US government to pass a focus on salt within the Consolidated Appropriations Act of 2008. A part of this act tasked the CDC, under guidance from the IOM, to make recommendations for Americans to reduce dietary sodium intake. This task is ongoing and involves “studying government approaches (regulatory and legislative actions), food supply approaches (new product development, food reformulation), and information/education strategies for the public and professionals.”Jane E. Henney, Christine L. Taylor, and Caitlin S. Boon, eds., *Strategies to Reduce Sodium Intake in the United States*, by Committee on Strategies to Reduce Sodium Intake, Institute of Medicine (Washington, D.C.: National Academies Press, 2010): 19. http://www.nap.edu/openbook.php?record_id=12818&page= 19#p2001bcf59960019001.

Dietary recommendations to lower blood pressure are as follows. The DASH diet and MyPlate are two diets that meet these recommendations.

- decrease sodium intake
- exercise and lose weight if overweight
- limit consumption of alcohol (one to two drinks per day)
- increase your intake of calcium, potassium, magnesium and vitamin C

Interactive

The National Heart, Lung, and Blood Institute has prepared an informative fact sheet on the DASH diet.

http://www.nhlbi.nih.gov/health/public/heart/hbp/dash/new_dash.pdf.

Use the food group charts to help design a daily menu that follows the DASH eating plan.

Salt Sensitivity

High dietary intake of sodium is one risk factor for hypertension and contributes to high blood pressure in many people. However, studies have shown that not everyone’s blood pressure is affected by lowering sodium intake. About 10 to 20 percent of the population is considered to be salt-sensitive, meaning their blood pressure is affected by salt intake. Genetics, race, gender, weight, and physical activity level are determinants of salt sensitivity. African Americans, women, and overweight individuals are more salt-sensitive than others. Also, if hypertension runs in a person’s family, that person is more likely to be salt-sensitive. Because reducing dietary salt intake will not work for everyone with hypertension or a risk for developing the condition, there are many opponents of reducing dietary salt intake at the national level. Among such opponents is the Salt Institute, a nonprofit trade organization that states, “No evidence demonstrates that current salt intake levels lead to worse health outcomes such as more heart attacks or higher cardiovascular mortality.”The Salt Institute. “Salt and Health.” © 2011 Salt Institute. Accessed October 2, 2011. www.saltinstitute.org/Issues-in-focus/Food-salt-health.

Key Takeaways

- Dehydration decreases blood volume. Dehydration is a primary cause of heat stroke.
- Chronic dehydration is linked to higher incidences of some diseases.
- Hypertension is a risk factor for cardiovascular disease and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke. Many large studies suggest that high sodium intake is linked to an increase in blood

pressure.

- The Dietary Approaches to Stop Hypertension (DASH)-Sodium trial concluded that sodium intake is effective in decreasing blood pressure.
- About 10 to 20 percent of the population is considered to be salt-sensitive. Genetics, race, gender, body weight and physical activity level are determinants of salt sensitivity.

Discussion Starter

1. Does salt restriction need to be a public policy? Compare it to having a public policy on water intake to prevent dehydration in children during school-sponsored sports events.

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11.7: Water Concerns

Learning Objectives

- List sources of fluid intake.
- Learn to examine beverage labels carefully and determine nutritional adequacy.
- Describe the major shifts in beverage consumption in the United States and identify the potentially related health problems.

At this point, you have learned how critical water is to support human life, how it is distributed and moved in the body, how fluid balance and composition is maintained, and the recommended amount of fluids a person should consume daily. In America, you have a choice of thousands of different beverages. Which should you choose to receive the most health benefit and achieve your recommended fluid intake?



Figure 11.7.1: Out of the thousands of beverage choices, which ones are the best dietary choice?

Reading the Label

Most beverages marketed in the United States have a Nutrition Facts panel and ingredients list, but some, such as coffee (for home consumption), beer, and wine, do not. As with foods, beverages that are nutrient-dense are the better choices, with the exception of plain water, which contains few to no other nutrients. Beverages do not make you full; they satiate your thirst. Therefore, the fewer calories in a beverage the better it is for avoiding weight gain. For an estimate of kilocalories in various beverages (Table 11.7.1).

Table 11.7.1 : Calories in Various Beverages

Beverage	*Serving Size (oz)*	*Kilocalories*
Soda	12.0	124–189
Diet soda	12.0	0–7
Bottled sweet tea	12.0	129–143
Brewed tea (unsweetened)	12.0	4
Orange juice (unsweetened)	12.0	157–168
Apple juice (unsweetened)	12.0	169–175
Tomato/vegetable juice	12.0	80
Cranberry juice cocktail	12.0	205
Whole milk	12.0	220
Nonfat milk	12.0	125
Soy milk	12.0	147–191
Coffee, black	12.0	0–4
Coffee, with cream	12.0	39–43

Beverage	*Serving Size (oz)*	*Kilocalories*
Caffe latte, whole milk	12.0	200
Caffe latte, nonfat milk	12.0	120
Sports drink	12.0	94
Energy drink	12.0	160
Beer	12.0	153
Red wine	5.0	125
White wine	5.0	122
Hard liquor (80 proof)	1.5	96

Source: WebMD.com. “Calories in Drinks and Popular Beverages.” Healthy Weight Neighborhood. © 2012 WebMD, LLC. All rights reserved. http://www.webmd.com/community/healthy-weight-8/calorie-chart.

Beverage Consumption in the United States

According to the Beverage Marketing Corporation, in the United States in 2010 Americans consumed 29,325 millions of gallons of refreshment beverages including soft drinks, coffee, tea, sports drinks, energy drinks, fruit drinks, and bottled water.Beverage Marketing Corporation. “US Liquid Refreshment Beverage Market Increased by 1.2% in 2010, Beverage Marketing Corporation Reports.” Accessed March 17, 2011. http://www.beveragemarketing.com/?section=pressreleases. As in the past, carbonated soft drinks remained the largest category of consumed beverages. In recent decades total caloric consumption has increased in the United States and is largely attributed to increased consumption of snacks and caloric beverages. People between the ages of nineteen and thirty-nine obtain 10 percent of their total energy intake from soft drinks.The Beverage Panel, University of North Carolina, Chapel Hill. “Beverage Intake in the United States.” Accessed October 2, 2011. http://www.cpc.unc.edu/projects/beverage. (Figure 11.7.2). In all age groups, the consumption of total beverages provides, on average, 21 percent of daily caloric intake. This is 7 percent higher than the IOM acceptable caloric intake from beverages. Moreover, the high intakes of soft drinks and sugary beverages displace the intake of more nutrient-dense beverages, such as low-fat milk.

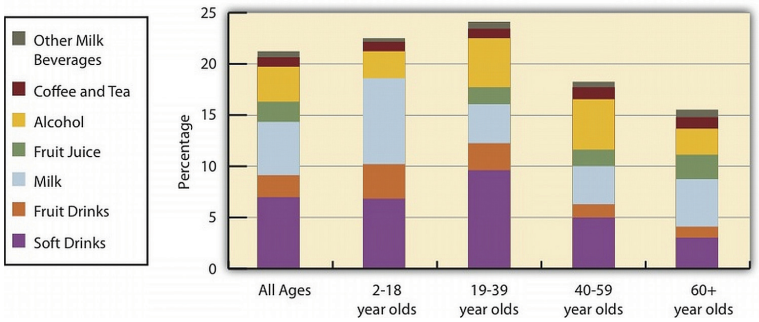


Figure 11.7.2: Percentage of Daily Caloric Intake from Beverage Groups. Source: University of North Carolina, Chapel Hill. US Beverage Guidance Council. “You Are What You Drink, and We Are Drinking Far Too Many Calories from Beverages!” Accessed November 6, 2012. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel/.

Scientific studies have demonstrated that while all beverages are capable of satisfying thirst they do not make you feel full, or satiated. This means that drinking a calorie-containing beverage with a meal only provides more calories, as it won’t be offset by eating less food. The Beverage Panel of the University of North Carolina, Chapel Hill has taken on the challenge of scientifically evaluating the health benefits and risks of beverage groups and providing recommendations for beverage groups (Table 7.7.2). In regards to soft drinks and fruit drinks, The Beverage Panel states that they increase energy intake, are not satiating, and that there is little if any reduction in other foods to compensate for the excess calories. All of these factors contribute to increased energy intake and obesity.Beverage Marketing Corporation. “US Liquid Refreshment Beverage Market Increased by 1.2% in 2010, Beverage Marketing Corporation Reports.” Accessed March 17, 2011. http://www.beveragemarketing.com/?section=pressreleases. The Beverage Panel recommends an even lower intake of calories from beverages than IOM—10 percent or less of total caloric intake.

Table 11.07.2: Recommendations of the Beverage Panel

Beverage	Servings per day*
Water	≥ 4 (women), ≥ 6 (men)
Unsweetened coffee and tea	≤ 8 for tea, ≤ 4 for coffee
Nonfat and low-fat milk; fortified soy drinks	≤ 2
Diet beverages with sugar substitutes	≤ 4
100 percent fruit juices, whole milk, sports drinks	≤ 1
Calorie-rich beverages without nutrients	≤ 1, less if trying to lose weight
*One serving is eight ounces.	

Source: University of North Carolina, Chapel Hill. US Beverage Guidance Council. “Beverage Panel Recommendations and Analysis.” Accessed November 6, 2012. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel.

Sources of Drinking Water

The Beverage Panel recommends that women drink at least 32 ounces and men drink at least 48 ounces of water daily. In 1974, the US federal government enacted The Safe Drinking Water Act with the intention of providing the American public with safe drinking water. This act requires the Environmental Protection Agency (EPA) to set water-quality standards and assure that the 150,000-plus public water systems in the country adhere to the standards. About 15 percent of Americans obtain drinking water from private wells, which are not subject to EPA standards.

Interactive

For more information on the health risks of and the maintenance of private wells visit the EPA website.

http://water.epa.gov/drink/info/well/index.cfm

Producing water safe for drinking involves some or all of the following processes: screening out large objects, removing excess calcium carbonate from hard water sources, flocculation, which adds a precipitating agent to remove solid particles, clarification, sedimentation, filtration, and disinfection These processes aim to remove unhealthy substances and produce high-quality, colorless, odorless, good-tasting water (watch video 11.7.1).



***Video 11.7.1**: The Water Treatment Process. Here is a brief video on how drinking water is treated (click to see video).*

Most drinking water is disinfected by the process of chlorination, which involves adding chlorine compounds to the water. Chlorination is cheap and effective at killing bacteria. However, it is less effective at removing protozoa, such as *Giardia lamblia*. Chlorine-resistant protozoa and viruses are instead removed by extensive filtration methods. In the decades immediately following the implementation of water chlorination and disinfection methods in this country, water-borne illnesses, such as cholera and

typhoid fever, essentially disappeared in the United States (Figure 7.7.2). In fact, the treatment of drinking water is touted as one of the top public-health achievements of the last century.

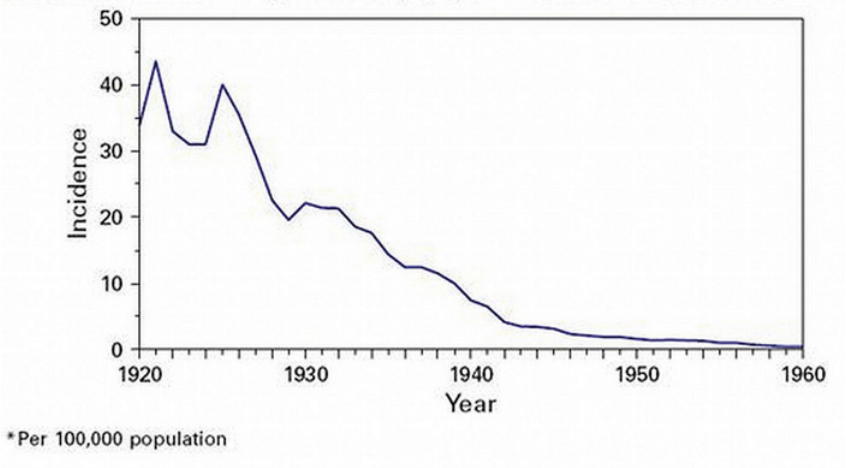


Figure 11.7.3: *Deadly water-borne illnesses decreased to almost nonexistent levels in the United States after the implementation of water disinfection methods. Source: Image credit Robert Tauxe. Centers for Disease Control and Prevention. "Drinking Water Week." Reviewed May 17, 2012. http://www.cdc.gov/features/drinkingwater/graph.html.*

Chlorine reaction with inadequately filtered water can result in the formation of potentially harmful substances. Some of these chlorinated compounds, when present at extremely high levels, have been shown to cause cancer in studies conducted in rodents. In addition to many other contaminants, the EPA has set maximum contaminant levels (legal threshold limits) for these chlorinated compounds in water, in order to guard against disease risk. The oversight of public water systems in this country is not perfect and water-borne illnesses are significantly underreported; however, there are far fewer cases of water-borne illnesses than those attributed to foodborne illnesses that have occurred in the recent past.

Interactive

For a full list of contaminants regulated by the EPA view the tables on the EPA website.

http://water.epa.gov/drink/contaminants/index.cfm

Hard versus Soft Water

The characteristics of hard water are attributed to higher concentration of calcium and magnesium salts. Hard water is prevalent in the mountain and central time zones and in the Midwestern United States. Hard water is characterized by a calcium carbonate concentration of at least 60 milligrams per liter. Higher concentrations of cations in hard water make it difficult to get soap to lather and clean effectively. Also, the cations precipitate as salts in pipes, dishes, and industrial equipment and can reduce the palatability of drinking water. The average dietary contribution of calcium and magnesium from water ranges between 5 and 20 percent.World Health Organization. "Hardness in Drinking Water." © 2011. http://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf The World Health Organization states that there is no convincing evidence that consumption of hard water adversely affects human health.World Health Organization. "Hardness in Drinking Water." © 2011. http://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf On the contrary, there is some evidence from observational studies that consuming hard water is inversely associated with the incidence of some chronic diseases, including cardiovascular disease and some cancers, although the studies have not been consistent and often have multiple confounding variables.

Soft water is produced primarily by running water through a resin system which exchanges sodium cations for calcium and magnesium ions. Treating exceptionally hard waters can significantly increase the sodium concentration in drinking water. The practical benefits of soft water are that soap scum no longer makes dishes and bathrooms dingy, clothes are softer, and there is less of a toll on household and industrial equipment. On the other hand, the increased sodium in soft water can make it taste worse and potentially exacerbate health problems such as hypertension, especially in salt-sensitive populations. Soft water can be treated by a

process called “reverse osmosis,” which removes the sodium ions. These filtration systems can be purchased for home use, although their cost is a bit high.

Is Bottled Water a Better than Tap Water?

Bottled water is not regulated by the EPA but by FDA. For bottled water, the FDA adheres to the same quality standards as those set by the EPA for tap water. Therefore, the contaminant levels set by the EPA for tap water are not different for bottled water; although there is much less testing, monitoring, and oversight of bottled water in comparison to tap water. Similar to tap water the source and treatment of bottled water determines its taste and quality. Depending on where you live, tap water can be a dietary source of minerals (such as calcium and magnesium), but remember that food rather than water serves as a more prominent dietary source of these minerals.

Distilled and purified bottled waters have had all minerals removed during processing, but not all bottled waters have had minerals removed. Mineral waters, sparkling waters, and Artesian waters are examples of bottled waters that contain some minerals, but they are more expensive. Tap water in the United States costs, on average, much less than one cent per gallon, while bottled water is upwards of three dollars per gallon. Moreover, bottled water uses more resources and produces more waste in comparison to tap water. Iowa State University reports that in the United States alone, the making of plastic bottles for bottled water consumption uses more than 1.5 million barrels of oil every year, which is more than the fuel required for one hundred thousand cars.Iowa State University. “Bottled Water, Know the Facts.” Accessed October 2, 2011. http://www.extension.iastate.edu/publications/pm1813.pdf.



Figure 11.7.4: The consumption of bottled water in the United States creates a mound of plastic waste. © Shutterstock

See Table 11.07.3 for a list of the definitions of different types of marketed bottled waters. Soda, seltzer, and tonic waters are not considered bottled waters and are classified as soft drinks by the FDA. Recently, flavored and nutrient-added water beverages have arrived on the market and are regulated by the FDA in accordance with the regulation of bottled waters.

Table 11.07.3: Bottled Water Labels and Corresponding Meanings

Label	Meaning
Artesian	Water from a confined aquifer
Mineral	Water containing > 250 ppm total dissolved solids; from protected underground water source (no minerals are added)
Purified	Water treated by distillation, deionization, reverse osmosis or other processes*
Sterile	Meets the definition of purified water*
Spring	Water derived from an underground formation from which water flows naturally to the surface of the earth
*Meets the definition of “purified water” in the United States. Pharmacopeia, 23d Revision, Jan. 1, 1995. It may also be called “demineralized water” or “deionized water.”	
ppm = parts per million	

Label	Meaning
Well	Water from a hole-bored, drilled, or otherwise constructed in the ground which taps the water of an aquifer
Sparkling	Water that replaces (by treatment) natural (contained within source) carbon dioxide levels
*Meets the definition of “purified water” in the United States. Pharmacopeia, 23d Revision, Jan. 1, 1995. It may also be called “demineralized water” or “deionized water.”	
ppm = parts per million	

Source: US Food and Drug Administration. “Bottled Water Regulation and the FDA.” Ask the Regulators. February/March 2002. www.fda.gov/Food/FoodSafety/Product-SpecificInformation/BottledWaterCarbonatedSoftDrinks/ucm077079.htm.

What Is Bisphenol A and Is It a Health Hazard?

Bisphenol A (BPA) is a chemical added to plastics, mostly polycarbonate (which is used to make bottled water containers), and to epoxy resins (which are used to line metal-based containers, such as those used for packaging infant formulas). It has been utilized for these purposes and many others since the 1940s. Most studies evaluating the toxicity of BPA demonstrate it does not cause adverse health effects to humans at the levels it exists in for beverage and food containers. However, in January of 2010, the FDA issued an update on BPA uses in the food industry.US Food and Drug Administration. “Update on Bisphenol A (BPA) for Use in Food Contact Applications.” Last updated March 30, 2012. www.fda.gov/NewsEvents/PublicHealthFocus/ucm197739.htm. This update reports that the FDA, along with the IOM and the National Toxicology Program, “have some concern about the potential effects of BPA on the brain, behavior, and prostate gland in fetuses, infants, and young children.”US Food and Drug Administration. “Update on Bisphenol A (BPA) for Use in Food Contact Applications.” Last updated March 30, 2012. To address these potential health concerns studies are currently being conducted to further evaluate the risk of adverse health effects associated with exposure to low levels of BPA. In the interim, the FDA is taking steps to reduce human exposure to BPA. Many bottled water companies have switched to “BPA-free” plastic containers.

Tools for Change

Make a more sustainable choice and enjoy a glass of water from the tap right in your home.

Save some money, reduce your exposure to BPA, and be more sustainable in your water consumption by drinking more tap water than bottled water. If your tap water has a bad smell or taste, purchase a home water filter. If you still prefer bottled water, do not buy purified water. Also, buy larger volumes of bottled water with less packaging and use a reusable bottle for drinking, or better yet try a water glass from the kitchen cupboard. If you have questions about the safety of your tap water, visit the website of the municipality in which you live. They are required by law to provide this information to the public.

Key Takeaways

- Beverages do not make you full rather, they satiate your thirst. Therefore, the fewer calories in a beverage, the better it is for avoiding weight gain.
- In all age groups, the consumption of total beverages provides, on average, 21 percent of daily caloric intake. This is 7 percent higher than the IOM acceptable caloric intake from beverages and 11 percent higher than that recommended by The Beverage Panel.
- In 1974, the US federal government enacted The Safe Drinking Water Act in order to help provide the American public with safe drinking water.
- In the decades immediately following the implementation of water chlorination and disinfection methods, water-borne illnesses, such as cholera and typhoid fever, essentially disappeared in the United States. In fact, the treatment of drinking water is touted as one of the top public-health achievements of the last century.
- There is some evidence from observational studies that consuming hard water is inversely associated with the incidence of some chronic diseases, including cardiovascular disease and some cancers.
- Bottled water is not regulated by the EPA but by the FDA. The contaminant levels set by the EPA for tap water are not different for bottled water, but there is much less testing, monitoring, and oversight of bottled water in comparison to tap water.

Discussion Starters

1. What is your favorite bottled water? Look up its source and treatment and compare your information with others in your class.

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11.E: Water, Electrolytes, Acid-Base Balance (Exercises)

It's Your Turn

1. Make a flow chart of the physiological events that trigger thirst.
2. Calculate your sodium intake in a day. Is it lower, average, or higher than the recommended intake?
3. Tear the labels off of, or bring in the whole can or bottle of, your favorite beverages. Make a chart of the fluid amount, calories, and nutrients in each beverage.
4. Determine how much caffeine you consume each day and its sources (use Table 7.12 to help you). Then, rank your consumption levels based on the guidelines provided in this chapter.

Apply It

1. Make a list of ten things you do that use water and then another of ten things the body does with water.
2. Calculate your daily sodium intake for a week. Is your daily intake lower, average, or higher than the recommended intake? How does it vary during the week?
3. Perform an experiment in class by conducting a taste-test of tap water and bottled waters. Make a chart of the results.

Expand Your Knowledge

1. Diagram two physiological mechanisms that regulate water output.
2. Read this article and summarize in a paragraph if it is or is not the time to "end the war on salt." (http://www.scientificamerican.com/article.cfm?id=its-time-to-end-the-war-on-salt). Can you find a reference that disputes the conclusions of this article?
3. Visit the website of The Beverage Panel and review how they used the knowledge of health and nutrition to set recommendations for particular beverages (http://www.cpc.unc.edu/projects/beverage/panel_recommendations).

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CHAPTER OVERVIEW

12: Maternal, Infant, Childhood, and Adolescent Nutrition

This chapter is the first of two that exploring nutrition through the life cycle and it looks at pregnancy through the toddler years. Topics include pregnancy, breastfeeding, introducing solid foods, and nutrition during the toddler years.

12.1: Chapter Introduction
12.2: The Human Life Cycle
12.3: Pregnancy and Nutrition
12.4: Infancy and Nutrition
12.5: Nutrition in the Toddler Years
12.6: Childhood and Nutrition
12.7: Puberty and Nutrition
12.8: Older Adolescence and Nutrition
12.E: Exercises

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12.1: Chapter Introduction

Big Idea

Breastfeeding promotion and support greatly influences infant health.



Figure 12.1.1: The choice to breastfeed is one that all new mothers face. Support from family members, friends, employers, and others can greatly help with both the decision-making process during pregnancy and the practice of breastfeeding after the baby's birth. (public domain; Yves Picq http://veton.picq.fr)

The World Health Organization (WHO) recommends that infants should be given only breast milk for the first six months of life. Exclusive breastfeeding is one of the best ways a mother can support the growth and protect the health of her infant child. Breast milk contains all of the nutrients that a newborn requires and gives a child the best start to a healthy life. Many women want to breastfeed their babies. Unfortunately, a mother's intention alone may not be enough to make this practice possible. Around the world, less than 40 percent of infants under the age of six months are breastfed exclusively.World Health Organization. "10 Facts on Breastfeeding." Accessed February 21, 2012. http://www.who.int/features/factfiles/breastfeeding/en/. In the United States, about 75 percent of babies start out being breastfed. Yet by the age of six months, when solid foods should begin to be introduced into a child's diet along with breast milk, only 15 percent of infants in the United States were still breastfed exclusively, according to the Centers for Disease Control and Prevention (CDC).Centers for Disease Control and Prevention. "Breastfeeding: Promotion and Support." Last updated August 2, 2011. http://www.cdc.gov/breastfeeding/promotion/index.htm. However, the approval and assistance of family members, friends, employers, health-care providers, and policymakers can make an enormous difference and provide the needed promotion and support for mothers who wish to breastfeed their children.

Education about breastfeeding typically begins with health-care providers. During prenatal care and often soon after a woman has given birth, doctors, nurses, and other clinicians can explain the benefits of breastfeeding and describe the proper technique. Nearly all births in the United States and Canada occur in hospital settings, and hospital practices in labor, delivery, postpartum care, and discharge planning can inform and support women who want to breastfeed. Once a new mother has left the hospital for home, she needs access to a trained individual who can provide consistent information. International Board Certified Lactation Consultants (IBCLCs) are health-care professionals (often a registered nurse or registered dietitian) certified in breastfeeding management that works with new mothers to solve problems and educate families about the benefits of this practice. Research shows that breastfeeding rates are higher among women who had infants in hospitals that make IBCLCs available to new mothers, rather than those who gave birth in institutions without these professionals on staff.US Department of Health and Human Services, Office of the Surgeon General. "Executive Summary: The Surgeon General's Call to Action to Support Breastfeeding." January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf. In addition, spouses, partners, and other family members can play critical roles in helping a pregnant woman make the decision to breastfeed and assisting with feeding after the baby is born.

Employment can also factor into a woman's decision to breastfeed or her ability to maintain the practice. Employed mothers have been less likely to initiate breastfeeding and tend to breastfeed for a shorter period of time than new mothers who are not employed or who have lengthy maternity leaves. In 2010 in the United States, the passage of the Affordable Care Act (ACA) called for

employers to provide accommodations within the workplace for new mothers to pump breast milk. This law requires a private and clean space within the workplace, other than a restroom, along with adequate break time for a woman to express milk.US Department of Health and Human Services, Office of the Surgeon General. “Executive Summary: The Surgeon General’s Call to Action to Support Breastfeeding.” January 20, 2011. http://www.surgeongeneral.gov/topics/breastfeeding/executivesummary.pdf.

Members of a community can also promote and support breastfeeding. New mothers can join peer counseling groups or turn to other women within their community who have previous experience with breastfeeding. In addition, community-based programs can provide education and support. The US Department of Agriculture’s Women, Infants, and Children program provides information on breastfeeding for low-income families. Launched in 2004, the Loving Support program combines peer counseling with breastfeeding promotion efforts to increase duration rates across the United States. La Leche League is an international program that provides mother-to-mother support, encouragement, and education about breastfeeding for women around the world.

You Decide

How can you help to promote and support breastfeeding practices in your community?

Although breastfeeding should be recommended and encouraged for almost all new mothers, it is important to remember that the decision to breastfeed is a personal choice and women should not be made to feel guilty if they cannot or choose not, to breastfeed their infants. In some rare cases, a woman is unable to breastfeed or it is not in the baby’s best interest.

Nutritional choices that parents make, such as the decision to breastfeed or bottle-feed, not only affect early childhood development, but also a child’s health and wellness later in life. Therefore, it is imperative to promote and support the best practices for the well-being of infants and mothers alike. Throughout this chapter, we will examine how dietary choices—from the daily caloric intake for pregnant women to serving sizes for toddlers—impact health and wellness during pregnancy and the early childhood years.

Video 12.1.1: Breastfeeding and Working

This video from the Colorado Breastfeeding Coalition focuses on the importance of making workplace accommodations for employees who are breastfeeding their infants. (click to see video)

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12.2: The Human Life Cycle

Learning Objectives

- Identify and define the different stages of the human lifecycle.
- Explain how the human body develops from infancy through the toddler years.

According to the *American Journal of Clinical Nutrition*, the human life span, or the maximum length of time possible for human life, is 130 years.Ordovas, J. M. “Living Well to 100: Nutrition, Genetics, Inflammation.” *Am J Clin Nutr* 83 (2006): 401S490S. Human bodies change significantly over time, and food is the fuel for those changes. People of all ages need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to sustain life and health. However, the amounts of nutrients needed differ. Throughout the human life cycle, the body constantly changes and goes through different periods known as stages. The major stages of the human lifecycle are defined as follows:

- **Pregnancy.** The development of a zygote into an embryo and then into a fetus in preparation for childbirth.
- **Infancy.** The earliest part of childhood. It is the period from birth through age one.
- **Toddler years.** Occur during ages two and three and are the end of early childhood.
- **Childhood.** Takes place from ages four to eight.
- **Puberty.** The period from ages nine to thirteen, which is the beginning of adolescence.
- **Older adolescence.** The stage that takes place between ages fourteen and eighteen.
- **Adulthood.** The period from adolescence to the end of life and begins at age nineteen.
- **Middle age.** The period of adulthood that stretches from age thirty-one to fifty.
- **Senior years, or old age.** Extend from age fifty-one until the end of life.

Changes during Pregnancy

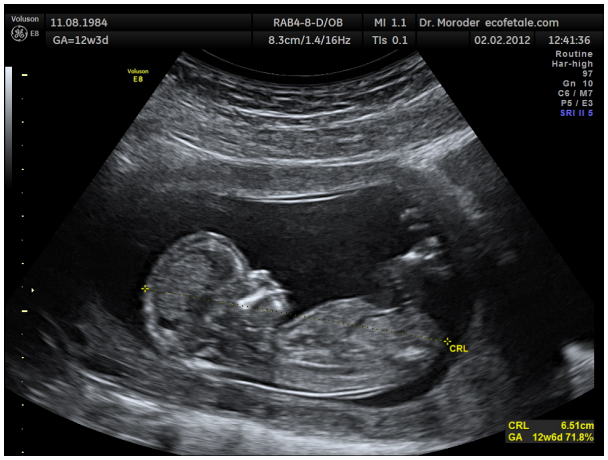


Figure 12.2.1: This ultrasound image shows a four-month-old fetus. Ultrasound image of a fetus in the womb, viewed at 12 weeks of pregnancy (bidimensional-scan). ***Wolfgang Moroder***.

In this chapter, we will focus on the human life cycle from the prenatal period into early childhood. We begin with pregnancy, a developmental marathon that lasts about forty weeks. It begins with the first trimester (weeks one to week twelve), extends into the second trimester (weeks thirteen to week twenty-seven), and ends with the third trimester (week twenty-eight to birth). At conception, a sperm cell fertilizes an egg cell, creating a zygote. The zygote rapidly divides into multiple cells and within two weeks becomes an embryo and implants itself in the uterine wall, where it develops into a fetus. Some of the major changes that occur include the branching of nerve cells to form primitive neural pathways at eight weeks. At the twenty-week mark, physicians typically perform an ultrasound to acquire information about the fetus and check for abnormalities. By this time, it is possible to know the sex of the baby. At twenty-eight weeks, the unborn baby begins to add body fat in preparation for life outside of the womb.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 81–82. Throughout this entire process, a pregnant woman’s nutritional choices affect not only fetal development but also her own health and the future health of her newborn.

Changes during Infancy

A number of major physiological changes occur during infancy. The trunk of the body grows faster than the arms and legs, while the head becomes less prominent in comparison to the limbs. Organs and organ systems grow at a rapid rate. Also during this period, countless new synapses form to link brain neurons. Two soft spots on the baby's skull, known as fontanels, allow the skull to accommodate rapid brain growth. The posterior fontanel closes first, by the age of eight weeks. The anterior fontanel closes about a year later, at eighteen months on average. Developmental milestones include sitting up without support, learning to walk, teething, and vocalizing among many, many others. All of these changes require adequate nutrition to ensure development at the appropriate rate.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 248.

Changes during the Toddler Years

Major physiological changes continue into the toddler years. Unlike in infancy, the limbs grow much faster than the trunk, which gives the body a more proportionate appearance. By the end of the third year, a toddler is taller and more slender than an infant, with a more erect posture. As the child grows, bone density increases and bone tissue gradually replaces cartilage. This process known as ossification is not completed until puberty.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F.A. Davis Company, 2003), 108. Developmental milestones include running, drawing, toilet training, and self-feeding. How a toddler acts, speaks, learns, and eats offers important clues about their development.



Figure 12.2.2: *As children mature, their friends can exert a strong influence on their nutritional choices. (CC-BY-SA 2.0; USDA)*

Changes during Childhood

Early childhood encompasses infancy and the toddler years, from birth through age three. The remaining part of childhood is the period from ages four through eight and is the time when children enter school. A number of critical physiological and emotional changes take place during this life stage. For example, a child's limbs lengthen steadily, while the growth of other body parts begins to slow down. By age ten, the skull and the brain have grown to near-adult size.Beverly McMillan, *Human Body: A Visual Guide* (Sydney, Australia: Weldon Owen, 2006), 258. Emotional and psychological changes occur as well. Children's attitudes and opinions about food deepen. They not only begin taking their cues about food preferences from family members, but also from peers and the larger culture. All of these factors should impact the nutritional choices parents make for their children. This time in a child's life provides an opportunity for parents and other caregivers to reinforce good eating habits and to introduce new foods into the diet while remaining mindful of a child's preferences. Parents should also serve as role models for their children, who will often mimic their behavior and eating habits.

Changes during Puberty

The onset of puberty is the beginning of adolescence and is the bridge between the childhood years and young adulthood. Medically, adolescence is defined as the period between ages eleven and fourteen for girls and between twelve to fifteen for boys. For the purpose of discussing the influence of nutritional choices during the life cycle, this text will follow the *2010 Dietary Guidelines for Americans*, which divides the adolescent years into two stages: ages nine to thirteen, or puberty, and ages fourteen to eighteen, or late adolescence. We will discuss puberty first. Some of the important physiological changes that take place during this stage include the development of primary sex characteristics, or the reproductive organs, along with the onset of menstruation in females. This life stage is also characterized by the appearance of secondary sex characteristics, such as the growth of facial and body hair, the development of breasts in girls, and the deepening of the voice in boys. Other physical changes include rapid growth and alterations in body proportions.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 170–71. All of these changes, as well as the accompanying mental and emotional adjustments, should be supported with sound nutrition.

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Changes in Late Adolescence

The *Dietary Guidelines* defines the next phase of the human life-cycle, late adolescence, as the period from ages fourteen to eighteen. After puberty, the rate of physical growth slows down. Girls stop growing taller around age sixteen, while boys continue to grow taller until ages eighteen to twenty. One of the psychological and emotional changes that take place during this life stage includes the desire for independence as adolescents develop individual identities apart from their families.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 171–76. As teenagers make more and more of their dietary decisions, parents or other caregivers and authority figures should guide them toward appropriate, nutritious choices.

Key Takeaways

The human body constantly develops and changes throughout the human life cycle, and food provides the fuel for those changes. The major stages of the human lifecycle include pregnancy, infancy, the toddler years, childhood, puberty, older adolescence, adulthood, middle age, and the senior years. Proper nutrition and exercise ensure health and wellness at each stage of the human lifecycle.

Discussion Starter

1. In preparation for this chapter and the next, predict how you think nutrient needs might differ at the beginning of life compared to the end of life. Then, after reading this chapter and the one that follows, discuss if your predictions were correct or incorrect.

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12.3: Pregnancy and Nutrition

Learning Objectives

- Summarize prenatal nutritional requirements and dietary recommendations.
- Discuss the most important nutritional concerns during pregnancy.
- Explore the relationship between fetal development and nutritional choices.

It is crucial to consume healthy foods at every phase of life, beginning in the womb. Good nutrition is vital for any pregnancy and not only helps an expectant mother remain healthy but also impacts the development of the fetus and ensures that the baby thrives in infancy and beyond. During pregnancy, a woman's needs increase for certain nutrients more than for others. If these nutritional needs are not met, infants could suffer from low birth weight (a birth weight less than 5.5 pounds, which is 2,500 grams), among other developmental problems. The best predictor of a successful birth is appropriate maternal weight gain. Therefore, it is crucial to make careful dietary choices.

The Early Days of Pregnancy

For medical purposes, pregnancy is measured from the first day of a woman's last menstrual period until childbirth and typically lasts about forty weeks. Major changes begin to occur in the earliest days, often weeks before a woman even knows that she is pregnant. During this period, adequate nutrition supports cell division, tissue differentiation, and organ development. As each week passes, new milestones are reached. Therefore, women who are trying to conceive should make proper dietary choices to ensure the delivery of a healthy baby. Fathers-to-be should also consider their eating habits. A sedentary lifestyle and a diet low in fresh fruits and vegetables may affect male fertility. Men who drink too much alcohol may also damage the quantity and quality of their sperm.Mayo Clinic. "Healthy Sperm: Improving Your Fertility." © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. http://www.mayoclinic.com/health/fertility/MC00023. For both men and women, adopting healthy habits also boosts general well-being and makes it possible to meet the demands of parenting.

Tools for Change

A pregnancy may happen unexpectedly. Therefore, it is important for all women of childbearing age to get 400 micrograms of folate per day prior to pregnancy and 600 micrograms per day during pregnancy. Folate, which is also known as folic acid, is crucial for the production of DNA and RNA and the synthesis of cells. A deficiency can cause megaloblastic anemia, or the development of abnormal red blood cells, in pregnant women. It can also have a profound effect on the unborn baby. Typically, folate intake has the greatest impact during the first eight weeks of pregnancy, when the neural tube closes. The neural tube develops into the fetus's brain, and adequate folate reduces the risk of brain abnormalities or neural tube defects, which occur in one in a thousand pregnancies in North America each year. This vital nutrient also supports the spinal cord and its protective coverings. Inadequate folic acid can result in birth defects, such as spina bifida, which is the failure of the spinal column to close. The name "folate" is derived from the Latin word *folium* for leaf, and leafy green vegetables such as spinach and kale are excellent sources of it. Folate is also found in legumes, liver, and oranges. Additionally, since 1998, food manufacturers have been required to add folate to cereals and other grain products.MedlinePlus, a service of the National Institutes of Health. "Folic Acid." © 1995–2012 Therapeutic Research Faculty, publishers of Natural Medicines Comprehensive Database, Prescriber's Letter, Pharmacist's Letter. Last reviewed August 7, 2011. http://www.nlm.nih.gov/medlineplus/druginfo/natural/1017.html.

Weight Gain during Pregnancy

During pregnancy, a mother's body changes in many ways. One of the most notable and significant changes is weight gain. If a pregnant woman does not gain enough weight, her unborn baby will be at risk. Poor weight gain, especially in the third trimester, could result not only in low birth weight but also infant mortality and intellectual disabilities. Therefore, it is vital for a pregnant woman to maintain a healthy weight, and her weight prior to pregnancy has a major effect. Infant birth weight is one of the best indicators of a baby's future health. Pregnant women of normal weight should gain between 25 and 35 pounds in total through the entire pregnancy. The precise amount that a mother should gain usually depends on her beginning body mass index (BMI). See Table 12.3.1 for The Institute of Medicine (IOM) recommendations.

Table 12.3.1: Body Mass Index and Pregnancy

Prepregnancy BMI	Weight Category	Recommended Weight Gain
Below 18.5	Underweight	28–40 lbs.
18.5–24.9	Normal	25–35 lbs.
25.0–29.9	Overweight	15–25 lbs.
Above 30.0	Obese (all classes)	11–20 lbs.

Source: Institute of Medicine. “Weight Gain during Pregnancy: Reexamining the Guidelines.” May 2009. www.iom.edu/~/media/Files/Report%20Files/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines/Resource%20Page%20-%20Weight%20Gain%20During%20Pregnancy.pdf.



Figure 12.3.1: The weight an expectant mother gains during pregnancy is almost all lean tissue, including the placenta and fetus. Weight gain is not the only major change. A pregnant woman also will find that her breasts enlarge and that she has a tendency to retain water. Source: Utah Department of Health, Baby Your Baby. “Weight Gain during Pregnancy.” © 2012 Baby Your Baby. http://www.babyyourbaby.org/pregnancy/during.

Starting weight below or above the normal range can lead to different complications. Pregnant women with a prepregnancy BMI below twenty are at a higher risk of a preterm delivery and an underweight infant. Also, their nutrient stores may be inadequate. Pregnant women with a prepregnancy BMI above thirty have an increased risk of the need for a cesarean section during delivery. Therefore, it is optimal to have a BMI in the normal range prior to pregnancy. They are also at increased risk of gestational diabetes.

Generally, women gain 2 to 5 pounds in the first trimester. After that, it is best not to gain more than one pound per week. Some of the new weight is due to the growth of the fetus, while some are due to changes in the mother’s body that support the pregnancy. Weight gain often breaks down in the following manner: 6 to 8 pounds of fetus, 1 to 2 pounds for the placenta (which supplies nutrients to the fetus and removes waste products), 2 to 3 pounds for the amniotic sac (which contains fluids that surround and cushion the fetus), 1 to 2 pounds in the breasts, 1 to 2 pounds in the uterus, 3 to 4 pounds of maternal blood, 3 to 4 pounds maternal fluids, and 8 to 10 pounds of extra maternal fat stores that will be needed for breastfeeding and delivery. Women who are pregnant with more than one fetus are advised to gain even more weight to ensure the health of their unborn babies.

The pace of weight gain is also important. If a woman puts on weight too slowly, her physician may recommend nutrition counseling. Low weight gain is considered less than 15 pounds and is linked to an increased risk of birth asphyxia, infections, and illness. Also, infants may have difficulty regulating their blood glucose and calcium after birth. Babies born prematurely have lung and liver immaturity while full-term babies that are underweight are considered small for gestational age (SGA). These infants are 40 times likely to die during infancy and have trouble regulating blood glucose and body temperature. Growth may be retarded and neural development impaired.

If she gains weight too quickly, especially in the third trimester, it may be the result of edema, or swelling due to excess fluid accumulation. Rapid weight gain may also result from increased calorie consumption or a lack of exercise. This may result in a baby with a high birth weight, greater than 9 lbs. Large babies are difficult to deliver vaginally and may require a cesarean section (C-section). These infants are at a greater risk of poor health and death compared to normal weight babies, and there is a doubled risk of neural tube defects that are not related to a folate deficiency. The mother may experience increased blood pressure that may lead to preeclampsia. On average, a full-term infant at birth weighs 7 to 8 lbs and is about twenty inches long.

Weight Loss Before and After Pregnancy

Weight loss during pregnancy is not recommended, even if you are overweight. Inadequate dietary carbohydrate intake can reduce glucose to the fetus which can impact development particularly the brain. Dieting may slow weight gain which can lead to the same problems discussed in the previous section.

During labor, new mothers lose some of the weight they gained during pregnancy with the delivery of their child. In the following weeks, they continue to shed weight as they lose accumulated fluids and their blood volume returns to normal. Some studies have hypothesized that breastfeeding also helps a new mother lose some of the extra weight, although research is ongoing.Stuebe, A. M., MD, MSc and J. W. Rich-Edwards, Sc. D. “The Reset Hypothesis: Lactation and Maternal Metabolism.” © Thieme Medical Publishers, *Am J Perinatol* 26, no.1 (2009): 81–88. doi: 10.1055/s-0028-1103034. New mothers who gain a healthy amount of weight and participate in regular physical activity during their pregnancies also have an easier time shedding weight post pregnancy. However, women who gain more weight than needed for a pregnancy typically retain that excess weight as body fat. If those few pounds increase a new mother’s BMI by a unit or more, that could lead to complications such as hypertension or Type 2 diabetes in future pregnancies or later in life.

Nutritional Requirements

As a mother’s body changes, so do her nutritional needs. Pregnant women must consume more calories and nutrients in the second and third trimesters than other adult women. However, the average recommended daily caloric intake can vary depending on activity level and the mother’s normal weight. Also, pregnant women should choose a high-quality, diverse diet, consume fresh foods, and prepare nutrient-rich meals. Steaming is the best way to cook vegetables. Vitamins are destroyed by overcooking, whereas uncooked vegetables and fruits have the highest vitamin content. It is also standard for pregnant women to take prenatal supplements to ensure adequate intake of the needed micronutrients.

Energy

During the first trimester, a pregnant woman has the same energy requirements as normal (before pregnancy) and should consume the same number of calories as usual—about 1,800 calories for a woman living a sedentary lifestyle, about 2,000 calories for a woman who is moderately active, and about 2,200 for a woman who is active. However, as the pregnancy progresses, a woman must increase her caloric intake. According to the IOM, she should consume an additional 340 calories per day during the second trimester, and an additional 450 calories per day during the third trimester. This is partly due to an increase in metabolism, which rises during pregnancy and contributes to increased energy needs. A woman can easily meet these increased needs by consuming more nutrient-dense foods. For example, an additional 340 calories could include a medium-sized banana (about 100 calories), a cup of nonfat yogurt with fruit on the bottom (about 140 calories), and a slice of whole-wheat toast (about 75 calories).

- ## Carbohydrates

  The recommended daily allowance, or RDA, of carbohydrates during pregnancy is about 175 to 265 grams per day to fuel fetal brain development with a minimum of 135 grams per day. The best food sources for pregnant women include whole-grain bread and cereals, brown rice, root vegetables, legumes, and fruits. These and other unrefined carbohydrates provide nutrients, phytochemicals, antioxidants, and fiber. These foods also help to build the placenta and supply energy for the growth of the

unborn baby. Refined carbohydrates, such as white bread, cookies and other baked desserts, pretzels, and chips are nutritionally deficient and should be kept to a minimum.

Protein

During pregnancy, extra protein is needed for the synthesis of new maternal and fetal tissues. Protein builds muscle and other tissues, enzymes, antibodies, and hormones in both the mother and the unborn baby. Additional protein also supports increased blood volume and the production of amniotic fluid. The RDA of protein during pregnancy is 71 grams per day, which is 25 grams (50%) above the normal recommendation. However, in most instances, there is no need for a pregnant woman to make an effort to increase protein intake as long as she has a normal appetite because even nonpregnant women in North America typically eat that much protein. Protein should be derived from healthy sources, such as lean red meat, white-meat poultry, legumes, nuts, seeds, eggs, and fish. Low-fat milk and other dairy products also provide protein, along with calcium and other nutrients.

Fat

There are no specific recommendations for fats in pregnancy, apart from following normal dietary guidelines. Fats should make up 25 to 35 percent of daily calories, and those calories should come from healthy fats, such as avocados. Foods with unhealthy fats, including French fries and other fast food, should be avoided. Also, it is not recommended for pregnant women to be on a very low-fat diet since it would be hard to meet the needs of essential fatty acids and fat-soluble vitamins. Fatty acids are important during pregnancy because they support the baby's brain and eye development. In particular, the brain depends on omega-3 and omega-6 fatty acids, such as the kind found in salmon and sunflower or safflower oil, for function, structure, and growth. Fats can also help the placenta grow and may help to prevent premature birth and low birth weight.

Fiber



Figure 12.3.2: Fresh fruit and whole grains, such as a bowl of muesli, are excellent sources of fiber during a pregnancy. Dry muesli mix served with milk and bananas. (CC SA- BY 3.0; VirtualSteve)

Ideally, a pregnant woman should eat 25 to 30 grams of dietary fiber per day. There are two types of fiber, and pregnant women should consume both. Insoluble fiber acts as a natural laxative, which softens stools and speeds the elimination of waste material through the colon to avoid constipation. Sources of insoluble fiber include whole grains, fruits, vegetables, dried peas, and beans. Soluble fiber has little effect on the intestines, however, it helps to lower blood cholesterol levels and regulate blood glucose. Sources of soluble fiber include fruits, vegetables, and beans, along with oats, barley, and other fiber-filled whole grains.

- ## Fluids

Fluid intake must also be monitored. According to the IOM, pregnant women should drink 2.3 liters (about 10 cups) of liquids per day to provide enough fluid for blood production. It is also important to drink liquids during physical activity or when it is hot and humid outside, to replace fluids lost through perspiration. The combination of a high-fiber diet and lots of liquids also

helps to eliminate waste.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm.

- ## Vitamins and Minerals

  Pregnancy requires certain conditionally essential nutrients, which are nutrients that are supplied only under special conditions, such as stress, illness, or aging. The daily requirements for nonpregnant women change with the onset of a pregnancy. Taking a daily prenatal supplement or multi vitamin helps to meet many nutritional needs. However, most of these requirements should be fulfilled with a healthy diet. The following table compares the normal levels of required vitamins and minerals to the levels needed during pregnancy. For pregnant women, the RDA of nearly all vitamins and minerals increases these are highlighted in red. The other vitamins (D, E, and K) and minerals (Na, Cl, Ca, P and F) do not change.

- Source: Institute of Medicine. "Nutrition during Pregnancy: Part I: Weight Gain, Part II: Nutrient Supplements." January 1, 1990. iom.edu/Reports/1990/Nutrition-During-Pregnancy-Part-I-Weight-Gain-Part-II-Nutrient-Supplements.aspx.

Table 12.3.2: Recommended Nutrient Intakes during Pregnancy

Nutrient	Nonpregnant Women	Pregnant Women
Vitamin A (mcg)	700.0	770.0
Vitamin B_6 (mg)	1.5	1.9
Vitamin B_{12} (mcg)	2.4	2.6
Vitamin C (mg)	75.0	85.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Calcium (mg)	1,000.0	1,000.0
Folate (mcg)	400.0	600.0
Iron (mg)	18.0	27.0
Magnesium (mg)	320.0	360.0
Niacin (B_3) (mg)	14.0	18.0
Phosphorus	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4
Thiamine (B_1) (mg)	1.1	1.4
Zinc (mg)	8.0	11.0

The micronutrients involved with building the skeleton—vitamin D, calcium, phosphorus, and magnesium—are crucial during pregnancy to support fetal bone development. Although the levels are the same as those for nonpregnant women, many women do not typically consume adequate amounts and should make an extra effort to meet those needs.

There is an increased need for all B vitamins during pregnancy. Adequate vitamin B_6 supports the metabolism of amino acids, while more vitamin B_{12} is needed for the synthesis of red blood cells and DNA. Additional zinc is crucial for cell development and protein synthesis. The need for vitamin A also increases, and extra iron intake is important because of the increase in blood supply during pregnancy and to support the fetus and placenta. Iron is the one micronutrient that is almost impossible to obtain in adequate amounts from food sources only. Therefore, even if a pregnant woman consumes a healthy diet, there still is a need to take an iron supplement, in the form of ferrous salts. Also, remember that folate needs increase during pregnancy to 600 micrograms per day to prevent neural tube defects. This micronutrient is crucial for fetal development because it helps produce the extra blood a woman's body requires during pregnancy. Vitamin B12 is also important.

For most other minerals, recommended intakes are similar to those for nonpregnant women, although it is crucial for pregnant women to make sure to meet the RDAs to reduce the risk of birth defects. In addition, pregnant mothers should avoid exceeding any recommendations. Taking megadose supplements can lead to excessive amounts of certain micronutrients, such as vitamin A and zinc, which may produce toxic effects that can also result in birth defects.

- ## Guide to Eating during Pregnancy

  While pregnant women have an increased need for energy, vitamins, and minerals, energy increases are proportionally less than other macronutrient and micronutrient increases. So, nutrient-dense foods, which are higher in proportion of macronutrients and micronutrients relative to calories, are essential to a healthy diet. Examples of nutrient-dense foods include fruits, vegetables, whole grains, peas, beans, reduced-fat dairy, and lean meats. Notice, that these are also lower fat choices. Pregnant women should be able to meet almost all of their increased needs via a healthy diet as long as they choose wisely. However, expectant mothers should take a prenatal supplement to ensure an adequate intake of iron and folate.

  - Eat iron-rich or iron-fortified foods, including meat or meat alternatives, breads, and cereals, to help satisfy the increased need for iron and prevent anemia.
  - Include vitamin C-rich foods, such as orange juice, broccoli, or strawberries, to enhance iron absorption.
  - Eat a well-balanced diet, including fruits, vegetables, whole grains, calcium-rich foods, lean meats, and a variety of cooked seafood (excluding fish that are high in mercury, such as swordfish and shark).
  - Drink additional fluids, water especially.

- ## Foods to Avoid

  A number of substances can harm a growing fetus. Therefore, it is vital for women to avoid them throughout a pregnancy. Some are so detrimental that a woman should avoid them even if she suspects that she might be pregnant. For example, consumption of alcoholic beverages results in a range of abnormalities that fall under the umbrella of fetal alcohol spectrum disorders. They include learning and attention deficits, heart defects, and abnormal facial features. Alcohol enters the unborn baby via the umbilical cord and can slow fetal growth, damage the brain, or even result in miscarriage. The effects of alcohol are most severe in the first trimester when the organs are developing. As a result, there is no safe amount of alcohol that a pregnant woman can consume. Although pregnant women in the past may have participated in behavior that was not known to be risky at the time, such as drinking alcohol or smoking cigarettes, today we know that it is best to avoid those substances completely to protect the health of the unborn baby.

  Pregnant women should also limit caffeine intake, which is found not only in coffee, but also tea, colas, cocoa, chocolate, and some over-the-counter painkillers. Some studies suggest that very high amounts of caffeine have been linked to babies born with low birth weights. The *American Journal of Obstetrics and Gynecology* released a report, which found that women who consume 200 milligrams or more of caffeine a day (which is the amount in 10 ounces of coffee or 25 ounces of tea) increase the risk of miscarriage.Weng X, Odouli R, and Li D-K. “Maternal caffeine consumption during pregnancy and the risk of miscarriage: a prospective cohort study.” *Am J Obstet Gynecol* 2008;198:279.e1-279.e8. Consuming large quantities of caffeine affects the pregnant mother as well, leading to irritability, anxiety, and insomnia. Most experts agree that small amounts of caffeine each day are safe (about one 8-ounce cup of coffee a day or less). American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 495. However, that amount should not be exceeded.

  One should keep sugar substitutes to a minimum although there are no direct scientific links to birth defects.

- ## Vegetarianism

  Lacto-ovo and lactovegetarians have no special problems beyond those common to vegetarians. Women who are vegans need to be concerned about their protein, vitamin B_6 and zinc intake because these nutrients may be low. She may need to take a supplement to boost her intake of vitamin B6, zinc as well as iron, calcium, vitamin D, and vitamin B12.

Foodborne Illness

For both mother and child, foodborne illness can cause major health problems. For example, the foodborne illness caused by the bacteria *Listeria monocytogenes* can cause spontaneous abortion and fetal or newborn meningitis. According to the CDC, pregnant women are twenty times more likely to become infected with this disease, which is known as listeriosis, than nonpregnant, healthy adults. Symptoms include headaches, muscle aches, nausea, vomiting, and fever. If the infection spreads to the nervous system, it can result in a stiff neck, convulsions, or a feeling of disorientation. American Pregnancy Association.

“Listeria and Pregnancy.” © 2000–2012 American Pregnancy Association. http://www.americanpregnancy.org/pregnancycomplications/listeria.html.

Foods more likely to contain the bacteria are unpasteurized dairy products, especially soft cheeses and blue-veined cheeses, and also smoked seafood, hot dogs, paté, cold cuts, and uncooked meats. To avoid consuming contaminated foods, women who are pregnant or breastfeeding should take the following measures:

- Thoroughly rinse fruits and vegetables before eating them
- Keep cooked and ready-to-eat food separate from raw meat, poultry, and seafood
- Store food at 40° F (4° C) or below in the refrigerator and at 0° F (−18° C) in the freezer
- Refrigerate perishables, prepared food, or leftovers within two hours of preparation or eating
- Clean the refrigerator regularly and wipe up any spills right away
- Check the expiration dates of stored food once per week

You will learn more about foodborne illness and its consequences in other chapters

- ### Food Contaminants

  It is always important to avoid consuming contaminated food to prevent food poisoning. This is especially true during pregnancy. Heavy metal contaminants, particularly mercury, lead, and cadmium, pose risks to pregnant mothers. As a result, vegetables should be washed thoroughly or have their skins removed to avoid heavy metals.

  Pregnant women can eat fish, ideally 8 to 12 ounces of different types each week. Expectant mothers are able to eat cooked shellfish such as shrimp, farm-raised fish such as salmon, and a maximum of 6 ounces of albacore, or white, tuna. However, they should avoid fish with high methyl mercury levels, such as shark, swordfish, tilefish, and king mackerel. Pregnant women should also avoid consuming raw shellfish to avoid foodborne illness. The Environmental Defense Fund eco-rates fish to provide guidelines to consumers about the safest and most environmentally friendly choices. You can find ratings for fish and seafood at http://www.edf.org.

- ### Physical Activity during Pregnancy

  For most pregnant women, physical activity is a must and is recommended in the *2020 Dietary Guidelines for Americans*. Regular exercise of moderate intensity, about thirty minutes per day most days of the week, keeps the heart and lungs healthy. It also helps to improve sleep and boosts mood and energy levels. In addition, women who exercise during pregnancy report fewer discomforts and may have an easier time losing excess weight after childbirth. Low to moderate exercises like brisk walking, swimming, or an aerobics class geared toward expectant mothers are all great ways to get exercise during pregnancy. Healthy women who already participate in vigorous activities, such as running, can continue doing so during pregnancy provided they discuss an exercise plan with their physicians.



Figure 12.3.3: Walking is an excellent way for an expectant mother to get moderate exercise.

However, pregnant women should avoid pastimes that could cause injuries, such as soccer, football, and other contact sports, or activities, or that could lead to falls, such as horseback riding and downhill skiing. It may be best for pregnant women not to participate in certain sports, such as tennis, that require you to jump or change direction quickly. Scuba diving should also be avoided because it might result in the fetus developing decompression sickness. This potentially fatal condition results from a rapid decrease in pressure when a diver ascends too quickly.National Institutes of Health, and Friends of the National Library of Medicine. "Should I Exercise During My Pregnancy?" *NIH Medline Plus 3*, no. 1 (Winter 2008): 26. http://www.nlm.nih.gov/medlineplus/magazine/issues/winter08/articles/winter08pg26.html.

When exercising, the warm-up should be 5-10 minutes followed by low to moderate exercises 30-40 minutes in length at a heart rate below 150 beats per minute. Cool-down should be 5-10 minutes. Plenty of fluids should be consumed and a hot, humid climate avoided. Three to four days of exercise is recommended with adequate rest between exercises. Pregnant women should avoid exercising if they are sick; avoid exercising on their back after the first trimester; and avoid standing for prolonged periods of time to prevent venous pooling.

- Common Discomforts During Pregnancy

  Pregnancy can lead to certain discomforts, from back strain to swollen ankles. Also, a pregnant woman is likely to experience constipation because increased hormone levels can slow digestion and relax muscles in the bowels. Constipation and pressure from the growth of the uterus can result in hemorrhoids, which are another common discomfort.US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm. Getting mild to moderate exercise and drinking enough fluids can help prevent both conditions. Also, eating a high-fiber diet softens the stools and reduces the pressure on hemorrhoids.

  Heartburn can occur during the early months of pregnancy due to an increase in the hormone progesterone, and during the later months due to the expanding size of the fetus, which limits stomach contraction. Avoiding chocolate, mint, and greasy foods, and remaining upright for an hour after meals can help pregnant women avoid heartburn. In addition, it can be helpful to drink fluids between meals, instead of with food.

  Other common complaints can include leg cramps and bloating. Regular exercise can help to alleviate these discomforts. A majority of pregnant women develop gastrointestinal issues, such as nausea and vomiting. Many also experience food cravings and aversions. All of these can impact a pregnant woman's nutritional intake and it is important to protect against adverse effects.

- ## Nausea and Vomiting

  Nausea and vomiting are gastrointestinal issues that strike many pregnant women, typically in the first trimester. Nausea tends to occur more frequently than vomiting. These conditions are often referred to as “morning sickness,” although that’s something of a misnomer because nausea and vomiting can occur all day long, although it is often the worst in the first part of the day.

  Increased levels of the pregnancy hormone human chorionic gonadotropin may cause nausea and vomiting, although that is speculative. Another major suspect is estrogen because levels of this hormone also rise and remain high during pregnancy. Given that a common side effect of estrogen-containing oral contraceptives is nausea this hormone likely has a role. Nausea usually subsides after sixteen weeks, possibly because the body becomes adjusted to higher estrogen levels.

  It can be useful for pregnant women to keep a food diary to discover which foods trigger nausea, so they can avoid them in the future. Other tips to help avoid or treat nausea and vomiting include the following:

  - Avoid spicy foods
  - Avoid strong or unusual odors
  - Eat dry cereal, toast, or crackers
  - Eat frequent, small meals
  - Consume more unrefined carbohydrates
  - Get moderate aerobic exercise
  - Drink ginger tea, which aids in stomach upset
  - Seek fresh air when a bout of nausea comes on

  A severe form of nausea and vomiting is a condition known as hyperemesis gravidarum. It is marked by prolonged vomiting, which can result in dehydration and require hospitalization. This disorder is relatively rare and impacts only 0.3 to 2 percent of all pregnant women.Eliakim, R., O. Abulafia, and D. M. Sherer. “Hyperemesis Gravidarum: A Current Review.” *Am J Perinatol* 17, no. 4 (2000): 207–18.

- ## Food Cravings and Aversions, and Pica

  Food aversions and cravings do not have a major impact unless food choices are extremely limited. The most common food aversions are milk, meats, pork, and liver. For most women, it is not harmful to indulge in the occasional craving, such as the desire for pickles and ice cream. However, a medical disorder known as pica is willingly consuming foods with little or no nutritive value, such as dirt, clay, and laundry starch. In some places, this is a culturally accepted practice. However, it can be harmful if these substances take the place of nutritious foods or contain toxins. This is not a real physiological need. For example, craving pickles does not mean the woman needs salt, and craving ice cream does not mean the woman or fetus needs calcium. Instead, food cravings and aversions are due to the effect of pregnancy on taste and smell sensitivity.

- ## Complications during Pregnancy

  Expectant mothers may face different complications during the course of their pregnancy. They include certain medical conditions that could greatly impact a pregnancy if left untreated, such as gestational hypertension and gestational diabetes, which have diet and nutrition implications.

- ## Gastrointestinal

  Heartburn can occur during pregnancy. Here are a number of suggestions to relieve the condition:

  - Relax and eat slowly
  - Chew food thoroughly
  - Eat small frequent meals
  - Drink liquids between meals not during the meal
  - Avoid spicy and greasy foods
  - Sit up while eating and keep one's head elevated while sleeping
  - Wait an hour before lying down
  - Wait two hours before exercising

  Constipation and hemorrhoids are also gastrointestinal problems that occur during pregnancy. Exercising regularly, eating foods high in fiber, increasing your food intake to at least 8 glasses per day, and responding promptly to the urge to defecate are ways

to improve constipation and hemorrhoids. Mineral oil as a laxative is not recommended because it interferes with the absorption of the fat-soluble vitamins.

Morning sickness which includes nausea and/or vomiting occurs during the first semester for some pregnant women due to hormonal imbalances. Morning sickness can affect one's food intake for the day. There are several measures one can take to minimize morning sickness such as rising slow when you first get up in the morning, eating dry toast or crackers, eating small, frequent meals, and chewing gum or sucking hard candies. Pregnant women should avoid disagreeable smelly foods. If she feels nauseated, carbonated beverages instead of citrus fruit, water, milk, coffee, or tea, may help relieve the upset stomach,

Gestational Hypertension

Gestational hypertension is a condition of high blood pressure during the second half of pregnancy. Also referred to as pregnancy-induced hypertension, this condition affects about 6 to 8 percent of all pregnant women. First-time mothers are at greater risk, along with women who have mothers or sisters who had gestational hypertension, women carrying multiple fetuses, women with a prior history of high blood pressure or kidney disease, and women who are overweight or obese when they become pregnant.

Hypertension can prevent the placenta from getting enough blood, which would result in the baby getting less oxygen and nutrients. This can result in low birth weight, although most women with gestational hypertension can still deliver a healthy baby if the condition is detected and treated early. Some risk factors can be controlled, such as diet, while others cannot, such as family history. If left untreated, gestational hypertension can lead to a serious complication called preeclampsia, which is sometimes referred to as toxemia. This disorder is marked by elevated blood pressure (hypertension) and protein in the urine (proteinuria) and is associated with swelling (whole body edema). This can lead to reduced blood flow to the fetus and maternal organs, cerebral hemorrhage, convulsion and coma (eclampsia). Preeclampsia and eclampsia are very serious health problems that lead to the mother and/or fetus's death. To prevent preeclampsia, the WHO recommends increasing calcium intake for women consuming diets low in that micronutrient, administering a low dosage of aspirin (75 milligrams), and increasing prenatal check-ups.World Health Organization. “WHO Recommendations for Prevention and Treatment of Preeclampsia and Eclampsia.” 2011. Accessed June 8, 2012. http://whqlibdoc.who.int/publications/2011/9789241548335_eng.pdf.

Video 12.3.1: Gestational Hypertension and Preeclampsia

This video focuses on the signs and risk factors of gestational hypertension and preeclampsia. (click to see video)

- ### Gestational Diabetes

  About 4 percent of pregnant women suffer from a condition known as gestational diabetes, which is abnormal glucose tolerance during pregnancy. It is most common in women with a family history of diabetes. The body becomes resistant to the hormone insulin, which enables cells to transport glucose from the blood. Gestational diabetes is usually diagnosed around twenty-four to twenty-six weeks, although it is possible for the condition to develop later into a pregnancy. Signs and symptoms of this disease include extreme hunger, thirst, or fatigue. If blood sugar levels are not properly monitored and treated, the baby might gain too much weight and require a cesarean delivery. Diet and regular physical activity can help to manage this condition. Most patients who suffer from gestational diabetes also require daily insulin injections to boost the absorption of glucose from the bloodstream and promote the storage of glucose in the form of glycogen in liver and muscle cells. Gestational diabetes usually resolves after childbirth, although some women who suffer from this condition develop Type 2 diabetes later in life, particularly if they are overweight.

Key Takeaways

During pregnancy, it is imperative that a woman meets the nutritional needs both she and her unborn child require, which includes an increase in certain micronutrients, such as iron and folate. Starting BMI determines how much weight a woman needs to gain throughout her pregnancy. In an average pregnancy, a woman gains an extra 30 pounds. During the second and third trimesters, a woman’s energy requirements increase by 340 calories per day for the second trimester and 450 calories per day for the third trimester. Common discomforts that can impact nutritional intake during pregnancy include nausea and vomiting, heartburn, and constipation. Gestational hypertension is a condition that impacts about 6 to 8 percent of pregnant women and results in a rise in blood pressure levels. This condition can lead to preeclampsia during a pregnancy. Gestational diabetes is a condition that impacts about 4 percent of pregnant women and results in a rise in blood glucose levels. This condition can lead to Type 2 diabetes later in life.

Discussion Starter

1. Discuss the changing nutritional requirements for iron and vitamin A during pregnancy. Use what you know about each kind of micronutrient and its impact on the body to explain why the increase in RDA might be exponentially greater for one of these nutrients than for the other.

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12.4: Infancy and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for infants.
- Describe the physiologic basis for lactation and the specific components of breast milk.
- Discuss the benefits and barriers related to breastfeeding.
- Examine feeding problems that parents and caregivers may face with their infants.

Diet and nutrition have a major impact on a child's development from infancy into the adolescent years. A healthy diet not only affects growth, but also immunity, intellectual capabilities, and emotional well-being. One of the most important jobs of parenting is making sure that children receive an adequate amount of needed nutrients to provide a strong foundation for the rest of their lives.

Infancy (Birth to Age One)

The term infant is derived from the Latin word *infans*, which means "unable to speak." Healthy infants grow steadily, but not always at an even pace. For example, during the first year of life, height increases by 50 percent, while weight triples. Physicians and other health professionals can use growth charts to track a baby's development process. Because infants cannot stand, length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age. Nationally-accepted growth charts are based on data collected by the National Center for Health Statistics. These charts allow for tracking trends over time and comparing with other infants among percentiles within the United States. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as failure-to-thrive (FTT), which is characterized by poor growth. FTT can happen at any age, but in infancy, it typically occurs after six months. Some causes include poverty, lack of enough food, feeding inappropriate foods, and excessive intake of fruit juice. The greatest changes in weight and length occur during the first year of life.

Nutritional Requirements

Requirements for macronutrients and micronutrients on a per-kilogram basis are higher during infancy than at any other stage in the human life cycle. These needs are affected by the rapid cell division that occurs during growth, which requires energy and protein, along with the nutrients that are involved in DNA synthesis. During this period, babies are entirely dependent on their parents or other caregivers to meet these needs. For almost all infants six months or younger, breast milk is the best source to fulfill nutritional requirements. An infant may require feedings eight to twelve times a day or more in the beginning. After six months, infants can gradually begin to consume solid foods to help meet nutrient needs.

Energy

Energy needs relative to size are much greater in an infant than an adult because of the large surface area of its body. A baby's resting metabolic rate is two times that of an adult. The RDA to meet energy needs changes as an infant matures and puts on more weight. The IOM uses a set of equations to calculate the total energy expenditure and resulting energy needs. For example, the equation for the first three months of life is *(89 x weight [kg] −100) + 175 kcal*.

Based on these equations, the estimated energy requirement for infants from zero to six months of age is 472 to 645 kilocalories per day for boys and 438 to 593 kilocalories per day for girls (100-120 kcal per kg body weight per day). For infants ages six to twelve months, the estimated requirement is 645 to 844 kilocalories per day for boys and 593 to 768 kilocalories per day for girls. From the age one to age two, the estimated requirement rises to 844–1,050 kilocalories per day for boys and 768–997 kilocalories per day for girls.Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, Institute of Medicine of the National Academies (Washington, D.C.: The National Academies Press, 2005), 169–70. How often an infant wants to eat will also change over time due to growth spurts, which typically occur at about two weeks and six weeks of age, and again at about three months and six months of age.

Macronutrients

The dietary recommendations for infants are based on the nutritional content of human breast milk. Carbohydrates make up about 45 to 65 percent of the caloric content in breast milk, which amounts to a RDA of about 130 grams. Almost all of the carbohydrate in human milk is lactose, which infants digest and tolerate well. In fact, lactose intolerance is practically nonexistent in infants. Protein makes up about 5 to 20 percent of the caloric content of breast milk, which amounts to 13 grams per day (or 1.52 grams per kg body weight per day). Infants have a high need for protein to support growth and development, though excess protein (which is only a concern with bottle-feeding) can cause dehydration, diarrhea, fever, and acidosis in premature infants. About 30 to 40 percent of the caloric content in breast milk is made up of fat. A high-fat diet is necessary to encourage the development of neural pathways in the brain and other parts of the body. However, saturated fats and trans fatty acids inhibit this growth. Infants who are over the age of six months, which means they are no longer exclusively breastfed, should not consume foods that are high in these types of fats.

- ## Micronutrients

  Almost all of the nutrients that infants require can be met if they consume an adequate amount of breast milk. There are a few exceptions, though. Human milk is low in vitamin D, which is needed for calcium absorption and building bone, among other things. Therefore, breastfed children often need to take a vitamin D supplement in the form of drops. Infants at the highest risk for vitamin D deficiency are those with darker skin and no exposure to sunlight. Breast milk is also low in vitamin K, which is required for blood clotting, and deficits could lead to bleeding or hemorrhagic disease. Babies are born with limited vitamin K, so supplementation may be needed initially and some states require a vitamin K injection after birth. Also, breast milk is not high in iron, but the iron in breast milk is well absorbed by infants. After four to six months, however, an infant needs an additional source of iron other than breast milk.

- ## Fluids

  Infants have a high need for fluids, 1.5 milliliters per kilocalorie (150 - 170 ml per kg body weight per day) consumed compared to 1.0 milliliters per kilocalorie consumed for adults. This is because children have larger body surface area per unit of body weight and a reduced capacity for perspiration. Therefore, they are at greater risk of dehydration. However, parents or other caregivers can meet an infant's fluid needs with breast milk or formula. As solids are introduced, parents must make sure that young children continue to drink fluids throughout the day.

- ## Breastfeeding

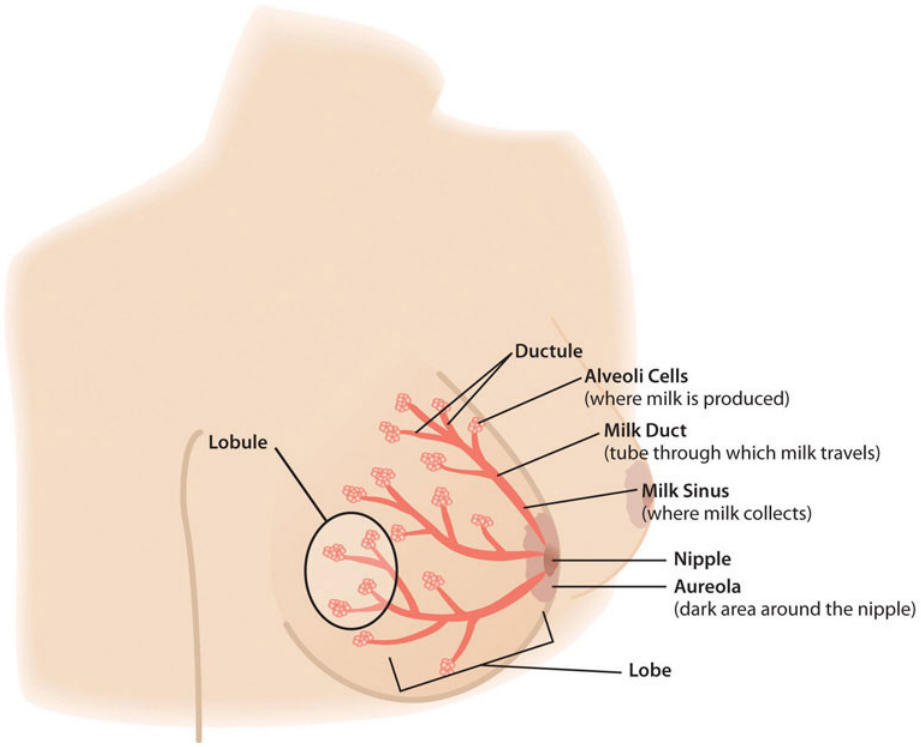


Figure 12.4.1: Anatomy of the breast.

The alveoli cells produce milk. To secrete it, they contract and push milk into the ductules and the milk sinus, which collects the milk. When a nursing infant's gums press on the areola and nipple, the sinuses squeeze the milk into the baby's mouth. The nipple tissue becomes firmer with stimulation, which makes it more flexible and easier for the baby to grasp in the mouth.

After the birth of the baby, nutritional needs must be met to ensure that an infant not only survives but thrives from infancy into childhood. Breastfeeding provides the fuel a newborn needs for rapid growth and development. As a result, the WHO recommends that breastfeeding is done exclusively for the first six months of an infant's life. New mothers must also pay careful consideration to their own nutritional requirements to help their bodies recover in the wake of the pregnancy. This is particularly true for women who breastfeed their babies, which calls for an increased need for certain nutrients.

- ## Lactation

Lactation is the process that makes breastfeeding possible and is the synthesis and secretion of breast milk. Early in a woman's pregnancy, her mammary glands begin to prepare for milk production. Hormones play a major role in this, particularly during the second and third trimesters. At that point, levels of the hormone prolactin increase to stimulate the growth of the milk duct system, which initiates and maintains milk production. Levels of the hormone oxytocin also rise to promote the release of breast milk when the infant suckles, which is known as the milk ejection reflex or let-down reflex. However, levels of the hormone progesterone need to decrease for successful milk production, because progesterone inhibits milk secretion. Shortly after birth, the expulsion of the placenta triggers progesterone levels to fall, which activates lactation.King, J. "Contraception and Lactation: Physiology of Lactation." *Journal of Midwifery and Women's Health* 52, no. 6 (2007): 614–20. © 2007 Elsevier Science, Inc.

New mothers need to adjust their caloric and fluid intake to make breastfeeding possible. The RDA is 330 additional calories during the first six months of lactation and 400 additional calories during the second six months of lactation. The energy needed to support breastfeeding comes from both increased intake and from stored fat. For example, during the first six months after her baby is born, the daily caloric cost for a lactating mother is 500 calories, with 330 calories derived from increased intake and 170 calories derived from maternal fat stores. This helps explain why breastfeeding may promote weight loss in new mothers. Lactating women should also drink 3-4 liters of liquids per day (about 13 cups) to maintain milk production, according to the IOM. Carbohydrate and protein needs are higher during lactation. An additional 25 grams of protein is needed per day. Fluid needs increase to 3-4 liters while vitamins and minerals are not a concern if the woman is eating an adequate diet. A lack of nutrients will reduce the quantity in breast milk, not the quality.

As is the case during pregnancy, the RDA of nearly all vitamins and minerals increases for women who are breastfeeding their babies. The following table compares the recommended vitamins and minerals for lactating women to the levels for nonpregnant and pregnant women from Table 12.2. The DRI is higher is for vitamins A, E, B_1, B_2, biotin, pantothenic acid, B_6, B_{12}, choline, zinc, iodine, and selenium during lactation than pregnancy and before pregnancy. The mother may need to take an iron supplement.

Table 12.4.1: Recommended Nutrient Intakes during Lactation

Nutrient	Nonpregnant Women	Pregnant Women	Lactating Women
Vitamin A (mcg)	700.0	770.0	1,300.0
Vitamin B_6 (mg)	1.5	1.9	2.0
Vitamin B_{12} (mcg)	2.4	2.6	2.8
Vitamin C (mg)	75.0	85.0	120.0
Vitamin D (mcg)	5.0	5.0	5.0
Vitamin E (mg)	15.0	15.0	19.0
Calcium (mg)	1,000.0	1,000.0	1,000.0
Folate (mcg)	400.0	600.0	500.0
Iron (mg)	18.0	27.0	9.0
Magnesium (mg)	320.0	360.0	310.0
Niacin (B_3) (mg)	14.0	18.0	17.0
Phosphorus	700.0	700.0	700.0
Riboflavin (B_2) (mg)	1.1	1.4	1.6
Thiamine (B_1) (mg)	1.1	1.4	1.4
Zinc (mg)	8.0	11.0	12.0

Source: Institute of Medicine, www.iom.edu.

Calcium requirements do not change during breastfeeding because of more efficient absorption, which is the case during pregnancy, too. However, the reasons for this differ. During pregnancy, there is enhanced absorption within the gastrointestinal tract. During lactation, there is enhanced retention by the kidneys. The RDA for phosphorus, fluoride, and molybdenum also remains the same.

- ## Components of Breast Milk

Human breast milk not only provides adequate nutrition for infants, it also helps to protect newborns from disease. In addition, breast milk is rich in cholesterol, which is needed for brain development. It is helpful to know the different types and components of breast milk, along with the nutrients they provide to enable an infant to survive and thrive. The amount of milk produced generally is determined by the infant's demand.

- ## Colostrum

Colostrum is produced immediately after birth, prior to the start of milk production, and lasts for several days after the arrival of the baby. Colostrum is thicker than breast milk and is yellowish or creamy in color. This protein-rich liquid fulfills an infant’s nutrient needs during those early days. Although low in volume, colostrum is packed with concentrated nutrition for newborns. This special milk is high in fat-soluble vitamins, minerals, and immunoglobulins (antibodies) that pass from the mother to the baby. Immunoglobulins provide passive immunity for the newborn and protect the baby from bacterial and viral diseases.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm. Bifidus factors promote the growth of friendly

bacteria such as L*actobacillus*, that protect against infection. Colostrum also contains lactoferrin, a protein that protects iron from digestion by harmful bacteria, and lactaherin, a protein that binds viruses responsible for infant diarrhea. Antibodies are also present that protect against intestinal infections.

- ## Transitional Milk

  Two to four days after birth, colostrum is replaced by transitional milk. Transitional milk is a creamy liquid that lasts for approximately two weeks and includes high levels of fat, lactose, and water-soluble vitamins. It also contains more calories than colostrum. After a new mother begins to produce transitional milk, she typically notices a change in the volume and type of liquid secreted and an increase in the weight and size of her breasts.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

- ## Mature Milk

  Mature milk is the final fluid that a new mother produces. In most women, it begins to secrete at the end of the second week post childbirth. There are two types of mature milk that appear during a feeding. Foremilk occurs at the beginning and includes water, vitamins, and protein. Hind-milk occurs after the initial release of milk and contains higher levels of fat, which is necessary for weight gain. Combined, these two types of milk ensure that a baby receives adequate nutrients to grow and develop properly.American Pregnancy Association. “Breastfeeding: Overview.” Last updated January 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingoverview.htm.

  About 90 percent of mature milk is water, which helps an infant remain hydrated. The other 10 percent contains carbohydrates, proteins, and fats, which support energy and growth. Similar to cow’s milk, the main carbohydrate of mature breast milk is lactose. Breast milk contains vital fatty acids, such as docosahexaenoic acid (DHA) and arachidonic acid (ARA). In terms of protein, breast milk contains more whey than casein (which is the reverse of cow’s milk). Whey is much easier for infants to digest than casein. Complete protein, which means all of the essential amino acids, is also present in breast milk. Complete protein includes lactoferrin, an iron-gathering compound that helps to absorb iron into an infant’s bloodstream.

  In addition, breast milk provides adequate vitamins and minerals. Although absolute amounts of some micronutrients are low, they are more efficiently absorbed by infants. Other essential components include digestive enzymes that help a baby digest the breast milk. Human milk also provides the hormones and growth factors that help a newborn to develop.

- ## Diet and Milk Quality

  A mother’s diet can have a major impact on milk production and quality. As during pregnancy, lactating mothers should avoid illegal substances and cigarettes. Some legal drugs and herbal products can be harmful as well, so it is helpful to discuss them with a health-care provider. Some mothers may need to avoid certain things, such as spicy foods, that can produce gas in sensitive infants. Lactating women can drink alcohol, though they must avoid breastfeeding until the alcohol has completely cleared from their milk. Typically, this takes two to three hours for 12 ounces of beer, 5 ounces of wine, or 1.5 ounces of liquor, depending on a woman’s body weight.Harms, R., MD. “Breast-Feeding and Alcohol: Is It Okay to Drink?” © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. www.mayoclinic.com/health/breast-feeding-and-alcohol/AN02131. Precautions are necessary because exposure to alcohol can disrupt an infant’s sleep schedule.

- ## Benefits of Breastfeeding

  Breastfeeding has a number of benefits, both for the mother and for the child. Breast milk is the ideal food and contains immunoglobulins, enzymes, immune factors, and white blood cells. As a result, breastfeeding boosts the baby’s immune system and lowers the incidence of diarrhea, along with respiratory diseases, gastrointestinal problems, and ear infections. Breastfed babies also are less likely to develop asthma and allergies, and breastfeeding lowers the risk of sudden infant death syndrome. In addition, human milk encourages the growth of healthy bacteria in an infant’s intestinal tract. All of these benefits remain in place after an infant has been weaned from breast milk. Some studies suggest other possible long-term effects. For example, breast milk may improve an infant’s intelligence and protect against Type 1 diabetes and obesity, although research is ongoing in these areas.Healthy Children.org. “Breastfeeding Benefits Your Baby’s Immune System.” © 2012 American Academy of Pediatrics. Accessed February 21, 2012. http://www.healthychildren.org/English/ages-stages/baby/breastfeeding/pages/Breastfeeding-Benefits-Your-Baby%27s-Immune-System.aspx.

  Breastfeeding has a number of other important benefits. It is easier for babies to digest breast milk than bottle formula, which contains proteins made from cow’s milk that require an adjustment period for infant digestive systems. Breastfed infants are

sick less often than bottle-fed infants. Breastfeeding is more sustainable and results in less plastic waste and other trash. Breastfeeding can also save families money because it does not incur the same cost as purchasing formula. Other benefits include that breast milk is always ready. It does not have to be mixed, heated, or prepared. Also, breast milk is sterile and is always at the right temperature.

In addition, the skin-to-skin contact of breastfeeding promotes a close bond between mother and baby, which is an important emotional and psychological benefit. The practice also provides health benefits for the mother. Breastfeeding helps a woman's bones stay strong, which protects against fractures later in life. Studies have also shown that breastfeeding reduces the risk of breast and ovarian cancers.National Cancer Institute. "Reproductive History and Breast Cancer Risk." Accessed February 6, 2012. http://www.cancer.gov/cancertopics/factsheet/Risk/reproductive-history.

Other benefits for the mother include a low-cost feeding option, convenient way to feed their baby and a more rapid weight loss for the mother (up to 1-2 pounds per month while lactating) targeted at the specific areas she gained weight. The quality and quantity of milk are not affected by moderate exercise. Along with bone protection, breastfeeding can reduce the risk of breast, ovarian and type II diabetes. During breastfeeding, the uterus shrinks and amenorrhea (no menstruation) occurs which conserves iron stores.

The Baby-Friendly Hospital Initiative

In 1991, the WHO and UNICEF launched the Baby-Friendly Hospital Initiative (BFHI), which works to ensure that all maternities, including hospitals and free-standing facilities, become centers of breastfeeding support. A maternity can be denoted as "baby-friendly" when it does not accept substitutes to human breast milk and has implemented ten steps to support breastfeeding. These steps include having a written policy on breastfeeding communicated to health-care staff on a routine basis, informing all new mothers about the benefits and management of breastfeeding, showing new mothers how to breastfeed their infants, and how to maintain lactation, and giving newborns no food or drink other than breast milk, unless medically indicated. Since the BFHI began, more than fifteen thousand facilities in 134 countries, from Benin to Bangladesh, have been deemed "baby friendly." As a result, more mothers are breastfeeding their newborns and infant health has improved, in both the developed world and in developing nations.United Nations Children's Fund. "The Baby-Friendly Hospital Initiative." Accessed June 8, 2012. http://www.unicef.org/programme/breastfeeding/baby.htm.

• Barriers to Breastfeeding

Although breast milk is ideal for almost all infants, there are some challenges that nursing mothers may face when starting and continuing to breastfeed their infants. These obstacles include painful engorgement or fullness in the breasts, sore and tender nipples, milk leakage that can be embarrassing, inverted nipples, infection, and inadequate storage for milk. There are societal barriers too and these include lack of comfort or confidence to breastfeed in public and lack of accommodation to breastfeed or express milk in the workplace.

One of the first challenges nursing mothers face is learning the correct technique. It may take a little time for a new mother to help her baby properly latch on to her nipples. Improper latching can result in inadequate intake, which could slow growth and development. However, International Board Certified Lactation Consultants (IBCLCs), OB nurses, and registered dietitians are all trained to help new mothers learn the proper technique. Education, the length of maternity leave, and laws to protect public breastfeeding, among other measures, can all help to facilitate breastfeeding for many lactating women and their newborns.

• Contraindications to Breastfeeding

Although there are numerous benefits to breastfeeding, in some cases there are also risks that must be considered. In the developed world, a new mother with HIV should not breastfeed, because the infection can be transmitted through breast milk. These women typically have access to bottle formula that is safe and can be used as a replacement for breast milk. However, in developing nations where HIV infection rates are high and acceptable infant formula can be difficult to come by, many newborns would be deprived of the nutrients they need to develop and grow. Also, inappropriate or contaminated bottle formulas cause 1.5 million infant deaths each year. As a result, the WHO recommends that women infected with HIV in the developing world should nurse their infants while taking antiretroviral medications to lower the risk of transmission.World Health Organization. "Infant and Young Child Feeding." July 2010. http://www.who.int/mediacentre/factsheets/fs342/en/index.html

Breastfeeding also is not recommended for women undergoing radiation or chemotherapy treatment for cancer. Additionally, if an infant is diagnosed with galactosemia, meaning an inability to process the simple sugar galactose, the child must be on a

galactose-free diet, which excludes breast milk. This genetic disorder is a very rare condition, however, and only affects 1 in thirty- to sixty thousand newborns.Genetics Home Reference, a service of the US National Library of Medicine. “Galactosemia.” July 9, 2012. http://ghr.nlm.nih.gov/condition/galactosemia. When breastfeeding is contraindicated for any reason, feeding a baby formula enables parents and caregivers to meet their newborn’s nutritional needs.

- ## Lactation Guidelines

Babies cry for many reasons and one reason may be that they are hungry. It is a late indicator of hunger. About 10-15 minutes per breast is recommended. It is best if you allow the infant to feed on both breasts. Food flavors from the foods mom eats can appear in breast milk, for example, spicy foods. These flavors may annoy the baby. Also, mom's cow milk intake may bother the infant. Alcohol enters breast milk so it is best to avoid alcohol during lactation or wait at least 2 hours after drinking an alcoholic beverage to breastfeed. Alcohol can reduce the infant's intake of breast milk. Chemicals from cigarette smoke and caffeine also pass into milk. One should limit their caffeine-containing beverage intake to no more than 1-2 cups per day. Caffeine can cause the infant to be irritable and wakeful. Estrogen-containing oral contraceptive can reduce milk output and protein content.

Bottle-Feeding

Most women can and should breastfeed when given sufficient education and support. However, as discussed, a small percentage of women are unable to breastfeed their infants, while others choose not to. For parents who choose to bottle-feed, infant formula provides a balance of nutrients. However, not all formulas are the same and there are important considerations that parents and caregivers must weigh. Standard formulas use cow’s milk which is very different from human milk as a base although soy-based are available too. They have 20 calories per fluid ounce, similar to breast milk, with vitamins and minerals added. Soy-based formulas are usually given to infants who develop diarrhea, constipation, vomiting, colic, or abdominal pain, or to infants with a cow’s milk protein allergy. Hypoallergenic protein hydrolysate formulas are usually given to infants who are allergic to cow’s milk and soy protein. This type of formula uses hydrolyzed protein, meaning that the protein is broken down into amino acids and small peptides, which makes it easier to digest. Preterm infant formulas are given to low birth weight infants if breast milk is unavailable. Preterm infant formulas have 24 calories per fluid ounce and are given until the infant reaches the desired weight.

Infant formula comes in three basic types:

1. Powder that requires mixing with water. This is the least expensive type of formula.
2. Concentrates, which are liquids that must be diluted with water. This type is slightly more expensive.
3. Ready-to-use liquids that can be poured directly into bottles. This is the most expensive type of formula. However, it requires the least amount of preparation. Ready-to-use formulas are also convenient for traveling.

Most babies need about 2.5 ounces of formula per pound of body weight each day. Therefore, the average infant should consume about 24 fluid ounces of breast milk or formula per day. When preparing formula, parents and caregivers should carefully follow the safety guidelines, since an infant has an immature immune system. All equipment used in formula preparation should be sterilized. Prepared, unused formula should be refrigerated to prevent bacterial growth. Parents should make sure not to use contaminated water to mix formula in order to prevent foodborne illnesses. Follow the instructions for powdered and concentrated formula carefully—formula that is over diluted would not provide adequate calories and protein, while over-concentrated formula provides too much protein and too little water which can impair kidney function.

It is important to note again that both the American Academy of Pediatrics and the WHO state that breast milk is far superior to infant formula. This table compares the advantages of giving a child breast milk to the disadvantages of using bottle formula.

Table 12.4.2: Breast Milk versus Bottle Formula

Breast Milk	Bottle Formula
Antibodies and lactoferrin in breast milk protect infants.	Formula does not contain immunoprotective factors.
The iron in breast milk is absorbed more easily.	Formula contains more iron than breast milk, but it is not absorbed as easily.
The feces that babies produce do not smell because breastfed infants have different bacteria in the gut.	The feces that bottle-fed infants produce tends to have a foul-smelling odor.

Breast Milk	Bottle Formula
Breast milk is always available and is always at the correct temperature.	Formula must be prepared, refrigerated for storage, and warmed before it is given to an infant.
Breastfed infants are less likely to have constipation.	Bottle-fed infants are more likely to have constipation.
Breastfeeding ostensibly is free, though purchasing a pump and bottles to express milk does require some expense.	Formula must be purchased and is expensive.
Breast milk contains the fatty acids DHA and ARA, which are vital for brain and vision development.	Some formulas contain DHA and ALA.

Source: American Pregnancy Association. "Breastfeeding versus Bottle Feeding." November 5, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandbottle.html.

There are problems if a powdered formula is not correctly diluted with water. If it is too dilute, i.e. too much water is added, then the infant will have inadequate nutrient intake and may fail to grow as well as experience water intoxication. If the dry powder is mixed with too little water, then the infant may become dehydrated. The source of water used to make the formula should be free of contamination, for example, lead, to prevent infection or diarrhea which is common in developing countries that have poor water sanitation.

Video 12.4.1: Breastfeeding Mothers—La Leche League Canada

This video explains the benefits of breastfeeding for both mothers and infants. (click to see video)

- ## Introducing Solid Foods

Infants should be breastfed or bottle-fed exclusively for the first six months of life according to the WHO. (The American Academy of Pediatrics recommends breast milk or bottle formula exclusively for at least the first four months, but ideally for six months.) Infants should not consume solid foods prior to six months because solids do not contain the right nutrient mix that infants need. Also, eating solids may mean drinking less breast milk or bottle formula. If that occurs, an infant may not consume the right quantities of various nutrients. If parents try to feed an infant who is too young or is not ready, their tongue will push the food out, which is called an extrusion reflex. After six months, the suck-swallow reflexes are not as strong, and infants can hold up their heads and move them around, both of which make eating solid foods more feasible.

Solid baby foods can be bought commercially or prepared from regular food using a food processor, blender, food mill, or grinder at home. Usually, an infant cereal can be offered from a spoon between four to six months. By nine months to a year, infants are able to chew soft foods and can eat solids that are well chopped or mashed.

Infants who are fed solid foods too soon are susceptible to developing food allergies. Therefore, as parents and caregivers introduce solids, they should feed their child only one new food at a time (starting with rice cereal, followed by fruits or vegetables), to help identify allergic responses or food intolerances. An iron supplement or iron-fortified cereal is also recommended at this time because iron stores are depleted by about six months.

Nutrient-dense foods should be offered that are iron-rich foods like fortified cereals, pureed meat and vitamin C-rich foods that will help with iron absorption. Fruit juices should be limited to 4-6 ounces per day because they can cause diarrhea. One food should be introduced per week and it does not matter if fruit or vegetables are introduced first. Wheat cereal should be offered last.

Here are simple dietary guidelines for the last half of the infant's first year of life.

- • At about 6 months, introduce infants to nutrient-dense complementary foods.

  • Introduce infants to potentially allergenic foods along with other complementary foods.

  • Encourage infants and toddlers to consume a variety of foods from all food groups. Include foods rich in iron and zinc, particularly for infants fed human milk.

  • Avoid foods and beverages with added sugars.

  • Limit foods and beverages higher in sodium.

• As infants wean from human milk or infant formula, transition to a healthy dietary pattern

- ## Learning to Self-Feed

  Solid foods should be introduced when the infant is physiologically, immunologically, and developmentally ready which is around 6 months. At this time starch digestion capacity has developed and the kidneys can handle the increased protein found in food. Also, fat digestion is increased with bile acid secretion. Immunologically, the gastrointestinal tract lining has closed decreasing antigen access and the gut immune system is better developed reducing the risk of infection and food allergies. Developmentally, body weight has doubled and the baby can hold their head up and sit. The extrusion reflex has diminished and the infant is interacting with their environment. They may be asking for food and can indicate satiety by turning away and leaning back. They may be able to chew and bring the food to their mouth.

  With the introduction of solid foods, young children begin to learn how to handle food and how to feed themselves. At six to seven months, infants can use their whole hand to pick up items (this is known as the palmer grasp). They can lift larger items, but picking up smaller pieces of food is difficult. At eight months, a child might be able to use a pincer grasp, which uses fingers to pick up objects. After the age of one, children slowly begin to use utensils to handle their food. Unbreakable dishes and cups are essential, since very young children may play with them or throw them when they become bored with their food.

- ## Feeding Problems during Infancy

  Parents and caregivers should be mindful of certain diet-related problems that may arise during infancy. Certain foods are choking hazards, including foods with skins or foods that are very small, such as grapes. Other examples of potential choking hazards include raw carrots and apples, raisins, hard candy, hot dogs, gum, marshmallows, whole grapes, cherries, popcorn, raw carrots, celery, whole beans, nuts and peanut butter. These foods should be avoided.

  Egg whites, chocolate, nuts and unprocessed cow's milk should be avoided until after the first year of life. Honey, Corn syrup can contain the botulism toxin so should be avoided as well as unpasteurized juices or milk products, and raw or undercooked eggs, meat, fish poultry, and shellfish. Parents should also avoid adding salt or seasonings to an infant's food as well as canned vegetables because the sodium can present a problem. Sugar alcohols can cause diarrhea so these foods should be avoided too. Baby desserts or concentrated sweets are not recommended.

  Heating an infant's food presents a risk of accidental injury or burns, which may occur if the food is heated unevenly or excessively. Keep in mind that an infant cannot communicate that the food is too hot. Also, parents and caregivers should never leave a baby alone at mealtime, because an infant can accidentally choke on pieces of food that are too big or have not been adequately chewed. Raw honey and corn syrup both contain spores of *Clostridium botulinum*. They produce a poisonous toxin in a baby's intestines, which can cause the foodborne illness botulism. After the age of one, it is safe to give an infant honey or corn syrup. However, honey as an ingredient in food, such as in cereal, is safe for all ages because it has been adequately heat-treated.

- ## Overnutrition

  Overnutrition during infancy is a growing problem. Overfed infants may develop dietary habits and metabolic characteristics that last a lifetime. According to the *American Journal of Clinical Nutrition*, the consequences of overnutrition and growth acceleration in infancy include long-term obesity, along with Type 2 diabetes and cardiovascular disease later in life.Singhal, A. et al. "Nutrition in Infancy and Long-Term Risk of Obesity: Evidence from Two Randomized Control Trials." *Am J Clin Nutr* 92 (2010): 1133–44. Therefore, parents and other caregivers should restrain from overfeeding, and ideally give their infants breast milk to promote health and well-being.

- ## Food Allergies

  Food allergies impact four to six percent of young children in America. Common food allergens that can appear just before or after the first year include peanut butter, egg whites, wheat, cow's milk, and nuts. For infants, even a small amount of a dangerous food can prove to be life-threatening. If there is a family history of food allergies, it is a good idea to delay giving a child dairy products until one year of age, eggs until two years of age, and shellfish, fish, and nuts until three years of age.

  However, lactating women should not make any changes to their diets. Research shows that nursing mothers who attempt to ward off allergies in their infants by eliminating certain foods may do more harm than good. According to the American Academy of Allergy, Asthma, and Immunology, mothers who avoided certain dairy products showed decreased levels in their

breast milk of an immunoglobulin specific to cow's milk. This antibody is thought to protect against the development of allergies in children. Even when an infant is at higher risk for food allergies, there is no evidence that alterations in a mother's diet make a difference.Gever, J. "Nursing Mom's Diet No Guard Against Baby Allergies." Medpage Today. © 2012 Everyday Health, Inc. March 7, 2012. http://www.medpagetoday.com/MeetingCoverage/AAAAIMeeting/31527?utm_content=&utm_medium=email&utm _campaign=DailyHeadlines&utm_source=WC&eun=g330425d0r&userid=330425&email=mzimmerman@cox.net&mu_id=. Approximately one percent of formula-fed infants develop a food allergy.

- ## Early Childhood Caries

  Primary teeth are at risk for a disorder known as early childhood caries from breast milk, formula, juice, or other drinks fed through a bottle. Liquids can build up in a baby's mouth, and the natural or added sugars lead to decay. Early childhood caries is caused not only by the kinds of liquids given to an infant but also by the frequency and length of time that fluids are given. Giving a child a bottle of juice or other sweet liquids several times each day, or letting a baby suck on a bottle longer than a mealtime, either when awake or asleep, can also cause early childhood caries. Bacteria in the mouth feed on the carbohydrate and cause teeth decay. In addition, this practice affects the development and position of the teeth and the jaw. The risk of early childhood caries continues into the toddler years as children begin to consume more foods with a high sugar content. Therefore, parents should avoid giving their children sugary snacks and beverages.

- ## Gastroesophageal Reflux

  Small amounts of spitting up during a feeding are normal. However, there is cause for concern if it is too difficult to feed an infant due to gastroesophageal reflux. This condition occurs when stomach muscles open at the wrong times and allow milk or food to back up into the esophagus. Symptoms of gastroesophageal reflux in infants include severe spitting up, projectile vomiting, arching of the back as though in pain, refusal to eat or pulling away from the breast during feedings, gagging or problems with swallowing, and slow weight gain. For most infants, making adjustments in feeding practices addresses the issue. For example, a parent can feed their baby in an upright position, wait at least an hour after eating for play time, burp more often, or give a child smaller, more frequent feedings.

- ## Diarrhea and Constipation

  Diarrhea is often caused by a gastrointestinal infection and can dehydrate an infant. It is characterized by stool frequency and consistency that deviates substantially from the norm. Diarrhea may indicate a bacterial or viral infection or food intolerance. Chronic diarrhea can cause growth failure. If an infant has had several bouts of this condition, they will need to replace lost fluids and electrolytes. A common recommendation is to give a child an oral rehydration solution. Because of the immunoprotective factors in breast milk, breastfed infants are less likely to contract gastrointestinal viral illness and experience diarrhea.

  Infant constipation—which is the passage of hard, dry bowel movements, but not necessarily the absence of daily bowel movements—is another common problem. This condition frequently begins when a baby transitions from breast milk to formula or begins eating solid foods. Pediatricians can provide the best guidance for handling the problem. Common recommendations include applying a small amount of water-based lubricant to an infant's anus to ease the passage of hard stools, and feeding an infant on solid foods pureed pears or prunes, or providing barley cereal in place of rice cereal.Mayo Clinic. "Infant and Toddler Health." March 16, 2011. © 1998–2012 Mayo Foundation for Medical Education and Research. www.mayoclinic.com/health/infant-and-toddler-health/MY00362. Parents can also offer their child a little more water in between feedings to help alleviate the condition.

- ## Colic

  Colic is a common problem during infancy, characterized by crankiness and crying jags. It is defined as crying that lasts longer than three hours per day for at least three days per week and for at least three weeks (which is commonly known as the "rule of 3's"), and is not caused by a medical problem. About one-fifth of all infants develop colic, usually between the second and third weeks. Crying spells can occur around the clock but often worsen in the early evening. Also, colicky babies may have stomachs that are enlarged or distended with gas.

  There is no definitive explanation for colic. Often, colic occurs when a child is unusually sensitive to stimulation. In breastfed babies, colic can be a sign of sensitivity to the mother's diet. Lactating mothers can try to eliminate caffeine, chocolate, and any other potentially irritating foods from their meals.Medline Plus, a service of the US National Library of Medicine. "Colic and

Crying.” Last updated August 2, 2011. www.nlm.nih.gov/medlineplus/ency/article/000978.htm. However, since colic usually subsides over time, any improvement that occurs with food elimination may coincide with the natural healing process.

Parents and caregivers who are feeding bottle formula to colicky babies should talk with pediatricians about replacing it with a protein hydrolysate formula.American Academy of Pediatrics. “Colic.” HealthyChildren.org. © American Academy of Pediatrics. Last updated May 12, 2011. http://www.healthychildren.org/English/ages-stages/baby/crying-colic/pages/Colic.aspx. Whether breastfeeding or bottle-feeding, it is also important not to overfeed infants, which could make them uncomfortable and more likely to have crying fits. In general, it is best to wait between two and three hours from the start of one feeding to the start of the next. If food sensitivity is the cause, colic should cease within a few days of making changes. Eventually, the problem goes away. Symptoms usually begin to dissipate after six weeks and are gone by twelve weeks.Medline Plus, a service of the US National Library of Medicine. “Colic and Crying.” Last updated August 2, 2011. www.nlm.nih.gov/medlineplus/ency/article/000978.htm.

- ## Newborn Jaundice

Newborn jaundice is another potential problem during infancy. This condition can occur within a few days of birth and is characterized by yellowed skin or yellowing in the whites of the eyes, which can be harder to detect in dark-skinned babies. Jaundice typically appears on the face first, followed by the chest, abdomen, arms, and legs. This disorder is caused by elevated levels of bilirubin in a baby’s bloodstream. Bilirubin is a substance created by the breakdown of red blood cells and is removed by the liver. Jaundice develops when a newborn’s liver does not efficiently remove bilirubin from the blood. There are several types of jaundice associated with newborns:

- **Physiologic jaundice.** The most common type of newborn jaundice and can affect up to 60 percent of full-term babies in the first week of life.
- **Breast-milk jaundice.** The name for a condition that persists after physiologic jaundice subsides in otherwise healthy babies and can last for three to twelve weeks after birth. Breast-milk jaundice tends to be genetic and there is no known cause, although it may be linked to a substance in the breast milk that blocks the breakdown of bilirubin. However, that does not mean breastfeeding should be stopped. As long as bilirubin levels are monitored, the disorder rarely leads to serious complications.
- **Breastfeeding jaundice.** Occurs when an infant does not get enough milk. This may happen because a newborn does not get a good start breastfeeding, does not latch on to the mother’s breast properly, or is given other substances that interfere with breastfeeding (such as juice). Treatment includes increased feedings, with help from a lactation consultant to ensure that the baby takes in adequate amounts.



Figure 12.4.2: Yellowing skin is one sign of newborn jaundice. IMage used with permission (CC BY-SA 3.0; Martybugs).

Newborn jaundice is more common in a breastfed baby and tends to last a bit longer. If jaundice is suspected, a pediatrician will run blood tests to measure the amount of bilirubin in an infant’s blood. Treatment often involves increasing the number of feedings to increase bowel movements, which helps to excrete bilirubin. Within a few weeks, as the baby begins to mature and red blood cell levels diminish, jaundice typically subsides with no lingering effects.American Pregnancy Association. “Breastfeeding and Jaundice.” © 2000–2012 American Pregnancy Association. Accessed February 21, 2012. http://www.americanpregnancy.org/firstyearoflife/breastfeedingandjaundice.htm.

Iron Deficiency Anemia

A poor transition from breast milk, which is a poor source of iron, to solid foods can cause an iron deficiency or anemia. Remember, during the first six months of life, the infant is drawing on his/her iron stores which were accumulated *in utero*. By six months of age, the infant's iron stores are low so it is important they are given iron-rich foods for their first foods. In children drinking cow's milk, milk anemia may develop if 2-3 cups of cow's milk is consumed per day. The milk displaces the iron making it unavailable for absorption.

Vegetarian Diets

For the first six months of life, infants are lactovegetarian because the consume milk. After six months, maintaining a vegan status becomes more challenging. Vegans should consult a pediatrician and a registered dietitian if they want to continue their infant as a vegan. Continued breastfeeding or formula feeding may be recommended with supplementary feeding to assure adequate iron and energy intake.

Key Takeaways

Parents and other caregivers should use growth charts to track an infant's development and determine how to best meet their child's nutritional needs. For the first four to six months of life, children should consume breast milk exclusively. For the next six months, solid foods should be introduced gradually into an infant's diet as parents and caregivers continue to provide breast milk. Breast milk is ideal for infants and provides all of the nutrients they need to grow and develop. Breastfeeding provides a number of benefits for both a mother and her infant. For babies, breast milk boosts the immune system to protect against disease. For mothers, breastfeeding has several health benefits, such as reducing the risk of breast cancer and ovarian cancer. For both, breastfeeding promotes an emotional bond between mother and child. Some problems related to food and nutrition that may occur during infancy include overnutrition, early childhood caries, gastroesophageal reflux, diarrhea, constipation, and colic.

Discussion Starter

1. Why do some women choose to breastfeed their infants? Why do others decline to breastfeed? Discuss this crucial decision that parents make in the first stages of an infant's life and the possible consequences of each choice.

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12.5: Nutrition in the Toddler Years

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for toddlers.
- Explore the introduction of solid foods into a toddler's diet.
- Examine feeding problems that parents and caregivers may face with their toddlers.

By the age of two, children have advanced from infancy and are on their way to becoming school-aged children. Their physical growth and motor development slow compared to the progress they made as infants. However, toddlers experience enormous intellectual, emotional, and social changes. Of course, food and nutrition continue to play an important role in a child's development. During this stage, the diet completely shifts from breastfeeding or bottle-feeding to solid foods along with healthy juices and other liquids. The toddler's metabolism slows compared to the infant so their appetite decreases. Parents of toddlers also need to be mindful of certain nutrition-related issues that may crop up during this stage of the human lifecycle. For example, fluid requirements relative to body size are higher in toddlers than in adults because children are at greater risk of dehydration. Toddlers should drink about 1.3 liters of fluids per day, ideally liquids that are low in sugar. Compared to infants, toddler fluid, energy and protein requirements per kilogram are lower.

Several assessments will be used to determine if the child is the appropriate size for their age. These include charts of height and weight: height-for-age and weight-for-age. If the child is less than the fifth percentile they would be considered stunted or underweight, respectively. BMI may also be calculated as a screening tool to give an indirect measurement of body fatness. If it is less than the fifth percentile the child would be considered underweight. If it is greater than the 95th percentile then the child is overweight. Head circumference will be measured too.

The Toddler Years (Ages Two to Three)

During this phase of human development, children are mobile and grow more slowly than infants, but are much more active. Their nutritional needs increase with age but decrease per kg body weight. The toddler years pose interesting challenges for parents or other caregivers, as children learn how to eat on their own and begin to develop personal preferences. However, with the proper diet and guidance, toddlers can continue to grow and develop at a healthy rate.

Nutritional Requirements

MyPlate may be used as a guide for the toddler's diet (www.choosemyplate.gov/preschoolers.html). A toddler's serving sizes should be approximately one-quarter that of an adult's. One way to estimate serving sizes for young children is one tablespoon for each year of life. For example, a two-year-old child would be served 2 tablespoons of fruits or vegetables at a meal, while a four-year-old would be given 4 tablespoons or a quarter cup. Here is an example of a toddler-sized meal:

- 1 ounce of meat or chicken, or 2 to 3 tablespoons of beans
- One-quarter slice of whole-grain bread
- 1 to 2 tablespoons of cooked vegetable
- 1 to 2 tablespoons of fruit

Energy

The energy requirements for ages two to three are about 1,000 to 1,400 calories a day. The following formula can also be used to calculate energy needs: kcal/d = ((89*weight in kg)-100_+20. In general, a toddler needs to consume about 40 calories for every inch of height. For example, a young child who measures 32 inches should take in an average of 1,300 calories a day. However, the recommended caloric intake varies with each child's level of activity. Toddlers require small, frequent, nutritious snacks and meals to satisfy energy requirements. The amount of food a toddler needs from each food group depends on daily calorie needs. See Table 12.5 for some examples.

Table 12.5.1: Serving Sizes for Toddlers

Food Group	Daily Serving	Examples
Grains	About 3 ounces of grains per day, ideally whole grains	• 3 slices of bread • 1 slice of bread, plus ⅓ cup of cereal, and ¼ cup of cook
Proteins	2 ounces of meat, poultry, fish, eggs, or legumes	• 1 ounce of lean meat or chicken, plus one egg • 1 ounce of fish, plus ¼ cup of cooked beans
Fruits	1 cup of fresh, frozen, canned, and/or dried fruits, or 100 percent fruit juice	• 1 small apple cut into slices • 1 cup of sliced or cubed fruit • 1 large banana
Vegetables	1 cup of raw and/or cooked vegetables	• 1 cup of pureed, mashed, or finely chopped vegetables (s broccoli, or tomato sauce)
Dairy Products	2 cups per day	• 2 cups of fat-free or low-fat milk • 1 cup of fat-free or low-fat milk, plus 2 slices of cheese • 1 cup of fat-free or low-fat milk, plus 1 cup of yogurt

Source: Academy of Nutrition and Dietetics. "It's about Eating Right: Size-Wise Nutrition for Toddlers." © 1995–2012, Academy of Nutrition and Dietetics, all rights reserved. www.eatright.org/public/content.aspx?id=8055.

Macronutrients

For carbohydrate intake, the Acceptable Macronutrient Distribution Range (AMDR) is 45 to 65 percent of daily calories (113 to 163 grams for 1,000 daily calories). Toddlers' needs increase to support their body and brain development. Brightly-colored unrefined complex carbohydrates, such as peas, orange slices, tomatoes, and bananas are not only nutrient-dense, they also make a plate look more appetizing and appealing to a young child. Low sugar snacks over snacks with added sugar should be emphasized. The RDA of protein is 5 to 20 percent of daily calories (13 to 50 grams for 1,000 daily calories). The AMDR for fat for toddlers is 30 to 40 percent of daily calories (33 to 44 grams for 1,000 daily calories). Essential fatty acids are vital for the development of the eyes, along with nerve and other types of tissue. However, toddlers should not consume foods with high amounts of trans fats and saturated fats. Instead, young children require the equivalent of 3 teaspoons of healthy oils, such as canola oil, each day.

Micronutrients

As a child grows bigger, the demands for micronutrients increase. Generally, well-nourished children do not need supplements but there are three exceptions: fluoride, iron, and vitamin D. These needs for vitamins and minerals can be met with a balanced diet, with a few exceptions. According to the American Academy of Pediatrics, toddlers and children of all ages need 600 international units of vitamin D per day. Vitamin D-fortified milk and cereals can help to meet this need. However, toddlers who do not get enough of this micronutrient should receive a supplement otherwise.

Pediatricians may also prescribe a fluoride supplement for toddlers who live in areas with fluoride-poor water. Iron deficiency is also a major concern for children between the ages of two and three. You will learn about iron-deficiency anemia later in this section.

If the child does not eat enough fruits and vegetables, their intake of vitamin A and C may be inadequate. If they avoid dairy or don't eat and drink enough dairy, then their calcium intake may be low.

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Learning How to Handle Food

As children grow older, they enjoy taking care of themselves, which includes self-feeding. During this phase, it is important to offer children foods that they can handle on their own and that helps them avoid choking and other hazards. Examples include fresh fruits that have been sliced into pieces, orange or grapefruit sections, peas or potatoes that have been mashed for safety, a cup of yogurt, and whole-grain bread or bagels cut into pieces. Even with careful preparation and training, the learning process can be messy. As a result, parents and other caregivers can help children learn how to feed themselves by providing the following:

- small utensils that fit a young child's hand
- small cups that will not tip over easily
- plates with edges to prevent food from falling off
- small servings on a plate
- high chairs, booster seats, or cushions to reach a table

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Feeding Problems in the Toddler Years

During the toddler years, parents may face a number of problems related to food and nutrition. Possible obstacles include difficulty helping a young child overcome a fear of new foods, or fights over messy habits at the dinner table. Even in the face of problems and confrontations, parents and other caregivers must make sure their preschooler has nutritious choices at every meal. For example, even if a child stubbornly resists eating vegetables, parents should continue to provide them. Before long, the child may change their mind, and develop a taste for foods once abhorred. It is important to remember this is the time to establish or reinforce healthy habits.

Nutritionist Ellyn Satter states that feeding is a responsibility that is split between parent and child. According to Satter, parents are responsible for *what* their infants eat, while infants are responsible for *how much* they eat. In the toddler years and beyond, parents are responsible for *what* children eat, *when* they eat, and *where* they eat, while children are responsible for *how much* food they eat and *whether* they eat. Satter states that the role of a parent or a caregiver in feeding includes the following:

- selecting and preparing food (including the toddler can be fun)
- providing regular meals and snacks
- making meal times interactive and enjoyable
- showing children what they must learn about mealtime behavior
- Introducing new foods at the beginning of the meal when the child is hungry
- avoiding letting children eat in between meal- or snack-times (Ellyn Satter Associates. "Ellyn Satter's Division of Responsibility in Feeding." © 2012 by Ellyn Satter. www.ellynsatter.com/ellyn-satters-division-of-responsibility -in-feeding-i-80.html.)

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High-Risk Choking Foods

Certain foods are difficult for toddlers to manage and pose a high risk of choking. Big chunks of food should not be given to children under the age of four. Also, globs of peanut butter can stick to a younger child's palate and choke them. Popcorn and nuts should be avoided as well because toddlers are not able to grind food and reduce it to a consistency that is safe for swallowing. Certain raw vegetables, such as baby carrots, whole cherry tomatoes, whole green beans, and celery are also serious choking hazards. However, there is no reason that a toddler cannot enjoy well-cooked vegetables cut into bite-size pieces.

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Picky Eaters

The parents of toddlers are likely to notice a sharp drop in their child's appetite. Children at this stage are often picky about what they want to eat. They may turn their heads away after eating just a few bites. Or, they may resist coming to the table at mealtimes. They also can be unpredictable about what they want to consume for specific meals or at particular times of the day. Although it may seem as if toddlers should increase their food intake to match their level of activity, there is a good reason for picky eating. A child's growth rate slows after infancy, and toddlers ages two and three do not require as much food.

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Food Jags

For weeks, toddlers may go on a food jag and eat one or two preferred foods—and nothing else. It is important to understand that preferences will be inconsistent as a toddler develops eating habits. This is one way that young children can assert their individuality and independence. However, parents and caregivers should be concerned if the same food jag persists for several months, instead of several weeks. Options for addressing this problem include rotating acceptable foods while continuing to offer diverse foods, remaining low-key to avoid exacerbating the problem and discussing the issue with a pediatrician. Also, children should not be forced to eat foods that they do not want. It is important to remember that food jags do not have a long-term effect on a toddler's health, and are usually temporary situations that will resolve themselves.

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Toddler Obesity

Another potential problem during the early childhood years is toddler obesity. According to the US Department of Health and Human Services, in the past thirty years, obesity rates have more than doubled for all children, including infants and toddlers.Head Start, US Department of Health and Human Services. "Prevention of Overweight and Obesity in Infants and Toddlers." 2005. Accessed February 21, 2012. http://eclkc.ohs.acf.hhs.gov/hslc/tta-system/family Almost 10 percent of infants and toddlers weigh more than they should considering their length, and slightly more than 20 percent of children ages two to five are overweight or obese.Institute of Medicine of the National Academies. "Early Childhood Obesity Prevention Policies." June 23, 2011. www.iom.edu/Reports/2011/Early-Childhood -Obesity-Prevention-Policies.aspx Obesity during early childhood tends to linger as a child matures and cause health problems later in life.

There are a number of reasons for this growing problem. One is a lack of time. Parents and other caregivers who are constantly on the go may find it difficult to fit home-cooked meals into a busy schedule and may turn to fast food and other conveniences that are quick and easy, but not nutritionally sound. Another contributing factor is a lack of access to fresh fruits and vegetables. This is a problem particularly in low-income neighborhoods where local stores and markets may not stock fresh produce or may have limited options. Physical inactivity is also a factor, as toddlers who live a sedentary lifestyle are more likely to be overweight or obese. Another contributor is a lack of breastfeeding support. Children who were breastfed as infants show lower rates of obesity than children who were bottle-fed.

To prevent or address toddler obesity parents and caregivers can do the following:

- Eat at the kitchen table instead of in front of a television to monitor what and how much a child eats.
- Offer a child healthy portions. The size of a toddler's fist is an appropriate serving size.
- Plan time for physical activity, about sixty minutes or more per day. Toddlers should have no more than sixty minutes of sedentary activity, such as watching television, per day.

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Early Childhood Caries

Early childhood caries remains a potential problem during the toddler years. The risk of early childhood caries continues as children begin to consume more foods with a high sugar content. According to the National Health and Nutrition Examination Survey, children between ages of two and five consume about 200 calories of added sugar per day.US Department of Health and Human Services. "Consumption of Added Sugar among US Children and Adolescents." *NCHS Data Brief*, No. 87 (March 2012). Therefore, parents with toddlers should avoid processed foods, such as snacks from vending machines, and sugary beverages, such as soda. Parents also need to instruct a child on brushing their teeth at this time to help a toddler develop healthy habits and avoid tooth decay.

Iron-Deficiency Anemia

An infant who switches to solid foods, but does not eat enough iron-rich foods, can develop iron-deficiency anemia. This condition occurs when an iron-deprived body cannot produce enough hemoglobin, a protein in red blood cells that transports oxygen throughout the body. The inadequate supply of hemoglobin for new blood cells results in anemia. Iron-deficiency anemia causes a number of problems including weakness, pale skin, shortness of breath, and irritability. It can also result in intellectual, behavioral, or motor problems. In infants and toddlers, iron-deficiency anemia can occur as young children are weaned from iron-rich foods, such as breast milk and iron-fortified formula. They begin to eat solid foods that may not provide enough of this nutrient. As a result, their iron stores become diminished at a time when this nutrient is critical for brain growth and development.

There are steps that parents and caregivers can take to prevent iron-deficiency anemia, such as adding more iron-rich foods to a child's diet, including lean meats, fish, poultry, eggs, legumes, and iron-enriched whole-grain breads and cereals. A toddler's diet should provide 7 to 10 milligrams of iron daily. Although milk is critical for the bone-building calcium that it provides, intake should not exceed the RDA to avoid displacing foods rich with iron. Children may also be given a daily supplement, using infant vitamin drops with iron or ferrous sulfate drops. If iron-deficiency anemia does occur, treatment includes a dosage of 3 milligrams per kilogram once daily before breakfast, usually in the form of a ferrous sulfate syrup. Consuming vitamin C, such as orange juice, can also help to improve iron absorption.Kazal Jr., L. A., MD. "Prevention of Iron Deficiency in Infants and Toddlers." *American Academy of Family Physicians* 66, no. 7 (October 1, 2002): 1217—25. www.aafp.org/afp/2002/1001/p1217.html.

Toddler Diarrhea

As with adults, a variety of conditions or circumstances may give a toddler diarrhea. Possible causes include bacterial or viral infections, food allergies, or lactose intolerance, among other medical conditions. Excessive fruit juice consumption (more than one 6-ounce cup per day) can also lead to diarrhea.American Academy of Pediatrics, Committee on Nutrition 1999–2000. "The Use and Misuse of Fruit Juice in Pediatrics." *Pediatrics* 119, no. 2 (February 2007): 405. doi:10.1542/peds.2006-3222. Diarrhea presents a special concern in young children because their small size makes them more vulnerable to dehydration. Parents should contact a pediatrician if a toddler has had diarrhea for more than twenty-four hours, if a child is also vomiting, or if they exhibit signs of dehydration, such as a dry mouth or tongue, or sunken eyes, cheeks, or abdomen. Preventing or treating dehydration in toddlers includes the replacement of lost fluids and electrolytes (sodium and potassium). Oral rehydration therapy, or giving special fluids by mouth, is the most effective measure.

Developing Habits

Eating habits develop early in life. They are typically formed within the first few years and it is believed that they persist for years, if not for life. So it is important for parents and other caregivers to help children establish healthy habits and avoid problematic ones. Children begin expressing their preferences at an early age. Parents must find a balance between providing a child with an opportunity for self-expression, helping a child develop healthy habits, and making sure that a child meets all of their nutritional needs. Following Ellyn Satter's division of responsibility in feeding (see above) can help a child eat the right amount of food, learn mealtime behavior, and grow at a healthy and predictable rate.

Bad habits and poor nutrition have an accrual effect. The foods you consume in your younger years will impact your health as you age, from childhood into the later stages of life. As a result, good nutrition today means optimal health tomorrow. In the next chapter, you will learn about how nutritional needs change from the later childhood years, through adolescence and adulthood, and into old age. The choices that you make at every age accumulate over time and greatly impact your health into the golden years.

Video 12.4: Introducing Your Toddler to New Foods

This video focuses on ways to encourage toddlers to try new foods. (click to see video)

Lead Poisoning

Lead poisoning is a leading cause of poisoning in this age and usually occurs from ingesting lead paint. Lead is a heavy metal and it accumulates in the bones, brain, teeth, and kidneys. lead poisoning causes iron deficiency, learning disabilities and behavioral changes, paralysis, nerve damage, and death with severe toxicity.

Effect of Food on Behavior

Sugar and food additives have been promoted to cause hyperactivity. There is no scientific evidence to support these claims. Eating sugar laden foods will increase short-term activity, but that will decrease quickly. A high dose of sugar can act as a sedative after the initial stimulation.

Caffeine can be found in a variety of different foods, not just coffee. Sodas and chocolate can contain caffeine so you need to read the ingredient list to if it is present in the product. Caffeine is a stimulant and may cause hyperactivity in some children. Other children are sensitive to caffeine.

Scientific studies have shown that breakfast improves school performance. Children who skip breakfast have a shorter attention span and poorer concentration.

Key Takeaways

By the toddler years, young children are able to self-feed and begin to develop eating habits and preferences. The energy requirements for ages two to three are about 1,000 to 1,400 calories per day, and in general, a toddler needs to consume about 40 calories for every inch of height. Growth slows during the toddler years, but children are more active at this stage and undergo a great deal of intellectual, emotional, and social development. Some food- and nutrition-related problems that can occur during the toddler years include choking, picky eating, food jags, early childhood caries, iron-deficiency anemia, and toddler diarrhea.

Discussion Starter

1. How do the nutritional needs of a child change from infancy into the toddler years? Discuss the changing needs for energy, macronutrients, and micronutrients as young children mature.

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12.6: Childhood and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for school-aged children.
- Discuss the most important nutrition-related concerns during childhood.

Nutritional needs change as children leave the toddler years. From ages four to eight, school-aged children grow consistently, but at a slower rate than infants and toddlers. They also experience the loss of deciduous, or “baby,” teeth and the arrival of permanent teeth, which typically begins at age six or seven. As new teeth come in, many children have some malocclusion, or malposition, of their teeth, which can affect their ability to chew food. Other changes that affect nutrition include the influence of peers on dietary choices and the kinds of foods offered by schools and afterschool programs, which can make up a sizable part of a child’s diet. Food-related problems for young children can include tooth decay, food sensitivities, and malnourishment. Also, excessive weight gain early in life can lead to obesity into adolescence and adulthood.

- Childhood (Ages Four to Eight): “Growing Pains”



Figure 12.6.1: In school-aged children, muscle mass and strength increase and motor skills show improvement. (Public Domain; Tysto)

At this life stage, a healthy diet facilitates physical and mental development and helps to maintain health and wellness. School-aged children experience steady, consistent growth, with an average growth rate of 2–3 inches (5–7 centimeters) in height and 4.5–6.5 pounds (2–3 kilograms) in weight per year. In addition, the rate of growth for the extremities is faster than for the trunk, which results in more adult-like proportions. Long-bone growth stretches muscles and ligaments, which results in many children experiencing “growing pains,” at night time in particular.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 150–51.

Energy

Children’s energy needs vary, depending on their growth and level of physical activity. Energy requirements also vary according to gender. Girls ages four to eight require 1,200 to 1,800 calories a day, while boys need 1,200 to 2,000 calories daily, and, depending on their activity level, maybe more. Also, recommended intakes of macronutrients and most micronutrients are higher relative to body size, compared with nutrient needs during adulthood. Therefore, children should be provided nutrient-dense food at meal- and snack-time. However, it is important not to overfeed children, as this can lead to childhood obesity, which is discussed in the next section. Parents and other caregivers can turn to the MyPlate website for guidance: http://www.choosemyplate.gov/.

Macronutrients

For carbohydrates, the Acceptable Macronutrient Distribution Range (AMDR) is 45–65 percent of daily calories (which is a recommended daily allowance of 135–195 grams for 1,200 daily calories). Carbohydrates high in fiber should make up the bulk of intake. The AMDR for protein is 10–30 percent of daily calories (30–90 grams for 1,200 daily calories). Children have a high need for protein to support muscle growth and development. High levels of essential fatty acids are needed to support growth (although not as high as in infancy and the toddler years). As a result, the AMDR for fat is 25–35 percent of daily calories (33–47 grams for 1,200 daily calories). Children should get 17–25 grams of fiber per day.

Micronutrients

Micronutrient needs should be met with foods first. Parents and caregivers should select a variety of foods from each food group to ensure that nutritional requirements are met. Because children grow rapidly, they require foods that are high in iron, such as lean meats, legumes, fish, poultry, and iron-enriched cereals. Adequate fluoride is crucial to support strong teeth. One of the most important micronutrient requirements during childhood is adequate calcium and vitamin D intake. Both are needed to build dense bones and a strong skeleton. Children who do not consume adequate vitamin D should be given a supplement of 10 micrograms (400 international units) per day. Table 12.6.1 shows the micronutrient recommendations for school-aged children. (Note that the recommendations are the same for boys and girls. As we progress through the different stages of the human life cycle, there will be some differences between males and females regarding micronutrient needs.)

Table 12.6.1: Micronutrient Levels during Childhood

Nutrient	Children, Ages 4–8
Vitamin A (mcg)	400.0
Vitamin B_6 (mcg)	600.0
Vitamin B_{12} (mcg)	1.2
Vitamin C (mg)	25.0
Vitamin D (mcg)	5.0
Vitamin E (mg)	7.0
Vitamin K (mcg)	55.0
Calcium (mg)	800.0
Folate (mcg)	200.0
Iron (mg)	10.0
Magnesium (mg)	130.0
Niacin (B_3) (mg)	8.0
Phosphorus (mg)	500.0
Riboflavin (B_2) (mcg)	600.0
Selenium (mcg)	30.0
Thiamine (B_1) (mcg)	600.0
Zinc (mg)	5.0

Source: Institute of Medicine. www.iom.edu.

Factors Influencing Intake

A number of factors can influence children's eating habits and attitudes toward food. Family environment, societal trends, taste preferences, and messages in the media all impact the emotions that children develop in relation to their diet. Television commercials can entice children to consume sugary products, fatty fast foods, excess calories, refined ingredients, and sodium. Therefore, it is critical that parents and caregivers direct children toward healthy choices.

One way to encourage children to eat healthy foods is to make meal- and snack-time fun and interesting. Parents should include children in food planning and preparation, for example selecting items while grocery shopping or helping to prepare part of a meal, such as making a salad. At this time, parents can also educate children about kitchen safety. It might be helpful to cut sandwiches, meats, or pancakes into small or interesting shapes. In addition, parents should offer nutritious desserts, such as fresh fruits, instead of calorie-laden cookies, cakes, salty snacks, and ice cream. Also, studies show that children who eat family meals on a frequent basis consume more nutritious foods. Dakota County, Minnesota. “Research on the Benefits of Family Meals.” © 2006. Last revised April 30, 2012. www.co.dakota.mn.us/Departments/PublicHealth/Projects/ResearchFamilyMeals.htm.

- ## Children and Malnutrition

Malnutrition is a problem many children face, in both developing nations and the developed world. Even with the wealth of food in North America, many children grow up malnourished, or even hungry. The US Census Bureau characterizes households into the following groups:

- food secure
- food insecure without hunger
- food insecure with moderate hunger
- food insecure with severe hunger

Millions of children grow up in food-insecure households with inadequate diets due to both the amount of available food and the quality of food. In the United States, about 20 percent of households with children are food insecure to some degree. In half of those, only adults experience food insecurity, while in the other half both adults and children are considered to be food insecure, which means that children did not have access to adequate, nutritious meals at times.Coleman-Jensen, A. et al. “Household Food Security in the United States in 2010.” US Department of Agriculture, *Economic Research Report*, no. ERR-125 (September 2011).

Growing up in a food-insecure household can lead to a number of problems. Deficiencies in iron, zinc, protein, and vitamin A can result in stunted growth, illness, and limited development. Federal programs, such as the National School Lunch Program, the School Breakfast Program, and Summer Feeding Programs, work to address the risk of hunger and malnutrition in school-aged children. They help to fill the gaps and provide children living in food-insecure households with greater access to nutritious meals.

The National School Lunch Program

Beginning with preschool, children consume at least one of their meals in a school setting. Many children receive both breakfast and lunch outside of the home. Therefore, it is important for schools to provide meals that are nutritionally sound. In the United States, more than thirty-one million children from low-income families are given meals provided by the National School Lunch Program. This federally-funded program offers low-cost or free lunches to schools, and also snacks to after school facilities. School districts that take part receive subsidies from the US Department of Agriculture (USDA) for every meal they serve. School lunches must meet the *2020 Dietary Guidelines for Americans* and need to provide one-third of the RDAs for protein, vitamin A, vitamin C, iron, and calcium. However, local authorities make the decisions about what foods to serve and how they are prepared.US Department of Agriculture. “National School Lunch Program Fact Sheet.” 2019. Accessed April 28, 2022. https://fns-prod.azureedge.us/sites/...PFactSheet.pdf. The Healthy School Lunch Campaign works to improve the food served to children in school and to promote children’s short- and long-term health by educating government officials, school officials, food service workers, and parents. Sponsored by the Physicians Committee for Responsible Medicine, this organization encourages schools to offer more low-fat, cholesterol-free options in school cafeterias and in vending machines.Physicians Committee for Responsible Medicine. “Healthy School Lunches.” Accessed April 28, 2012. https://www.pcrm.org/good-nutrition/healthy-communities/healthy-school-food.



Video 12.6.1: *The USDA Introduces New School Lunch Standards. (click to see video). This video focuses on changes to the National School Lunch Program in the United States.*

- ## Children and Vegetarianism

  Another issue that some parents face with school-aged children is the decision to encourage a child to become a vegetarian or a vegan. Some parents and caregivers decide to raise their children as vegetarians for health, cultural, or other reasons. Preteens and teens may make the choice to pursue vegetarianism on their own, due to concerns about animals or the environment. No matter the reason, parents with vegetarian children must take care to ensure vegetarian children get healthy, nutritious foods that provide all the necessary nutrients.

- ## Types of Vegetarian Diets

  There are several types of vegetarians, each with certain restrictions in terms of diet:

  - **Ovo-vegetarians.** Ovo-vegetarians eat eggs but do not eat any other animal products.
  - **Lacto-ovo-vegetarians.** Lacto-ovo-vegetarians eat eggs and dairy products but do not eat any meat.
  - **Lacto-vegetarians.** Lacto-vegetarians eat dairy products but do not eat any other animal products.
  - **Vegans.** Vegans eat food only from plant sources, no animal products at all.

  Children who consume some animal products, such as eggs, cheese, or other forms of dairy, can meet their nutritional needs. For a child following a strict vegan diet, planning is needed to ensure adequate intake of protein, iron, calcium, vitamin B_{12}, and vitamin D. Legumes and nuts can be eaten in place of meat, soy milk fortified with calcium and vitamins D and B_{12} can replace cow's milk.

- ## Food Allergies and Food Intolerance

  The development of food allergies is a concern during the toddler years. This remains an issue for school-aged children. Recent studies show that three million children under age eighteen are allergic to at least one type of food.American Academy of Allergy, Asthma and Immunology. "Allergy Statistics." Accessed on March 5, 2012. http://www.aaaai.org/about-the-aaaai/newsroom/allergy-statistics.aspx. Some of the most common allergenic foods include peanuts, milk, eggs, soy, wheat, and shellfish. An allergy occurs when a protein in food triggers an immune response, which results in the release of antibodies, histamine, and other defenders that attack foreign bodies. Possible symptoms include itchy skin, hives, abdominal pain, vomiting, diarrhea, and nausea. Symptoms usually develop within minutes to hours after consuming a food allergen. Children can outgrow a food allergy, especially allergies to wheat, milk, eggs, or soy.

  Anaphylaxis is a life-threatening reaction that results in difficulty breathing, swelling of the mouth and throat, decreased blood pressure, shock, or even death. Milk, eggs, wheat, soybeans, fish, shellfish, peanuts, and tree nuts are the most likely to trigger this type of response. A dose of the drug epinephrine is often administered via a "pen" to treat a person who goes into anaphylactic shock.National Institutes of Health, US Department of Health and Human Services. "Food Allergy Quick Facts." Accessed March 5, 2012. http://www.niaid.nih.gov/topics/foodallergy/understanding/pages/quickfacts.aspx.

  Some children experience a food intolerance, which does not involve an immune response. A food intolerance is marked by unpleasant symptoms that occur after consuming certain foods. Lactose intolerance, though rare in very young children, is one

example. Children who suffer from this condition experience an adverse reaction to the lactose in milk products. It is a result of the small intestine's inability to produce enough of the enzyme lactase, which is produced by the small intestine. Symptoms of lactose intolerance usually affect the GI tract and can include bloating, abdominal pain, gas, nausea, and diarrhea. An intolerance is best managed by making dietary changes and avoiding any foods that trigger the reaction.National Digestive Disease Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health. "Lactose Intolerance." *NIH Publication No. 09–2751* (June 2009). Last updated April 23, 2012. digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/.

- ### The Threat of Lead Toxicity

  There is a danger of lead toxicity, or lead poisoning, among school-aged children. Lead is found in plumbing in old homes, in lead-based paint, and occasionally in the soil. Contaminated food and water can increase exposure and result in hazardous lead levels in the blood. Children under age six are especially vulnerable. They may consume items tainted with lead, such as chipped, lead-based paint. Another common exposure is lead dust in carpets, with the dust flaking off of paint on walls. When children play or roll around on carpets coated with lead, they are in jeopardy. Lead is indestructible, and once it has been ingested it is difficult for the human body to alter or remove it. It can quietly build up in the body for months, or even years, before the onset of symptoms. Lead toxicity can damage the brain and central nervous system, resulting in impaired thinking, reasoning, and perception.

  Treatment for lead poisoning includes removing the child from the source of contamination and extracting lead from the body. Extraction may involve chelation therapy, which binds with lead so it can be excreted in urine. Another treatment protocol, EDTA therapy, involves administering a drug called ethylenediaminetetraacetic acid to remove lead from the bloodstream of patients with levels greater than 45 mcg/dL.Mayo Foundation for Medical Education and Research. "Lead poisoning." ©1998–2012 Accessed March 5, 2012. www.mayoclinic.com/health/lead-poisoning/FL00068. Fortunately, lead toxicity is highly preventable. It involves identifying potential hazards, such as lead paint and pipes, and removing them before children are exposed to them.

Key Takeaways

The recommended intakes of macronutrients and micronutrients for children are higher relative to body size compared with nutrient needs during adulthood. Also, children's daily energy needs vary depending on their level of physical activity and their gender. Girls ages four to eight require 1,200 to 1,800 calories, while boys ages four to eight need 1,200 to 2,000 calories. Some food- and nutrition-related problems that can affect school-aged children include malnutrition, food allergies, food intolerances, and lead toxicity.

Discussion Starter

1. Which nutritional issues should parents who raise their children as vegans consider? Examine the vegan lifestyle and its impact on childhood development. Visit the following websites for more information on veganism:

   http://www.vrg.org/nutshell/kids.htm

   http://kidshealth.org/parent/nutrition_center/healthy_eating/vegan.html

   www.fcs.uga.edu/ext/pubs/html/FDNS-E-18.html

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12.7: Puberty and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for preteens.
- Discuss the most important nutrition-related concerns at the onset of puberty.
- Discuss the growing rates of childhood obesity and the long-term consequences of it.

Puberty is the beginning of adolescence. The onset of puberty brings a number of changes, including the development of primary and secondary sex characteristics, growth spurts, an increase in body fat, and an increase in bone and muscle development. All of these changes must be supported with adequate intake and healthy food choices.

The Onset of Puberty (Ages Nine to Thirteen)

This period of physical development is divided into two phases. The first phase involves height increases from 20 to 25 percent. Puberty is second to the prenatal period in terms of rapid growth as the long bones stretch to their final, adult size. Girls grow 2–8 inches (5–20 centimeters) taller, while boys grow 4–12 inches (10–30 centimeters) taller. The second phase involves weight gain related to the development of bone, muscle, and fat tissue. Also in the midst of puberty, the sex hormones trigger the development of reproductive organs and secondary sexual characteristics, such as pubic hair. Girls also develop “curves,” while boys become broader and more muscular.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 258.



Figure 12.7.1: Puberty typically begins slightly earlier in girls than in boys. For girls, puberty often begins around age eleven, while for boys it begins around age twelve. (Public Domain; Leifern)

Energy

The energy requirements for preteens differ according to gender, growth, and activity level. Energy requirements during this time are the highest based on daily need, not body weight. For ages nine to thirteen, girls should consume about 1,400 to 2,200 calories per day and boys should consume 1,600 to 2,600 calories per day. Physically active preteens who regularly participate in sports or exercise need to eat a greater number of calories to account for increased energy expenditures.

Macronutrients

For carbohydrates, the AMDR is 45 to 65 percent of daily calories (which is a recommended daily allowance of 158–228 grams for 1,400–1,600 daily calories). Carbohydrates that are high in fiber should make up the bulk of intake. Protein is needed for rapid growth. The AMDR for protein is 10 to 30 percent of daily calories (35–105 grams for 1,400 daily calories for girls and 40–120 grams for 1,600 daily calories for boys). The AMDR for fat is 25 to 35 percent of daily calories (39–54 grams for 1,400 daily calories for girls and 44–62 grams for 1,600 daily calories for boys), depending on caloric intake and activity level.

Micronutrients

Key vitamins needed during puberty include vitamins D, K, and B_{12}. Adequate calcium intake is essential for building bone and preventing osteoporosis later in life. Young females need more iron at the onset of menstruation, while young males need additional

iron for the development of lean body mass. Almost all of these needs should be met with dietary choices, not supplements (iron is an exception). Table 12.7.1 shows the micronutrient recommendations for young adolescents.

The B vitamins are needed for energy and protein metabolism. Folate and vitamin B_{12} are needed for DNA and cell growth. Many adolescents avoid milk which puts them at risk of developing a riboflavin, vitamin D, and calcium deficiency. Vitamin D and calcium are of particular concern since the bones are lengthening and this is a critical time to lay down bone mass. Iron is also at risk of deficiency; females because menstruation starts and males to do increase muscle mass.

Table 12.7.1: Micronutrient Levels during Puberty

Nutrient	Preteens, Ages 9–13
Vitamin A (mcg)	600.0
Vitamin B_6 (mg)	1.0
Vitamin B_{12} (mcg)	1.8
Vitamin C (mg)	45.0
Vitamin D (mcg)	5.0
Vitamin E (mg)	11.0
Vitamin K (mcg)	60.0
Calcium (mg)	1,300.0
Folate (mcg)	300.0
Iron (mg)	8.0
Magnesium (mg)	240.0
Niacin (B_3) (mg)	12.0
Phosphorus (mg)	1,250.0
Riboflavin (B_2) (mcg)	900.0
Selenium (mcg)	40.0
Thiamine (B_1) (mcg)	900.0
Zinc (mg)	8.0
Source: Institute of Medicine. www.iom.edu.	

Childhood Obesity

Children need an adequate caloric intake for growth, and it is important not to impose very restrictive diets. However, exceeding caloric requirements on a regular basis can lead to childhood obesity, which has become a major problem in North America. Nearly one of three US children and adolescents are overweight or obese. Let's Move. "Learn the Facts." Accessed March 5, 2012. www.letsmove.gov/learn-facts/epidemic-childhood-obesity. In Canada, approximately 26 percent of children and adolescents are overweight or obese.Childhood Obesity Foundation. "Statistics." Accessed March 5, 2012. http://www.childhoodobesityfoundation.ca/statistics.



Figure 12.7.2: *A sedentary lifestyle along with poor diet contributes to childhood obesity. (CC SA-By 2.5; Robert Lawton);*

There are a number of reasons behind the problem of childhood obesity, including:

- larger portion sizes
- limited access to nutrient-rich foods
- increased access to fast foods and vending machines
- lack of breastfeeding support
- declining physical education programs in schools
- insufficient physical activity and a sedentary lifestyle
- media messages encouraging the consumption of unhealthy foods
- high fat, high energy snacks

Children who suffer from obesity are more likely to become overweight or obese adults. Obesity has a profound effect on self-esteem, energy, and activity level. Even more importantly, it is a major risk factor for a number of diseases later in life, including cardiovascular disease, Type 2 diabetes, stroke, hypertension, and certain cancers.World Health Organization. “Obesity and Overweight Fact Sheet.” Last revised March 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

A percentile for body mass index (BMI) specific to age and sex is used to determine if a child is overweight or obese. This is more appropriate than the BMI categories used for adults because the body composition of children varies as they develop, and differs between boys and girls. If a child gains weight inappropriate to growth, parents and caregivers should limit energy-dense, nutrient-poor snack foods. Also, children ages three and older can follow the National Cholesterol Education Program guidelines of no more than 35 percent of calories from fat (10 percent or less from saturated fat), and no more than 300 milligrams of cholesterol per day. In addition, it is extremely beneficial to increase a child’s physical activity and limit sedentary activities, such as watching television, playing video games, or surfing the Internet.

Programs to address childhood obesity can include behavior modification, exercise counseling, psychological support or therapy, family counseling, and family meal-planning advice. For most, the goal is not weight loss, but rather allowing height to catch up with weight as the child continues to grow. Rapid weight loss is not recommended for preteens or younger children due to the risk of deficiencies and stunted growth.



Video 12.7.1: Voice of America: Adolescent Obesity Raises Risk of Severe Obesity in Adulthood. This video provides information about the link between adolescent obesity and adult obesity.

Avoiding Added Sugars

One major contributing factor to childhood obesity is the consumption of added sugars. Added sugars include not only sugar added to food at the table, but also are ingredients in items such as bread, cookies, cakes, pies, jams, and soft drinks. The added sugar in store-bought items may be listed as white sugar, brown sugar, high-fructose corn syrup, honey, malt syrup, maple syrup, molasses, anhydrous dextrose, crystal dextrose, and concentrated fruit juice. (Not included are sugars that occur naturally in foods, such as the lactose in milk or the fructose in fruits.) In addition, sugars are often "hidden" in items added to foods after they're prepared, such as ketchup, salad dressing, and other condiments. According to the National Center for Health Statistics, young children and adolescents consume an average of 322 calories per day from added sugars or about 16 percent of daily calories.National Center for Health Statistics. "Consumption of Added Sugar among US Children and Adolescents, 2005–2008." *NCHS Data Brief*, no. 87, (March 2012). http://www.cdc.gov/nchs/data/databriefs/db87.pdf. The primary offenders are processed and packaged foods, along with soda and other beverages. These foods are not only high in sugar, they are also light in terms of nutrients and often take the place of healthier options. Intake of added sugar should be limited to 100–150 calories per day to discourage poor eating habits.

Tools for Change

The *2008 Physical Activity Guidelines for Americans* call for sixty minutes of moderate to vigorous physical activity daily for preteens and teens. This includes aerobic activity, along with bone- and muscle-strengthening exercises.US Department of Health and Human Services. "2008 Physical Activity Guidelines for Americans." Accessed March 5, 2012. www.health.gov/paguidelines/pdf/paguide.pdf. However, many young people fall far short of this goal. Preteens must be encouraged to lead more active lifestyles to prevent or treat childhood obesity. In the United States, the Let's Move! campaign inspires kids to start exercising. This program, launched in 2010 by First Lady Michelle Obama, works to solve the problem of rising obesity rates among children, preteens, and teens. It offers information to parents and educators, works to provide healthier food choices in schools and afterschool programs, and helps children become more active. One way the program promotes physical activity is by encouraging preteens and teens to find something they love to do. When kids find an activity they enjoy, whether riding a bike, playing football, joining a soccer team, or participating in a dance crew, they are more likely to get moving and stay healthy. You can learn more about Let's Move! and efforts to encourage physical activity among adolescents at this website: www.letsmove.gov/.

Concluding Comments

During puberty, preteens experience growth spurts, along with the development of primary and secondary sex characteristics. The daily energy requirements for preteens differ according to gender, growth, and activity level. Girls ages nine to thirteen should consume 1,400 to 2,200 calories per day, and boys should consume 1,600 to 2,600 calories per day. Nutritional concerns for older children include malnutrition and obesity. Preteens should be encouraged to develop good habits, including consuming a healthy diet and regularly participating in sports or an exercise program.

Discussion Starter

1. What would you recommend to help families prevent obesity among their children? What tips would you provide? What lifestyle changes might help? Use the dietary guidelines at this website to discuss suggestions. http://www.choosemyplate.gov/.

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12.8: Older Adolescence and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for teens.
- Discuss the most important nutrition-related concerns during adolescence.
- Discuss the effect of eating disorders on health and wellness.

In this section, we will discuss the nutritional requirements for young people ages fourteen to eighteen. One way that teenagers assert their independence is by choosing what to eat. They have their own money to purchase food and tend to eat more meals away from home. Older adolescents also can be curious and open to new ideas, which includes trying new kinds of food and experimenting with their diet. For example, teens will sometimes skip a main meal and snack instead. That is not necessarily problematic. Their choice of food is more important than the time or place.

However, too many poor choices can make young people nutritionally vulnerable. Teens should be discouraged from eating fast food, which has a high fat and sugar content, or frequenting convenience stores and using vending machines, which typically offer poor nutritional selections. Other challenges that teens may face include obesity and eating disorders. At this life stage, young people still need guidance from parents and other caregivers about nutrition-related matters. It can be helpful to explain to young people how healthy eating habits can support activities they enjoy, such as skateboarding or dancing, or connect to their desires or interests, such as a lean figure, athletic performance, or improved cognition.

Adolescence (Ages Fourteen to Eighteen): Transitioning into Adulthood

As during puberty, growth and development during adolescence are different in males than in females. In teenage girls, fat assumes a larger percentage of body weight, while teenage boys experience greater muscle and bone increases, and a decrease in body fat. For both, primary and secondary sex characteristics have fully developed and the rate of growth slows with the end of puberty. Also, the motor functions of an older adolescent are comparable to those of an adult.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 171–173. Again, adequate nutrition and healthy choices support this stage of growth and development. Acne, substance use and abuse, obesity and adolescent pregnancy put the adolescent at risk of developing a nutrient deficiency that can have last lifetime effect.

Energy

Adolescents have increased appetites due to increased nutritional requirements. Nutrient needs are greater in adolescence than at any other time in the life cycle, except during pregnancy. The energy requirements for ages fourteen to eighteen are 1,800 to 2,400 calories for girls and 2,000 to 3,200 calories for boys, depending on activity level. The extra energy required for physical development during the teenage years should be obtained from foods that provide nutrients instead of “empty calories.” Also, teens who participate in sports must make sure to meet their increased energy needs.

Macronutrients

Older adolescents are more responsible for their dietary choices than younger children, but parents and caregivers must make sure that teens continue to meet their nutrient needs. For carbohydrates, the AMDR is 45 to 65 percent of daily calories (203–293 grams for 1,800 daily calories). Adolescents require more servings of grain than younger children and should eat whole grains, such as wheat, oats, barley, and brown rice. The Institute of Medicine recommends higher intakes of protein for growth in the adolescent population. The AMDR for protein is 10 to 30 percent of daily calories (45–135 grams for 1,800 daily calories), and lean proteins, such as meat, poultry, fish, beans, nuts, and seeds are excellent ways to meet those nutritional needs.

The AMDR for fat is 25 to 35 percent of daily calories (50–70 grams for 1,800 daily calories), and the AMDR for fiber is 25–34 grams per day, depending on daily calories and activity level. It is essential for young athletes and other physically active teens to intake enough fluids because they are at a higher risk for becoming dehydrated.

Micronutrients

Micronutrient recommendations for adolescents are mostly the same as for adults, though children this age need more of certain minerals to promote bone growth (e.g., calcium and phosphorus, along with iron and zinc for girls). Again, vitamins and minerals

should be obtained from food first, with supplementation for certain micronutrients only (such as iron).

The most important micronutrients for adolescents are calcium, vitamin D, vitamin A, and iron. Adequate calcium and vitamin D are essential for building bone mass. The recommendation for calcium is 1,300 milligrams for both boys and girls. Low-fat milk and cheeses are excellent sources of calcium and help young people avoid saturated fat and cholesterol. It can also be helpful for adolescents to consume products fortified with calcium, such as breakfast cereals and orange juice. Iron supports the growth of muscle and lean body mass. Adolescent girls also need to ensure sufficient iron intake as they start to menstruate. Girls ages twelve to eighteen require 15 milligrams of iron per day. Increased amounts of vitamin C from orange juice and other sources can aid in iron absorption. Also, adequate fruit and vegetable intake allows for meeting vitamin A needs. Table 12.8.1 shows the micronutrient recommendations for older adolescents, which differ slightly for males and females, unlike the recommendations for puberty.

Table 12.8.1: Micronutrient Levels during Older Adolescence

Nutrient	Males, Ages 14–18	Females, Ages 14–18
Vitamin A (mcg)	900.0	700.0
Vitamin B_6 (mg)	1.3	1.2
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	75.0	65.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	75.0	75.0
Calcium (mg)	1,300.0	1,300.0
Folate mcg)	400.0	400.0
Iron (mg)	11.0	15.0
Magnesium (mg)	410.0	360.0
Niacin (B_3) (mg)	16.0	14.0
Phosphorus (mg)	1,250.0	1,250.0
Riboflavin (B_2) (mg)	1.3	1.0
Selenium (mcg)	55.0	55.0
Thiamine (B_1) (mg)	1.2	1.0
Zinc (mg)	11.0	9.0

Source: Institute of Medicine. www.iom.edu.

Acne

Some teens develop acne which is not caused by eating chocolate, sugary or greasy foods. Instead, it is caused by an infection of the sebaceous gland in the skin. The gland duct becomes clogged and skin oils accumulate. When this happens, the gland becomes irritated, inflamed and the associated "heads" occur. Acne is worsened by stress and tends to run in families (hereditary link). Treatment includes reducing the factors that are causing the stress, antibiotics, topical ointments and/or the drug Accutane. Accutane is similar to vitamin A so toxicity from the drug will be monitored closely.

Eating Disorders

Do you know any of these people: Demi Lovato, Paula Abdul, Russell Brand, Lady Gaga, Alanis Morissette, Diana, Princess of Wales, Elton John, or Jane Fonda? They all have an eating disorder.

Many teens struggle with an eating disorder, which can have a detrimental effect on diet and health. A study published by North Dakota State University estimates that these conditions impact twenty-four million people in the United States and seventy million worldwide.North Dakota State University. “Eating Disorder Statistics.” Accessed March 5, 2012. http://www.ndsu.edu/fileadmin/counseling/Eating_Disorder_Statistics.pdf. These disorders are more prevalent among adolescent girls but have been increasing among adolescent boys in recent years. Because eating disorders often lead to malnourishment, adolescents with an eating disorder are deprived of the crucial nutrients their still-growing bodies need.

The cause of eating disorders is unknown and most likely multiple factors contribute to its development. These factors may be biological, psychological and/or social and several factors may interact to cause the condition. Biological factors appear as a consequence of pubertal hormone changes and may be genetic. Personality and behavioral changes occur during puberty and these may promote the development of an eating disorder. Finally, mass media influences our perception of body weight and sets unrealistic notions of desirable body weight. Often, adolescent athletes have the misconception that less weight is better performance.

Eating disorders involve extreme behavior related to food and exercise. Sometimes referred to as “starving or stuffing,” they encompass a group of conditions marked by undereating or overeating. Some of these conditions include:

- **Anorexia Nervosa.** Anorexia nervosa is a potentially fatal condition characterized by under eating and excessive weight loss. People with this disorder are preoccupied with dieting, calories, and food intake to an unhealthy degree. Anorexics have a poor body image, which leads to anxiety, avoidance of food, a rigid exercise regimen, fasting, and a denial of hunger. The condition predominantly affects females. Between 0.5 and 1 percent of American women and girls suffer from this eating disorder. Five percent are men. Two to five percent of adolescent girls experience anorexia nervosa.
  The American Psychiatry Association sets standards to diagnosis eating disorders. The DMS-IV criteria for anorexia nervosa are 1) refusal to maintain body mass over a minimal weight for age and height (15% below expected body mass).; 2) intense fear of gaining weight or becoming fat despite being underweight, 3) distorted self-image and/or denial of the severity of low body mass (satisfied with certain body parts but critical of other areas); and 4) absence of at least three consecutive menstrual cycles. The individual may have an emaciated physical appearance with rough, dry, cold skin, hair loss, and tooth loss. Psychologically they may be competitive, obsessive, and have very high standards. Their family may be over-involved, rigid, over protective, and conflictive.
  Protein-energy malnutrition is a common nutritional complication of anorexia nervosa. Medical complications are a lower immune function (reduced white blood cells); lower basal metabolic rate, body temperature, heart rate, and bone mass; anemia; constipation; amenorrhea; multiple organ failures; and an increased risk of suicide.
  Therapy should involve a medical team trained to treat anorexia nervosa. The nutrition goal is a slow weight gain and this is done by gradually increasing food intake (approximately 200 kcal per day) Supplements may be required to make sure the diet is nutritionally adequate. Food habits need to be changed so it is important to identify the emotional factors and ways to control their behavior. This may be done using family, group/individual, and/or relapse therapy.
- **Binge-Eating Disorder (also called compulsive overeating).** People who suffer from binge-eating disorder experience regular episodes of eating an extremely large amount of food in a short period of time but don't purge. This eating disorder is the most common and is common in the severely obese. Binge eating is a compulsive behavior, and people who suffer from it typically feel it is beyond their control. This behavior often causes feelings of shame and embarrassment and leads to obesity, high blood pressure, high cholesterol levels, Type 2 diabetes, and other health problems. Both males and females suffer from binge-eating disorder. It affects 1 to 5 percent of the population.
  The diagnosis of binge eating includes recurrent binges at least two days per week for six months. The individual feels they are eating out of control and eat large amounts of food even when they are not hungry. Often, they eat alone because they are embarrassed about the amount of food they ate and feel disgusted and guilty for overeating. Most people with this eating disorder are overweight or obese. They have a low self-esteem and may be depressed. Medical complications are related to their excess adipose stores and treatment involves weight loss and changing their lifestyle to maintain the weight lost.
- **Bulimia Nervosa.** Bulimia nervosa is more prevalent than anorexia nervosa and is characterized by alternating cycles of overeating and undereating. People who suffer from it partake in binge eating, followed by compensatory behavior, such as self-induced vomiting, laxative use, diuretics, enemas, medications, fasting, and compulsive exercise. Most experience a loss of control over eating during their binge episode. As with anorexia, most people with this condition are female and may be single, well-educated and near ideal body weight. Approximately 1 to 2 percent of American women and girls have this eating disorder.National Eating Disorders Association. “Learn Basic Terms and Information on a Variety of Eating Disorder Topics.” Accessed March 5, 2012. www.nationaleatingdisorders.org/information-resources/general -information.php.

The DMS-IV criteria for bulimia nervosa are 1) recurrent episodes of binge-eating, 2) recurrent, inappropriate, compensatory behavior in order to prevent weight gain; 3) binge eating and compensatory behavior both occur on average at least twice a week for three months; 4) dissatisfaction and/or distortion of body image, and 5) disturbance does not occur in episodes of anorexia nervosa. People with this eating disorder may have normal weight or experience a rapid change in weight by twenty percent.

This eating disorder may develop after unsuccessful dieting. The individual may be a perfectionist, have low self-esteem, a high-stress level, be depressed, and/or passive. usually, they know the behavior is abnormal. Their family may be disengaged and permissive. Medical complications can include poor kidney function, decreased immune function, increased number of urinary tract infections, low blood potassium (hypokalemia) and irregular heart beat. If they purge by vomiting, they may experience infections of the esophagus and salivary glands, rupturing their esophagus and/or stomach, erosion of their teeth, and loss of potassium. Treatment includes developing normal eating habits, meal planning, food diaries and maintaining constant body weight and food intake. Psychologically they must break the purge cycle, develop a better body image, build self-esteem, treat depression, and develop a healthy attitude about their body image and food.

Eating disorders stem from stress, low self-esteem, and other psychological and emotional issues. It is important for parents to watch for signs and symptoms of these disorders, including sudden weight loss, loose clothing, lethargy, drop in grades, social isolation like eating alone, vomiting after meals, and the use of appetite suppressants. Eating disorders can lead to serious complications or even be fatal if left untreated. Treatment includes cognitive, behavioral, and nutritional therapy and requires a trained professional.



Video 12.8.1: Eating Disorders: Anorexia. This video provides more information about the eating disorder anorexia nervosa.

Muscle Dysmorphia (Adonis Complex)

Adonis Complex is the preoccupation with not being sufficiently lean and muscular. It has many similarities to anorexia nervosa but clearly, the individual has a distorted image of their body. Most people with this eating disorder are large and muscular. They have a preoccupation with being lean and muscular and frequently weigh themselves and/or look at themselves in the mirror (narcissistic). They like to wear baggy clothes or modify their clothes to enhance their muscularity. To achieve the muscularity, they engage in excessive exercise and abuse dietary supplements or adhere to a strict dietary regime. Amazingly, they view themselves as frail and small, even though they are not, and they may spend greater than three hours thinking about their muscularity.

Concluding Comments

Older adolescents experience numerous physical changes and must increase their energy intake to support these changes and meet nutrient needs. Nutrient needs are greater during adolescence than at any other time in the life cycle, except during pregnancy. The daily energy requirements for ages fourteen to eighteen are 1,800 to 2,400 calories for girls, and 2,000 to 3,200 calories for boys, depending on activity level. Nutritional concerns for older adolescents include eating disorders.

Discussion Starter

1. Research the biological, social, and psychological aspects of eating disorders at this website. Then, brainstorm a list of risk factors and warning signs for parents, teachers, and physicians.

http://www.nationaleatingdisorders.org/

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12.E: Exercises

It's Your Turn

1. Plan a day's worth of meals for a pregnant woman that contain the RDA of vitamin C. To help determine the vitamin C content in foods, visit the USDA National Nutrient Database: www.nal.usda.gov/fnic/foodcomp/search.
2. Create a brochure or plan a peer-to-peer campaign that encourages pregnant women to breastfeed their newborns and includes the major benefits of this practice.
3. After watching the video, which recommends snacks for adults and older children, use these ideas and what you have learned to create a list of toddler-friendly healthy snacks for parents. Take into account potential problems for young children, such as foods that are choking hazards.

   Eating Healthy Snacks

   (click to see video)

Apply It

1. Create a chart that compares the energy requirements and fluid recommendations for the following phases: the second trimester of pregnancy, the third trimester of pregnancy, the first six months of lactation, and the second six months of lactation.
2. Visit a store and study the labels of three different brands of infant formula. Record the nutrition facts for each brand, such as the calories, amount of carbohydrates, amount of protein, and so on.
3. Research ways to adjust the behavior of picky eaters at this website: http://www.healthychildren.org. Then, create a list of four to five tips for parents of toddlers. Apply Ellyn Satter's division of responsibility as you create your suggestions.

Expand Your Knowledge

1. How might statistics regarding unplanned pregnancies relate to the recommendation that all women should regularly take a multivitamin with folic acid? Use your knowledge of the impact of folate to explain your response.
2. Write a short speech that you would give to local government officials to recommend ways that they can promote and support the practice of breastfeeding in your community. Or prepare an email or letter to explain to a friend or family member why you have made the choice to breastfeed your child or to support your partner in the practice of breastfeeding.
3. Visit http://www.healthychildren.org and research ways to introduce solid foods into an infant's diet. Then create an eating plan to help parents gradually introduce solids to their babies, beginning at the age of six months.

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13: Nutrition From Adulthood to the Elderly Years

In this Chapter. we continue to explore nutrition through the life cycle, this time looking at adulthood to the elderly years.

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13.1: Chapter Introduction

Big Idea

The human lifespan, the maximum number of years of human life, has remained unchanged and is around 130 years. Very few people have reached that age and the records show the oldest person lived 122 years and 164 days. Good nutritional choices reduce the risk of chronic disease during the middle-aged and elderly years.

One hundred years ago, when many families sat down to dinner, they might have eaten boiled potatoes or corn, leafy vegetables such as cabbage or collards, fresh-baked bread, and, if they were fortunate, a small amount of beef or chicken. Young and old alike benefited from a sound diet that packed a real nutritional punch. Times have changed. Many families today fill their dinner plates with fatty foods, such as French fries cooked in vegetable oil, a hamburger that contains several ounces of ground beef, and a white-bread bun, with a single piece of lettuce and a slice or two of tomato as the only vegetables served with the meal.



Figure 13.1.1: The emergence of the obesity epidemic not only relates to what we eat and drink but also how much we consume on a daily basis. (CC-BY-SA 2.0; XP-ert).

Our diet has changed drastically as processed foods, which did not exist a century ago, and animal-based foods now account for a large percentage of our calories. Not only has what we eat changed, but the amount of it that we consume has greatly increased as well, as plates and portion size have grown much larger. All of these choices impact our health, with short- and long-term consequences as we age. Possible effects in the short-term include excess weight gain and constipation. The possible long-term effects, primarily related to obesity, include the risk of cardiovascular disease, Type 2 diabetes, hypertension, stroke, osteoarthritis, sleep apnea, respiratory problems, liver and gallbladder disease, and certain cancers (endometrial, breast, and colon) among middle-aged and elderly adults.Centers for Disease Control and Prevention. “Overweight and Obesity: Health Consequences.” Last updated March 3, 2011. www.cdc.gov/obesity/causes/health.html.

It is best to start making healthy choices from a young age and maintain them as you mature. However, a recent report published in the *American Journal of Clinical Nutrition*, suggests that adopting good nutritional choices later in life, during the forties, fifties, and even the sixties, may still help to reduce the risk of chronic disease as you grow older.Rivlin, R. S. “Keeping the Young-Elderly Healthy: Is It Too Late to Improve Our Health through Nutrition?” *Am J Clin Nutr* 86, supplement (2007): 1572S–6S. Even if past nutritional and lifestyle choices were not aligned with dietary guidelines, older adults can still do a great deal to reduce their risk of disability and chronic disease. As we age, we tend to lose lean body mass. This loss of muscle and bone can have critical health implications. For example, a decrease in body strength can result in an increased risk for fractures because older adults with weakened muscles are more likely to fall and to sustain serious injuries when they do. However, improving your diet while increasing physical activity helps to control weight, reduce fat mass, and maintain muscle and bone mass.

There are a number of changes middle-aged adults can implement, even after years of unhealthy choices. Choices include eating more dark, green, leafy vegetables, substituting high-fat proteins with lean meats, poultry, fish, beans, and nuts, and engaging in moderate physical activity for thirty minutes per day, several days per week. The resulting improvements in body composition will go a long way toward providing greater protection against falls and fractures and helping to ward off cardiovascular disease and

hypertension, among other chronic conditions.Rivlin, R. S. “Keeping the Young-Elderly Healthy: Is It Too Late to Improve Our Health through Nutrition?” *Am J Clin Nutr* 86, supplement (2007): 1572S–6S.

Life Expectancy

Life expectancy has increased over time. Now, in the USA, women can expect to live on average 81 years while the life expectancy for men on average is 71 years. In the last few years, life expectancy has decreased due to the obesity epidemic. For our forefathers, death was usually due to an infectious disease but the discovery of antibiotics, advances in medical treatment, improvement in nutrition and an abundant food supply has doubled life expectancy in the twentieth century.

Demographics have been changing. In 1900, only one out of twenty-five people were 65 years or older. Now, the number of people over the age of sixty-five has tripled and by 2060, the number will double again to 98 million people in the USA. The fastest growing group are those over the age of 85 years. This group has increased seven-fold since the 1950s. Amazingly, in the last decade, the number of centurions has doubled. Only 20-30% of the longevity is contributed to genes, most are due to health-related behaviors. Most of the elderly have chronic diseases that are related to nutrition. These include heart disease, diabetes, hypertension, osteoporosis, and obesity.

Causes of Aging

Scientists have proposed a number of theories to explain why the human body ages but one single theory has not immerged. The rate and manner in which humans age is influenced by genes, the environment, and lifestyle. A complex interplay between each of these determines life expectancy.

Characteristics of Longer Life Expectancy

Why do some people live longer? There are common characteristics among those that live longer. They sleep regularly and adequately. They are physically active on a regular basis which is a powerful predictor of mobility. They don't smoke and they maintain a healthy body weight. Their diets are charactered by well-balanced, regular meals, including breakfast. They eat between 18-27% of their calories from fat. Their meat consumption is low, and their fruit and vegetable intake is high. They don't drink alcohol or they drink in moderation.

You Decide:

What is one nutritional choice that you can make today to reduce your risk of chronic disease tomorrow?

Previously, we focused on the effects of dietary choices during pregnancy, infancy, and the toddler years. Our examination of nutrition through the human life cycle continues as we study the remainder of childhood into adulthood and the elderly years. Nutritional choices remain critical throughout a person’s life and influence overall health and wellness. The nutritional choices we make today affect not only our present health but also our future well-being.

Video 13.1.1: Weight Gain and Body-Composition Changes, Midlife into Older Age

This video focuses on the consequences of changing body composition from the middle-aged years into old age. (click to see video)

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13.2: The Human Life Cycle Continues

Learning Objectives

- Identify and define the different stages of the human lifecycle.
- Explain how the human body develops from childhood through the elderly years.

As discussed previously, all people need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to maintain life and health. However, the amounts of needed nutrients change as we pass from one stage of the human lifecycle to the next. Young children require a higher caloric intake relative to body size to facilitate physical and mental development. On the other hand, inactive senior citizens need fewer calories than other adults to maintain their weight and stay healthy. Psychological, emotional, and social issues over the span of a human life can also influence diet and nutrition. For example, peer pressure during adolescence can greatly affect the nutritional choices a teenager makes. Therefore, it is important to weigh a number of considerations when examining how nutrient needs change. In this chapter, we will focus on diet, nutrition, and the human life cycle from adulthood into the elderly years.

Changes in Young Adulthood

The phase after adolescence is young adulthood, and this period spans ages nineteen to thirty. It is a stable time compared to childhood and adolescence. Physical growth has been completed and all of the organs and body systems are fully developed. Typically, a young adult who is active has reached his or her physical peak and is in prime health. For example, vital capacity, or the maximum amount of air that the lungs can inhale and exhale, is at its peak between the ages of twenty and forty.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–93. Proper nutrition and adequate physical activity at this stage not only promote wellness in the present but also provide a solid foundation for the future.

Changes in Middle Age

Nutritionally speaking, middle age is defined as the period from age thirty-one to fifty. The early period of this stage is very different from the end. For example, during the early years of middle age, many women experience pregnancy, childbirth, and lactation. In the latter part of this life stage, women face perimenopause, which is a transition period that leads up to menopause, or the end of menstruation. A number of physical changes take place in the middle-age years, including the loss of bone mass in women due to dropping levels of estrogen during menopause. In both men and women, visual acuity declines, and by age forty there can be a decreased ability to see objects at a close distance, a condition known as presbyopia.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–93. All of these are signs of aging, as the human body begins to change in subtle and not-so-subtle ways. However, a middle aged person can remain vital, healthy, and near his or her physical peak with proper diet and adequate exercise.

Changes in the Older Adult Years

The senior, or elderly, years are the period from age fifty-one until the end of life. A number of physiological and emotional changes take place during this life stage. For example, many elderly adults face serious health challenges, such as cancer, heart disease, diabetes, or dementia. Both men and women experience a loss of muscle mass and strength and undergo changes in body composition. Fat deposits build up in the abdominal area, which increases the risk for Type 2 diabetes and cardiovascular disease. The skin becomes thinner and may take longer to heal after an injury. Around age seventy, men begin to experience bone loss when estrogen and testosterone levels begin to decline.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 512. Healthy nutritional choices can help to prevent or manage disability and chronic conditions.

In addition, disorders of the nervous system can have profound effects. Dementia is the umbrella term for changes in the normal activity of the brain. Elderly adults who suffer from dementia may experience memory loss, agitation, and delusions. One in eight people over age sixty-four and almost half of all people over eighty-five suffer from the brain disorder Alzheimer's disease, which

is the most common form of dementia.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 421. Neurological disorder and psychological conditions, such as depression, can influence attitudes toward food, along with the ability to prepare or ingest food. They might lead some adults to overindulge to compensate for stress or emotions that are difficult to handle. Other adults might eat less or pay less attention to their diet and nutritional needs. Elderly adults may also need guidance from dietitians and healthcare professionals to make the best dietary choices for this stage of life.

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Changing Needs and Nutrition

Nutritional needs continue to change at each stage of life. It is important to adjust your diet and physical activity to meet these changing needs and ensure health and wellness throughout your life. Parents must continue to help their school-aged children and adolescents establish healthy eating habits and attitudes toward food. Their primary role is to bring a wide variety of health-promoting foods into the home so that their children can make good choices. As children become adults, they must be mindful of the choices they make and how those choices affect their health, not only in the present but also in the future.

Key Takeaways

The human body constantly changes throughout the life cycle, from childhood into adulthood and old age. Proper nutrition and physical activity ensure health and wellness at each stage of the human lifecycle.

Discussion Starter

1. In preparation for this chapter, predict how nutrient needs might change as a healthy young adult matures into old age. Then, after reading the text, discuss if your predictions were correct or incorrect.

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13.3: Young Adulthood and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for young adults.
- Discuss the most important nutrition-related concerns during young adulthood.
- Explain how nutritional and lifestyle choices can affect current and future health.

With the onset of adulthood, good nutrition can help young adults enjoy an active lifestyle. For most people, this is the time when their bodies are in the best condition. The body of an adult does not need to devote its energy and resources to support the rapid growth and development that characterizes youth. However, the choices made during those formative years can have a lasting impact. Eating habits and preferences developed during childhood and adolescence influence health and fitness into adulthood. Some adults have gotten a healthy start and have established a sound diet and regular activity program, which helps them remain in good condition from young adulthood into the later years. Others carry childhood obesity into adulthood, which adversely affects their health. However, it is not too late to change course and develop healthier habits and lifestyle choices. Therefore, adults must monitor their dietary decisions and make sure their caloric intake provides the energy that they require, without going into excess.

Young Adulthood (Ages Nineteen to Thirty): At Your Peak

At this time, growth is completed and people reach their physical peak. Major organs and body systems have fully matured by this stage of the life cycle. For example, the human body reaches maximum cardiac output between ages twenty and thirty. Also, bone and muscle mass are at optimal levels, and physical activity helps to improve muscle strength, endurance, and tone.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 192–193. In order to maintain health and fitness at this age, it is important to continue to practice good nutrition. Healthy eating habits promote metabolic functioning, assist repair and regeneration, and prevent the development of chronic conditions. In addition, the goals of a young adult, such as beginning a career or seeking out romantic relationships, can be supported with good habits.

Energy

Young men typically have higher nutrient needs than young women. For ages nineteen to thirty, the energy requirements for women are 1,800 to 2,400 calories, and 2,400 to 3,000 calories for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding, who require a higher energy intake.

Macronutrients

For carbohydrates, the AMDR is 45 to 65 percent of daily calories. All adults, young and old, should eat fewer energy-dense carbohydrates, especially refined, sugar-dense sources, particularly for those who lead a more sedentary lifestyle. The AMDR for protein is 10 to 35 percent of total daily calories, and should include a variety of lean meat and poultry, eggs, beans, peas, nuts, and seeds. The guidelines also recommend that adults eat two 4-ounce servings (or one 8-ounce serving) of seafood per week.

It is also important to replace proteins that are high in trans fats and saturated fat with ones that are lower in solid fats and calories. All adults should limit total fat to 20 to 35 percent of their daily calories and keep saturated fatty acids to less than 10 percent of total calories by replacing them with monounsaturated and polyunsaturated fatty acids. Avoid trans fats by limiting foods that contain synthetic sources, such as partially hydrogenated oils. The AMDR for fiber is 22 to 28 grams per day for women and 28 to 34 grams per day for men. Soluble fiber may help improve cholesterol and blood sugar levels, while insoluble fiber can help prevent constipation.

Tools for Change

A healthy diet of nutrient-rich meals incorporates a variety of whole foods. Whole foods are unprocessed or unrefined, or have been created with as little processing as possible. They do not include a lot of added ingredients, such as sugar, sodium, or fat, and are free of preservatives or other chemicals that are often added to food products. Examples of whole foods with no processing

include legumes and fresh fruits and vegetables. Examples of whole foods with minimal processing include whole-grain breads and cereals. Dietitians recommend consuming whole foods for a variety of reasons. Whole foods provide nutrients in their natural state, with all of the vitamins and minerals intact. Food processing can remove some nutrients during manufacturing. Also, diets rich in whole foods contain high concentrations of fiber and antioxidants, and can protect against chronic disease.

Micronutrients

Micronutrient needs in adults differ slightly according to sex. Young men and women who are very athletic and perspire a great deal also require extra sodium, potassium, and magnesium. Males require more of vitamins C and K, along with thiamine, riboflavin, and niacin. Females require extra iron due to menstruation. Therefore, it can be beneficial for some young adults to follow a daily multivitamin regimen to help meet nutrient needs. But as always, it is important to remember "food first, supplements second." Table 13.3.1 shows the micronutrient recommendations for adult men and women.

Table 13.3.1: Micronutrient Levels during Adulthood

Nutrient	Adult Males	Adult Females
Vitamin A (mcg)	900.0	700.0
Vitamin B_6 (mg)	1.3	1.3
Vitamin B_{12} (mcg)	2.4	2.4
Vitamin C (mg)	90.0	75.0
Vitamin D (mcg)	5.0	5.0
Vitamin E (mg)	15.0	15.0
Vitamin K (mcg)	120.0	90.0
Calcium (mg)	1,000.0	1,000.0
Folate (mcg)	400.0	400.0
Iron (mg)	8.0	18.0
Magnesium (mg)	400.0	310.0
Niacin (B_3) (mg)	16.0	14.0
Phosphorus (mg)	700.0	700.0
Riboflavin (B_2) (mg)	1.3	1.1
Selenium (mcg)	55.0	55.0
Thiamine (B_1) (mg)	1.2	1.1
Zinc (mg)	11.0	8.0

Source: Institute of Medicine. www.iom.edu.

Nutritional Concerns in Young Adulthood

There are a number of intake recommendations for young adults. According to the IOM, an adequate intake (AI) of fluids for men is 3.7 liters per day, from both food and liquids. The AI for women is 2.7 liters per day, from food and liquids.Institute of Medicine. "Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate." Accessed March 5, 2012. www.iom.edu/Reports/2004/Dietary-Reference-Intakes-Water-Potassium-Sodium-Chloride-and-Sulfate.aspx. It is best when fluid intake is from water, instead of sugary beverages, such as soda. Fresh fruits and vegetables, including watermelon and cucumbers, are excellent food sources of fluid. In addition, young adults should avoid consuming excessive amounts of sodium. The health

consequences of high sodium intake include high blood pressure and its complications. Therefore, it is best to limit sodium to less than 2,300 milligrams per day.

Gastrointestinal Integrity

Good nutrition during the young adult years can help to support gastrointestinal integrity and prevent digestive disorders, such as constipation and diarrhea. Dietary fiber helps bind indigestible food together and normalize bowel movements. It also holds more water in the stool to make it softer for those who suffer from constipation. Excellent sources of fiber include oats, barley, rye, wheat, brown rice, celery, carrots, nuts, seeds, dried beans, oranges, and apples. In addition, healthy intestinal microflora can be supported by prebiotics which are found in fruits and vegetables and stimulate the growth of beneficial bacteria already in the colon and by probiotics which are live bacteria in the food you eat that change or improve the bacterial balance in the gut. An example of a prebiotic is walnuts and an example of a probiotic is yogurt.

Obesity during Adulthood

Obesity remains a major concern into young adulthood. For adults, a BMI above 25 is considered overweight, and a BMI of 30 or higher is obese. By that measurement, about two-thirds of all adults in the United States are overweight or obese, with 35.7 percent considered to be obese.Centers for Disease Control, National Center for Health Statistics. “Prevalence of Obesity in the United States, 2009–2010.” *NCHS Data Brief*, No. 82, January 2012, accessed on March 5, 2012. http://www.cdc.gov/nchs/data/databriefs/db82.pdf. As during childhood and adolescence, physical inactivity and poor dietary choices are major contributors to obesity in adulthood. Solid fats, alcohol, and added sugars (SoFAAS) make up 35 percent of total calories for most people, leading to high levels of saturated fat and cholesterol and insufficient dietary fiber. Therefore, it is important to limit unrefined carbohydrates and processed foods.

Concluding Comments

Young adults typically have reached their physical peak and can support health and wellness with adequate nutrition and exercise. For ages nineteen to thirty, the daily energy requirements are 1,800 to 2,400 calories for women and 2,400 to 3,000 calories for men, depending on activity level. Nutritional concerns for young adults include adequate energy and fluid intake, sodium intake, and the consumption of fiber. Young adults should avoid consuming solid fats, added sugars, and alcohol in excess.

Discussion Starter

1. How do your intake of carbohydrates, proteins, and fats compare to the AMDR? What can you do to make changes and meet the nutritional recommendations?

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13.4: Middle Age and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for middle-aged adults.
- Discuss the most important nutrition-related concerns during middle age.
- Define “preventive nutrition” and give an applied example.

During this stage of the human life cycle, adults begin to experience the first outward signs of aging. Wrinkles begin to appear, joints ache after a highly active day, and body fat accumulates. There is also a loss of muscle tone and elasticity in the connective tissue.Elaine U. Polan, RNC, MS and Daphne R. Taylor, RN, MS, *Journey Across the Life Span: Human Development and Health Promotion* (Philadelphia: F. A. Davis Company, 2003), 212–213. Throughout the aging process, good nutrition can help middle-aged adults maintain their health and recover from any medical problems or issues they may experience.

Middle Age (Ages Thirty-One to Fifty): Aging Well

Many people in their late thirties and in their forties notice a decline in endurance, the onset of wear-and-tear injuries (such as osteoarthritis), and changes in the digestive system. Wounds and other injuries also take longer to heal. Body composition changes due to fat deposits in the trunk. To maintain health and wellness during the middle-aged years and beyond, it is important to:

- maintain a healthy body weight
- consume nutrient-dense foods
- drink alcohol moderately or not at all
- be a non-smoker
- engage in moderate physical activity at least 150 minutes per week

Energy

The energy requirements for ages thirty-one to fifty are 1,800 to 2,200 calories for women and 2,200 to 3,000 calories for men, depending on activity level. These estimates do not include women who are pregnant or breastfeeding (see Chapter 12). Middle-aged adults must rely on healthy food sources to meet these needs. In many parts of North America, typical dietary patterns do not match the recommended guidelines. For example, five foods—iceberg lettuce, frozen potatoes, fresh potatoes, potato chips, and canned tomatoes—account for over half of all vegetable intake.Adam Drewnowski and Nicole Darmon. “Food Choices and Diet Cost: an Economic Analysis.” *The Journal of Nutrition*. © 2005 The American Society for Nutritional Sciences. Accessed March 5, 2012. http://jn.nutrition.org/content/135/4/900.full. Following the dietary guidelines in the middle-aged years provides adequate but not excessive energy, macronutrients, vitamins, and minerals.

Video 13.4.1: Caloric Restriction

This video focuses on the possible connection between caloric restriction and longevity. (click to see video)

Macronutrients and Micronutrients

The AMDRs for carbohydrate, protein, fat, fiber, and fluids remain the same from young adulthood into middle age (see Section 13.3 of this chapter). It is important to avoid putting on excess pounds and limiting an intake of SoFAAS to help avoid cardiovascular disease, diabetes, and other chronic conditions.

There are some differences, however, regarding micronutrients. For men, the recommendation for magnesium increases to 420 milligrams daily, while middle-aged women should increase their intake of magnesium to 320 milligrams per day. Other key vitamins needed during the middle-aged years include folate and vitamins B_6 and B_{12} to prevent elevation of homocysteine, a byproduct of metabolism that can damage arterial walls and lead to atherosclerosis, a cardiovascular condition. Again, it is important to meet nutrient needs with food first, then supplementation, such as a daily multivitamin, if you can’t meet your needs through food.

Preventive/Defensive Nutrition

During the middle-aged years, preventive nutrition can promote wellness and help organ systems to function optimally throughout aging. Preventive nutrition is defined as dietary practices directed toward reducing disease and promoting health and well-being. Healthy eating in general—such as eating unrefined carbohydrates instead of refined carbohydrates and avoiding trans fats and saturated fats—helps to promote wellness. However, there are also some things that people can do to target specific concerns. One example is consuming foods high in antioxidants, such as strawberries, blueberries, and other colorful fruits and vegetables, to reduce the risk of cancer.



Figure 13.4.1: Brightly colored tomatoes are another example of foods that are high in antioxidants. (CC BY-SA, 3.0; Aravind Sivaraj).

Phytochemicals are compounds in fruits and vegetables that act as defense systems for plants. Different phytochemicals are beneficial in different ways. For example, carotenoids, which are found in carrots, cantaloupes, sweet potatoes, and butternut squash, may protect against cardiovascular disease by helping to prevent the oxidation of cholesterol in the arteries, although research is ongoing.Sari Voutilainen, Tarja Nurmi, Jaakko Mursu, and Tiina H. Rissanen. "Carotenoids and Cardiovascular Health." *Am J Clin Nutr* 83 (2006): 1265–71. http://www.ajcn.org/content/83/6/1265.full.pdf. According to the American Cancer Society, some studies suggest that a phytochemical found in watermelons and tomatoes called lycopene may protect against stomach, lung, and prostate cancer, although more research is needed.American Cancer Society. "Lycopene." Last revised May 13, 2010. http://www.cancer.org/Treatment/TreatmentsandSideEffects/ComplementaryandAlternativeMedicine/DietandNutrition/lycopene.

Omega-3 fatty acids can help to prevent coronary artery disease. These crucial nutrients are found in oily fish, including salmon, mackerel, tuna, herring, cod, and halibut. Other beneficial fats that are vital for healthy functioning include monounsaturated fats, which are found in plant oils, avocados, peanuts, and pecans.

Menopause

In the middle-aged years, women undergo a specific change that has a major effect on their health. They begin the process of menopause, typically in their late forties or early fifties. The ovaries slowly cease to produce estrogen and progesterone, which results in the end of menstruation. Menopausal symptoms can vary, but often include hot flashes, night sweats, and mood changes. The hormonal changes that occur during menopause can lead to a number of physiological changes as well, including alterations in body composition, such as weight gain in the abdominal area. Bone loss is another common condition related to menopause due to the loss of female reproductive hormones. Bone thinning increases the risk of fractures, which can affect mobility and the ability to complete everyday tasks, such as cooking, bathing, and dressing.Academy of Nutrition and Dietetics. "Eating Right During Menopause." © 1995–2012. Accessed March 5, 2012. www.eatright.org/Public/content.aspx?id=6809. Recommendations for women experiencing menopause or perimenopause (the stage just prior to the end of the menstruation) include:

- consuming a variety of whole grains, and other nutrient-dense foods
- maintaining a diet high in fiber, low in fat, and low in sodium
- avoiding caffeine, spicy foods, and alcohol to help prevent hot flashes

- eating foods rich in calcium, or taking physician-prescribed calcium supplements and vitamin D
- doing stretching exercises to improve balance and flexibility and reduce the risk of falls and fractures

Key Takeaways

Middle-aged adults begin to experience signs of aging and must continue to support their health and wellness with nutrition and exercise. The daily energy requirements for ages thirty-one to fifty are 1,800 to 2,200 calories for women and 2,200 to 3,000 calories for men, depending on activity level. Nutritional concerns for middle-aged adults relate to menopause and the prevention of chronic disease.

Discussion Starter

1. Visit the following websites to learn more about nutrition during the years of perimenopause and menopause. Discuss with classmates what you believe to be the three most important nutritional concerns for women during this phase of life. http://www.medicinenet.com/script/main/art.asp?articlekey=59895 and http://www.webmd.com/menopause/guide/staying-healthy-through-good-nuitrition

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13.5: Old Age and Nutrition

Learning Objectives

- Summarize nutritional requirements and dietary recommendations for elderly adults.
- Discuss the most important nutrition-related concerns during the senior years.
- Discuss the influence of diet on health and wellness in old age.

Beginning at age fifty-one, requirements change once again and relate to the nutritional issues and health challenges that older people face. After age sixty, blood pressure rises and the immune system may have more difficulty battling invaders and infections. The skin becomes more wrinkled and hair has turned gray or white or fallen out, resulting in hair thinning. Older adults may gradually lose an inch or two in height. Also, short-term memory might not be as keen as it once was.Beverly McMillan, *Illustrated Atlas of the Human Body* (Sydney, Australia: Weldon Owen, 2008), 260.

In addition, many people suffer from serious health conditions, such as cardiovascular disease and cancer. Being either underweight or overweight is also a major concern for the elderly. However, many older adults remain in relatively good health and continue to be active in their golden years. Good nutrition is often the key to maintaining health later in life. In addition, the fitness and nutritional choices made earlier in life set the stage for continued health and happiness.

Older Adulthood (Ages Fifty-One and Older): The Golden Years

An adult's body changes during old age in many ways, including a decline in hormone production, muscle mass, and strength. Also in the later years, the heart has to work harder because each pump is not as efficient as it used to be. Kidneys are not as effective in excreting metabolic products such as sodium, acid, and potassium, which can alter water balance and increase the risk for over- or underhydration. In addition, immune function decreases and there is lower efficiency in the absorption of vitamins and minerals.

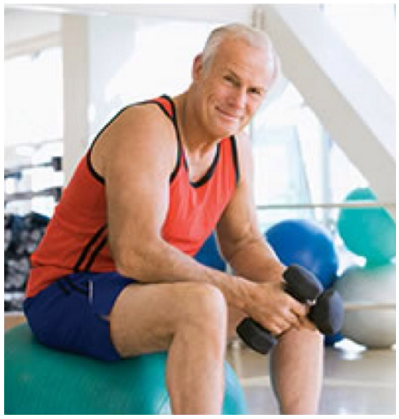


Figure Runaway argument for \eatSpaces?: .5.1: Regular exercise, along with a nutritious diet, can help older adults maintain their health. (Public Domain; National Institutes of Health).

Older adults should continue to consume nutrient-dense foods and remain physically active. However, deficiencies are more common after age sixty, primarily due to reduced intake or malabsorption. The loss of mobility among frail, homebound elderly adults also impacts their access to healthy, diverse foods.

Energy

Due to reductions in lean body mass and metabolic rate, older adults require less energy than younger adults. An energy deficit and weight loss are common problems. The energy requirements for people ages fifty-one and over are 1,600 to 2,200 calories for women and 2,000 to 2,800 calories for men, depending on activity level. The decrease in physical activity that is typical of older adults also influences nutritional requirements. Including physical activity in their daily routine allows for a higher energy intake and a greater likely hood they will meet their other nutrient requirements. It also helps maintain body composition and weight.

Macronutrients

The AMDRs for carbohydrates, protein, and fat remain the same from middle age into old age. Older adults should substitute more unrefined carbohydrates for refined ones, such as whole grains and brown rice. Fiber is especially important in preventing constipation and diverticulitis, and may also reduce the risk of colon cancer. Protein should be lean, and healthy fats, such as omega-3 fatty acids, are part of any good diet. Fat intake should be lower to increase nutrient density.

Micronutrients

An increase in certain micronutrients can help maintain health during this life stage. Iron needs increase because of lower absorption due to lower stomach acid. The recommendations for calcium increase to 1,200 milligrams per day for both men and women to slow bone loss. Also to help protect bones, vitamin D recommendations increase to 10–15 micrograms per day for men and women. Vitamin B_6 recommendations rise to 1.7 milligrams per day for older men and 1.5 milligrams per day for older women to help lower levels of homocysteine and protect against cardiovascular disease. As adults age, the production of stomach acid can decrease and lead to an overgrowth of bacteria in the small intestine. This can affect the absorption of vitamin B_{12} and cause a deficiency. As a result, older adults need more B_{12} than younger adults and require an intake of 2.4 micrograms per day, which helps promote healthy brain functioning. For elderly women, higher iron levels are no longer needed post menopause and recommendations decrease to 8 milligrams per day. People over age fifty should eat foods rich with all of these micronutrients and antioxidants.

Nutritional Concerns for Older Adults

Dietary choices can help improve health during this life stage, postpone some chronic diseases, and address some of the nutritional concerns that many older adults face. In addition, there are specific concerns related to nutrition that affect adults in their later years. They include medical problems, such as disability and disease, which can impact diet and activity level. For example, dental problems can lead to difficulties with chewing and swallowing, which in turn can make it hard to maintain a healthy diet. The use of dentures (not as effective as real teeth) or the preparation of pureed or chopped foods can help solve this problem. There also is a decreased thirst response in the elderly, and the kidneys have a decreased ability to concentrate urine, both of which can lead to dehydration. Adequate fluid intake is necessary to facilitate excretion of metabolic waste. At least six cups of fluid are recommended a day and some medications may increase the need for more fluids.

Other factors can affect an older person's decision to eat and thus their nutritional status. These factors can include medications, emotional state such as depression, confusion or memory loss, availability of money, physical hindrances and loss of friends and spouse. Many older people take multiple drugs that are important to maintain their health. These drugs can interact with each other or by themselves causing nutritional deficiencies. For example, diuretics cause water loss and some nutrient losses, while other drugs can decrease appetite. Depression occurs in about ten to fourteen percent of older people and lowers food intake.

Here are guidelines for improving nutrient intake in the elderly. Meals should be regular, small and frequent. Quick, easily prepared foods like convenience foods may be appropriate to assure the elderly are eating. Different flavorings and seasonings should be encouraged to make food more interesting. Eating is a social event so eating with others should be encouraged as well as sharing meal preparation and responsibilities with others. Community resources are available to help with shopping and cooking and their use encouraged. Physical activity improves appetite and independence.

Sensory Issues

At about age sixty, taste buds begin to decrease in size and number. As a result, the taste threshold is higher in older adults, meaning that more of the same flavor must be present to detect the taste. Many elderly people lose the ability to distinguish between salty, sour, sweet, and bitter flavors. This can make food seem less appealing and decrease the appetite. An intake of foods high in sugar and sodium can increase due to an inability to discern those tastes. The sense of smell also decreases, which impacts attitudes toward food. Sensory issues may also affect the digestion because the taste and smell of food stimulate the secretion of digestive enzymes in the mouth, stomach, and pancreas.

Gastrointestinal Problems

A number of gastrointestinal issues can affect food intake and digestion among the elderly. Saliva production decreases with age, which affects chewing, swallowing, and taste. Digestive secretions decline later in life as well, which can lead to atrophic gastritis (inflammation of the lining of the stomach). This interferes with the absorption of some vitamins and minerals. Reduction of the digestive enzyme lactase results in a decreased tolerance for dairy products. Slower gastrointestinal motility can result in more constipation, gas, and bloating, and can also be tied to low fluid intake, decreased physical activity, and a diet low in fiber, fruits, and vegetables.

Other gastrointestinal problems include atrophic gastritis which is a chronic inflammation of the stomach mucosa. Most often this is caused by a bacterial overgrowth and leads to a loss of HCl and intrinsic factor impairing absorption of several important nutrients. About thirty percent of those over 60 suffer from this condition. Some older people experience ulcers and this can increase their need for iron.

Dysphagia

Some older adults have difficulty getting adequate nutrition because of the disorder dysphagia, which impairs the ability to swallow. Any damage to the parts of the brain that control swallowing can result in dysphagia, therefore stroke is a common cause. Dysphagia is also associated with advanced dementia because of overall brain function impairment. To assist older adults suffering from dysphagia, it can be helpful to alter food consistency. For example, solid foods can be pureed, ground, or chopped to allow more successful and safe swallow. This decreases the risk of aspiration, which occurs when food flows into the respiratory tract and can result in pneumonia. Typically, speech therapists, physicians, and dietitians work together to determine the appropriate diet for dysphagia patients.

Video 13.5.1: Dysphagia

This video provides information about the symptoms and complications of dysphagia. (click to see video)

Obesity in Old Age

Similar to other life stages, obesity is a concern for the elderly. Being moderately overweight if over sixty-five may be okay; being obese is not. Adults over age sixty are more likely to be obese than young or middle-aged adults. As explained throughout this chapter, excess body weight has severe consequences. Being overweight or obese increases the risk for potentially fatal conditions that can afflict the elderly. They include cardiovascular disease, which is the leading cause of death in the United States, and Type 2 diabetes, which causes about seventy thousand deaths in the United States annually.Centers for Disease Control, National Center for Health Statistics. “Deaths and Mortality.” Last updated January 27, 2012. http://www.cdc.gov/nchs/fastats/deaths.htm. Obesity is also a contributing factor for a number of other conditions, including arthritis.

For older adults who are overweight or obese, dietary changes to promote weight loss should be combined with an exercise program to protect muscle mass. This is because dieting reduces muscle as well as fat, which can exacerbate the loss of muscle mass due to aging. Although weight loss among the elderly can be beneficial, it is best to be cautious and consult with a healthcare professional before beginning a weight-loss program.

Anorexia of Aging

In addition to concerns about obesity among senior citizens, being underweight can be a major problem. A condition known as the anorexia of aging is characterized by poor food intake, which results in dangerous weight loss. This major health problem among the elderly leads to a higher risk for immune deficiency, frequent falls, muscle loss, and cognitive deficits. Reduced muscle mass and physical activity mean that older adults need fewer calories per day to maintain a normal weight. It is important for health care providers to examine the causes of anorexia of aging among their patients, which can vary from one individual to another. Understanding why some elderly people eat less as they age can help health-care professionals assess the risk factors associated with this condition. Decreased intake may be due to disability or the lack of a motivation to eat. Also, many older adults skip at least one meal each day. As a result, some elderly people are unable to meet even reduced energy needs.

Nutritional interventions should focus primarily on a healthy diet. Remedies can include increasing the frequency of meals and adding healthy, high-calorie foods (such as nuts, potatoes, whole-grain pasta, and avocados) to the diet. Liquid supplements between meals may help to improve caloric intake.Morley, J. E. “Anorexia of Aging: Physiologic and Pathologic.” *Am J Clin Nutr* 66 (1997): 760–73. http://www.ajcn.org/content/66/4/760.full.pdf. Healthcare professionals should consider a patient’s habits and preferences when developing a nutritional treatment plan. After a plan is in place, patients should be weighed on a weekly basis until they show improvement.

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Bone Health

Bone mass and density decrease with age because calcium and other minerals are lost. The spine compresses shrinking our stature while the long bones remain the same length but become more brittle as minerals are lost. Because of the changes in bones, posture and walking are affected, for example, the walking gait becomes slower. Diet can contribute to the loss of bone mass and density because good sources of calcium and vitamin D are lacking in the diet.

Vision Problems

Many older people suffer from vision problems and a loss of vision. Age-related macular degeneration is the leading cause of blindness in Americans over age sixty.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 413. This disorder can make food planning and preparation extremely difficult and people who suffer from it often must depend on caregivers for their meals. Self-feeding also may be difficult if an elderly person cannot see his or her food clearly. Friends and family members can help older adults with shopping and cooking. Food-assistance programs for older adults (such as Meals on Wheels) can also be helpful.

Diet may help reduce the risk of macular degeneration. Consuming colorful fruits and vegetables, rich in antioxidants, increases the intake of lutein and zeaxanthin. Several studies have shown that these antioxidants provide protection for the eyes. Lutein and zeaxanthin are found in green, leafy vegetables such as spinach, kale, and collard greens, and also corn, peaches, squash, broccoli, Brussels sprouts, orange juice, and honeydew melon.American Medical Association, *Complete Guide to Prevention and Wellness* (Hoboken, NJ: John Wiley & Sons, Inc., 2008), 415.

Cataracts is the thickening of the lenses of the eye and develops when aging or injury causes changes in the lenses of your eye. There are many causes, for example, UV light exposure and oxidative stress can contribute to its development. Even obesity can increase the risk of developing cataracts. Eating foods rich in vitamin C, E and carotenoids may reduce the risk.

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Neurological Conditions

Elderly adults who suffer from dementia may experience memory loss, agitation, and delusions. One in eight people over the age sixty-four and almost half of all people over eighty-five suffer from Alzheimer’s, which is the most common form of dementia. These conditions can have serious effects on diet and nutrition as a person increasingly becomes incapable of caring for himself or herself, which includes the ability to buy and prepare food, and to self-feed.

Nutrient insufficiencies can also contribute to diminished brain function. For example, inadequate intake of vitamin B_{12}, vitamin C, and vitamin E have been linked to short-term memory. Changes in problem-solving performance have been observed with inadequate intake of vitamin B_2, folate, vitamin B_{12} and vitamin C while changes in cognition have been observed with insufficient intake of folate, vitamin B_6, vitamin B_{12}, iron and vitamin E. Several neurotransmitters are synthesized from nutrients, for example, tyrosine is the precursor for dopamine and tryptophan is the precursor for serotonin. Choline is also important for the production of the neurotransmitter acetylcholine. Chronically low consumption of vitamin B_1, vitamin B_3, zinc and folate can alter brain health.

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Arthritis

Arthritis is the painful inflammation and stiffness of the joints. It is many diseases, not just one. There are several different types of arthritis: degenerative, inflammatory, infectious, and metabolic. Osteoarthritis is the most common degenerative arthritis and is associated with being overweight. Rheumatoid arthritis is an example of inflammatory arthritis. If this form of arthritis is caught early, drug therapy can help put it in remission. Eating foods rich in omega-3 fatty acids, and/or the antioxidants vitamin C, vitamin E, and carotenoids may help relieve the pain associated with this type of arthritis. Gout is a type of metabolic arthritis where uric

acid crystals are deposited in the joints. The old wives tale is that rich food causes gout is not true. Foods rich in purines, for example, meat and seafood, increase the risk.

Longevity and Nutrition

The foods you consume in your younger years influence your health as you age. Good nutrition and regular physical activity can help you live longer and healthier. Conversely, poor nutrition and a lack of exercise can shorten your life and lead to medical problems. The right foods provide numerous benefits at every stage of life. They help an infant grow, an adolescent develop mentally and physically, a young adult achieve his or her physical peak, and an older adult cope with aging. Nutritious foods form the foundation of a healthy life at every age.

Key Takeaways

As adults age, physical changes impact nutrient needs and can result in deficiencies. The daily energy requirements for adults ages fifty-one and over are 1,600 to 2,200 calories for women and 2,000 to 2,800 calories for men, depending on activity level. Older adults are more susceptible to medical problems, such as disability and disease, which can impact appetite, the ability to plan and prepare food, chewing and swallowing, self-feeding, and general nutrient intake. A nutrient-dense, plant-based diet can help prevent or support the healing of a number of disorders that impact the elderly, including macular degeneration and arthritis.

Discussion Starter

1. Revisit the predictions you made at the beginning of this chapter about how nutrient needs might change as a healthy young adult matures into old age. Which predictions were correct? Which were incorrect? What have you learned?

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13.E: Exercises

It's Your Turn

1. Create a list of nutritional tips for adults who are caring for their elderly parents after watching the following video:

   Nutrition for Senior Citizens

   (click to see video)

Apply It

1. After watching the video, hold a small group discussion to discuss the influence of environment, economics, culture, and lifestyle on dietary choices.

   The Obesity Epidemic

   (click to see video)

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CHAPTER OVERVIEW

14: Alcohol

Alcohol is produced when yeast in the absence of oxygen ferment a food source like grains or grapes. The sugar in these food sources is converted to alcohol. Humankind has been drinking beverages that contain alcohol for thousands of years. In fact, the ancient Egyptians paid their slaves with beer. Along with a low alcohol content, these ancient beers were a good source of vitamins and antibiotics like tetracycline, the reason some mummies glow under ultraviolet lights. Today, alcohol containing beverages do not have the plethora of vitamins and tetracycline because society has focused on maximizing the alcohol content.

14.1: Introduction to Alcohol

14.2: Alcohol Absorption and Metabolism

14.3: Pros and Cons of Drinking Alcohol

14.4: How Much to Drink?

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14.1: Introduction to Alcohol

Learning Objectives

- Explain the impacts of excessive alcohol intake (both acutely and chronically) on health.

Alcohol is both a beverage providing some sustenance and a drug. For thousands of years, alcohol has been consumed in a medicinal, celebratory, and ritualistic manner. It is drunk in just about every country and often in excessive amounts. Alcohol is a psychoactive drug. A psychoactive drug is any substance that crosses the blood-brain barrier primarily affecting the functioning of the brain, be it altering mood, thinking, memory, motor control, or behavior. Alcohols in chemistry refer to a group of similar organic compounds, but in beverages the only alcohol consumed is ethanol. Ethanol is an organic compound that contains a hydroxyl (OH) group. It is the byproduct of yeast fermentation of sugars, like maltose, in an anaerobic environment.

The Behavioral Risk Factor Surveillance System survey reported that more than half of the adult US population drank alcohol in the past thirty days (Centers for Disease Control and Prevention. “Alcohol and Public Health.” Last updated March 5, 2012. http://www.cdc.gov/alcohol/). The 2015 National Survey on Drug Use and Health (NSDUH) estimated that 86.4% of people 18 and older drank at some time during their life and 70.1% reported they drank in the last year[1]. Of the total population who drank alcohol, approximately 7 percent drank heavily, while 26.9 percent of people ages 18 or older reported they engaged in binge drinking at some point in their life.[2] Binge drinking (as defined by the National Institute on Alcohol Abuse and Alcoholism) is when men consume five or more drinks, and when women consume four or more drinks, in two hours or less (Centers for Disease Control and Prevention. “Alcohol and Public Health.” Last updated March 5, 2012. http://www.cdc.gov/alcohol/). Alcohol in excess is detrimental to health; however, since its beginnings, it has been suspected and promoted as a benefit to the body and mind when consumed in moderation, but recent studies suggest no amount of alcohol is safe. In the United States, the *Dietary Guidelines* define moderate alcohol intake as no more than one drink per day for women and up to two drinks per day for men (US Department of Agriculture and US Department of Health and Human Services. “Alcoholic Beverages.” In *Dietary Guidelines for Americans 2020*. (Washington D. C.: US Department of Health and Human Services and US Department of Agriculture, 2020). Dietary_Guidelines_for_Americans_2020-2025.pdf). Although drunkenness has pervaded many cultures, drinking in moderation has long been a mantra of multiple cultures with access to alcohol.



Figure 14.1.1: One-half ounce of hard liquor.

Beer, wine, and hard liquor are the alcohol types familiar to most people and each contains pure ethanol in different amounts. Beer and wine will give the amount of alcohol in a percent based on volume. So if a beer is labeled as 5.9% alcohol that means a 12 ounce can contain 0.71 ounces of alcohol. On average, one can of beer contains about 15 grams of ethanol which does not seem like much except it will take the liver approximately one hour to metabolize and clear that amount.

Example 14.1.1: Beer 12 fluid ounces

Alcohol % varies. If alcohol content is 5.0% by volume:

$$\begin{aligned}(12 \text{ ounces of beer}) \times \left(29.5735 \frac{milliliters}{ounce}\right) \times \left(0.05 \frac{milliliters}{milliliters}\right) \times \left(0.789 \frac{grams}{milliliters}\right) \\ \approx 14 \text{ grams of alcohol}\end{aligned}$$

1. 29.5735 is the conversion factor for ounces to grams
2. 0.05 is the percent alcohol
3. 0.789 is the density of alcohol

The ethanol content of hard liquor is stated as proof which is half the percentage of alcohol. So, one ounce of hard liquor is 30 grams of ethanol or 200 proof or 100% alcohol.

Discussion Starters

1. Weekends seem to be the time to party on campus. How many people do you know that drink? How much do they drink and why?

References

1. Substance Abuse and Mental Health Services Administration (SAMHSA). 2015 National Survey on Drug Use and Health (NSDUH). Table 2.41B—Alcohol Use in Lifetime, Past Year, and Past Month among Persons Aged 12 or Older, by Demographic Characteristics: Percentages, 2014 and 2015. Available at: https://www.samhsa.gov/data/sites/default/files/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015.htm#tab2-41b. Accessed 1/18/17.
2. Substance Abuse and Mental Health Services Administration (SAMHSA). 2015 National Survey on Drug Use and Health (NSDUH). Table 2.46B—Alcohol Use, Binge Alcohol Use, and Heavy Alcohol Use in Past Month among Persons Aged 12 or Older, by Demographic Characteristics: Percentages, 2014 and 2015. Available at: https://www.samhsa.gov/data/sites/default/files/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015/NSDUH-DetTabs-2015.htm#tab2-46b. Accessed 1/18/17.

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14.2: Alcohol Absorption and Metabolism

Learning Objectives

- Explain the digestion and metabolism of alcohol

In this section, we will discuss how alcohol is absorbed and metabolized.

Absorption

Alcohol is passively absorbed primarily in the small intestine although small amounts may be absorbed in the mouth, stomach and large intestine. The rate of absorption depends on body size; the larger the person, the slower absorption. So a person who weighs 180 lbs will take longer to absorb one beer than someone who weighs 120 lbs. For example, someone who weighs 180 lbs will absorb 9-16 grams of alcohol per hour while someone weighing 120 lbs will absorb 6-10 grams of alcohol per hour. Other factors also affect alcohol absorption. Eating food, particularly fat, protein and fiber, while drinking alcohol will slow absorption while carbonated alcoholic beverages are absorbed faster. Women are more proficient at absorbing alcohol than men. Once absorbed, alcohol reaches the brain quickly where it alters mental and physical functions.

Metabolism

More than 90 percent of ingested alcohol is metabolized in the liver at a rate of approximately half an ounce per hour, but the rate varies from person to person. The rate of degradation and clearance in the liver depends on a variety of genetic and environmental factors including body size, previous alcohol exposure, food intake and one's general health. While waiting to be degraded, alcohol stays in the blood and some will be excreted through the breath (which is how Breathalyzers work), urine, saliva, and sweat.

There are three systems in the liver for degrading or detoxifying alcohol (14.2.1). These are the alcohol dehydrogenase (ADH) system, the microsomal ethanol-oxidizing system (MEOS), and the acetaldehyde dehydrogenase (ALDH) system. ADH and ALDH work together to break alcohol down to acetate which is easier to remove from the body. ADH degrades ethanol to acetaldehyde, a known carcinogen. Some ADH exists in the stomach and levels of this enzyme are diminished by fasting. ALDH quickly degrades the acetaldehyde to acetate which is further broken down to carbon dioxide and water in extrahepatic tissues. People of Asian descent have reduced levels of ALDH and this contributes to the flushing commonly experienced after drinking alcohol. Other side effects of acetaldehyde build up is rapid heartbeat and hyper ventalation. One fifth of the alcohol absorbed is degraded by MEOS to acetaldehyde.

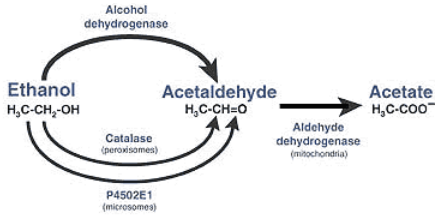


Figure 14.2.1: Break down of alcohol into acetaldehyde and acetate.

The chemical pathways involved in degrading ethanol use NAD^+ and take it from other pathways such as glycolysis (the breakdown of glucose) and the TCA (tricarboxylic acid) cycle (also known as the Krebs cycle) which generates energy from glucose. As a result, $NADH_2$ accumulates and slows the TCA cycle causing acetyl CoA to accumulate. Excess acetyl CoA is diverted to fatty acid synthesis and the fatty acids are incorporated into triglycerides. These triglycerides can accumulate in the liver and over time clog the liver and impair function. This is one of the proposed mechanisms by which fatty accumulates in the liver following alcohol intake.

When alcohol is consumed in excess, ethanol circulates in the blood until liver enzymes are available to degrade it. The byproduct of degradation, acetaldehyde, is harmful. Also, alcohol decreases the production of antidiuretic hormone (ADH) and decreased levels of ADH prevents the retention of water so water and water soluble vitamin losses are increased. Alcoholic beverages do not hydrate and excess intake can lead to dehydration.

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14.3: Pros and Cons of Drinking Alcohol

Learning Objectives

- Explain the impacts of excessive alcohol intake (both acutely and chronically) on health.

Pros and Cons

Alcohol, when drunk in moderation, has beneficial effects. However, drinking any type of alcoholic beverage, beer, wine or hard liquor, can lead to dependency on the substance and the level of tolerance is different for everyone. Here we explore the beneficial and harmful effects of so that you will be better able to make wise decisions about drinking beverages that contain alcohol. It is important to remember when you consume alcohol, you are also consuming calories, seven calories per gram, that do not contain other beneficial nutrients. So alcohol is a source of "empty" or "naked" calories.

Health Benefits of Moderate Alcohol Intake

In contrast to excessive alcohol intake, moderate alcohol intake has been shown to provide health benefits. The data is most convincing for preventing heart disease in middle-aged and older people. A review of twenty-nine studies concluded that moderate alcohol intake reduces the risk of coronary heart disease by about 30 percent in comparison to those who do not consume alcohol.*Ronksley, P. E.* et al. “Association of Alcohol Consumption with Selected Cardiovascular Disease Outcomes: A Systematic Review and Meta-Analysis.” *BMJ* 342, no. d671 (2011). doi: 10.1136/bmj.d671. Several other studies demonstrate that moderate alcohol consumption reduces the incidences of stroke and heart attack, and also death caused by cardiovascular and heart disease. The drop in risk for these adverse events ranges between percent. Moreover, there is some scientific evidence that moderate alcohol intake reduces the risk for metabolic syndrome, Type 2 diabetes, and gallstones. In addition to providing some health benefits, moderate alcohol intake has long served as a digestive aid and a source of comfort and relaxation, and it induces social interaction, thereby benefiting all aspects of the health triangle. It has not been clearly demonstrated that moderate alcohol consumption benefits younger populations, and the risks of any alcohol consumption do not outweigh the benefits for pregnant women, those who are taking medications that interact with alcohol, and those who are unable to drink in moderation.

Health Consequences of Alcohol Abuse

Distilled spirits have exceptionally few nutrients, but beer and wine do provide some nutrients, vitamins, minerals, and beneficial plant chemicals along with calories. A typical beer is 150 kilocalories, a glass of wine contains approximately 80 kilocalories, and an ounce of hard liquor (without a mixer) is around 65 kilocalories. Alcoholic drinks in excess contribute to weight gain by substantially increasing caloric intake. However, alcohol displays its two-faced character again in its effects on body weight, making many scientific studies contradictory. Multiple studies show high intakes of hard liquor are linked to weight gain, although this may be the result of the regular consumption of hard liquor with sugary soft drinks, juices, and other mixers. On the other hand drinking beer and, even more so, red wine, is not consistently linked to weight gain and in some studies actually, decreases weight gain. The contradictory results of scientific studies that have examined the association of alcohol intake with body weight are partly due to the fact that alcohol contributes calories to the diet, but when drunk in excess reduces the secretion of pancreatic juice and damages the lining of the gastrointestinal system, impairing nutrient digestion and absorption. The impaired digestion and absorption of nutrients in alcoholics contributes to their characteristic “skinniness” and multiple associated micronutrient deficiencies. The most common macro nutrient deficiency among alcoholics is water, as it is excreted in excess. Commonly associated micronutrient deficiencies include thiamine, pyridoxine, folate, vitamin A, magnesium, calcium, and zinc. Furthermore, alcoholics typically replace calories from alcohol with those of nutritious foods, sometimes getting 50 percent or more of their daily caloric intake from alcoholic beverages. Alcohol can also interfere with the ability of organs to use nutrients.

Effects of Alcohol Abuse on the Brain

- Alcohol can adversely affect nearly every area of the brain. When BAC rises, the central nervous system is depressed. Alcohol disrupts the way nerve cells communicate with each other by interfering with receptors on certain cells. The immediate impact of alcohol on the brain can be seen in the awkwardly displayed symptoms of confusion, blurred vision, slurred speech, and other signs of intoxication. These symptoms will go away once drinking stops, but abusive alcohol consumption over time can lead to long-

lasting damage to the brain and nervous system. This is because alcohol and its metabolic byproducts kill brain cells. Excessive alcohol intake has the following effects on specific areas of the brain:

1. **Medulla.** This area controls automatic functions, such as heart rate. When alcohol first limits its functioning, people feel sleepy. With greater BAC levels, unconsciousness, comas, and death can result.
2. **Cerebellum.** This is where conscious movement is coordinated. With too much alcohol, balance and motor skills are impaired.
3. **Cerebral cortex.** Senses and thoughts are processed here, and this is where action is initiated. When BAC levels increase, the ability to think, exercise good judgment and feel pain decrease.
4. **Hypothalamus and pituitary gland.** Alcohol increases sexual desire but decreases sexual performance. It also prompts signals which increase urine production.
5. **Limbic system.** When alcohol affects this area, individuals may become very emotional and lose memory function.

Effects of Alcohol Abuse on the Liver

According to the CDC, 19,388 Americans died from alcohol-related liver diseases in 2014. Although not every alcoholic or heavy drinker will die from liver problems, the liver is one of the body's main filtering organs and is severely stressed by alcohol abuse. The term Alcoholic Liver Disease (ALD) is used to describe liver problems linked to excessive alcohol intake. ALD can be progressive, with individuals first suffering from a fatty liver and going on to develop cirrhosis. It is also possible to have different forms of ALD at the same time.

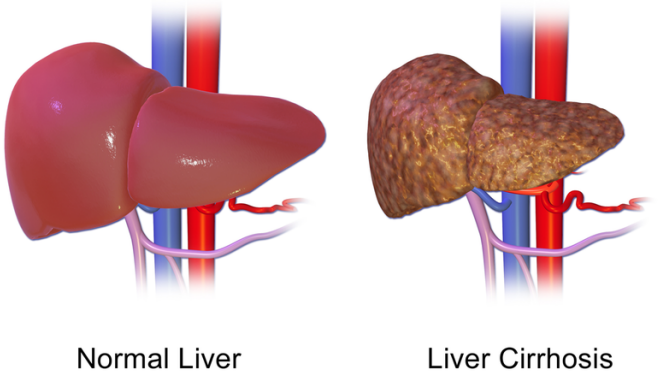


Figure 14.3.1*: Liver Cirrhosis. Excessive alcohol consumption causes the destruction of liver cells. In an attempt to repair itself, the liver initiates an inflammatory and reparation process causing scar tissue to form. In the liver's attempt to replace the dead cells, surviving liver cells multiply. The result is clusters of newly formed liver cells, also called regenerative nodules, within the scar tissue. This state is called cirrhosis of the liver.* See a full animation of this medical topic. from BruceBlaus (via Wikipedia).

The three most common forms of ALD are:

- **Fatty liver.** A rather benign disorder that develops after excessive alcohol consumption; however, it can progress to more fatal diseases. Fatty liver is reversible if alcohol use is brought under control. Large fat droplets occur in the liver due to increased triglyceride synthesis, decreased fatty acid breakdown, and decreased VLDL release from the liver to transport the triglyceride to extrahepatic tissues. Fatty liver is associated with chronic alcohol consumption, generally, not one night of binge-drinking.
- **Alcoholic hepatitis.** The symptoms of this alcohol-induced liver inflammation are a swollen liver, abdominal pain, nausea, fever, jaundice, and vomiting. Although linked to alcohol use, even people who drink moderately can sometimes develop this condition, and not all alcohol abusers do. If a person stops drinking alcohol, the liver damage can be reversed. But if they continue, cirrhosis may develop and death can result.
- **Cirrhosis.** Long term excessive alcohol consumption can cause cirrhosis. This serious and sometimes fatal form of ALD develops when liver cells die and form scar tissue, which blocks blood flow and causes wastes and toxins, like ammonia, to build up in the system. Normal liver function is disrupted and causes damage to the brain. Strictly speaking, cirrhosis cannot be cured. It can, however, be stopped with medical treatment and complications can be managed if the individual stops drinking, and many do survive. Not all cases of cirrhosis are strictly due to alcoholism or chronic consumption of alcohol, and not all alcoholics develop the disease. Symptoms of cirrhosis include the buildup of abdominal fluid (ascites), abdominal pain, fever, thirst, confusion, and fatigue.

Fetal Alcohol Spectrum Disorders

Fetal alcohol spectrum disorders (FASDs) are a group of conditions that can occur in a person whose mother drank alcohol during pregnancy. These symptoms can include physical problems and problems with behavior and learning. Often, a person with FASD has a mix of these problems. Different terms are used to describe FASD depending on the symptoms.

Fetal alcohol syndrome (FAS) is growth, mental, and physical problems that may occur in a baby when a mother drinks alcohol during pregnancy.The Institute of Medicine estimated 1996 that fetal alcohol syndrome (FAS) was between 0.5 and 3.0 cases per 1,000 (Stratton, K.; Howe, C.; Battaglia, F.; Eds. *Fetal Alcohol Syndrome: Diagnosis, Epidemiology, Prevention, and Treatment)*. Washington, DC: Institute of Medicine, National Academy Press, 1996). More recent reports from other sites suggest the prevalence may be 2 to 7 cases per 1,000 or as high as 20 to 50 cases per 1,000 (May, P.A.; Gossage, J.P.; Kalberg, W.O.; et al. Prevalence and epidemiologic characteristics of FASD from various research methods with an emphasis on recent in-school studies. *Developmental Disabilities Research Reviews* 15(3):176–192, 2009. PMID: 19731384; May, P.A.; Keaster, C.; Bozeman, R.; et al. Prevalence and characteristics of fetal alcohol syndrome and partial fetal alcohol syndrome in a Rocky Mountain Region City. *Drug and Alcohol Dependence* 155:118–127, 2015. PMID: 26321671)

There is no safe level of alcohol during pregnancy. If you are planning on becoming pregnant, you should stop drinking 4 to 6 weeks before conception. Alcohol consumed during the first trimester causes physical damage to developing tissues and organs. During the second trimester, the risk of spontaneous abortion increases and during the third trimester, both body and brain growth problems develop. the impact on the fetus and subsequent baby can manifest in a variety of symptoms including poor growth while in the womb and after birth, decreased muscle tone and poor coordination, and delayed developmental milestones. Characteristic facial features can occur with chronic alcoholism and these include small head circumference; narrow, receding forehead; flattened (low) nasal bridge; short, upturned nose; underdeveloped jaw and receding chin; extra skin folds on eyelids, drooping eyelids, or downward slant of eyes; short-sightedness, and inability focus; uneven or poorly formed ears; and absence of a groove in the upper lip.

Alcohol-related neurodevelopmental disorder (ARND) is another alcohol related disorder which is associated with behavioral, cognitive, or central nervous system abnormalities. It is associated with prenatal alcohol exposure. Often women do not know they are pregnant and continue to drink. People with ARND tend to do poorly at school.

Also, prenatal alcohol exposure can result in skeletal and organ malformation termed alcohol-related birth defects (ARBD).

Key Takeaways

- Alcohol in excess is detrimental to health; in moderation, however, it is promoted as a benefit to the body and mind. The US *Dietary Guidelines* define moderate alcohol intake as no more than one drink per day for women and no more than two drinks per day for men.
- Moderate intake of alcohol has been shown in multiple scientific studies to provide health benefits, including reducing the risks of heart disease, cardiovascular disease, metabolic syndrome, Type 2 diabetes, and gallstones.

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14.4: How Much to Drink?

Learning Objectives

- Knowledge of different levels of alcohol intake and ways people consume alcohol
- Understanding of the mental and physical effects of alcohol at different levels of intake

How Much to Drink?

Most likely, you have observed people drinking alcohol, or been with people who are drinking, or drank alcohol yourself. What did you observe? People can consume alcohol in a variety of different ways for a variety of different reasons. The National Institute on Alcohol Abuse and Alcoholism (NIAAA) has defined different levels of drinking. Where do you or those around you fit in?

Table 14.4.1: Definitions of different levels of drinking

Type of drinking	Definition
Moderate alcohol consumption	Moderate drinking is up to 1 drink per day for women and up to 2 drinks per day for men (Dietary_Guidelines_for_Americans_2020-2025.pdf)
Binge Drinking	NIAAA defines binge drinking as a pattern of drinking that brings blood alcohol concentration (BAC) levels to 0.08 g/dL. This typically occurs after 4 drinks for women and 5 drinks for men—in about 2 hours. The Substance Abuse and Mental Health Services Administration (SAMHSA), which conducts the annual National Survey on Drug Use and Health (NSDUH), defines binge drinking as 5 or more alcoholic drinks for males or 4 or more alcoholic drinks for females on the same occasion (i.e., at the same time or within a couple of hours of each other) on at least 1 day in the past month.
Heavy Alcohol Use	SAMHSA defines heavy alcohol use as binge drinking on 5 or more days in the past month.
NIAAA's Definition of Drinking at Low Risk for Developing Alcohol Use Disorder (AUD)	For women, low-risk drinking is defined as no more than 3 drinks on any single day and no more than 7 drinks per week. For men, it is defined as no more than 4 drinks on any single day and no more than 14 drinks per week. NIAAA research shows that only about 2 in 100 people who drink within these limits have AUD.
Those who should avoid alcohol:	• Individuals plan to drive a vehicle or operate machinery • Take medications that interact with alcohol • Have a medical condition that alcohol can aggravate • Are pregnant or trying to become pregnant

The blood alcohol concentration (BAC) is measured in milligrams percent, comparing units of alcohol to units of blood. BAC is a measurement used legally to assess intoxication and the impairment and ability to perform certain activities, as in driving a car. As a general rule, the liver can metabolize one standard drink (defined as 12 ounces of beer, 5 ounces of wine, or 1 ½ ounces of hard liquor) per hour. Drinking more than this, or more quickly, will cause BAC to rise to potentially unsafe levels. Table 14.4.2 summarizes the mental and physical effects associated with different BAC levels.

Table 14.4.2: Mental and Physical Effects of Different BAC Levels

BAC Percent	Typical Effects
0.02	Some loss of judgment, altered mood, relaxation, increased body warmth

BAC Percent	Typical Effects
0.05	Exaggerated behavior, impaired judgment, may have some loss of muscle control (focusing eyes), usually good feeling, lowered alertness, release of inhibition
0.08	Poor muscle coordination (balance, speech, vision, reaction time), difficulty detecting danger, and impaired judgment, self-control, reasoning, and memory
0.10	Clear deterioration of muscle control and reaction time, slurred speech, poor coordination, slowed thinking
0.15	Far less muscle control than normal, major loss of balance, vomiting

In addition to the one drink per hour guideline, the rate at which an individual's BAC rises is affected by the following factors:

- Sex (A woman's BAC will rise more quickly than a man's.)
- Weight (BAC will rise more slowly for heavier people.)
- Genetics
- Length of time as a heavy drinker
- Type of alcohol consumed
- Amount of alcohol consumed
- Consumption rate
- Consumption before or after a meal (food in the stomach slows absorption)
- Mixture (carbonated mixers speed absorption)
- Medications may increase the bioavailability of alcohol.



Figure 14.4.2: In moderation, alcohol promotes some aspects of health. However, caution is necessary because excessive alcohol intake can have detrimental effects on health.

Giving the liver enough time to fully metabolize the ingested alcohol is the only effective way to avoid alcohol toxicity. Drinking coffee or taking a shower will not help. The legal limit for intoxication in many states is a BAC of 0.08. Taking into account the rate at which the liver metabolizes alcohol after drinking stops, and the alcohol excretion rate, it takes at least five hours for a legally intoxicated person to achieve sobriety.

Myths About Drinking

- Alcohol does not warm you up.
- Mixing drinks does not lead to a hangover. Ethanol causes hangovers.
- Vitamins, tranquilizers, aspirin, drinking more water, breathing pure oxygen, exercising, and eating do not prevent a hangover or make it less worse.
- Drinking caffeinated beverages does not keep you from getting drunk or slow the intoxication process.
- Alcohol is a depressant
- Alcohol is a legal DRUG

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CHAPTER OVERVIEW

15: Nutrition and Exercise

Nutrition can improve athletic performance. What you eat and when you eat can make or break your workout or competition. if you eat the right types of foods at the right time, your body will have the nutrients it needs during physically demanding activities like running, bicycling, or lifting weights. This chapter will introduce you to the concepts of sports nutrition.

15.1: Chapter Introduction
15.2: Introduction to Nutrition and Physical Fitness
15.3: Aerobic Exercise
15.4: Anaerobic Exercise
15.5: Nutrients that are critical to athletes
15.6: Fitness Supplements and Steroids
15.7: Fitness and Health
15.8: Supplemental- Creating your own fitness plan

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15.1: Chapter Introduction



Physical activity is divided into three types: inactivity, non-exercise activity, and exercise. Sitting and laying down comprise physical inactivity. Many people spend a substantial portion of their day inactive or sedentary. How about you? Have you ever counted how many hours a day you spend inactive?

Non-exercise activity (also known as NEAT) includes activities that are not sleeping, eating or sports-like activities like walking, standing, gardening, typing, performing yard work, fidgeting, and cleaning house. Exercise is the third type of physical activity and includes anything that is a sport-like exercise, for example, swimming, running, and bicycling. Exercise activities can be further divided into aerobic and anaerobic which will be explained in this chapter.

Physical activity confers many benefits. It improves our mental outlook and capacity, our self-image, our self-confidence, and provides independence for the elderly. Moving can also increase lean body mass and decrease body fat. Research studies find people who are obese spend significantly more time during the day physically inactive than people who are not overweight or obese. Engaging in physical activity also increases bone mass, and heart, lung, and muscle function. Morbidly and mortality is lower in people who are physically active compared to people who are sedentary. Also, the risk is reduced for cardiovascular disease, hypertension, stroke, type II diabetes, cancer, particularly colon and breast, osteoporosis and gall bladder disease.

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15.2: Introduction to Nutrition and Physical Fitness

Physical fitness is a general state of health and well-being and, more specifically, the ability to perform aspects of sports, occupations and daily activities. Physical fitness is generally achieved through proper nutrition, moderate-vigorous physical exercise, physical activity, and sufficient rest. Before the industrial revolution, fitness was defined as the capacity to carry out the day's activities without undue fatigue. However, with automation and changes in lifestyles physical fitness is now considered a measure of the body's ability to function efficiently and effectively in work and leisure activities, to be healthy, to resist hypokinetic diseases, and to meet emergency situations.

Components of fitness include body composition, flexibility muscle strength and endurance, and cardiovascular endurance.

Figure 15.2.1: *Physical fitness can be achieved through exercise. Photo shows Rich Froning Jr. – four-time winner of "Fittest Man on Earth" title.*

Fitness

Fitness is defined as the quality or state of being fit. Around 1950, perhaps consistent with the Industrial Revolution and the treatise of World War II, the term "fitness" increased in western vernacular by a factor of ten. The modern definition of fitness describes either a person or machine's ability to perform a specific function or a holistic definition of human adaptability to cope with various situations. This has led to an interrelation of human fitness and attractiveness which has mobilized global fitness and fitness equipment industries. Regarding specific function, fitness is attributed to personnel who possess significant aerobic or anaerobic ability, i.e. strength or endurance. A holistic definition of fitness is described by Greg Glassman in the CrossFit journal as an increased work capacity across broad times and modal domains; mastery of several attributes of fitness including strength, endurance, power, speed, balance and coordination and being able to improve the amount of work done in a given time with any of these domains. A well-rounded fitness program will improve a person in all aspects of fitness, rather than one, such as only cardio/respiratory endurance or only weight training.

Figure 15.2.2: *A woman performs plank exercise for strengthening of muscles*

A comprehensive fitness program tailored to an individual typically focuses on one or more specific skills, and on age- or health-related needs such as bone health. Many sources also cite mental, social and emotional health as an important part of overall fitness. This is often presented in textbooks as a triangle made up of three points, which represent physical, emotional, and mental fitness. Physical fitness can also prevent or treat many chronic health conditions brought on by unhealthy lifestyle or aging. Working out can also help some people sleep better and possibly alleviate some mood disorders in certain individuals.

Developing research has demonstrated that many of the benefits of exercise are mediated through the role of skeletal muscle as an endocrine organ. That is, contracting muscles release multiple substances known as myokines which promote the growth of new tissue, tissue repair, and various anti-inflammatory functions, which in turn reduce the risk of developing various inflammatory diseases.

Activity guidelines

The Physical Activity Guidelines for Americans was created by the Office of Disease Prevention and Health Promotion. This publication suggests that all adults should avoid inactivity to promote good health mentally and physically. For substantial health benefits, adults should participate in at least 150 minutes (two hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week. For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount. Adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

Training

Specific or task-oriented fitness is a person's ability to perform a specific activity with a reasonable efficiency: for example, sports or military service. Specific training prepares athletes to perform well in their sports. Examples are:

- 100 m sprint: in a sprint, the athlete must be trained to work anaerobically throughout the race, an example of how to do this would be interval training.
- Middle distance running: athletes require both speed and endurance to gain benefit out of this training. The hard-working muscles are at their peak for a longer period of time as they are being used at that level for a longer period of time.
- Marathon: in this case, the athlete must be trained to work aerobically and their endurance must be built-up to a maximum.
- Many firefighters and police officers undergo regular fitness testing to determine if they are capable of the physically demanding tasks required of the job.
- Members of armed forces will often be required to pass a formal fitness test – for example, soldiers of the US Army must be able to pass the Army Physical Fitness Test (APFT).
- Hill sprints: requires a level of fitness, to begin with, the exercise is particularly good for the leg muscles. The army often trains doing mountain climbing and races.
- Sand running creates less strain on leg muscles than running on grass or concrete. This is because sand collapses beneath the foot softening the landing. Sand training is an effective way to lose weight and become fit as its proven you need more effort (one and a half times more) to run on the soft sand than on a hard surface.
- Aquajogging is a form of exercise that decreases strain on joints and bones. The water supplies minimal impact to muscles and bones which is good for those recovering from injury. Furthermore, the resistance of the water as one jogs through it provides an enhanced effect of exercise (the deeper you are the greater the force needed to pull your leg through).

Figure 15.2.3: *Swimmers perform squats prior to entering the pool in a U.S. military base, 2011*

- Swimming: Squatting exercise helps in enhancing a swimmer's start.

In order for physical fitness to benefit the health of an individual, an unknown response in the person called a stimulus will be triggered by the exertion. When exercise is performed with the correct amount of intensity, duration, and frequency, a significant amount of improvement can occur. The person may overall feel better but the physical effects on the human body take weeks or months to notice and possibly years for full development. For training purposes, exercise must provide a stress or demand on either a function or tissue. To continue improvements, this demand must eventually increase little over an extended period of time. This sort of exercise training has three basic principles: overload, specificity, and progression. These principles are related to health but also enhancement of physical working capacity.[22]

High-Intensity Interval Training (HIIT)

High-Intensity Interval Training consists of repeated, short bursts of exercise, completed at a high level of intensity. These sets of intense activity are followed by a predetermined time of rest or low-intensity activity. Studies have shown that exercising at a higher intensity has increased cardiac benefits for humans, compared to when exercising at a low or moderate level. When your workout consists of an HIIT session, your body has to work harder to replace the oxygen it lost. Research into the benefits of HIIT has revealed that it can be very successful for reducing fat, especially around the abdominal region. Furthermore, when compared to continuous moderate exercise, HIIT proves to burn more calories and increase the amount of fat burned post- HIIT session. Lack of time is one of the main reasons stated for not exercising; HIIT is a great alternative for those people because the duration of an HIIT session can be as short as 10 minutes, making it much quicker than conventional workouts.

Cardiovascular (Cardio-respiratory) training

Cardiovascular capacity can be measured using VO_2 max, a measure of the amount of oxygen the body can uptake and utilize. Cardiorespiratory training involves movement that increases the heart rate to improve the body's oxygen consumption. This form of exercise is an important part of all training regiments ranging from professional athletes to the everyday person. Also, it helps increase stamina.

Examples are:

- Jogging – Running at a steady and gentle pace. This form of exercise is great for maintaining weight.
- Elliptical Training – This is a stationary exercise machine used to perform walking, or running without causing excessive stress on the joints. This form of exercise is perfect for people with achy hips, knees, and ankles.

- Walking – Moving at a fairly regular pace for a short, medium or long distance.
- Treadmill training – Many treadmills have programs set up that offers a numerous amount of different workout plans. One effective cardiovascular activity would be to switch between running and walking. Typically warm up first by walking and then switch off between walking for three minutes and running for three minutes.
- Swimming – Using the arms and legs to keep oneself afloat and moving either forwards or backwards. This is a good full body exercise for those who are looking to strengthen their core while improving cardiovascular endurance.
- Cycling – Riding a bicycle typically involves longer distances than walking or jogging. This is another low-stress exercise on the joints and is great for improving leg strength.

Benefits of Fitness

Controlling blood pressure

Physical fitness has proven to result in positive effects on the body's blood pressure because staying active and exercising regularly builds up a stronger heart. The heart is the main organ in charge of systolic blood pressure and diastolic blood pressure. Engaging in a physical activity will create a rise in blood pressure, once the activity is stopped, however, the individual's blood pressure will return to normal. The more physical activity that one engages in, the easier this process becomes, resulting in a more 'fit' individual. A "normal" blood pressure is considered to be 120/80 or below. Through regular physical fitness, the heart does not have to work as hard to create a rise in blood pressure, which lowers the force on the arteries, and lowers the over all blood pressure.

Cancer prevention

Centers for disease control and prevention provide lifestyle guidelines of maintaining a balanced diet and engaging in physical activity to reduce the risk of disease. The WCRF/ American Institute for Cancer Research (AICR) published a list of recommendations that reflect the evidence they have found through consistency in fitness and dietary factors that directly relate to Cancer prevention. The WCRF/AICR recommendations include the following:

- "Be as lean as possible without becoming underweight
- Each week, adults should engage in at least 150 minutes of moderate intensity physical activity or 75 minutes of vigorous intensity physical activity
- Children should engage in at least one hour of moderate or vigorous physical activity each week
- Be physically active for at least thirty minutes every day
- Avoid sugar, limit the consumption of energy packed foods
- Balance your diet with a variety of vegetables, grains, fruits, legumes, etc.
- Limit sodium intake, the consumption of red meats and the consumption of processed meats
- Limit alcoholic drinks to two for men and one for women a day"

These recommendations are also widely supported by the American Cancer Society. The guidelines have been evaluated and individuals that have higher guideline adherence scores substantially reduce cancer risk as well as help towards control with a multitude of chronic health problems. Regular physical activity is a factor that helps reduce an individual's blood pressure and improves cholesterol levels, two key components that correlate with heart disease and Type 2 Diabetes. The American Cancer Society encourages the public to "adopt a physically active lifestyle" by meeting the criteria in a variety of physical activities such as hiking, swimming, circuit training, resistance training, lifting, etc. It is understood that cancer is not a disease that can be cured by physical fitness alone, however, because it is a multifactorial disease, physical fitness is a controllable prevention. The large associations tied with being physically fit and reduced cancer risk are enough to provide a strategy to reduce cancer risk. The American Cancer Society asserts different levels of activity ranging from moderate to vigorous to clarify the recommended time spent on a physical activity. These classifications of physical activity consider the intentional exercise and basic activities are done on a daily basis and give the public a greater understanding by what fitness levels suffice as future disease prevention.

Inflammation

Studies have shown an association between increased physical activity and reduced inflammation It produces both a short-term inflammatory response and a long-term anti-inflammatory effect. Physical activity reduces inflammation in conjunction with or independent of changes in body weight. However, the mechanisms linking physical activity to inflammation are unknown.

Immune system

Physical activity boosts the immune system. This is dependent on the concentration of endogenous factors (such as sex hormones, metabolic hormones and growth hormones), body temperature, blood flow, hydration status and body position. Physical activity has shown to increase the levels of natural killer (NK) cells, NK T cells, macrophages, neutrophils and eosinophils, complements, cytokines, antibodies and T cytotoxic cells. However, the mechanism linking physical activity to the immune system is not fully understood.

Cardiovascular disease prevention

Physical activity affects one's blood pressure, cholesterol levels, blood lipid levels, blood clotting factors and the strength of blood vessels. All factors that directly correlate to cardiovascular disease. It also improves the body's use of insulin. People who are at risk for diabetes, Type 2 (insulin resistant) especially, benefit greatly from physical activity because it activates a better usage of insulin and protects the heart. Those who develop diabetes have an increased risk of developing cardiovascular disease. In a study where a sample of around ten thousand adults from the Third National Health and Nutrition Examination Survey, physical activity and metabolic risk factors such as insulin resistance, inflammation, dyslipidemia were assessed. The study adjusted basic confounders with moderate/vigorous physical activity and the relation with CVD mortality. The results displayed physical activity is associated with a lower risk of CVD mortality that was independent of traditional metabolic risk factors.

The American Heart Association recommendations include the same findings as provided in the WCRF/ AICR recommendations list for people who are healthy. In regards to people with lower blood pressure or cholesterol, the association recommends that these individuals aim for around forty minutes of moderate to vigorous physical activity around three or four times a week.

Weight control

Achieving resilience through physical fitness promotes a vast and complex range of health related benefits. Individuals who keep up physical fitness levels generally regulate their distribution of body fat and stay away from obesity. Abdominal fat, specifically visceral fat, is most directly affected by engaging in aerobic exercise. Strength training has been known to increase the amount of muscle in the body, however, it can also reduce body fat. Sex steroid hormones, insulin, and an appropriate immune response are factors that mediate metabolism in relation to the abdominal fat. Therefore, physical fitness provides weight control through regulation of these bodily functions.

Neuropsychological effects

Regular exercise is effective for preventing the age-related decline in cognition and improving overall neuropsychological function. The increased synthesis of neurotrophic factors in the body and brain and the resulting neurogenesis in various brain structures are largely responsible for these effects. Exercise also has persistent antidepressant effects and has been found to serve as both a means to prevent and treat drug addictions, particularly psychostimulant addictions.

Menopause and physical fitness

Menopause is the term that is used to refer to the stretch of both before and after a woman's last menstrual cycle. there are an instrumental amount of symptoms connected to menopause, most of which can affect the quality of life of the women involved in this stage of her life. One way to reduce the severity of the symptoms is exercise and keeping a healthy level of fitness. Pre or during menopause as the women body changes there can be physical, physiological or internal changes to the body. These changes can be prevented or the reduced with the use of regular exercise. these changes include:

- Prevention of weight gain: around menopause women tend to lose their muscle mass and have it replaced with abdominal fat. Slight increases in physical exercise can help to prevent this.
- Reduce the risk of breast cancer: due to the weight loss from regular exercise, it may offer protection from breast cancer.
- Strengthen the bones of the body: Physical activity can slow the bone loss after menopause reducing the chance of bone fractures and osteoporosis.
- Reduce the risk of disease: Excess weight can increase the risk of heart disease and type 2 diabetes, and the regular physical activity can counter these effects.
- Boost the mood: By being involved in regular activities it can improve the psychological health, this can be the case at any age and not only for times during or after menopause.

The Melbourne Women's Midlife Health Project provided evidence that showed over an eight-year time period 438 were followed. Even though the physical activity was not associated with VMS in this cohort at the beginning. Women that reported they were

physically active every day at the beginning were 49% less likely to have reported bothersome hot flushes. This is in contrast to women who level of activity decreased were more likely to experience bothersome hot flushes.

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15.3: Aerobic Exercise

Aerobic exercise (also known as cardio) is physical exercise of low to high intensity that depends primarily on the aerobic energy-generating process. Aerobic literally means "relating to, involving, or requiring free oxygen", and refers to the use of oxygen to adequately meet energy demands during exercise. Generally, light-to-moderate intensity activities that are sufficiently supported by aerobic metabolism can be performed for extended periods of time. When practiced in this way, examples of cardiovascular/aerobic exercise are medium to long distance running/jogging, swimming, cycling, and walking, according to the first extensive research on aerobic exercise, conducted in the 1960s on over 5,000 U.S. Air Force personnel by Dr. Kenneth H. Cooper.

Figure 15.3.1: *Example of cardio exercise that is aerobic.*

Kenneth Cooper was the first person to introduce the concept of aerobic exercise. In the 1960s, Cooper started research into preventive medicine. He became intrigued by the belief that exercise can preserve one's health. In 1970 he created his own institute (the Cooper Institute) for non-profit research and education devoted to preventive medicine. He sparked millions into becoming active and is now known as the "father of aerobics".

Aerobic versus anaerobic exercise

Aerobic exercise and fitness can be contrasted with anaerobic exercise, of which strength training and short-distance running are the most salient examples. The two types of exercise differ by the duration and intensity of muscular contractions involved, as well as by how energy is generated within the muscle. Anaerobic exercise becomes necessary when the heart and lungs can not keep up with the oxygen demands of the muscle.

Remember from the chapter on energy metabolism that ATP is the energy needed for the cells in our body to live and function which includes muscle cells contraction. Within the muscle, ATP is not stored and it is quickly used in 3-10 seconds. Phosphocreatine is a very short term energy store used to regenerate ATP but it is depleted within 30 seconds. Glucose circulating in the blood or released from muscle glycogen stores is used to generate ATP and depending on availability and for intermediate exercise (65% of VO_2 max) provides energy for two hours. This process is called glycolysis.

When the amount of oxygen is inadequate as seen with high-intensity exercise, glucose can only be broken down to lactic acid because of a shortage of oxygen. The lactic acid accumulates in the muscle and decreases performance.

Fatty acids can be used to generate ATP but this process requires oxygen to be a fuel source. Muscle cells obtain fatty acids from two sources, small stores within the muscle and circulating fatty acids released from adipose stores. Remember, fatty acids are not water soluble so they are transported on albumin or within lipoproteins as triglycerides. Low to intermediate intensity exercise for a prolonged period burns fat.

Amino acids can be used as an energy source although they are not the preferred source. Amino acids are obtained from the intramuscular amino acid pool via the glucose-alanine cycle. At the most, amino acids can provide 10% of total energy.

New research on the endocrine functions of contracting muscles has shown that both aerobic and anaerobic exercise promote the secretion of myokines, which are beneficial hormones, with attendant benefits including the growth of new tissue, tissue repair, and various anti-inflammatory functions, which in turn reduce the risk of developing various inflammatory diseases. Myokine secretion, in turn, is dependent on the amount of muscle contracted, and the duration and intensity of contraction. As such, both types of exercise (aerobic and anaerobic) produce quite a number of health benefits.

Figure 15.3.2: *Fox and Haskell formula showing the split between aerobic (light orange) and anaerobic (dark orange) exercise and heart rate*

In almost all conditions, anaerobic exercise is accompanied by aerobic exercises because the less efficient anaerobic metabolism must supplement the aerobic system due to energy demands that exceed the aerobic system's capacity. What is generally called aerobic exercise might be better termed "solely aerobic", because it is designed to be low-intensity enough not to generate lactate (or lactic acid), so that all carbohydrate is aerobically turned into energy.

Initially, during increased exertion, muscle glycogen is broken down to produce glucose, which undergoes glycolysis producing pyruvate which then reacts with oxygen (Krebs cycle, Chemiosmosis) to produce carbon dioxide and water and releases energy. If there is a shortage of oxygen (anaerobic exercise, explosive movements), carbohydrate is consumed more rapidly because the

pyruvate ferments into lactate. If the intensity of the exercise exceeds the rate with which the cardiovascular system can supply muscles with oxygen, it results in a buildup of lactate and quickly makes it impossible to continue the exercise. Unpleasant effects of lactate buildup initially include the burning sensation in the muscles, and may eventually include nausea and even vomiting if the exercise is continued without allowing lactate to clear from the bloodstream.glycolysis producing pyruvate which then reacts with oxygen (Krebs cycle, Chemiosmosis) to produce carbon dioxide and water and releases energy. If there is a shortage of oxygen (anaerobic exercise, explosive movements), carbohydrate is consumed more rapidly because the pyruvate ferments into lactate. If the intensity of the exercise exceeds the rate with which the cardiovascular system can supply muscles with oxygen, it results in a buildup of lactate and quickly makes it impossible to continue the exercise. Unpleasant effects of lactate buildup initially include the burning sensation in the muscles, and may eventually include nausea and even vomiting if the exercise is continued without allowing lactate to clear from the bloodstream.

As glycogen levels in the muscle begin to fall, glucose is released into the bloodstream by the liver, and fat metabolism is increased so that it can fuel the aerobic pathways. Aerobic exercise may be fueled by glycogen reserves, fat reserves, or a combination of both, depending on the intensity. Prolonged moderate-level aerobic exercise at 65% VO_2 max (the heart rate of 150 bpm for a 30-year-old human) results in the maximum contribution of fat to the total energy expenditure. At this level, fat may contribute 40% to 60% of the total, depending on the duration of the exercise. Oxygen is required to burn fat. Vigorous exercise above 75% VO_2 max (160 bpm) primarily burns glycogen.

Major muscles in a rested, untrained human typically contain enough energy for about 2 hours of vigorous exercise. Exhaustion of glycogen is a major cause of what marathon runners call "hitting the wall". Training, lower intensity levels, and carbohydrate loading may allow postponement of the onset of exhaustion beyond 4 hours.

Aerobic exercise comprises innumerable forms. In general, it is performed at a moderate level of intensity over a relatively long period of time. For example, running a long distance at a moderate pace is an aerobic exercise, but sprinting is not. Playing singles tennis, with near-continuous motion, is generally considered aerobic activity, while golf or two people team tennis, with brief bursts of activity punctuated by more frequent breaks, may not be predominantly aerobic. Some sports are thus inherently "aerobic", while other aerobic exercises, such as fartlek training or aerobic dance classes, are designed specifically to improve aerobic capacity and fitness. It is most common for aerobic exercises to involve the leg muscles, primarily or exclusively. There are some exceptions. For example, rowing to distances of 2,000 m or more is an aerobic sport that exercises several major muscle groups, including those of the legs, abdomen, chest, and arms. Common kettle bell exercises combine aerobic and anaerobic aspects.

Among the recognized health benefits of doing regular aerobic exercise are:

- Strengthening the muscles involved in respiration, to facilitate the flow of air in and out of the lungs
- Strengthening and enlarging the heart muscle, to improve its pumping efficiency and reduce the resting heart rate, known as aerobic conditioning
- Improving circulation efficiency and reducing blood pressure
- Increasing the total number of red blood cells in the body, facilitating transport of oxygen
- Improved mental health, including reducing stress and lowering the incidence of depression, as well as increased cognitive capacity.
- Reducing the risk for diabetes. One meta-analysis has shown, from multiple conducted studies, that aerobic exercise does help lower Hb A_{1C}levels for type 2 diabetics.

As a result, aerobic exercise can reduce the risk of death due to cardiovascular problems. In addition, high-impact aerobic activities (such as jogging or using a skipping rope) can stimulate bone growth, as well as reduce the risk of osteoporosis for both men and women. In addition to the health benefits of aerobic exercise, there are numerous performance benefits:

- Increased storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance
- Neovascularization of the muscle sarcomeres to increase blood flow through the muscles
- Increasing speed at which aerobic metabolism is activated within muscles, allowing a greater portion of energy for intense exercise to be generated aerobically
- Improving the ability of muscles to use fats during exercise, preserving intramuscular glycogen
- Enhancing the speed at which muscles recover from high-intensity exercise
- Neurobiological effects: improvements in brain structural connections and increased gray matter density, new neuron growth, improved cognitive function (cognitive control and various forms of memory), and improvement or maintenance of mental health

Some drawbacks of aerobic exercise include:

- Overuse injuries because of repetitive, high-impact exercise such as distance running.
- Is not an effective approach to building muscle.
- Only effective for fat loss when used consistently.

Both the health benefits and the performance benefits, or "training effect", require a minimum duration and frequency of exercise. Most authorities suggest at least twenty minutes performed at least three times per week.

Supplementary Reading

https://www.sciencelearn.org.nz/reso...y-for-exercise

Aerobic Capacity

Aerobic capacity describes the functional capacity of the cardiorespiratory system, (the heart, lungs and blood vessels). Aerobic capacity refers to the maximum amount of oxygen consumed by the body during intense exercises, in a given time frame. It is a function both of cardiorespiratory performance and the maximum ability to remove and utilize oxygen from circulating blood. To measure maximal aerobic capacity, an exercise physiologist or physician will perform a VO_2 max test, in which a subject will undergo progressively more strenuous exercise on a treadmill, from an easy walk through to exhaustion. The individual is typically connected to a respirometer to measure oxygen consumption, and the speed is increased incrementally over a fixed duration of time. The higher the measured cardiorespiratory endurance level, the more oxygen has been transported to and used by exercising muscles, and the higher the level of intensity at which the individual can exercise. More simply put, the higher the aerobic capacity, the higher the level of aerobic fitness. The Cooper and multi-stage fitness tests can also be used to assess functional aerobic capacity for particular jobs or activities.

Figure 15.3.3: *Aerobic workout*

The degree to which aerobic capacity can be improved by exercise varies very widely in the human population: while the average response to training is an approximately 17% increase in VO_2max, in any population there are "high responders" who may as much as double their capacity, and "low responders" who will see little or no benefit from training. Studies indicate that approximately 10% of otherwise healthy individuals cannot improve their aerobic capacity with exercise at all. The degree of an individual's responsiveness is highly heritable, suggesting that this trait is genetically determined.

Table 15.3.1: Varieties of Aerobic Exercises

Indoor	Outdoor
• Stair climbing • Elliptical trainer • Indoor rower • Stairmaster • Stationary bicycle • Treadmill	• Walking • Cycling • Running • Cross-country skiing • Cross-country running • Nordic walking • Inline skating • Rowing

Alternatives

Higher intensity exercise, such as high-intensity interval training (HIIT), increases the resting metabolic rate (RMR) in the 24 hours following high-intensity exercise, ultimately burning more calories than lower intensity exercise; low-intensity exercise burns more calories during the exercise, due to the increased duration, but fewer afterward.

Aerobic exercise has long been a popular approach to achieving weight loss and physical fitness, often taking a commercial form.

- In the 1970s Judi Sheppard Missett helped create the market for commercial aerobics with her Jazzercise program
- In the 1980s Richard Simmons hosted an aerobic exercise show on television, and also released a series of exercise videos

- In the 1990s Billy Blanks's Tae Bo helped popularize cardio-boxing workouts that incorporated martial arts movements

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15.4: Anaerobic Exercise

Anaerobic exercise is a physical exercise intense enough to cause lactate to form. It is used by athletes in non-endurance sports to promote strength, speed and power and by body builders to build muscle mass. Muscle energy systems trained using anaerobic exercise develop differently compared to aerobic exercise, leading to greater performance in short duration, high-intensity activities, which last from mere seconds to up to about 2 minutes. Any activity lasting longer than about two minutes has a large aerobic metabolic component.

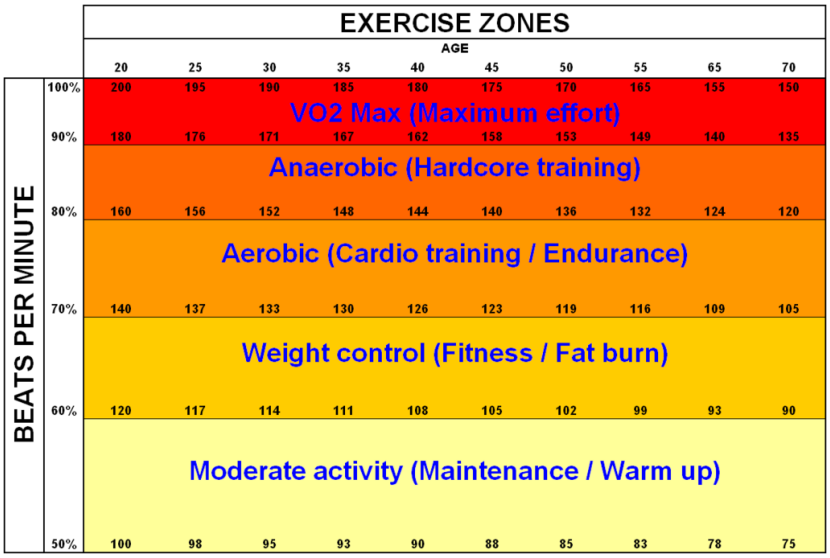


Figure 15.4.1: *Exercise work zones (Fox and Haskell formula between 20 and 70-year-old): VO2Max (red zone), anaerobic, aerobic, weight control and moderate activity. (CC BY-Sa 3.0;* Morgoth666 *)*

Metabolism

Anaerobic metabolism, or anaerobic energy expenditure, is a natural part of whole-body metabolic energy expenditure. Fast twitch muscle (as compared to slow twitch muscle) operates using anaerobic metabolic systems, such that any recruitment of fast twitch muscle fibers leads to increased anaerobic energy expenditure. Intense exercise lasting upwards of about four minutes (e.g., a mile race) may still have a considerable anaerobic energy expenditure component. High-intensity interval training, although based on aerobic exercises like running, cycling and rowing, effectively becomes anaerobic when performed in excess of 90% maximum heart rate. Anaerobic energy expenditure is difficult to accurately quantify, although several reasonable methods to estimate the anaerobic component to exercise are available.

In contrast, aerobic exercise includes lower intensity activities performed for longer periods of time. Activities such as walking, long slow runs, rowing, and cycling require a great deal of oxygen to generate the energy needed for prolonged exercise (i.e., aerobic energy expenditure). In sports which require repeated short bursts of exercise however, the anaerobic system enables muscles to recover for the next burst. Therefore training for many sports demands that both energy producing systems be developed.

The two types of anaerobic energy systems are:

1. high energy phosphates, adenosine triphosphate and creatine phosphate; and
2. anaerobic glycolysis.

The former is called **alactic anaerobic** and the latter **lactic anaerobic** system. High energy phosphates are stored in limited quantities within muscle cells. Anaerobic glycolysis exclusively uses glucose (and glycogen) as a fuel in the absence of oxygen, or more specifically when ATP is needed at rates that exceed those provided by aerobic metabolism. The consequence of such rapid glucose breakdown is the formation of lactic acid (or more appropriately, its conjugate base lactate at biological pH levels). Physical activities that last up to about thirty seconds rely primarily on the former, ATP-CP phosphagen system. Beyond this time both aerobic and anaerobic glycolysis-based metabolic systems begin to predominate.

The by-product of anaerobic glycolysis, lactate, has traditionally been thought to be detrimental to muscle function. However, this appears likely only when lactate levels are very high. Elevated lactate levels are only one of many changes that occur within and around muscle cells during intense exercise that can lead to fatigue. Fatigue, that is muscle failure, is a complex subject. Elevated muscle and blood lactate concentrations are a natural consequence of any physical exertion. The effectiveness of anaerobic activity can be improved through training

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15.5: Nutrients that are critical to athletes

Diet Needs

Physical activity requires energy and the type of activity, your body size, training and type of activity will determine your total daily energy expenditure. Obviously, non-exercise burns fewer calories and most people tend to spend more hours a day doing these types of activities than exercise. Tere are three energy macro nutrients as you have learned - carbohydrate, fat, and protein. Carbohydrate and fat are the preferred fuel sources. Both meal composition and timing relative to exercise are important for the athlete.

For athletes, an intake of more than 55% of calories from carbohydrate is recommended daily as carbohydrate is the preferred energy source. In some cases, athletes may carbohydrate load their muscles glycogen which may be useful for activities lasting more than 90 minutes. To carbohydrate load, one eats 7 -10 grams carbohydrate per kg body mass three days prior to the competitive event and after strenuous exercise that depletes the glycogen stores. Carbohydrate loading seems to work best in untrained people, not well-trained athletes and does not work in women. Recent scientific evidence suggests a better way to ensure adequate glycogen stores is to eat adequate amounts of carbohydrate (55% or greater) daily.

In the chapter on protein, you learned the RDA for protein is approximately 0.8 grams/kg body weight. Athletes need more protein (1.0 to 1.5 grams/kg/day or 10 to 15% of calories) but these levels may be less than they are currently consuming. The American diet generally contains more protein than required to build or maintain tissue. If carbohydrate is 55% or calories and protein is 10-15% of calories, then the remainder of the calories will be from fat (20-35%).

The timing of meals is important for the athlete. Any food should be eaten at least 30 minutes and best if 1-2 hours, before an event or workout. The foods selected should be rich in carbohydrates, low in fat, fiber, and protein. Within two hours after the event or workout, a post-meal should be eaten that is rich in carbohydrate to replace lost muscle glycogen, modest in protein to help rebuild used muscle and some fat.

Several minerals can be a concern for athletes. These minerals include calcium and iron. Weight bearing exercises will increase calcium retention in bones but many athletes avoid eating calcium rich foods like dairy so their calcium intake is inadequate. Depending on the type of exercise, iron deficiency can be a problem. a number of factors can contribute to this deficiency including inadequate iron intake, increased red blood breakdown, sweat loss and gastrointestinal damage that occurs in 8-23% of ultra-endurance athletes.

Vitamins are important for the athlete too but are generally not a concern with the athlete unless they are not eating a well-balanced diet such as that recommended by MyPlate.

Hydration

Hydration is important for the athlete. Water is essential to keep the body cool and thirst is not a reliable indicator of our body's need for water during exercise. During exercise, athletes may sweat and this water and electrolyte losses need to be replaced. Sweat is composed of water, sodium chloride, iron, zinc, copper, potassium, calcium, magnesium and other trace minerals. Depending on the length of the event and the intensity of sweating, the athlete should drink water during the workout or competition. Sodium, potassium, and chloride may not need to be replaced too. Water, which does not contain electrolytes, or a carbohydrate/electrolyte drink may be an appropriate selection. The recommendation is 6-12 oz every 15-20 minutes. After approximately two cups of water, electrolytes should be consumed for every pound of body weight lost.

Consuming too much water can dilute blood sodium concentration resulting in hyponatremia, a condition that leads to neurological dysfunction and possible death. Excessive sweating can also cause hyponatremia.

Female Athlete Triad

Ballet, gymnastics, and women long distance running are three sports that suffer from the female athlete triad. This condition is very serious and is characterized by disordered eating behavior, amenorrhea (because body fat stores are too low), and osteoporosis (usually manifested as stress fractures). Female athlete triad requires a medical team specifically trained to diagnose and treat.

Supplemental Reading

http://extension.colostate.edu/topic...athlete-9-362/

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15.6: Fitness Supplements and Steroids

Bodybuilding supplements are dietary supplements specifically marketed to those involved in bodybuilding, weightlifting, and athletics. Among the most widely used are vitamins, protein, branched-chain amino acids (BCAA), glutamine, essential fatty acids, meal replacement products, creatine, weight loss products and testosterone boosters. Supplements are sold either as single ingredient preparations or in the form of "stacks" - proprietary blends of various supplements marketed as offering "synergistic advantages". While many bodybuilding supplements are also consumed by the general public, their salience and frequency of use may differ when used specifically by bodybuilders. They may be marketed as a product to replace meals, enhance weight gain, promote weight loss or improve athletic performance. Annual sales of sport nutrition products in the US is over $2.7 billion (US) according to Consumer Reports.

History

Athletes in ancient Greece were advised to consume large quantities of meat and wine. A number of herbal concoctions and tonics have been used by strong men and athletes since ancient times across cultures for the enhancement of strength, vigor, prowess, and stamina. In the 1910s, Eugen Sandow, widely considered to be the first modern bodybuilder in the West, advocated the use of dietary control to enhance muscle growth. Later, bodybuilder Earle Liederman advocated the use of "beef juice" or "beef extract" (basically, consomme) as a way to enhance muscle recovery. In the 1950s with recreational and competitive bodybuilding becoming increasingly popular Irvin P. Johnson began to popularize and market egg-based protein powders marketed specifically at bodybuilders and physical athletes. The 1970s and 1980s marked a dramatic increase in the growth of the bodybuilding supplement industry, fueled by the widespread use of modern marketing techniques and a marked increase in recreational bodybuilding.

In October 1994, the Dietary Supplement Health and Education Act (DSHEA) was signed into law in the USA. Under DSHEA, responsibility for determining the safety of the dietary supplements changed from government to the manufacturer and supplements no longer required approval from the U.S. Food and Drug Administration (FDA) before distributing the product. Since that time manufacturers did not have to provide FDA with the evidence to substantiate safety or effectiveness unless a new dietary ingredient was added. It is widely believed that the 1994 DSHEA further consolidated the position of the supplement industry and lead to additional product sales.

Controversies of Fitness Supplements

Mislabeling: According to University of Helsinki food safety professor Marina Heinonen, more than 90% of dietary supplement health claims are incorrect. While many of the claims are based on scientifically based physiological or biochemical processes, their use in bodybuilding parlance is often heavily colored by bodybuilding lore and industry marketing and as such may deviate considerably from traditional scientific usages of the terms. In addition, ingredients listed have been found at times to be different from the contents. In 2015, Consumer Reports reported unsafe levels of arsenic, cadmium, lead, and mercury in several of the protein powders that were tested. Other studies in 2013 showed that one-third of the supplements tested contained unlisted steroids. In 2015 a CBC investigative report found that protein spiking (the addition of amino acid filler to manipulate analysis) was not uncommon, however many of the companies involved challenged these claims.

Health problems: The US FDA reports 50,000 health problems a year due to dietary supplements and these often involve bodybuilding supplements. For example, the "natural" best-seller Craze, 2012's "New Supplement of the Year" by bodybuilding.com, sold in Walmart, Amazon etc., was found to contain undisclosed amphetamine-like compounds. Also, other products by Matt Cahill have contained dangerous substances causing blindness or liver damages, and experts say that Cahill is emblematic for the whole industry.

Liver damage: The incidence of liver damage from dietary supplements has tripled in a decade, the majority of these involved bodybuilding supplements. This resulted in liver transplants and, in some cases, death to the patient. Some have argued that the liver damage is more often caused by prescription drugs rather than supplements.

Lack of effectiveness: In addition to being potentially harmful, some have argued that there is little evidence to indicate any benefit to using bodybuilding supplements. For example, according to the IOC, no consensus had been reached in determining whether an individual in exercise training benefits from protein and amino acid supplements. "In view of the lack of compelling evidence to the contrary, no additional dietary protein is suggested for healthy adults undertaking resistance or endurance exercise".

Protein

Bodybuilders may supplement their diets with protein for reasons of convenience, lower cost (relative to meat and fish products) and to avoid the concurrent consumption of carbohydrates and fats. In addition, some argue that bodybuilders, by virtue of their unique training and goals, require higher-than-average quantities of protein to support maximal muscle growth; however, there is no compelling evidence and no scientific consensus for bodybuilders to consume more protein than the recommended dietary allowance.



Figure 15.6.1: *Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement. (CC BY-SA 3.0;* Sandstein).

Protein supplements are sold in ready-to-drink shakes, bars, meal replacement products (see below), bites, oats, gels and powders. Protein powders are the most popular and may have flavoring added for palatability. The powder is usually mixed with water, milk or juice and is generally consumed immediately before and after exercising, or in place of a meal. The sources of protein are as follows, and differ in protein quality depending on their amino acid profile and digestibility:

- Whey protein contains high levels of all the essential amino acids and branched-chain amino acids. It also has the highest content of the amino acid cysteine, which aids in the biosynthesis of glutathione. For bodybuilders, whey protein provides amino acids used to aid in muscle recovery. Whey protein is derived from the process of making cheese from milk. There are three types of whey protein: whey concentrate, whey isolate, and whey hydrolysate. Whey concentrate is 29–89% protein by weight whereas whey isolate is 90%+ protein by weight. Whey hydrolysate is enzymatically predigested and therefore has the highest rate of digestion of all protein types. Whey protein is usually taken immediately before and after a workout
- Casein protein (or milk protein) has glutamine, and casomorphin. Casein is usually taken before going to bed.
- Soy protein from soybeans contain isoflavones, a type of phytoestrogen.
- Egg-white protein is a lactose- and dairy-free protein.
- Hemp protein from hemp seed contains highly-digestible protein, and hemp oil is high in essential fatty acids.
- Rice protein, when made from the whole grain, is a protein source that is highly digestible and allergen free. Since rice protein is low in the amino acid lysine, it is often combined with pea protein powder to achieve a superior amino acid profile.
- Pea protein is a hypoallergenic protein with a lighter texture than most other protein powders. Pea protein has an amino acid profile similar to that of soy, but pea protein does not elicit concerns about unknown effects of phytoestrogens. Pea protein is also less allergenic than soy. Pea protein has high fiber content and has no allergic ingredients and therefore is easy for digestion as compared to whey protein. Pea protein is a slow digesting protein and is able to keep you full longer.

Figure 15.6.2*: Shaker Bottle commonly used to mix supplements. Often has mesh or a metal whisk inside to break down lumps in the mixture.*

Some nutritionists claim that osteoporosis may occur from excessive protein intake because protein can put pressure on the kidneys and lead to bone loss due to calcium leaching. However, some have suggested that higher calcium excretion may be due to a corresponding increase in protein-induced calcium absorption in the intestines. In addition to complete proteins, some supplements will contain protein fragments such as branched-chain amino acids or individual amino acids (such as glutamine). Amino acids are considered to be inferior to whole protein and have been used by some companies to artificially inflate and falsify protein values in their product (protein spiking). Many protein supplements explicitly indicate on the label that no protein spiking has occurred.

Branched-chain amino acids

Amino acids are the building blocks of protein; the body breaks consumed protein into amino acids in the stomach and intestines. Amino acids are classified as essential, conditionally essential and non-essential. There are three branched-chain amino acids

(BCAAs): leucine, isoleucine, and valine. All three branched-chain amino acids are essential amino acids. Each has numerous benefits on various biological processes in the body. Unlike other amino acids, BCAAs are metabolized in the muscle and have an anabolic/anti-catabolic effect on it. There is some evidence that BCAA's may enhance muscle recovery after intense physical activity and no side effects have been reported at this time.

Glutamine

Glutamine is the most abundant amino acid found in human muscle and is commonly found in supplements or as a micronized, instantly soluble powder because supplement manufacturers claim the body's natural glutamine stores are depleted during anaerobic exercise. Some studies have shown there to be no significant effect of glutamine on bench press strength, knee-extension torque or lean muscle mass when compared to controls taking a placebo, though another study found that glutamine is beneficial in raising T-helper/suppressor cell ratio in long-distance runners.

Essential fatty acids

The essential fatty acids (alpha-linolenic acid and linoleic acid) may be important to supplement while bodybuilding; these cannot readily be made in the body, but are required for various functions within the body to take place. Fatty fish, such as fresh salmon and trout are rich in essential fatty acids and fish oils can also be taken in supplement form. Flaxseed oil, often sold as a supplement on its own, is an ideal source of alpha-linolenic acid, which can also be found in walnuts and pumpkin seeds.

Ergogenic Aids

Ergogenic Aids or supplements are substances purposefully taken to improve athletic performance. Not all ergogenic aids or supplements confer such benefits. Below, several substances that have some scientific evidence to support their athletic performance benefit are discussed.

Creatine

Creatine is an organic acid naturally occurring in the body that supplies energy to muscle cells for short bursts of energy (as required in lifting weights) via creatine phosphate replenishment of ATP. A number of scientific studies have shown that creatine can improve strength, energy, muscle mass, and recovery times. In addition, recent studies have also shown that creatine improves brain function. and reduces mental fatigue.Unlike steroids or other performance-enhancing drugs, creatine can be found naturally in many common foods such as herring, tuna, salmon, and beef.

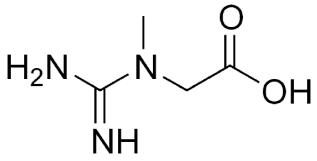


Figure 15.6.3: Skeletal formula of creatine

Creatine increases what is known as *cell volumization* by drawing water into muscle cells, making them larger. This *intracellular* retention should not be confused with the common myth that creatine causes bloating (or *intercellular* water retention). Creatine is sold in a variety of forms, including creatine monohydrate and creatine ethyl ester, amongst others. Though all types of creatine are sold for the same purposes, there are subtle differences between them, such as price and necessary dosage.

In *The New Encyclopedia of Modern Bodybuilding, 2nd ed.*, author Arnold Schwarzenegger states:

> *Creatine monohydrate is regarded as a necessity by most bodybuilders. Creatine monohydrate is the most cost-effective dietary supplement in terms of muscle size and strength gains. … There is no preferred creatine supplement, but it is believed that creatine works best when it is consumed with simple carbohydrates. This can be accomplished by mixing powdered creatine with grape juice, lemonade, or many high glycemic index drinks.*

Some studies have suggested that consumption of creatine with protein and carbohydrates can have a greater effect than creatine combined with either protein or carbohydrates alone.

β-Hydroxy β-methylbutyrate (HMB)

HMB is a metabolite of the amino acid leucine and leucines' keto acid, alpha-ketoisocaproate (KIC). It occurs naturally in small amounts in grapefruit, alfalfa, and catfish, and is naturally synthesized in the human body in the liver and muscle, probably in response to protein synthesis. When combined with an appropriate exercise program, dietary supplementation with β-hydroxy β-methylbutyrate (HMB) may augment gains in muscle hypertrophy (i.e., the size of a muscle), muscle strength, and lean body mass, reduce exercise-induced skeletal muscle damage, and expedite recovery from high-intensity exercise; however, there is insufficient scientific evidence to support these claims. HMB is believed to produce these effects by increasing muscle protein synthesis and decreasing muscle protein breakdown by various mechanisms, including activation of the mechanistic target of rapamycin (mTOR) and inhibition of the proteasome in skeletal muscles. The inhibition of exercise-induced skeletal muscle damage by HMB is affected by the time that it is used relative to exercise. The greatest reduction in skeletal muscle damage from a single bout of exercise appears to occur when calcium HMB is ingested 1–2 hours prior to exercise.

Meal Replacement Products (MRP)

Meal replacement products (MRPs) are either pre-packaged powdered drink mixes or edible bars designed to replace prepared meals. MRPs are generally high in protein, low in fat, have a low to moderate amount of carbohydrates, and contain a wide array of vitamins and minerals. The majority of MRPs use whey protein, casein (often listed as calcium caseinate or micellar casein), soy protein, and/or egg albumin as protein sources. Carbohydrates are typically derived from maltodextrin, oat fiber, brown rice, and/or wheat flour. Some MRPs also contain flax oil powder as a source of essential fatty acids.

MRPs can also contain other ingredients, such as creatine monohydrate, glutamine peptides, L-glutamine, calcium alpha-ketoglutarate, additional amino acids, lactoferrin, conjugated linoleic acid, and medium-chain triglycerides. A sub-class of MRPs are called 'weight gainers' and have a high ratio of carbohydrate:protein. Where a MRP would have a 0.25-2:1 ratio of carbohydrate:protein a weight gainer would have in the order of between 3-5:1 ratios.

The effect of HMB on skeletal muscle damage has been assessed in studies using four different biomarkers of muscle damage or protein breakdown: serum creatine kinase, serum lactate dehydrogenase, urinary urea nitrogen, and urinary 3-methylhistidine. When exercise intensity and volume are sufficient to cause skeletal muscle damage, such as during long-distance running or progressive overload, HMB supplementation has been demonstrated to attenuate the rise in these biomarkers by 20–60%.

Thermogenic products

A thermogenic is a broad term for any supplement that the manufacturer claims will cause thermogenesis, resulting in increased body temperature, increased metabolic rate, and consequently an increased rate in the burning of body fat and weight loss. Until 2004 almost every product found in this supplement category comprised the "ECA stack": ephedrine, caffeine, and aspirin. However, on February 6, 2004, the Food and Drug Administration (FDA) banned the sale of ephedra and its alkaloid, ephedrine, for use in weight loss formulas. Several manufacturers replaced the ephedra component of the "ECA" stack with bitter orange or citrus aurantium (containing synephrine) instead of the ephedrine.

Caffeine

Caffeine is a chemical called xanthine found in the seeds, leaves, and fruit of many plants, where it acts as a natural pesticide. It is the most widely consumed psychoactive substance and is such an important part of many people’s lives that they might not even think of it as a drug. Up to 90 percent of adults around the world use it on a daily basis. According to both the FDA and the American Medical Association, the moderate use of caffeine is “generally recognized as safe.” It is considered a legal psychoactive drug and, for the most part, is completely unregulated.

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Typical Doses and Dietary Sources

What is a “moderate intake” of caffeine? Caffeine intakes are described in the following manner:

- **Low–moderate intake.** 130–300 milligrams per day
- **Moderate intake.** 200–300 milligrams per day
- **High intake.** 400 or more milligrams per day

The average caffeine consumption for American adults is considered moderate at 280 milligrams per day, although it is not uncommon for people to consume up to 600 milligrams per day. This works out to almost 4 ½ cups of coffee per day. The bitter

taste of caffeine is palatable for many and coffee is the most readily available source of it, accounting for 70 percent of daily caffeine consumption. The second readily available source of caffeine is soft drinks, delivering 16 percent of daily caffeine. (In this case, the bitter caffeine taste is usually masked by a large amount of added sugar.) Tea is the third common source of caffeine, at 12 percent.

Just how much caffeine is there in a cup of coffee? It varies. The caffeine content of an average cup of coffee can range from 102 to 200 milligrams, and the range of tea is 40 to 120 milligrams. Table 15.6.2 provides useful information on the levels of caffeine found in common beverages. When estimating your total caffeine consumption remember its not only in beverages but also some foods and medicine.

Table 15.6.1: Caffeine Content in Various Beverages and Foods

Beverage/Food	Milligrams
Starbuck's Grande Coffee (16 oz.)	380
Plain brewed coffee (8 oz.)	102–200
Espresso (1 oz.)	30–90
Plain, decaffeinated coffee (8 oz.)	3–12
Tea, brewed (8 oz.)	40–120
Green tea (8 oz.)	25–40
Coca-Cola Classic (12 oz.)	35
Dr. Pepper (12 oz.)	44
Jolt Cola (12 oz.)	72
Mountain Dew (12 oz.)	54
Mountain Dew, MDX (12 oz.)	71
Pepsi-Cola (12 oz.)	38
Red Bull (8.5 oz.)	80
Full Throttle (16 oz.)	144
Monster Energy (16 oz.)	160
Spike Shooter (8.4 oz.)	300

Source: MedicineNet.com. "Caffeine." Accessed October 2, 2011. http://www.medicinenet.com/caffeine/article.htm.

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Health Benefits of Caffeine

The most renowned effects of caffeine on the body are increased alertness and delay of fatigue and sleep. How does caffeine stimulate the brain? Watch "Video 15.6.1" to see a graphic account of a brain on caffeine. Caffeine is chemically similar to a chemical in our brains (adenosine). Caffeine interacts with adenosine's specific protein receptor. It blocks the actions of the adenosine, and affects the levels of signaling molecules in the brain, leading to an increase in energy metabolism. At the molecular level, caffeine stimulates the brain, increasing alertness and causing a delay of fatigue and sleep. At high doses caffeine stimulates the motor cortex of the brain and interferes with the sleep-wake cycle, causing side effects such as shakiness, anxiety, and insomnia. People's sensitivity to the adverse effects of caffeine varies and some people develop side effects at much lower doses. The many effects caffeine has on the brain do not diminish with habitual drinking of caffeinated beverages.



Video 15.6.1: *A Brain on Caffeine. Watch this graphic account of the brain on caffeine.*

Scientific studies suggest caffeine can improve endurance capacity by increasing energy available during exercise. The effect may only work in non-caffeine drinkers and it only takes 1-3 days for the body to become "caffeine-naive."

Bicarbonate

The term bicarbonate refers to sodium bicarbonate a salt that disassociates in water to form sodium and bicarbonate ions. Remember, the small intestine produces and uses bicarbonate to neutralize the acid in your stomach. Baking soda is sodium bicarbonate. There is limited scientific evidence that bicarbonate can improve athletic performance. The mechanism of action is through increased buffering of the blood which may be beneficial for high-intensity exercise.

Growth Hormone

Growth hormone (GH) is a hormone our body produces. In sports, athletes use this the abbreviations GH or HGH (human growth hormone) to refer to growth hormone. GH is a prescription medication so possession and use of it without a prescription is illegal. There is limited scientific evidence that it will increase muscle mass and improve athletic performance. Adverse effects of inappropriately using GH include weakened heart wall and premature death.

Anabolic Steroids

While the use of anabolic steroids is prohibited in sports, there is scientific evidence that anabolic steroids can increase muscle mass and thus improve athletic performance. Anabolic steroids come in both synthetic and natural form so the athlete must be careful as these compounds can be hidden in foods from unsuspecting athletes. Anabolic steroids mimic the effects see in adolescents with muscle growth but have adverse effects and in some cases, these effects are irreversible. Side effects include extreme aggression, breathing difficulty, heart disease, blood clots, liver tumors, loss of libido, baldness, testicular atrophy, clitoral enlargement and muscularization in women.

Prohormone

Prohormones are precursors to hormones and are most typically sold to bodybuilders as a precursor to the natural hormone testosterone. This conversion requires naturally occurring enzymes in the body. Side effects are not uncommon, as prohormones can also convert further into DHT and estrogen. To deal with this, many supplements also have aromatase inhibitors and DHT blockers such as chrysin and 4-androstene-3,6,17-trione. To date, most prohormone products have not been thoroughly studied, and the health effects of prolonged use are unknown. Although initially available over the counter, their purchase was made illegal without a prescription in the US in 2004, and they hold similar status in many other countries. They remain legal, however, in the United Kingdom and the wider European Union. Their use is prohibited by most sporting bodies.

Sports Drinks

Scientific studies under certain circumstances show that consuming sports drinks (instead of plain water) during high-intensity exercise lasting longer than one hour significantly enhances endurance, and some evidence indicates it additionally enhances performance. There is no consistent evidence that drinking sports drinks instead of plain water enhance endurance or performance in individuals exercising less than one hour and at low to moderate intensities. A well-concocted sports drink contains sugar, water, and sodium in the correct proportions so that hydration is optimized. The sugar is helpful in maintaining blood-glucose levels

needed to fuel muscles, the water keeps an athlete hydrated, and the sodium enhances fluid absorption and replaces some of that lost in sweat. The American College of Sports Medicine states that the goal of drinking fluids during exercise is to prevent dehydration, which compromises performance and endurance.

The primary source of water loss during intense physical activity is sweat. Perspiration rates are variable and dependent on many factors including body composition, humidity, temperature, and type of exercise. The hydration goal for obtaining optimal endurance and performance is to replace what is lost, not to over-hydrate. A person's sweating rate can be approximated by measuring weight before and after exercise—the difference in weight will be the amount of water weight you lost.

The primary electrolyte lost in sweat is sodium. One liter of sweat can contain between 1,000–2,000 milligrams of sodium. Potassium, magnesium, and calcium are also lost, but in much lower amounts. If you are exercising at high intensity for greater than ninety minutes, it is important to replace sodium as well as water. This can be partly accomplished by consuming a sports drink. The highest content of sodium in commercial sports drinks is approximately 450 milligrams per liter and thus will not replace all lost sodium unless a person drinks several liters. This is NOT recommended, as water intoxication not only compromises performance but may also be deadly. The sodium in sports drinks enhances fluid absorption so that rehydration is more efficiently accomplished. If you are not exercising for more than ninety minutes at a high intensity, dietary intake of sodium and other electrolytes should be sufficient for replacing lost electrolytes.

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Who Needs Sports Drinks?

Children and adult athletes exercising for more than one hour at high-intensity (tennis, rowing, rugby, soccer, etc.) may benefit endurance-wise and possibly performance-wise from consuming a sports drink rather than water. However, consuming sports drinks provides no benefit over water to endurance, performance, or exercise recovery for those exercising less than an hour. In fact, as with all other sugary drinks containing few to no nutrients, they are only another source of calories. Drinking sports drinks when you are doing no exercise at all is not recommended.

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Sports Drink Alternatives

Instead of a sports drink, you can replenish lost fluids and obtain energy and electrolytes during exercise by drinking plain water and eating a sports bar or snack that contains carbohydrates, protein, and electrolytes. Post exercise, low-fat milk has been scientifically shown to be just as effective as a sports drink as a rehydration beverage and it is more nutrient-dense, containing carbohydrates, protein, and electrolytes, in addition to other vitamins.

Contributors and Attributions

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15.7: Fitness and Health

Learning Objectives

- Define fitness and explain the essential elements of physical fitness.
- List the physical, mental, and emotional benefits of physical activity.

Becoming physically fit is an important part of achieving optimal health. A well-rounded exercise program is crucial to become and remain healthy. Physical activity improves your health in a number of ways. It promotes weight loss, strengthens muscles and bones, keeps the heart and lungs strong, and helps to protect against chronic disease. There are four essential elements of physical fitness: cardiorespiratory endurance, muscle strength, muscle endurance, and flexibility. Some enthusiasts might argue the relative importance of each, but optimal health requires some degree of balance between all four. Neither a muscle-bound weight lifter unable to bend down to tie his shoes nor a flexible yoga enthusiast who cannot lift her suitcase can be considered completely fit. All four elements of physical fitness are vital.

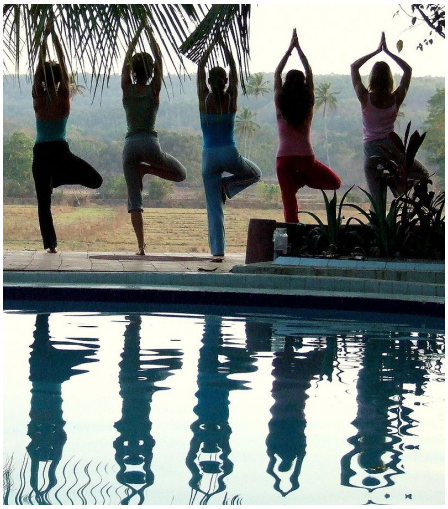


Figure 15.7.1: What does it mean to be physically fit? What does physical fitness encompass? A group of women demonstrating Vrksasana, the tree posture. from Judith on Flickr,

The Essential Elements of Physical Fitness

Building cardiorespiratory endurance through aerobic exercise is an excellent way to maintain a healthy weight. Working on this element of physical fitness also improves your circulatory system. It boosts your ability to supply the body's cells with oxygen and nutrients, and to remove carbon dioxide and metabolic waste. In addition, aerobic exercise makes you breathe faster and more deeply, which maximizes oxygen levels in the blood. Regular, moderate aerobic activity, about thirty minutes at a time for five days per week, trains the body to deliver oxygen more efficiently, which strengthens the heart and lungs and reduces the risk of cardiovascular disease.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

The most common standard for evaluating cardiorespiratory endurance is the **VO_2 max** test. VO_2 max is your maximal oxygen uptake, and the VO_2 max test measures the amount of oxygen (in relation to body weight) that you can use per minute. A test subject usually walks or runs on a treadmill with an air mask over their face to measure oxygen consumption as exercise intensity increases (Video 15.2). At some point, the amount of oxygen consumed no longer increases despite an increase in exercise intensity. This value of oxygen consumption is referred to as VO_2 max, 'V' meaning volume, and 'max' meaning the maximum amount of oxygen (O_2) consumed independent of exercise intensity. The higher the number, the more oxygen you can consume, and the faster or longer you can walk, run, bike, or swim, among other aerobic activities.Ed Eyestone, "How to Improve Your VO_2 Max," *Runner's World*, 9 January 2008. http://www.runnersworld.com/article/0,7120,s6-238-244--12408-0,00.html.



***Video 15.7.1**: VO_2 Max Test: The Human Body—A User's Guide. Watch two athletes take a VO_2 max test to measure their cardiorespiratory endurance. (click to see video).*

Muscle strength and muscle endurance are two other essential elements of physical activity. They are not just crucial for athletes and bodybuilders—building muscle strength and endurance is important for children, seniors, and everyone in between. The support that your muscles provide allows you to work, play, and live more efficiently. Strength training involves the use of resistance machines, resistance bands, free weights, or other tools. However, you do not need to pay for a gym membership or expensive equipment to strengthen your muscles. Homemade weights, such as plastic bottles filled with sand, can work just as well. You can also use your own body weight and do push-ups, leg squats, abdominal crunches, and other exercises to build your muscles. If strength training is performed at least twice a week, it can help to improve muscle strength and endurance and to increase bone strength. Strength training can also help you to maintain muscle mass during a weight-loss program.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

Flexibility is the range of motion available to your joints. Yoga, tai chi, Pilates, and stretching exercises work to improve this element of fitness. Stretching not only improves your range of motion, it also promotes better posture, and helps you perform activities that can require greater flexibility, such as chores around the house. In addition to working on flexibility, older adults should include balance exercises in their regular routine. Balance tends to deteriorate with age, which can result in falls and fractures.Mayo Clinic. "Fitness Training: Elements of a Well-Rounded Routine." September 3, 2011. www.mayoclinic.com/health/fitness-training/HQ01305.

Some forms of exercise confer multiple benefits, which can help you to balance the different elements of physical fitness. For example, riding a bicycle for thirty minutes or more not only builds cardiorespiratory endurance, it also improves muscle strength and muscle endurance. Some forms of yoga can also build muscle strength and endurance, along with flexibility. However, addressing fitness standards in all four categories generally requires incorporating a range of activities into your regular routine.

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Metabolic Fitness

Being fit also encompasses metabolic fitness. It relates to the number of calories you require to survive and the number of calories you burn during physical activity. Recall from Chapter 11 that **metabolism** is the sum of all chemical reactions that occur in the human body to conduct life's processes. Some are catabolic reactions that break down nutrients to supply the body with cellular energy. The rate at which a person burns calories depends on body shape, body composition, sex, age, nutritional status, and genetics.

One measurement of metabolic fitness is **resting metabolic rate**, or RMR, which is a measurement of the amount of energy required for the body to maintain its basic functions while at rest, i.e. breathing, heart beats, liver and kidney function, and so on. On average, RMR accounts for between 50 and 70 percent of a person's total daily energy expenditure. Different factors can affect the RMR, and as a result, it is not a perfect measurement for metabolic fitness. For example, a slender person who is tall has more body surface area and therefore has a higher RMR. Also, muscle utilizes more energy at rest than fat, and a person with more muscle mass has a higher RMR.Moninger, J. "Metabolism Hacks: Tap into Your Calorie-Burning Power." Web MD. Accessed December 21, 2011. http://www.webmd.com/diet/features/metabolism-hacks.

A second measurement of metabolic fitness is the number of calories burned during physical activity. The amount of calories burned depends on the rate at which the heart beats, how much oxygen is delivered to tissues, and how efficiently metabolic reactions consume oxygen and burn calories. One of the best estimates of energy expenditure during exercise is how much oxygen a person consumes. Recall that VO_2 max is used to measure cardiorespiratory endurance. Greater VO_2 max is indicative of better oxygen metabolism and cardiovascular fitness, meaning more calories burned.

In contrast to RMR, VO_2 max increases significantly with exercise training, from increasing blood flow to tissues to increase the strength of heart muscle contraction. Greater blood flow into the tissues means more oxygen to muscle, which means more calories burned.

Increasing your daily activity and shedding excess weight helps to improve metabolic fitness. However, you do not have to be the perfect weight to be metabolically fit. Metabolic fitness is highly individualized. Also, any improvement to metabolic fitness is beneficial and means a decrease in the risk of developing diabetes, or other chronic conditions.

Keeping Fit: The Benefits of Physical Activity

Regular physical activity is one of the best things you can do to achieve optimal health. Individuals who are physically active for about seven hours per week lower the risk of dying early by 40 percent compared to those who are active for less than thirty minutes per week.Centers for Disease Control and Prevention. "Physical Activity and Health: The Benefits of Physical Activity." Last updated February 16, 2011. http://www.cdc.gov/physicalactivity/everyone/health/index.html. Improving your overall fitness involves sticking with an exercise program on a regular basis. If you are nervous or unsure about becoming more active, the good news is that moderate-intensity activity, such as brisk walking, is safe for most people. Also, the health advantages of becoming active far outweigh the risks. Physical activity not only helps to maintain your weight, it also provides a wealth of benefits—physical, mental, and emotional.

Physical Benefits

Getting the recommended amount of physical activity each week, about 150 minutes of moderate, aerobic exercise, such as power walking or bicycling, does not require joining a gym, wearing spandex, or taking expensive, complicated classes. If you can't commit to a formal workout four to five days per week, you can become more active in simple ways—by taking the stairs instead of the elevator, by walking more instead of driving, by going out dancing with your friends, or by doing your household chores at a faster pace. It is not necessary to perform at the level of a professional dancer or athlete, or to work out for several hours every day, to see real gains from exercise. Even slightly increased activity can lead to physical benefits, such as:

- **Longer life.** A regular exercise program can reduce your risk of dying early from heart disease, certain cancers, and other leading causes of death.
- **Healthier weight.** Exercise, along with a healthy, balanced eating plan, can help you lose extra weight, maintain weight loss, or prevent excessive weight gain.
- **Cardiovascular disease prevention.** Being active boosts HDL cholesterol and decreases unhealthy triglycerides, which reduces the risk of cardiovascular diseases.
- **Management of chronic conditions.** A regular routine can help to prevent or manage a wide range of conditions and concerns, such as metabolic syndrome, Type 2 diabetes, depression, arthritis, and certain types of cancer.
- **Energy boosts.** Regular physical activity can improve muscle tone and strength and provide a boost to your cardiovascular system. When the heart and lungs work more efficiently, you have more energy.
- **Strong bones.** Research shows that aerobic activity and strength training can slow the loss of bone density that typically accompanies aging.

Mental and Emotional Benefits

The benefits of an exercise program are not just physical, they are mental and emotional as well. Anyone who has gone for a walk to clear their head knows the mental benefits of exercise firsthand. Also, you do not have to be a marathoner on a "runner's high" to enjoy the emotional benefits of becoming active. The mental and emotional benefits of physical activity include:

- **Mood improvement.** Aerobic activity, strength-training, and more contemplative activities such as yoga, all help break cycles of worry, absorption, and distraction, effectively draining tension from the body.
- **Reduced risk of depression, or limited symptoms of it.** Some people have called exercise "nature's antidepressant," and studies have shown that physical activity reduces the risk of and helps people cope with the symptoms of depression.
- **Cognitive skills retention.** Regular physical activity can help people maintain thinking, learning, and judgment as they age.
- **Better sleep.** A good night's sleep is essential for clear thinking, and regular exercise promotes healthy, sound sleep. It can also help you fall asleep faster and deepen your rest.

Changing to a More Active Lifestyle

A physically active lifestyle yields so many health benefits that it is recommended for everyone. Change is not always easy, but even small changes such as taking the stairs instead of the elevator, or parking farther away from a store to add a bit more walking into your day can lead to a more active lifestyle and set you on the road to optimal health. When people go one step further by walking or biking on a regular basis or becoming active by growing and maintaining a garden, they do more than promoting their own health—they safeguard the health of the planet, too.

As you change to a more active lifestyle, select an activity that you can integrate into your schedule smoothly, so you can maintain it. For example, instead of making time to get coffee with friends, you might suggest a walk, roller blading, or going for a swim in the campus pool. Also, find an activity that you will be motivated to do. Some people decide to participate in team sports, such as local soccer or softball leagues because they enjoy being active with others or like knowing that a team relies on them. Others prefer to take a class, such as spinning or yoga, that is led by an instructor who will motivate them. Still, others prefer more solitary pursuits, such as taking a jog alone in their neighborhood. No matter what your preference, you are more likely to stick to a workout program if you enjoy it.

Whatever activities people choose to do, if they expend an extra 500 calories per day, they will lose 1 pound per week, become more physically fit, and maintain a healthy nutritional profile. The exact number of calories expended per hour will vary, depending on an individual's weight and level of exertion. However, it can be helpful to keep these numbers in mind (which are for an adult who weighs about 160 pounds) when considering a program of aerobic activity:

- Walking at two miles per hour burns 204 calories per hour
- Bicycling burns 292 calories per hour
- Jogging burns 606 calories per hour
- Golf burns 314 calories per hour if players carry their clubs
- Ballroom dance burns 219 calories per hour
- Tennis burns 584 calories per hour Mayo Clinic. "Exercise for Weight Loss: Calories Burned in 1 Hour." © 1998–2012 Mayo Foundation for Medical Education and Research. Last updated August 2, 2011. www.mayoclinic.com/health/exercise/SM00109.

Key Takeaways

Physical fitness is an important part of the pursuit of optimal health. Regular exercise yields multiple benefits in terms of preventing disease and promoting health. The four essential elements of physical fitness are cardiorespiratory endurance, muscle strength, muscle endurance, and flexibility.

Discussion Starter

1. If exercise helps people feel better, why don't more people do it regularly? Discuss some ways to motivate more people to exercise. What are some of the ways that a regular routine could benefit someone currently leading a sedentary lifestyle?

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15.8: Supplemental- Creating your own fitness plan

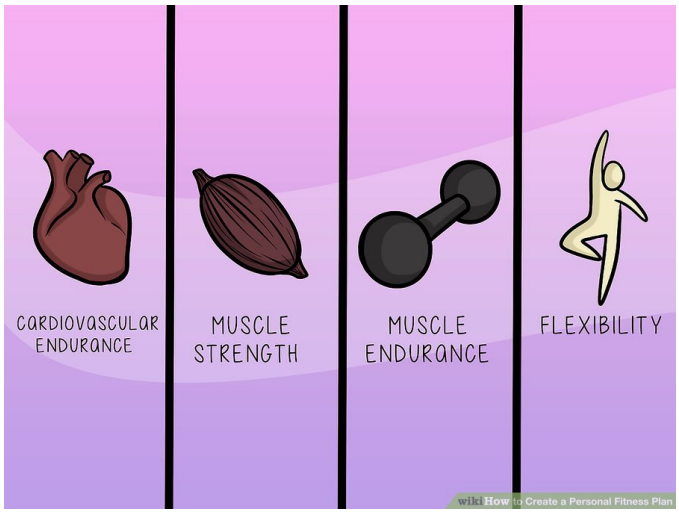
If you'd like to get stronger or faster, lose weight, or just improve the quality of your life, consider creating a personal fitness plan to meet your goals. There are many kinds of possible plans and most incorporate a mix of aerobic, resistance, and flexibility exercises. Assess your level of fitness and craft a plan suited to you

Part 1: Assessing your Fitness Level



Start with the basics. You've decided to get fit — that's a great first step. But don't just jump in without giving it some thought. Start with simple things: Is there anything stopping you from getting fit? Do you have any health issues? Should you talk to a doctor first?

- You probably don't need to talk to a doctor if you're under 50 and in good health, but it is always recommended before starting a new exercise program.
- If you're over 50 or have health issues — like high blood pressure, heart problems, dizzy spells, or arthritis — talk to your doctor first.
- Keep in mind that balance and strength decrease as you age. This can limit your ability to exercise or make injuries more likely, and harder to heal. But, by exercising with caution and a little guidance, you can improve these things through exercise.
- When in doubt, talk to a physician. Your physician can indicate any activities you should steer away from.



Test your current fitness level. Basic fitness is a mix of four things: cardiovascular endurance, muscle strength, muscle endurance, and flexibility. How do you measure up? Test yourself to see where you're fit and where you stand to improve. You'll need a watch, a measuring tape, a yardstick, tape, and a scale.

- Take a brisk 1 mile (1.6 km) walk to test your cardio health. Before you start, take your pulse rate in beats per minute and record the time. Take your pulse again afterward and note how long it took you.
- To get your pulse rate, just put your index and middle fingers on the side of your neck. Count the beats for 10 seconds and multiply by six.
- To test muscular strength, count how many push-ups you can do until you are unable to perform any more push-ups with correct form. If you are a woman, you can do modified push-ups (bend your knees) or classic push-ups. Men should do classic push-ups from the plank position. Record the number.
- For flexibility, secure a yardstick to the floor with some tape at the 15-inch mark. Sit next to the yardstick, with your feet roughly even with the tape. Reach forward as far as you can, holding the position long enough to note how far you were able to reach. Do this exercise three times, recording your farthest reach.
- Now for body composition: waist and Body Mass Index. First, measure and record your waist circumference around the body at the level of your belly button — where your waist is most narrow. To get your BMI (a rough indicator of body fat percentage), use an online calculator or divide your weight in lbs. by your height in inches, squared, times 703. If you're using metric, BMI = (Weight in Kilograms / (Height in Meters x Height in Meters))

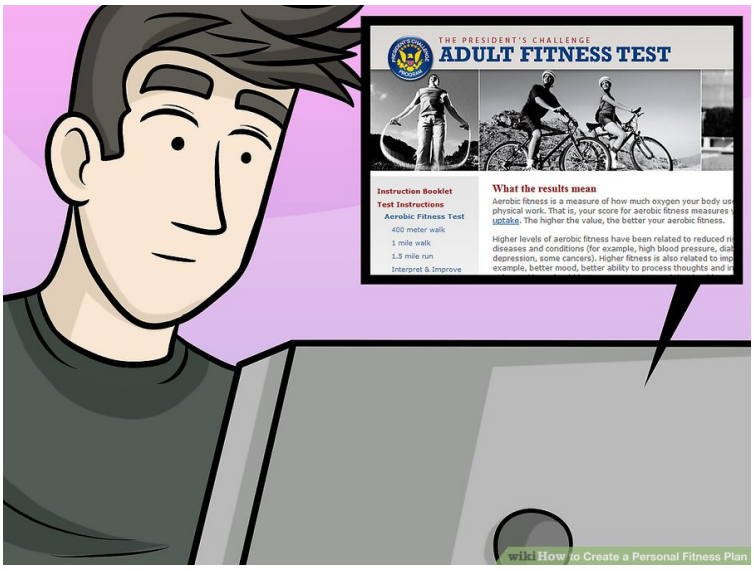


Figure out your goals. What to make of these test results? Well, they should give a rough guide to health based on averages for your age and sex, and also what your fitness plan should focus on. Plug in your results on the President's Challenge Adult Fitness Test website to see where you stand. The website will show you your results and your score in terms of your percentile score, which represents the average achievement of people in your age group performing the test.

- The mile walk measures your cardio fitness. Healthy adults should reach at least the 25 percentile. If you score below this, you may want a fitness plan with an emphasis on aerobic exercise.
- Scoring in the bottom quarter for push-ups means that you probably do not have developed upper body muscle strength — consider adding resistance training to your plan.
- The reach-and-stretch exercise measures how much flexibility your joints and muscles have. A poor result means that you should consider doing stretching exercises like yoga or pilates as part of your program. Ladies usually have a bit more flexibility than men. A woman aged 32 who stretches 12 inches scores in the 5th percentile, where a similar score for a man is in the 25th percentile.
- Finally, a BMI of 25 or more may mean that you are overweight and at higher risk for things like heart disease, high blood pressure, or diabetes. General weight loss might be a goal for your program.

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Plan it out. Give yourself added encouragement by planning your program in detail. You can either do this on your own or with outside help. A structured plan will allow you to set goals and stay on track.

- Try writing out your plan on paper, for example. Ask specific questions: What are my goals? What do I want to get out of this fitness program? How will I do it? Is it achievable?
- Be specific in your answers. For instance, do you want to be able to run for 30 minutes four times per week? Or do you want to lose 5 pounds in a month? Just saying "I want to get fit" doesn't give you a concrete, measurable goal to work toward. The more specific you can be, the easier it will be for you to know when you've met your goals.
- Post your plan where you'll see it every day, like in your office or on the bathroom mirror.
- If you want, you can also get a personal trainer. Personal trainers are fitness experts who will make sure you are using proper form while exercising, doing exercises that are appropriate for your fitness level, help you set goals and motivate you to reach them.

Part 2: Creating a Cardio Plan

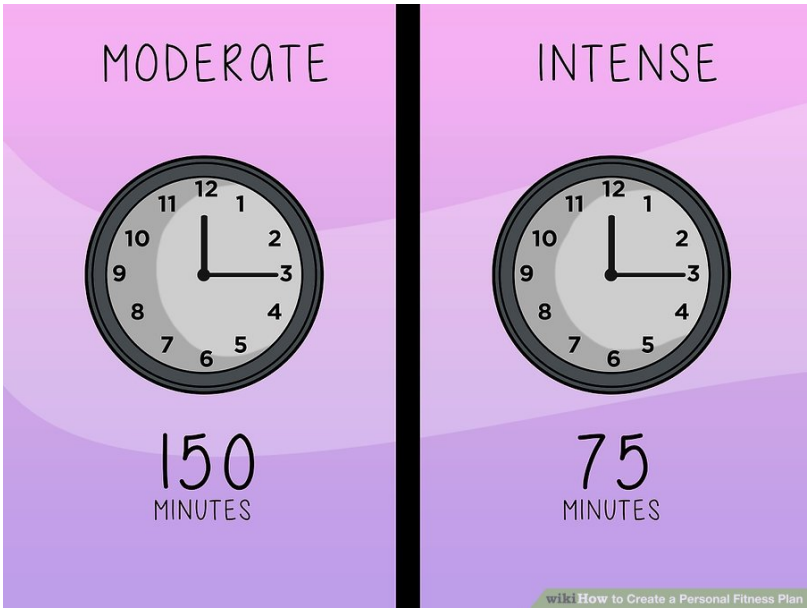
Pick exercises you can do and enjoy. Cardio is the bread and butter of fitness plans. When you do cardio, you work big muscle groups in your body, your heart rate rises, and you breathe faster and more deeply.



Cardio exercise will strengthen your heart, increase your endurance, and burn calories. It will also boost your mood and help you sleep better.

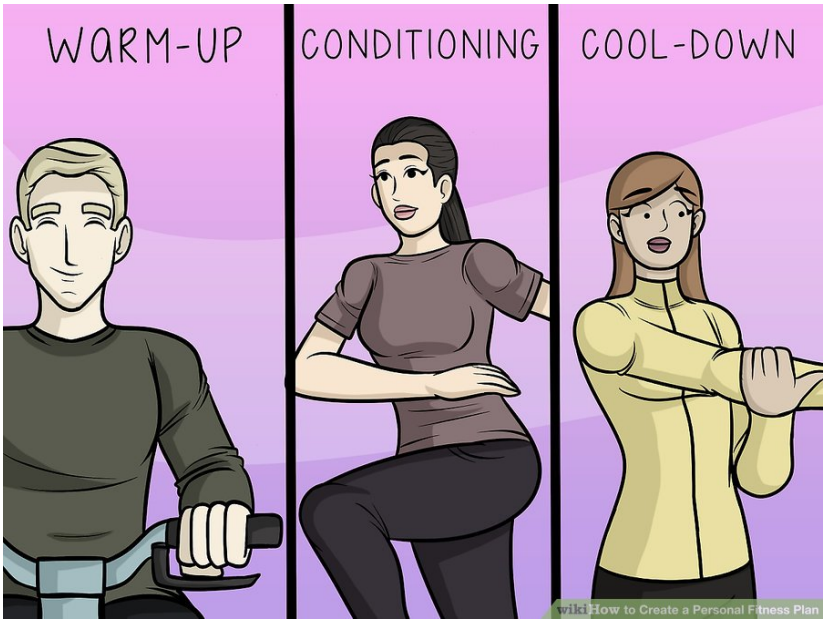
- Cardio is also known as aerobic exercise. The idea is to elevate your heart rate and breathing rate.

- Walking, running, rowing, swimming, bicycling, and dancing are all cardio exercises. So are most team sports, martial arts, and even golfing.
- Choose exercises that you like, but also make sure you are physically able to do them. Running is hard on the knees and feet, for instance, so you if you have bad knees you might need a lower impact exercise like brisk walking, cycling or swimming.
- Also keep in mind that you'll be working out often, so you may want to have several exercises and alternate. For instance, you might ride your bike, swim, and play golf on different days one week. Or, you might play soccer, run, and in-line skate.



Start slowly. Ease your way into the routine until you have more endurance. The US government recommends at least 150 minutes of moderate aerobic activity or 75 minutes of intense activity per week. You don't need to do all of this in two, three, or four sessions, however. Instead, spread it out through the week.

- Aerobic exercise should pass the "talk test," meaning you should be able to talk and carry on a conversation while exercising. If not, your heart rate is too high.
- Ideally, you should do at least 30 minutes of activity per day. If you can't manage that, try breaking up your exercise into smaller chunks. For example, go for a 10 minute walk several times per week in the beginning. As your body gets used to this, lengthen the walk to 15 minutes, then to 20, and then to 30.
- Don't feel the need to do high-intensity exercise at the beginning. Go at your own pace. Otherwise, you might get injured.



Use a three-pronged approach. Cardio isn't all-out exertion all the time. To get the most out of each session, incorporate three elements into your routine: warm-up, conditioning, and cool-down. Ease into the workout, ride your plateau, and then slow down.

- Before each session, warm up for about five to 10 minutes to get your heart going and to increase blood flow to your muscles.
- A low-intensity version of your exercise should do this. If you are riding a bike, for example, take a leisurely ride for a few blocks. If you're swimming, do two or three laps at half pace.
- Aim for around 30 minutes of conditioning after your warm-up. Conditioning is about reaching a "sweet spot" — a level that you can maintain but where your breathing and heart rate are higher than normal.
- End with another five to 10 minutes of cool-down. Slow yourself to a stop and let your heart rate come down. You can also stretch your main muscle groups, like your hamstrings, calf muscles, chest, shoulders, quadriceps, and back.



Work up to ideal length and frequency. Take stock of your progress after a few weeks and make adjustments. Chances are that you will be able to work out longer and harder, gaining aerobic capacity and endurance. Try to work up to doctor recommended guidelines: again, at least 150 minutes of moderate aerobic activity or at 75 minutes of vigorous activity per week. Ideally, you should aim for at least 30 minutes of cardio activity every day.

- Adding five minutes to your workout per week is a modest and doable goal. This means that at the end of a month, you'll be exercising 20 minutes more.

- If your goal is weight loss, you may have to push yourself harder or adopt harder exercises. Rather than working out for 30 minutes three or four times per week, go for 45 minutes five or six times per week.
- Some cardio exercises are better than others if your goal is weight loss. Aerobic dance (like Zumba) and cross-country skiing burn about 700 and 600 calories per hour, for example, compared to brisk walking (150) or golfing (350).
- That said, listen to your body. Take a break and let your body recover if you feel run down. **Stop** exercising and talk to a doctor if you feel pain, dizziness, or shortness of breath.

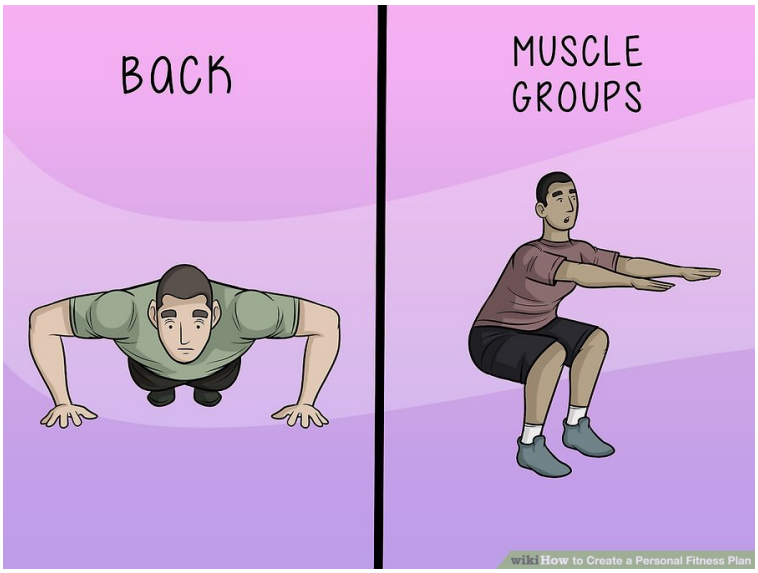
Part 3: Training for Strength

Learn good form. Strength training, also called weight or resistance training, is a different kind of exercise. Strength training builds up muscles and endurance. It will make you stronger, strengthen your bones, raise your stamina, and give you other mental and mood boosts.



The key to a good strength program is to work big muscle groups like the legs, arms, and core.

- In strength training, you use weights to create resistance and make your muscles work harder. You can do this with weight machines, free weights, exercise bands, or even just your own body weight.
- The resistance puts stress on your muscles and joints, so it’s important to learn and always use proper form. Otherwise, you are at risk for sprains, strains, breaks, or overuse injuries. In general, you’ll want to maintain good posture to protect your spine.
- Start with a weight that you can lift comfortably 12–15 times (whether that's on a machine or free weights) and move the joint through its full range of motion. Breathe out when you lift the weight and in when you lower it.
- Talk to people at your gym. A sports trainer or fitness specialist will be able to walk you through each exercise to be sure you’re doing it right.



Pick exercises for major muscle groups. A good strength program will work for all the major muscle groups. Choose exercises that isolate these or work for several groups together. Tailor your program to your own needs, but also to your physical limits. Take into account your strength, balance, and age.

- For example, good exercises for your upper body include push-ups. You can strengthen your arms and shoulders with bent over dumbbell rows and overhead presses. Bench presses will work your chest muscles.
- Exercises that use several muscle groups at once are really useful. For instance, squats will exercise your quadriceps and gluteal muscles at the same time. Lunges are another good example of this kind of exercise.

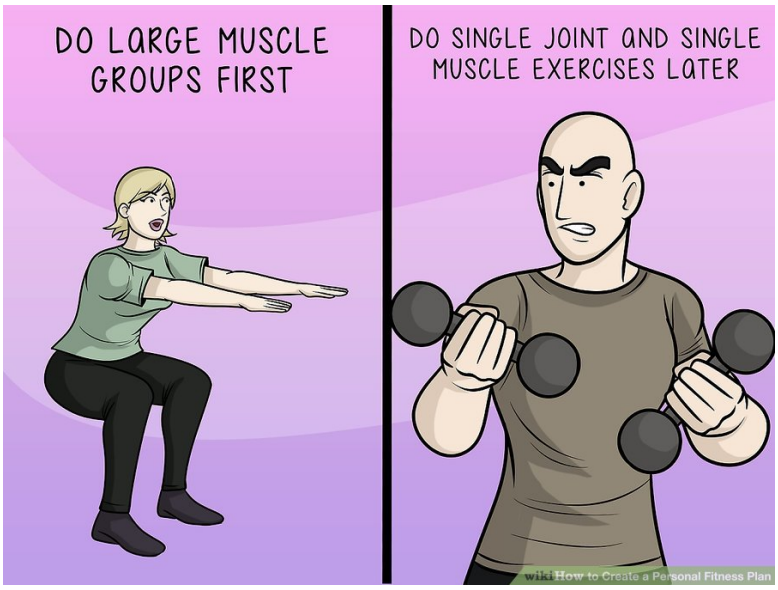
Split the program into rotations, sets, and reps. Your training program should be a cycle. Plan to focus on certain muscle groups on different days, and each day doing a number of specific exercises. You don't need to do a whole body workout every time.

- Your rotation might look something like this: bench-presses, rear flyes, pushups, and planks one day for your back, bicep and tricep curls another day to work your arms, and squats, lunges, bridges, calf raises, balance exercises, and leg curls for your legs the third day.
- During each rotation day, split up the exercises into sets and reps. A "rep" is one full motion of the exercise. A "set" is a series of consecutive reps.
- How many reps and sets should you do? Answers vary. The Mayo Clinic recommends one set of 12 reps for each exercise. Another rule of thumb is that light weight with many reps builds endurance and muscle tone, while heavy weight and fewer reps — but lots of sets (five or more) — builds strength.
- How long should you exercise? The answer is not that long. Most people will see results after about eight weeks with two or three 20 to 30-minute sessions per week, covering all groups. Prevent plateaus by changing up your routine every eight weeks or so.
- Remember to give your body time to rest and heal: always schedule at least 48–72 hours between sessions for each muscle group.



Use the three-pronged approach. Like cardio, use a three-stage approach in your resistance training: aerobic warm-up, post-lift stretching, and cool-down. These will help to get the blood flowing, the joints limber, and to stretch and relax the muscles after you are finished.

- Do a few minutes of low-intensity cardio before you hit the weights, like walking or jogging. “Warm” muscles are less prone to injury than “cold” ones.
- Do not stretch before resistance training.
- After your workout, take some time to cool down and stretch (one or two minutes for each muscle group).

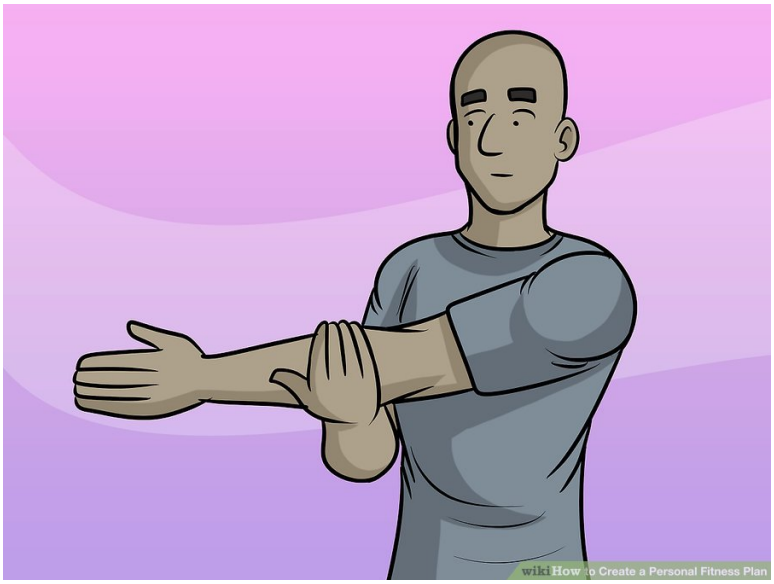


Do large muscle groups first. Experts recommend that your order of exercise should start with large or multiple muscle groups. That way, you’ll be able to do these harder exercises will more energy. You can isolate smaller or individual muscles afterward.

- Prioritize exercises that use several muscle groups at once. Also, do exercises that use multiple joints before those that use one joint.
- You might work out your legs and back first, for instance. Squats, for example, use your legs but also your gluteal and core muscles, and should be done early in the workout.
- Do single joint and single muscle exercises later. Bicep curls or shoulder shrugs can come later in the workout session.

Part 4: Adding Stretching and Flexibility Exercises

Focus on major muscles and joints. Flexibility sometimes gets a back seat in exercise programs. Still, you should be sure to add basic stretches to your program.



Stretching makes you limber, increases the range of motion in joints, increases blood flow to muscles, and can prevent injury. It can also help prevent postural problems and joint misalignment problems.

- Stretch major joints and muscle groups that you use every day, either during your workout or daily activities. The legs, arms, back, chest, shoulders, and hips are some common ones.



Warm-up beforehand. Don’t stretch cold muscles. You can injure yourself. Instead, do a few minutes of warm-up cardio to get the blood flowing before you start stretching.

- For example, walk, bike, or jog at a low intensity for five to 10 minutes beforehand. You can also stretch after your workout when you’re already warmed up.
- You might want to hold off on stretching before strength training or intense activity like running or other track and field sports. Some research shows that pre-event stretching can actually reduce your performance.



Hold the stretch. When you stretch, gently pull the muscle and joint in a smooth movement and hold it for about 30 seconds. You might need to hold for 60 seconds in problem areas, i.e. areas that are inflexible or tight.

- Try some yoga poses, too. In the simple balasana pose (or child's pose), kneel on the floor with your knees slightly apart. Then, lean your hips forward, touch your forehead to the ground, and hold your abdomen to the thighs for 20 to 30 seconds. Reach your arms out in front of you. This pose will gently stretch your lower back and upper body. Older adults should be cautious about this stretch, as it can be harmful to the spine.
- Don’t hold your breath when you stretch, but instead breathe into the movement. Also, don’t bounce. You should not be bouncing to reach farther. This “ballistic” stretching can tighten the muscle or, worse, cause injury.
- Be aware of your spine and don’t stretch it too far in an abnormal direction. The same goes for other joints – keep them soft and do not lock them in position.
- You should not feel pain when you stretch. Some tension or discomfort is normal, but if it hurts you’ve stretched too far.

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CHAPTER OVERVIEW

Back Matter

Index

Index

Glossary

Detailed Licensing

Index

A

alactic anaerobic
15.4: Anaerobic Exercise

B

bone
9.2: Bone Structure and Function
bone anatomy
9.2: Bone Structure and Function
bone structure
9.2: Bone Structure and Function

G

gastrointestinal tract
2: Gastrointestinal Tract

H

Harris Benedict Equation
6.5: Balancing Energy Input with Energy Output

L

lactic anaerobic
15.4: Anaerobic Exercise

M

minerals
6.4: Minerals Important for Metabolism and for Blood Function and Renewal

O

obesogenic
6.1: Chapter Introduction
osmosis
11.2: Overview of Fluid and Electrolyte Balance
osteocytes
9.2: Bone Structure and Function

R

resting metabolic rate
15.7: Fitness and Health

Index

A

alactic anaerobic
15.4: Anaerobic Exercise

B

bone
9.2: Bone Structure and Function
bone anatomy
9.2: Bone Structure and Function
bone structure
9.2: Bone Structure and Function

G

gastrointestinal tract
2: Gastrointestinal Tract

H

Harris Benedict Equation
6.5: Balancing Energy Input with Energy Output

L

lactic anaerobic
15.4: Anaerobic Exercise

M

minerals
6.4: Minerals Important for Metabolism and for Blood Function and Renewal

O

obesogenic
6.1: Chapter Introduction
osmosis
11.2: Overview of Fluid and Electrolyte Balance
osteocytes
9.2: Bone Structure and Function

R

resting metabolic rate
15.7: Fitness and Health

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    - 2.4: Nutrients Are Essential for Organ Function - *CC BY-NC-SA 3.0*
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    - 2.6: Gastrointestinal Tract and Your Health - *CC BY-NC-SA 3.0*
    - 2.E: Exercises - *CC BY-NC-SA 3.0*
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    - 3.2: A Closer Look at Carbohydrates - *CC BY-NC-SA 3.0*
    - 3.3: Digestion and Absorption of Carbohydrates - *CC BY-NC-SA 3.0*
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    - 3.5: Looking Closely at Diabetes - *CC BY-NC-SA 3.0*
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    - 4.1: Chapter Introduction - *CC BY-NC-SA 3.0*
    - 4.2: What Are Lipids? - *CC BY-NC-SA 3.0*
    - 4.3: How Lipids Work - *CC BY-NC-SA 3.0*

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- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal - *CC BY-NC-SA 3.0*
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- 9.5: Other Essential Micronutrients for Bone Health - *CC BY-NC-SA 3.0*
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  - 11.2: Overview of Fluid and Electrolyte Balance - *CC BY-NC-SA 3.0*
  - 11.3: Water's Importance to Vitality - *CC BY-NC-SA 3.0*
  - 11.4: Regulation of Water Balance - *CC BY-NC-SA 3.0*
  - 11.5: Electrolytes Important for Fluid Balance - *CC BY-NC-SA 3.0*
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  - 11.E: Water, Electrolytes, Acid-Base Balance (Exercises) - *CC BY-NC-SA 3.0*
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  - 12.2: The Human Life Cycle - *CC BY-NC-SA 3.0*
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  - 12.8: Older Adolescence and Nutrition - *CC BY-NC-SA 3.0*
  - 12.E: Exercises - *CC BY-NC-SA 3.0*
- 13: Nutrition From Adulthood to the Elderly Years - *CC BY-NC-SA 3.0*
  - 13.1: Chapter Introduction - *CC BY-NC-SA 3.0*
  - 13.2: The Human Life Cycle Continues - *CC BY-NC-SA 3.0*
  - 13.3: Young Adulthood and Nutrition - *CC BY-NC-SA 3.0*
  - 13.4: Middle Age and Nutrition - *CC BY-NC-SA 3.0*
  - 13.5: Old Age and Nutrition - *CC BY-NC-SA 3.0*
  - 13.E: Exercises - *CC BY-NC-SA 3.0*
- 14: Alcohol - *CC BY-NC-SA 3.0*
  - 14.1: Introduction to Alcohol - *CC BY-NC-SA 3.0*
  - 14.2: Alcohol Absorption and Metabolism - *CC BY-NC-SA 3.0*
  - 14.3: Pros and Cons of Drinking Alcohol - *CC BY-NC-SA 3.0*
  - 14.4: How Much to Drink? - *CC BY-NC-SA 3.0*
- 15: Nutrition and Exercise - *CC BY-NC-SA 3.0*
  - 15.1: Chapter Introduction - *CC BY-NC-SA 3.0*
  - 15.2: Introduction to Nutrition and Physical Fitness - *CC BY-NC-SA 3.0*
  - 15.3: Aerobic Exercise - *CC BY-NC-SA 3.0*
  - 15.4: Anaerobic Exercise - *CC BY-NC-SA 3.0*
  - 15.5: Nutrients that are critical to athletes - *CC BY-NC-SA 3.0*
  - 15.6: Fitness Supplements and Steroids - *CC BY-NC-SA 3.0*
  - 15.7: Fitness and Health - *CC BY-NC-SA 3.0*
  - 15.8: Supplemental- Creating your own fitness plan - *CC BY-NC-SA 3.0*
- Back Matter - *CC BY-NC-SA 3.0*
  - Index - *CC BY-NC-SA 4.0*
  - Index - *Undeclared*
  - Glossary - *CC BY-NC-SA 4.0*
  - Detailed Licensing - *Undeclared*

Index

A

alactic anaerobic
- 15.4: Anaerobic Exercise
- 15.4: Anaerobic Exercise

B

bone
- 9.2: Bone Structure and Function
- 9.2: Bone Structure and Function

bone anatomy
- 9.2: Bone Structure and Function
- 9.2: Bone Structure and Function

bone structure
- 9.2: Bone Structure and Function
- 9.2: Bone Structure and Function

C

carcinogenesis
- 7.2: Carcinogenesis

G

gastrointestinal tract
- 2: Gastrointestinal Tract
- 2: Gastrointestinal Tract

H

Harris Benedict Equation
- 6.5: Balancing Energy Input with Energy Output
- 6.5: Balancing Energy Input with Energy Output

L

lactic anaerobic
- 15.4: Anaerobic Exercise
- 15.4: Anaerobic Exercise

M

minerals
- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal
- 6.4: Minerals Important for Metabolism and for Blood Function and Renewal

O

obesogenic
- 6.1: Chapter Introduction
- 6.1: Chapter Introduction

osmosis
- 10.2: Overview of Fluid and Electrolyte Balance
- 11.2: Overview of Fluid and Electrolyte Balance

osteocytes
- 9.2: Bone Structure and Function
- 9.2: Bone Structure and Function

R

resting metabolic rate
- 15.7: Fitness and Health
- 15.7: Fitness and Health

Glossary

Sample Word 1 | Sample Definition 1

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