APUS: BASIC FOUNDATION OF NUTRITION FOR SPORTS PERFORMANCE (BYERLEY)



Unknown

LibreTexts™

APU: Basic Foundation of Nutrition for Sports Performance (Byerley)

This text is disseminated via the Open Education Resource (OER) LibreTexts Project (https://LibreTexts.org) and like the thousands of other texts available within this powerful platform, it is freely available for reading, printing, and "consuming."

The LibreTexts mission is to bring together students, faculty, and scholars in a collaborative effort to provide an accessible, and comprehensive platform that empowers our community to develop, curate, adapt, and adopt openly licensed resources and technologies; through these efforts we can reduce the financial burden borne from traditional educational resource costs, ensuring education is more accessible for students and communities worldwide.

Most, but not all, pages in the library have licenses that may allow individuals to make changes, save, and print this book. Carefully consult the applicable license(s) before pursuing such effects. Instructors can adopt existing LibreTexts texts or Remix them to quickly build course-specific resources to meet the needs of their students. Unlike traditional textbooks, LibreTexts' web based origins allow powerful integration of advanced features and new technologies to support learning.



LibreTexts is the adaptable, user-friendly non-profit open education resource platform that educators trust for creating, customizing, and sharing accessible, interactive textbooks, adaptive homework, and ancillary materials. We collaborate with individuals and organizations to champion open education initiatives, support institutional publishing programs, drive curriculum development projects, and more.

The LibreTexts libraries are Powered by NICE CXone Expert and were supported by the Department of Education Open Textbook Pilot Project, the California Education Learning Lab, the UC Davis Office of the Provost, the UC Davis Library, the California State University Affordable Learning Solutions Program, and Merlot. This material is based upon work supported by the National Science Foundation under Grant No. 1246120, 1525057, and 1413739.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation nor the US Department of Education.

Have questions or comments? For information about adoptions or adaptions contact info@LibreTexts.org or visit our main website at https://LibreTexts.org.

The LibreTexts name, logo, and book covers are trademarked by LibreTexts, Inc. (a 501(c)(3) not-for-profit organization) and protected against unauthorized use.

This text was compiled on 09/02/2026

TABLE OF CONTENTS

Licensing

1: An Introduction to the Athlete's Nutrient and Diet Basics

1.1: Introduction

1.2: Introduction to Nutrition and Physical Fitness

1.3: Defining Nutrition, Health, and Disease

1.4: Basic Physiology of Exercise

1.5: The Broad Role of Nutritional Science

1.6: A Healthy Philosophy toward Food

1.7: What Are Nutrients?

2: The Athlete's Diet Basics and Tools

2.1: Dietary Toolkit

2.2: Nutritional Balance - Moderation and Variety

2.3: Understanding the Bigger Picture of Dietary Guidelines

2.4: National Goals for Nutrition and Health - Healthy People 2030

2.5: Recommendations for Optimal Health

2.6: Understanding Dietary Reference Intakes

2.7: Discovering Nutrition Facts

2.8: When Enough is Enough

3: Digestion and Absorption

3.1: Introduction to Digestion and Absorption

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

3.3: The Digestion and Absorption Process

3.4: Nutrients Are Essential for Organ Function

3.5: Gastrointestinal Tract and Your Health

4: Metabolism and Energy

4.1: Metabolism Overview

4.2: Energy and Calories

4.3: Balancing Energy Input with Energy Output

4.4: Aerobic Exercise

4.5: Anaerobic Exercise

4.6: Nutrients that are critical to athletes

5: Carbohydrate Basics - The Athlete's Energy Powerhouse

5.1: Introduction to Carbohydrates

5.2: A Closer Look at Carbohydrates

5.3: Digestion and Absorption of Carbohydrates

5.4: The Functions of Carbohydrates in the Body

5.5: Health Consequences and Benefits of High-Carbohydrate Diets
5.6: Carbohydrates and Personal Diet Choices
5.7: The Food Industry - Functional Attributes of Carbohydrates and the Use of Sugar Substitutes
5.8: Glycemic Index
5.9: Glycemic Index and the Athlete
5.10: Paper - A Step Towards Personalized Sports Nutrition - Carbohydrate Intake During Exercise

6: Lipids Basics - Another Energy Source for the Athlete

6.1: Introduction to Lipids
6.2: What Are Lipids?
6.3: How Lipids Work
6.4: Digestion and Absorption of Lipids
6.5: Understanding Blood Cholesterol
6.6: Balancing Your Diet with Lipids
6.7: Lipids and the Food Industry
6.8: Lipids and Disease
6.9: A Personal Choice about Lipids
6.10: Exercise and fat oxidation

7: Protein Basics - The Athlete's Structure Builder

7.1: Chapter Introduction
7.2: Defining Protein
7.3: The Role of Proteins in Foods - Cooking and Denaturation
7.4: Protein Digestion, Absorption and Metabolism
7.5: Protein's Functions in the Body
7.6: Diseases Involving Proteins
7.7: Proteins, Diet, and Personal Choices
7.8: Protein and the Athlete

8: Vitamin and Mineral Basics - Metabolic Regulators

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
8.5: Bone Structure and Function
8.6: Bone Mineral Density is an Indicator of Bone Health
8.7: Micronutrients Essential for Bone Health - Calcium and Vitamin D
8.8: Deficiency, Supplementation, and Choices
8.9: Other Essential Micronutrients for Bone Health
8.10: Blood's Function in the Body and in Metabolism Support
8.11: Vitamins Important for Metabolism and for Blood Function and Renewal
8.12: Minerals Important for Blood Function and Renewal
8.13: Iron-Deficiency Anemia

8.14: Vitamins Important for Metabolism
8.15: Minerals Important for Metabolism and for Blood Function and Renewal

9: Fueling the Athlete
9.1: Fueling the Athlete

10: Hydration and Thermoregulation for Athletes
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
10.8: Water Requirements and Fluid Balance During Exercise
10.9: Exertional Heat

11: Sports Driven Nutrition
11.1: Sport Driven Nutrition

12: Body Composition and Maintaining, Gaining, and Losing Weight
12.1: Introduction to Body Composition and Maintaining, Gaining, and Losing Weight
12.2: Too Little or Too Much Weight?
12.3: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
12.4: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
12.5: Methods to Detect Body Composition in Sports
12.6: Diets and Weight Loss for Athletes

13: Supplements
13.1: Overview of Fitness Supplements and Steroids
13.2: IOC Statement on Supplements
13.3: Strength and Power Supplements
13.4: Whole Foods as Ergogenic Aids

14: Selective Topics- Anemia
14.1: Case Study
14.2: Iron Supplementation and Performance

15: Selective Topics - Alcohol
15.1: Introduction to Alcohol
15.2: Alcohol Absorption and Metabolism
15.3: Pros and Cons of Drinking Alcohol
15.4: How Much to Drink?
15.5: Alcohol and the Athlete

16: Selective Topics - Vegetarian

16.1: Vegetarian Athletes

17: Selective Topics - Athletic Needs throughout the Lifespan

17.1: Childhood and Nutrition

17.2: Puberty and Nutrition

17.3: Older Adolescence and Nutrition

17.4: Young Adulthood and Nutrition

17.5: Pregnancy and Nutrition

17.6: Lactation

17.7: Nutrition and the Active Female

17.8: Elite Young Athletes

17.9: IOC Consensus on Youth Athletic Development

17.10: Masters Athletes

17.11: Nutrition and Exercise Guidance for the Pregnant Athlete

18: Selective Topics - Female Athlete Triad

18.1: Female Athlete Triad

18.2: IOC New Definition

19: Selective Topics - Diabetic Athlete

19.1: Looking More Closely at Diabetes

19.2: Diabetes and the Athlete

20: Selective Topics - Disabled Athlete

20.1: Disabled Athlete

21: Selective Topics - Nutrition for Sports Injury

21.1: Nutrition for Sports Injury

22: Selective Topics - Nutrition Consulting

22.1: Nutrition Needs Analysis

22.2: Nutrition Consultation with Athletes

22.3: Scope of Practice for Exercise Professional

23: Putting It All Together

23.1: Putting It All Together

Index

Glossary

Detailed Licensing

This page titled APUS: Basic Foundation of Nutrition for Sports Performance (Byerley) is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

Licensing

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

This page titled Licensing is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1: AN INTRODUCTION TO THE ATHLETE'S NUTRIENT AND DIET BASICS

1.1: Introduction

1.2: Introduction to Nutrition and Physical Fitness

1.3: Defining Nutrition, Health, and Disease

1.4: Basic Physiology of Exercise

1.5: The Broad Role of Nutritional Science

1.6: A Healthy Philosophy toward Food

1.7: What Are Nutrients?

This page titled 1: An Introduction to the Athlete's Nutrient and Diet Basics is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.1: Introduction

Inactivity, non-exercise activity, and exercise are the three types of activity we participate in daily. Sitting and laying down are considered physical inactivity or sedentary, and many people spend a substantial portion of their day inactive. Calorie needs are only slightly more than what you need for basal metabolism. How about you? Have you ever counted how many hours a day you spend being inactive? Research studies find people who are obese spend significantly more time during the day physically inactive than people who are not overweight or obese (1).

Non-exercise activity (also known as NEAT) includes activities that are not sleeping, eating, or sports-like activities. Examples of NEAT are walking, standing, gardening, typing, performing yard work, fidgeting, and cleaning house. This type of activity involves muscular activity, so it burns calories and utilizes nutrients. You can significantly increase the number of calories you burn every day by spending more time doing NEAT activities.

Exercise is the third type of physical activity and includes anything that is a “sport-like” exercise, for example, swimming, running, and bicycling. Muscle movement and metabolism increase during exercise so nutrient and energy requirements increase.

Physical activity and/or exercise confers many benefits. It improves our mental outlook and capacity, our self-image and self-confidence, and provides independence for the elderly. Moving can also increase lean body mass and decrease body fat, increases bone mass, and improve heart, lung, and muscle function. Morbidly and mortality are 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 gallbladder disease.

References

1: Althoff T, Sosič R, Hicks JL, King AC, Delp SL, Leskovec J. Large-scale physical activity data reveal worldwide activity inequality. Nature. 2017 Jul 20;547(7663):336-339.

This page titled 1.1: Introduction is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.2: Introduction to Nutrition and Physical Fitness

- Define fitness and explain its importance in our daily health

Before we focus on nutrition, we need to better define activity and fitness. Activity is generally anything that involves muscle movement while 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Figure 1.2.1: *Physical fitness can be achieved through exercise. Photo shows Matt Fraser – a five-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 the 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 1.2.2: *A woman performs a 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 an 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 were 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 from 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 the 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 to do 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 it's proven you need more effort (one and a half times more) to run on the soft sand than on a hard surface.
- Aqua jogging 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 1.2.3: *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 a 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 activities 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 in 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 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 backward. 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.

Athletes

In this book, we will use the term athlete. If you ask 100 people to define an athlete, you will get 100 different answers. Athletes come in many different sizes, shapes, and ages. They can be weekend warriors, maybe one of you, to the elite athlete that is highly trained, for example, pro-sports athletes, Michael Phelps, Serena Williams, or Tom Brady. Regardless of one's training level, all athletes can benefit from nutrition.

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 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. "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 overall blood pressure.

Cancer prevention

Centers for Disease Control and Prevention provides lifestyle guidelines for maintaining a balanced diet and engaging in physical activity to reduce the risk of disease. The World Cancer Research Fund (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 to 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 physical activity. These classifications of physical activity consider the intentional exercise and basic activities done on a daily basis and give the public a greater understanding of what fitness levels suffice for 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 been shown to increase the levels of natural killer (NK) cells, NK T cells, macrophages, neutrophils, 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 directly correlated 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, and 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 their life. One way to reduce the severity of the symptoms is to exercise and keep a healthy level of fitness. Pre or during menopause as the woman's body changes there can be physical, physiological or internal changes to the body. These changes can be prevented or 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 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 regular physical activity can counter these effects.
- Boost the mood: By being involved in regular activities it can improve 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 (Guthrie, 2004) provided evidence that showed over an eight-year time period 438 were followed. Even though the physical activity was not associated with vasomotor symptoms, comprising night sweats and hot flashes, 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.

Contributors and Attributions

- Wikipedia
- Guthrie JR, Dennerstein L, Taffe JR, Lehert P, Burger HG. The menopausal transition: a 9-year prospective population-based study. The Melbourne Women's Midlife Health Project. Climacteric. 2004 Dec;7(4):375-89. PubMed PMID: 15799609.

This page titled 1.2: Introduction to Nutrition and Physical Fitness is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.3: Defining Nutrition, Health, and Disease

Learning Objective

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

Your View of Food

You and I are bombarded with images and messages about food everywhere we go. We see super athletes eating giant burgers, athletes selling you products promising to improve performance, or athletes promising their diet is the best. How do you use this information to build a nutritious meal? You don't - you use the knowledge you will gain from learning about sports nutrition to guide you in your choices. The construction of a nutritious meal requires learning about which foods are healthy and which foods are not-so-healthy, how foods and nutrients function in your body, and how to use scientific resources to make healthful choices for you and those you care about. This textbook is designed to provide you with the information necessary to make sound nutritional choices, optimize health, and help prevent disease for those actively involved in exercise sports.



© 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, but nutrition also 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. The figure below shows which groups of foods are generally low in the American diet. It also shows that sugar, fat, and sodium dominate our diet.

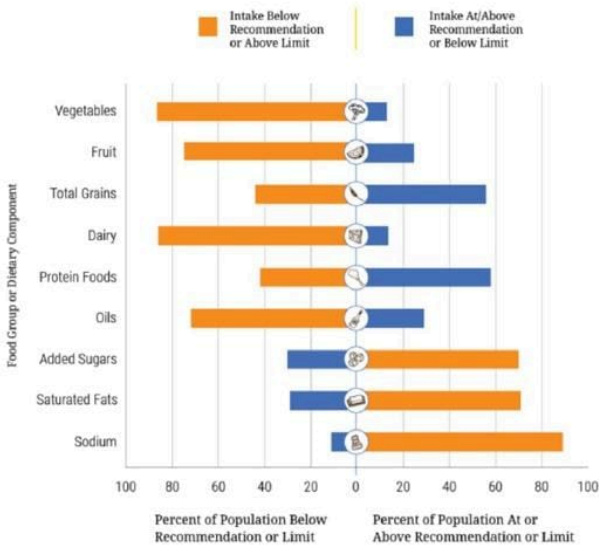


Figure 1.4.1. Current Eating Patterns in the United States % U.S. Population ≥1 yr Below, At, or Above Each Dietary Goal or Limit. The center (0) line is the goal or limit. For most, those represented by the orange sections of the bars, shifting toward the centerline will improve their eating pattern. Data Source: What We Eat in America, NHANES 2007-2010 for average intakes by age, sex group. Healthy U.S.- Style Food Patterns, which vary based on age, sex, and activity level, for recommended intakes and limits.

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. Many athletes refrigerators may look this way too.

Interactive 1.4.1

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 https://www.markmenjivar.com/untitled-gallery. 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." 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.

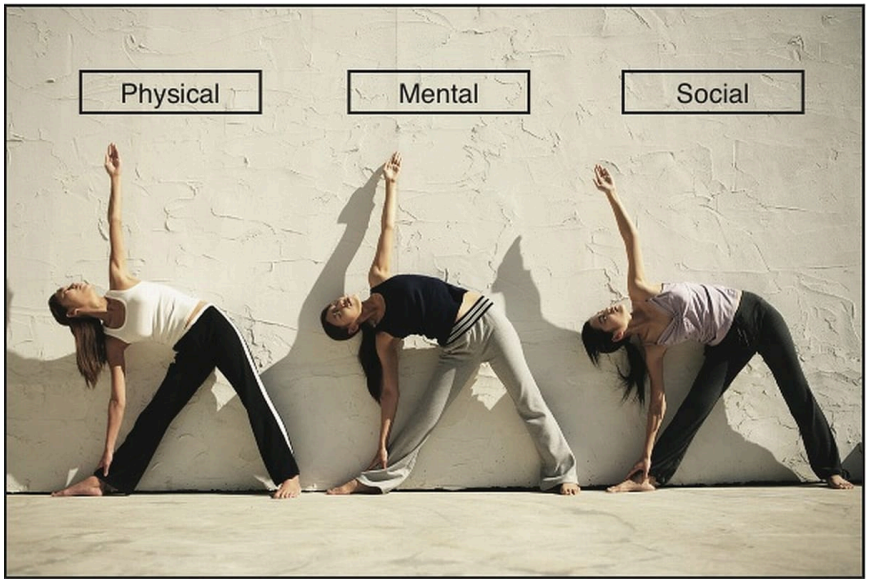


Figure 1.3.1: The Health Triangle. © Thinkstock

The foods we eat affect all three aspects of our health and exercise performance. For example, Venus Williams, Kyle Lowry, and Katie Ledecky are examples of athletes who improved when they made a commitment to a better diet.

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 wide distribution of the "Dietary Guidelines for Americans" 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 acknowledgement by President FDR of the nutritional inadequacy of the American diet evoked a united response between scientists and government, leading to the enrichment of flour (adding vitamins and minerals), the development of free or reduced-cost school lunch programs, and advancements of nutrition education in this country.

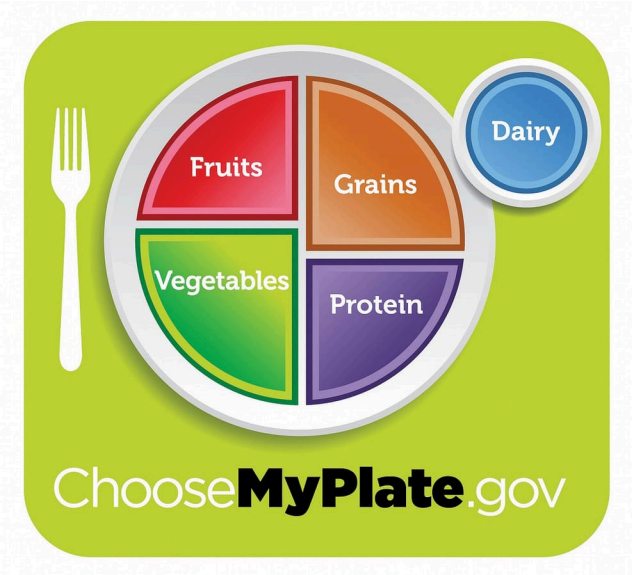


Figure 1.4.2: The Federal Government's New and Improved Tool for Nutritional Communication

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 "MyPlate," is available at https://www.myplate.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.
- 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?

This page titled 1.3: Defining Nutrition, Health, and Disease is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.4: Basic Physiology of Exercise

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

This page titled 1.4: Basic Physiology of Exercise is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.5: The Broad Role of Nutritional Science

earning 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 first making an observation. Once observations are made, they come up with a hypothesis, test their hypothesis, and then interpret the results. After this, they gather additional evidence from multiple sources and finally come up with a conclusion on whether the food suspect fits the claim. This organized process of inquiry used in forensic science, nutritional science, and every other science is called the scientific method.

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, from 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 (Table 1.5.1). In Chapter 2, 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/

Organization	Website
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, 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 grey hair often goes along with Alzheimer's Disease. Wouldn't it be silly for that scientist to predict that grey hair CAUSES Alzheimer's Disease? Could that scientist easily test that silly prediction? Suppose that scientists dyed a group of people's hair grey to see if the color grey 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.

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 treating 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 the 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. 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 1.5.1***:*** *Debate" This webcast from March 29, 2011 demonstrates how science is always evolving and how debate among nutrition science experts influences policy decisions.Source: Harvard School of Public Health, in collaboration with Reuters.*

Nutritional Science Evolution

One of the newest areas in the realm of nutritional 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.

https://extension.psu.edu/nutrigenomics

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

Using Science and Technology to Change the Future

As science evolves, so does technology. Both can be used to create a healthy diet, optimize health, and prevent disease. Picture yourself not too far into the future: you are wearing a small “dietary 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 (Figure 1.5.1:. 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". (CC BY 2.0; David Berkowitz)

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 in 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?

This page titled 1.5: The Broad Role of Nutritional Science is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.6: A Healthy Philosophy toward Food

Skills to Develop

- 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, Anthelme 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 1.6.1: Nutrition provides the body with the nutrients it needs to perform all activities, from taking a breath to strenuous athletic activity. © Dreamstime

Table** 1.6.1**: 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.

Under-nutrition, Over-nutrition, 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 over-nutrition 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 obvious 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. There are many reasons why a person may become malnourished. For example, 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. Over-nutrition 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 the proper growth and function of all body cells, tissue, and systems. Without proper amounts of nutrients, growth and development are stunted. Some nutrient deficiencies/excesses 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 on August 13, 2003. http://www.medicinenet.com/script/main/art.asp?articlekey=10054.



Figure 1.6.2: 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 1.6.3: 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 over-nourished. 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?

This page titled 1.6: A Healthy Philosophy toward Food is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

1.7: What Are Nutrients?

Learning Objective

- Define the word “nutrient” and identify the six classes of nutrients essential for health.
- List the three main energy (Calorie) yielding nutrients and how many Calories each of these nutrients provide.

What is in Food?

Your "diet" is defined as the foods you choose to eat and the diet of most people contains a variety of foods: breads, fruit, vegetables, and meat. The foods we eat contain nutrients. Nutrients are substances required by the body to perform its basic functions. Nutrients must be obtained from the diet, since the human body does not synthesize them, or does not synthesize them in large enough amounts for human health. Nutrients are used for many body functions such as: growing, moving your muscles, repairing tissues, and much more! There are six classes of essential nutrients required for the body to function and maintain overall health. These six classes of essential nutrients are carbohydrates, lipids (fats), proteins, water, vitamins, and minerals. Foods also contain non-nutrients. Some non-nutrients appear to be very important for human health, like phytochemicals and antioxidants, some non-nutrients may be harmful to human health such as preservatives, colorings, flavorings, and pesticide residues.

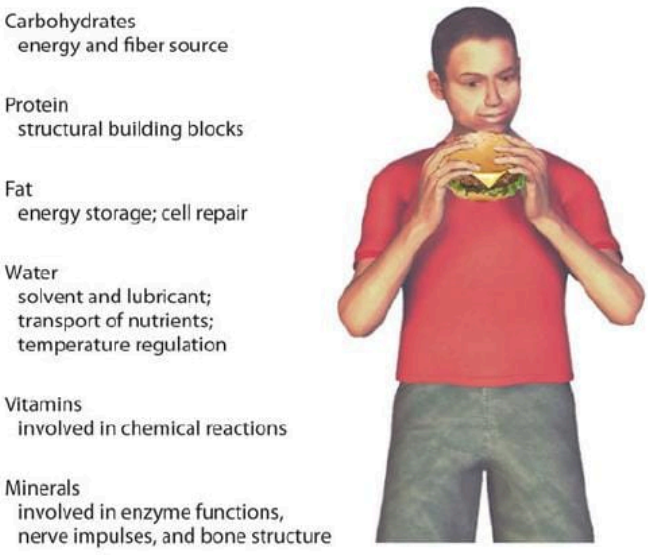


Figure Figure 1.7.1: The Six Classes of Nutrients. Source: www.chemistry.wustl.edu/~edudev/LabTutorials/Vitamins/vitamins.html.

Macronutrients

Nutrients that are needed in large amounts are called macronutrients. There are three major classes of macronutrients: carbohydrates, lipids, and proteins. All three of these nutrients are needed in relatively large amounts AND they contain Calories (note the capital C which indicates kilocalories) which can be "burned" in your body to create energy for your body cells. The energy from these 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. The next time you are eating a packaged food, look on the "Nutrition Facts" panel to find out how many Calories you getting when you eat one serving of that food. 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. One other possible component of the diet that can provide Calories is alcohol though it is NOT considered to be a nutrient. Alcohol (in the form of ethanol) provides about 7 Calories per gram.

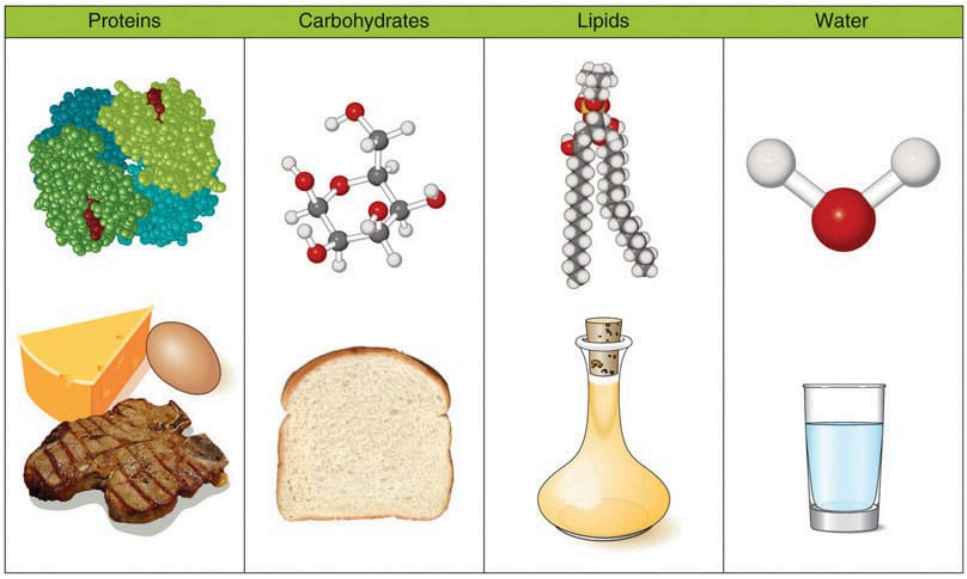


Figure 1.7.2: The Macronutrients: Carbohydrates, Lipids, Protein, and Water

Carbohydrates

When you eat a food that contains carbohydrates, like bread, for example, you will be receiving approximately 4 Calories for every gram of carbohydrate you eat. Carbohydrates are molecules composed of carbon, hydrogen, and oxygen. The major food sources of carbohydrates are grains, milk, fruits, and starchy vegetables like potatoes. Non-starchy 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 slow-releasing carbohydrates, often called "complex carbohydrates".

Fast-releasing carbohydrates consist of one or two basic sugar units. They are sometimes called "simple sugars" because their chemical structure is fairly simple with only one or two sugar units. If the carbohydrate has one sugar unit we call it a "monosaccharide". Mono means one and saccharide means sugar. Examples of monosaccharides you have heard of are glucose (the sugar that is in your blood), fructose (a sugar commonly found in fruit), and galactose (a sugar that is found as part of milk sugar). If the carbohydrate has two sugar units we call it a "disaccharide". Di means "two" and saccharide means "sugar." Examples of disaccharides you may be familiar with are sucrose (table sugar), lactose (milk sugar), and maltose (malt sugar). Sucrose is made of one glucose linked to one fructose molecule. Lactose is made from one glucose linked to one galactose molecule. Maltose is made of two glucose molecules bonded together. In order to digest a disaccharide, your body has to break the two sugars apart. We will talk more about this when we discuss lactose intolerance!

Need to insert images of monosaccharides and disaccharides here

Slow-releasing carbohydrates are long chains of simple sugars (polysaccharides) that can be branched or unbranched. Some polysaccharides that you have probably heard of are starch and fiber. During digestion, the body does its best to break down all slow-releasing carbohydrates like starch into simple sugars, mostly glucose. Glucose is then transported to all our cells where it is stored, 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 live in the large intestine break it down for us.

One gram of carbohydrates yields four Calories 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 the 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. 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 (triacylglycerols), phospholipids, and sterols. The main job of lipids is to store energy. Lipids provide more energy per gram than carbohydrates (nine Calories per gram of lipids versus four Calories 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. Amino acids are simple subunits composed of carbon, oxygen, hydrogen, and nitrogen. The food sources of proteins are meats, dairy products, seafood, and a variety of different plant-based foods, most notably soy. 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 Calories 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. Water does not provide any Calories. 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, organs would not be cushioned, 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.

Alcohol (not a nutrient)

Alcoholic drinks are a source of Calories even though they are not considered nutrients. Alcohol itself provides approximately 7 Calories for every gram consumed. In addition to alcohol, many alcoholic drinks contain other macronutrients as well.

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 sixteen essential minerals and thirteen vitamins (Tables 1.7.1 and 1.7.2 for a complete list and their major functions). In contrast to carbohydrates, lipids, and proteins, micronutrients do not contain Calories. This is often confusing because most people have heard how tired a person will feel if they are low in a micronutrient such as iron. The tiredness can be explained by the fact that micronutrients assist in the process of making energy by being part of enzymes (i.e., coenzymes). Enzymes catalyze chemical reactions in the body and are involved in many aspects of body functions from producing energy, to digesting nutrients, to building macromolecules. Micronutrients play many roles in the body.

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. Many minerals are critical for enzyme function, others are used to maintain fluid balance, build bone tissue, synthesize hormones, transmit nerve impulses, contract and relax muscles, and protect against harmful free radicals.

Table 1.7.1***: :*** *Minerals and Their Major Functions*

Minerals	Major Functions
Macro	

Minerals	Major Functions
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
Trace	
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

Vitamins

The thirteen vitamins are 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 such as making red blood cells, synthesizing bone tissue, and playing a role in normal vision, nervous system function, and immune system function.

Table 1.7.1*: 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

Vitamins	Major Functions
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 1.7.1). Other vitamins were also found to prevent certain disorders and diseases such as scurvy (vitamin C), night blindness (vitamin A), and rickets (vitamin D).

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 1.7.1*: This video provides a brief history of Dr. Joseph Goldberger’s discovery that pellagra was a diet-related disease.*

Food Energy

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.

Food Quality: Nutrient Density compared to Calorie Density

One way to think about the quality of your food is to consider how many nutrients you receive from a serving of that food compared to the number of calories you receive from one serving of the food. For example, a soda gives you quite a few calories but not very many of the essential nutrients. We would say that the soda has calorie density but low nutrient density. An apple, on the other hand, has quite a few essential nutrients but not very many calories. We would say that the apple has high nutrient density but low-calorie density.

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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 1.7.1*: This video explains a calorie.*

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 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.

Interacitve 1.7.1 Food: A Better Source of Nutrients

It is better to get all your micronutrients from the foods you eat as opposed to 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). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3868488/

Key Takeaways

- Foods contain nutrients that are essential for our bodies to function.
- Four of the classes of nutrients 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 1.7.1.

This page titled 1.7: What Are Nutrients? is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2: THE ATHLETE'S DIET BASICS AND TOOLS

2.1: Dietary Toolkit
2.2: Nutritional Balance - Moderation and Variety
2.3: Understanding the Bigger Picture of Dietary Guidelines
2.4: National Goals for Nutrition and Health - Healthy People 2030
2.5: Recommendations for Optimal Health
2.6: Understanding Dietary Reference Intakes
2.7: Discovering Nutrition Facts
2.8: When Enough is Enough

This page titled 2: The Athlete's Diet Basics and Tools is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.1: 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 2.1.1: 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, 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.

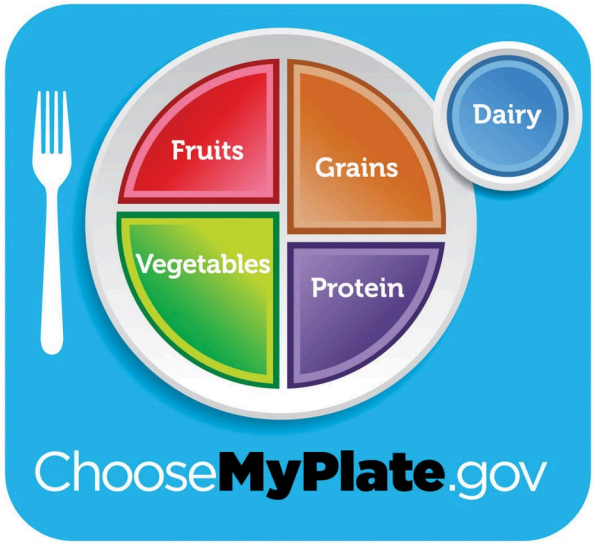


Figure 2.1.2: Today, the US government sets dietary guidelines that provide evidence-based nutrition information designed to improve the health of the population. Source: US Department of Agriculture.

This page titled 2.1: Dietary Toolkit is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.2: Nutritional Balance - Moderation and Variety

Skills to Develop

- 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 2.2.1**: 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

Instead of...	Replace with...
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
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 2.2.1: 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 on 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.

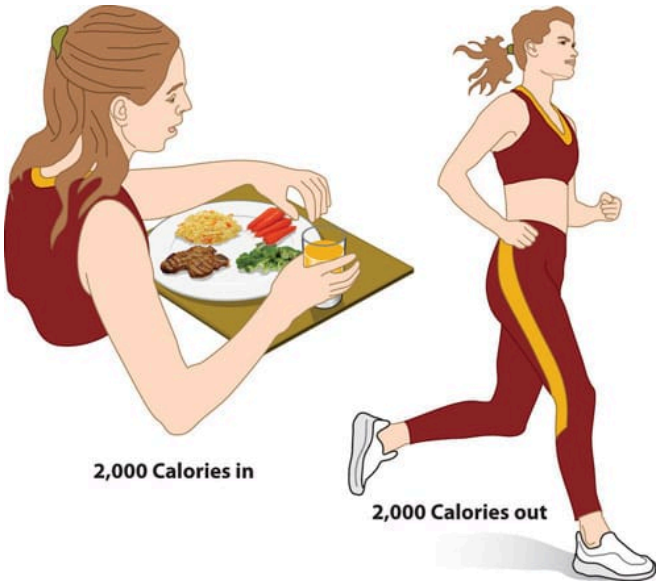


Figure 2.2.2: The number of calories consumed should always match the number of calories being expended by the body to maintain a healthy weight.© Networkgraphics

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 2.2.2: *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**

Grain	Vegetable	Fruit	Dairy	Protein
	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)
	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.				

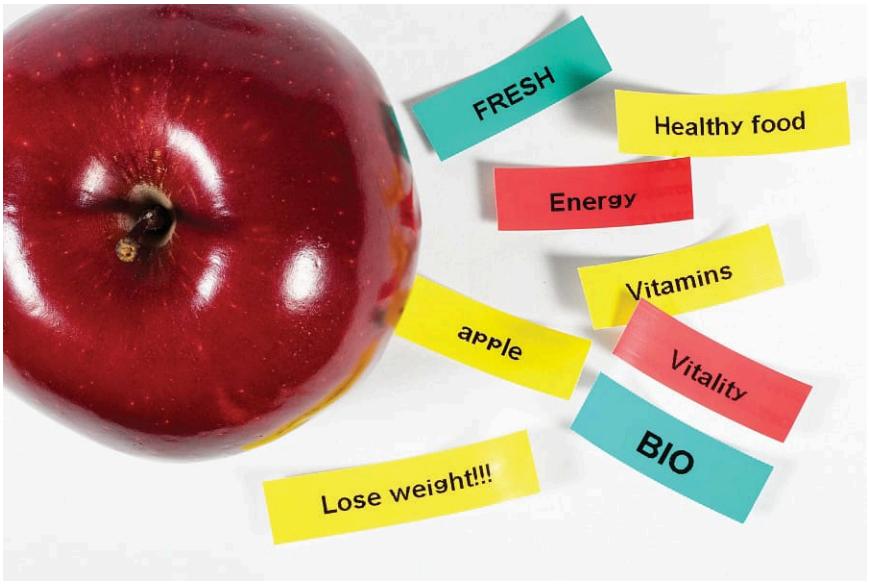


Figure 2.2.3: Scientific evidence confirms that a diet full of fresh whole foods reduces the risks for developing chronic disease and helps maintain a healthy weight. © Dreamstime

Video Link 2.2.1:

Different Types of Grains: In this video, a registered dietitian discusses the benefits of eating whole grains. https://www.youtube.com/watch?v=o_RxfQqpkkE

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 2.2.4: 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.

This page titled 2.2: Nutritional Balance - Moderation and Variety is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.3: Understanding the Bigger Picture of Dietary Guidelines

Skills to Develop

- Describe the major themes of the *2020 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.

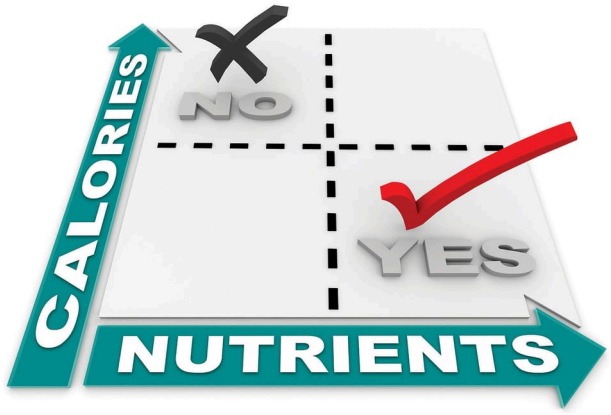


Figure 2.3.1: Dietary guidelines help people to stay on a healthful track by drawing attention to the overall scope of their diet and lifestyle. © Dreamstime

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 2.3.2: The major theme of the *2020 Dietary Guidelines for Americans* is a healthy eating pattern combined with regular physical activity.

Major Themes of the *2020 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:

· Follow a healthy dietary pattern at every life stage.

· Customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations

· Focus on meeting food group needs with nutrient-dense foods and beverages, and stay within calorie limits.

· 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, 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.

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 2.3.1: *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

Dietary Constituent	Health Implications	Recommendations
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 2.3.2).

***Table 2.3.2**: 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*.

This page titled 2.3: Understanding the Bigger Picture of Dietary Guidelines is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.4: National Goals for Nutrition and Health - Healthy People 2030

Skills to Develop

- 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 2.4.1: Preparing for the Next Decade

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.4.1: *Preparing for the Next Decade: A 2030 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 2.4.1: 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 2.4.2: Determinants of Health

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.4.2: *Determinants of Health Approach in Healthy People 2030 (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 2.4.2: 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 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 2.4.3: 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 in 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 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 the 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/.

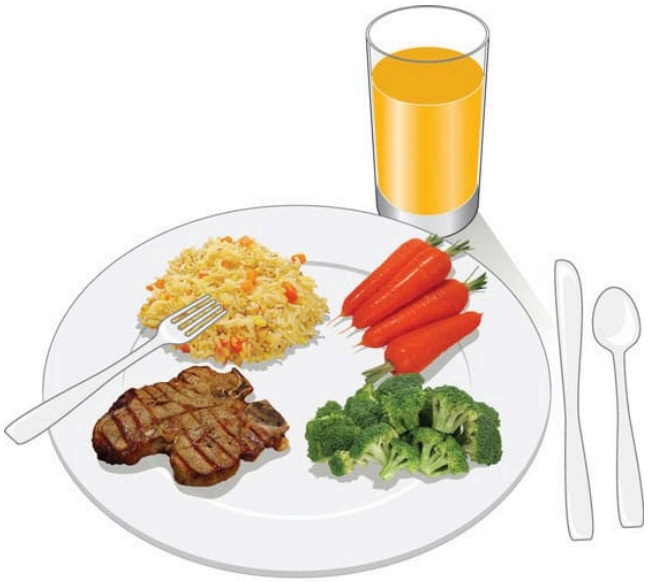


Figure 2.4.4: Following the *2020 Dietary Guidelines* will promote nutrition, weight loss, and weight maintenance as well as the reduction of chronic disease. © Networkgraphics

Video 1.13.3: Active versus Sedentary Lifestyles

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.4.3: *This video provides a short overview of leading an active life versus a sedentary life.*



Figure 2.4.5: 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 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 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? https://health.gov/our-work/national-health-initiatives/healthy-people

This page titled 2.4: National Goals for Nutrition and Health - Healthy People 2030 is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.5: Recommendations for Optimal Health

Skills to Develop

- 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. https://www.myplate.gov/.

Video 2.5.1: Introducing the New Food Icon: MyPlate

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.5.1: *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 2.5.2: Tools for Change

Consider the information in this video:

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.5.2: *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 2.5.1: 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 2.5.2: 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.

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 2.5.1**: Sample Menu Plan Containing 2,000 Calories*

Meal	Calories	Total Meal/Snack Calories
Breakfast		
1 scrambled egg	92	

Meal	Calories	Total Meal/Snack Calories
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	
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 2015 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 the American people. For more information on the HEI, visit this website: https://www.fns.usda.gov/healthy-eating-index-hei.

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?

This page titled 2.5: Recommendations for Optimal Health is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.6: Understanding Dietary Reference Intakes

Skills to Develop

- 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 includes 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

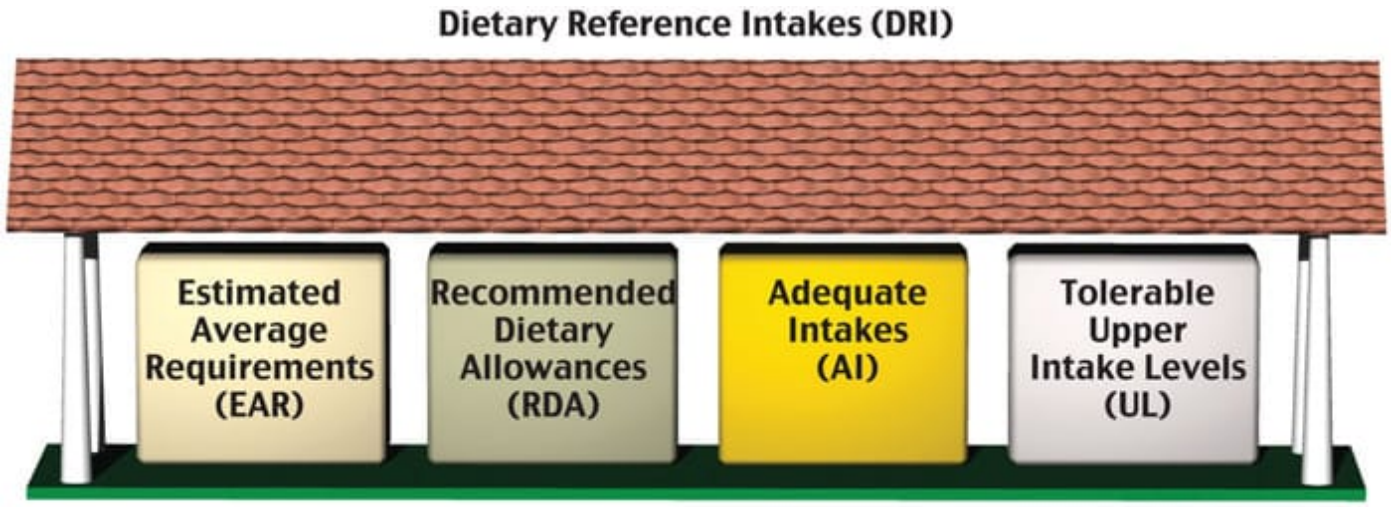


Figure 2.6.1: The DRIs are inclusive of all four reference values. © Networkgraphics

DRIs are important not only to help the average person determine whether their intake of a particular nutrient is adequate but they are also used by healthcare professionals and policymakers 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.

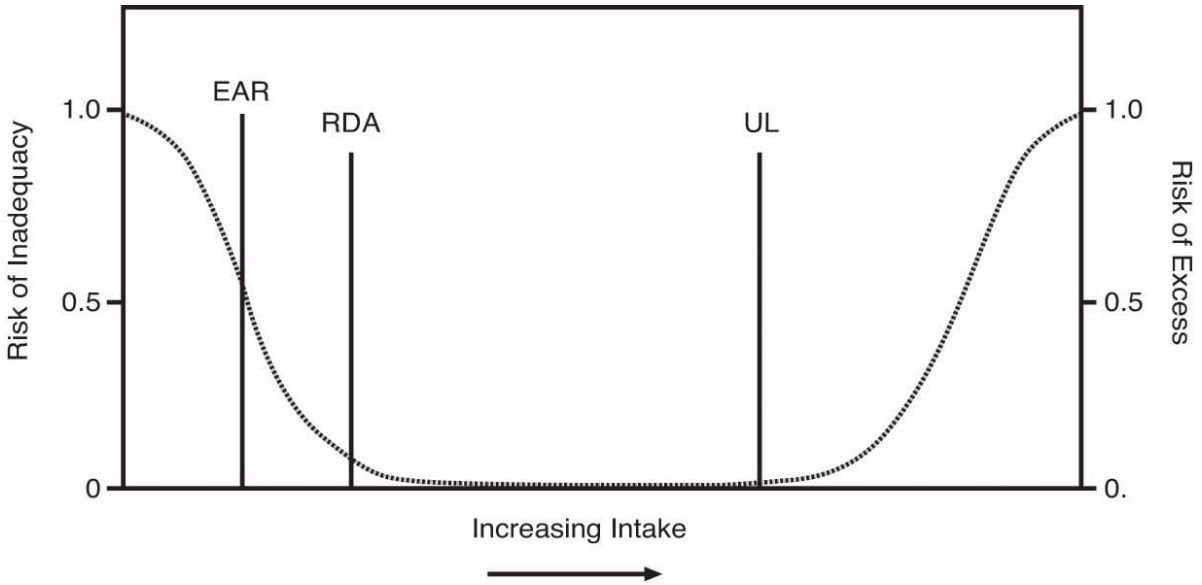


Figure 2.6.2: DRI Graph. This graph illustrates the risks of nutrient inadequacy and nutrient excess as we move from a low intake of a nutrient to a high intake. Starting on the left side of the graph, you can see that when you have a very low intake of a nutrient, your risk of nutrient deficiency is 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 2.6.1: *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.

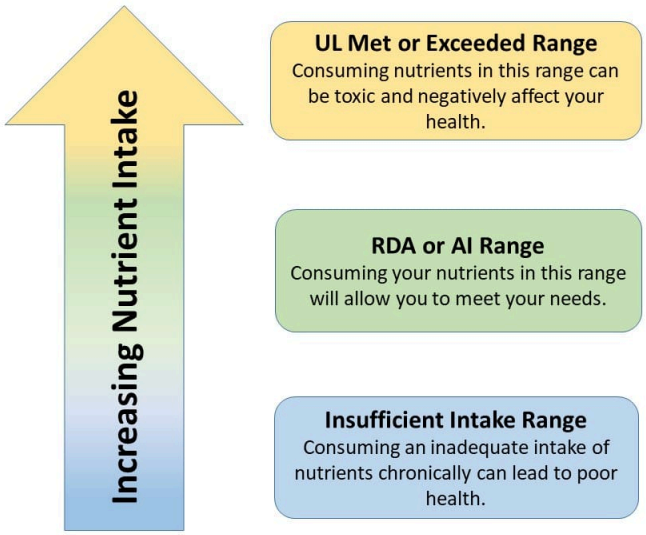


Figure 2.6.2: Relationship among insufficient intake, RDA, and UL.

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, and 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 include 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?

This page titled 2.6: Understanding Dietary Reference Intakes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.7: Discovering Nutrition Facts

Skills to Develop

- 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 was 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 the mandatory labeling of foods. Table 1.16.1 lists the mandatory and optional inclusions. These are regulated but the FDA.

Table 2.7.1: *Mandatory and Optional Inclusions on Nutrition Labels*

Mandatory Inclusion	Optional Inclusion
Total Calories	
Total fat	Calories from saturated fats
Saturated fat	Polyunsaturated fat
Trans fat	Monounsaturated fat
Cholesterol	
Sodium	
Total carbohydrates	Other carbohydrates
Dietary fiber	Soluble fiber
Total sugars	
Added sugars	Sugar alcohols
Protein	
Vitamins D	Percent vitamin A present as beta-carotene
Calcium	Other essential vitamins and minerals
Iron	
Potassium	
Source: US Food and Drug Administration. “Food Labeling Guide.” Last updated May 3, 2022. https://www.fda.gov/food/food-labeling-nutrition/changes-nutrition-facts-label	

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 2.7.1: The Food Label and You.

The FDA has prepared several videos about nutrition labeling that with helpful information. https://www.google.com/search?q=FDA+has+prepared+a+new+video+about+nutrition+labeling+that+is+packed+with+helpful+information&rlz=1C1UE

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) are 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 2.7.1**: 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 2.7.2:** 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 2.7.3 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 2.7.3: *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 calories
Calorie Claims	
Calorie-free	Less than 5 calories
Low calorie	40 calories or less

Nutrient Content Claim	What the Claim Means Per Serving
Reduced calories	At least 25% fewer calories*
Sugar Claims	
Sugar-free	Less than 0.5 gram sugar
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 sodium or less
Low sodium	140 milligrams sodium or less
Reduced sodium	At least 25% less sodium*
Light in sodium	At least 50% less sodium
Salt-free	Less than 5 milligrams of sodium
Fat Claims	

Nutrient Content Claim	What the Claim Means Per Serving
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

Nutrient Content Claim	What the Claim Means Per Serving
	*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 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 provides regulations 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?

This page titled 2.7: Discovering Nutrition Facts is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

2.8: When Enough is Enough

Skills to Develop

- 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.

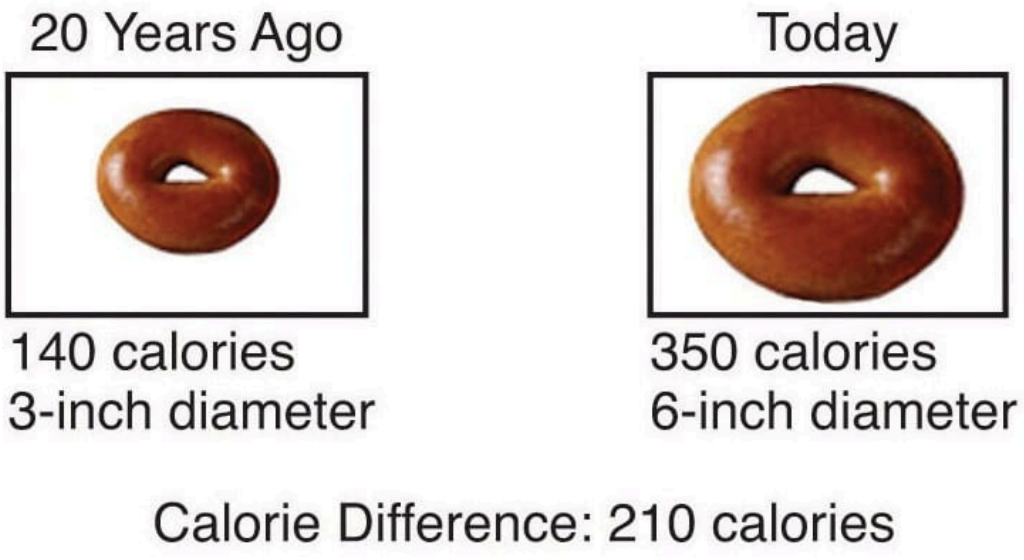


Figure 2.8.1: As food sizes and servings increase it is important to limit the portions of food consumed on a regular basis.

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 2.8.1**: 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

Food Product	Amount	Object Comparison	Hand Comparison
Milk or other beverages	1 c.	Fist	
Salad dressing	1 Tbsp.	Thumb	
Oil	1 tsp.	Thumb tip	

Video 2.8.1: Managing a Healthy Diet: Judging Healthy Portion Sizes

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 2.8.1: *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 2.8.2: *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

Carbohydrates	Meats/Proteins	Fats	Free Foods
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.

This page titled 2.8: When Enough is Enough is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3: DIGESTION AND ABSORPTION

3.1: Introduction to Digestion and Absorption
3.2: The Basic Structural and Functional Unit of Life - The Cell
3.3: The Digestion and Absorption Process
3.4: Nutrients Are Essential for Organ Function
3.5: Gastrointestinal Tract and Your Health

This page titled 3: Digestion and Absorption is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3.1: Introduction to Digestion and Absorption

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 3.1.1: 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 which 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 a 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.”

This page titled 3.1: Introduction to Digestion and Absorption is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

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

Skills to Develop

- 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 a 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.

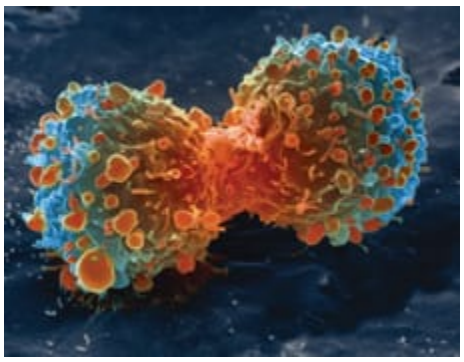


Figure 3.2.1: One cell divides into two, which begins the creation of millions of more cells that ultimately become you. (Public Domain; National Institutes of Health).

Independent single-celled organisms must conduct all the basic processes of life: they must take in nutrients (energy capture), excrete wastes, detect and respond to their 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 their 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.

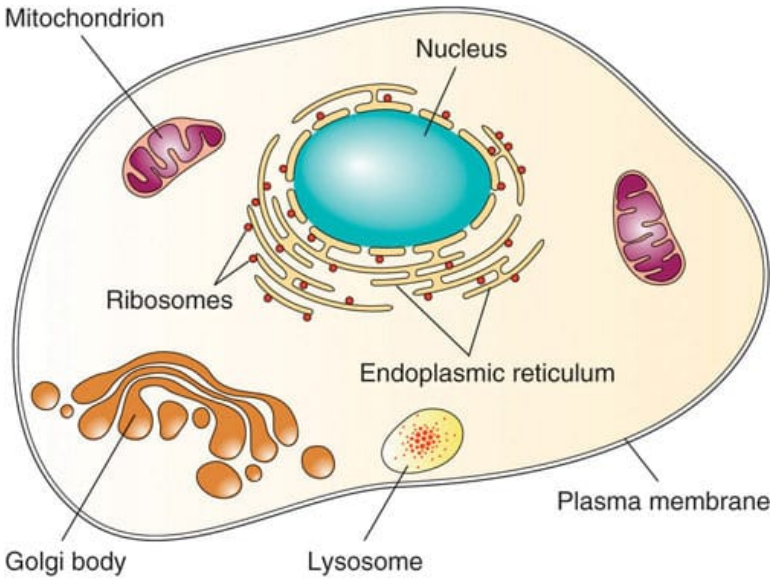


Figure 3.2.2: The cell is structurally and functionally complex.

Although we defined the cell as the "most basic" unit of life, it is structurally and functionally complex (Figure 3.2.1). 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 3.2.1: Discovery Video: Cells

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

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 a complete living system capable of conducting all of life's biological processes.

***Table 3.2.1**: 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
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

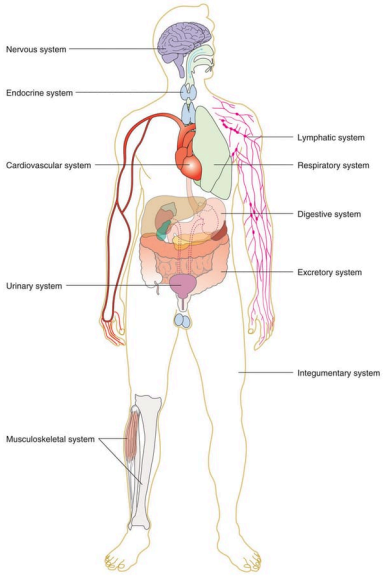


***Figure 3.2.3:** Organ Systems in the Human Body © Networkgraphics*

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 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.

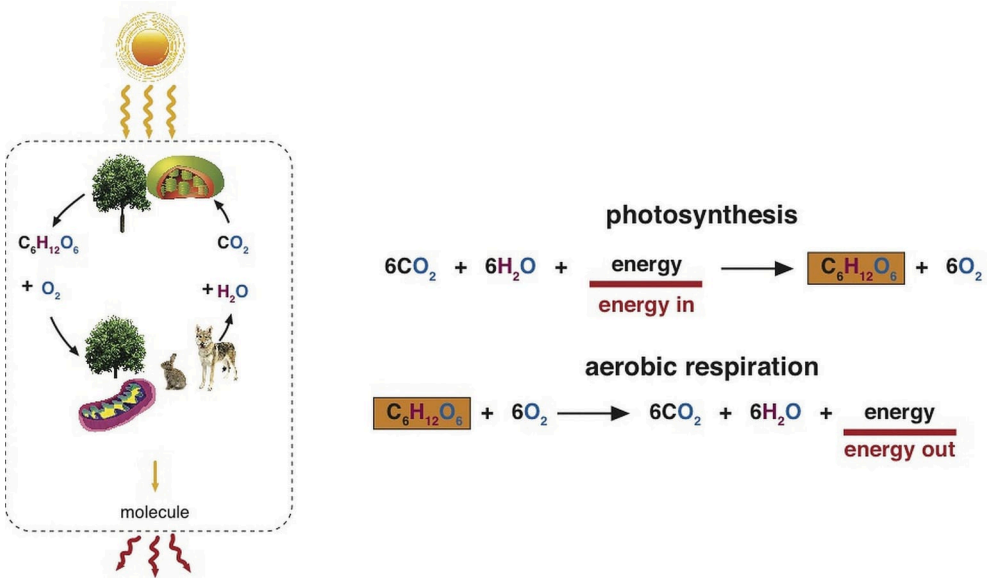


Figure 3.2.4: Plants harvest energy from the sun and capture it in the molecule, glucose. Humans harvest the energy in glucose and capture it into the molecule, ATP.

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)?

This page titled 3.2: The Basic Structural and Functional Unit of Life - The Cell is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3.3: The Digestion and Absorption Process

Skills to Develop

- 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.

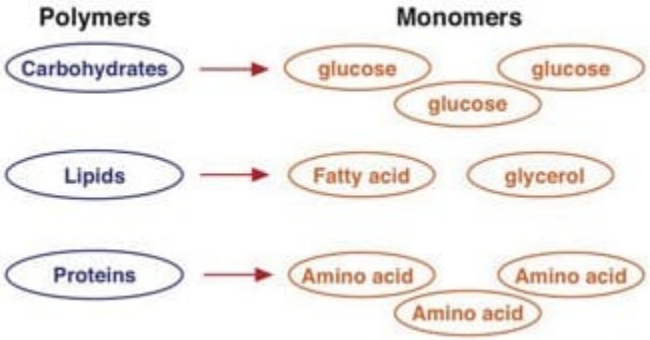


Figure 3.3.1: The Digestion Process. Digestion converts the food we eat into smaller particles, which will be processed into energy or used as building blocks.

Once you have eaten, your digestive system (Figure 3.3.1) 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 carbohydrates. 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 a 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.

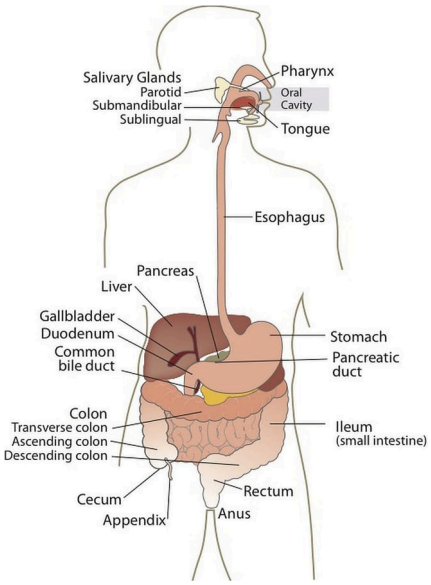


Figure 3.3.2: The Human Digestive System : © Networkgraphics

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, which 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 3.3.1: Digestion Video

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

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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, the 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 breakdown 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).

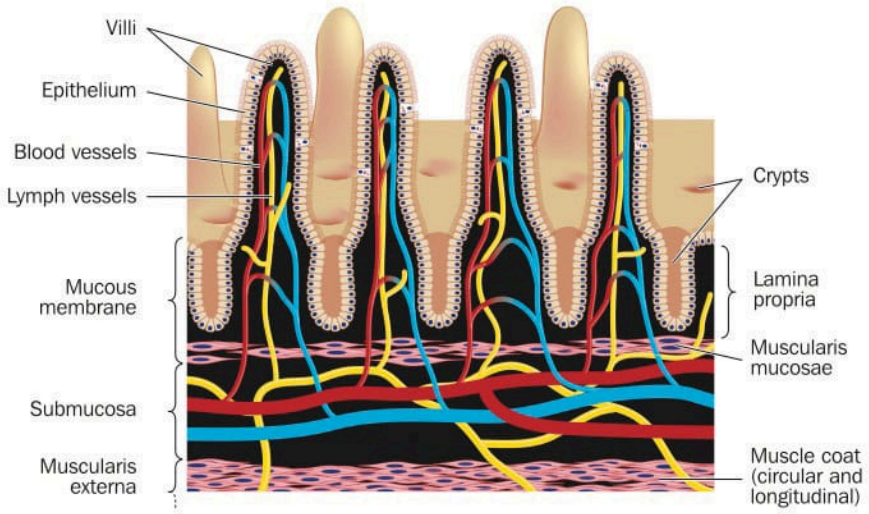


Figure 3.3.3: The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvillus. © Shutterstock

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 probiotics are 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 3.3.4: 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 3.3.2: The Stages of Digestion

This video reviews the sequence of events during food digestion.

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 carbohydrates. 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 which supplies the skin and muscle, and the autonomic system which supplies the 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 3.3.1: 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 the stomach) in the 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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

This page titled 3.3: The Digestion and Absorption Process is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3.4: Nutrients Are Essential for Organ Function

Skills to Develop

- 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 match 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.

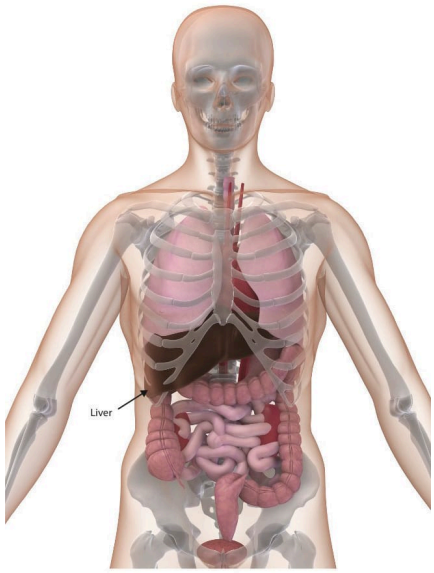


Figure 3.4.1: The liver is the checkpoint for metabolic activity. © Shutterstock

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.

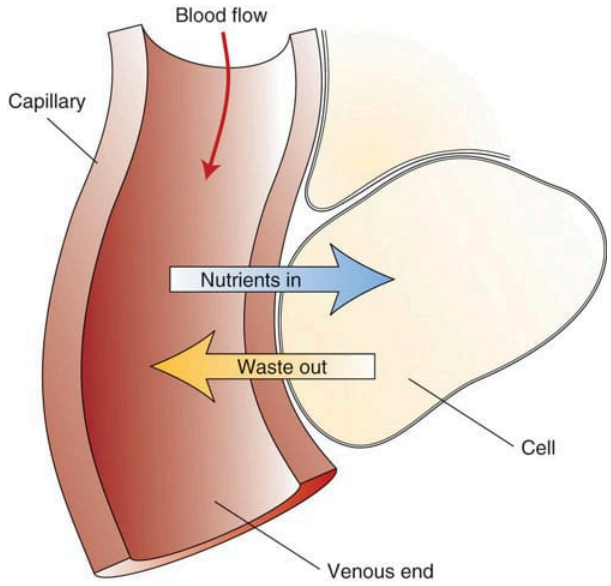


Figure 3.4.2: The Circulatory System: The circulatory system transports nutrients to all cells and carries wastes out.

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.

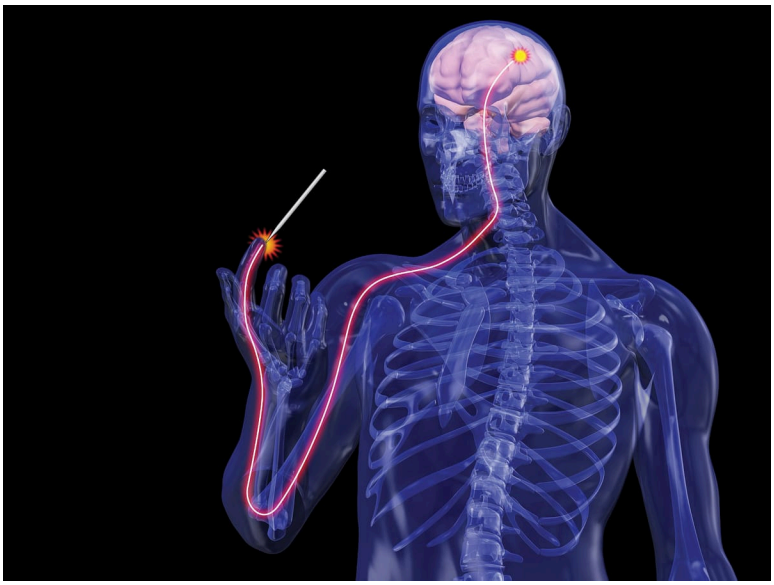


Figure 3.4.3: The brain has been compared to a central computer that controls all body functions. It relays messages to and from various body parts at lightning speed within a vast communication network of cells. © Shutterstock

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 on 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 on 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 the 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 as 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 3.4.4: 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 3.4.1: 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.

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 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, chickpeas, cashews, sesame seeds, peanuts, whole grains, and zinc-fortified cereals.



Figure 3.4.5 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 the 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

2. 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

   https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6120115/

   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 websites, discuss the importance of “good fats” in the diet for optimizing brain function and preventing diseases such as Alzheimer’s.

This page titled 3.4: Nutrients Are Essential for Organ Function is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

3.5: Gastrointestinal Tract and Your Health

Skills to Develop

- 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.

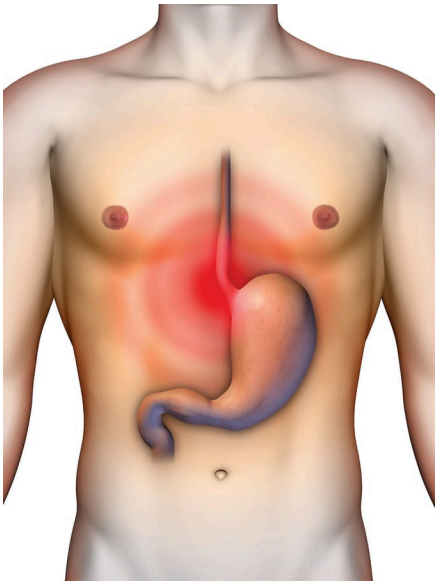


Figure 3.5.1: Heartburn is a burning sensation that radiates throughout the chest. © Shutterstock

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 vicious 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.

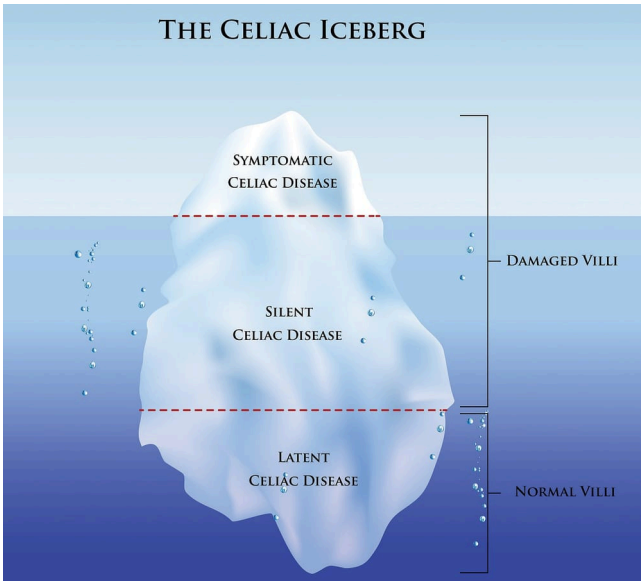


Figure 3.5.2: Celiac: Not everyone with celiac is diagnosed—many have "silent" or "latent" celiac disease. © Shutterstock

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 3.5.1).

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 the 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 deficiencies 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 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 test 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 3.5.3: *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 provide 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

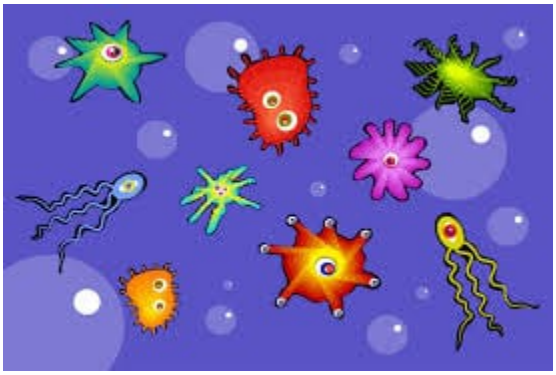


Figure 3.5.4: Cartoon of different types of bacteria.

Our body is covered with small microorganisms we cannot see. Within our gut, it is estimated that there are 100 trillion bacteria, which are 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 a prominent role in determining the specific microbial communities found in our intestinal tract. Prebiotic foods contain undigested material, like fiber, that our gut microbes digest while probiotic foods contain live bacteria.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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.

This page titled 3.5: Gastrointestinal Tract and Your Health is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4: METABOLISM AND ENERGY

4.1: Metabolism Overview
4.2: Energy and Calories
4.3: Balancing Energy Input with Energy Output
4.4: Aerobic Exercise
4.5: Anaerobic Exercise
4.6: Nutrients that are critical to athletes

This page titled 4: Metabolism and Energy is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.1: Metabolism Overview

Skills to Develop

- 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 into monosaccharides, lipids are broken down into fatty acids, and proteins are broken down into 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 pathways. 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.

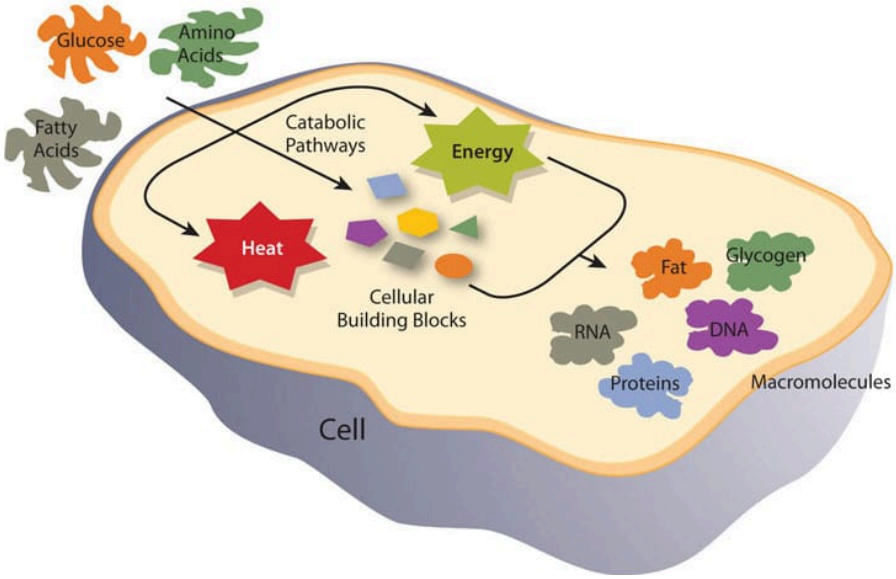


Figure 4.1.1: Metabolism is categorized into metabolic pathways that break down the molecules that release energy (catabolism) and the molecules that consume energy by building bigger molecules (anabolism).Caption here. (CC BY-SA-NC 3.0; anonymous)

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 glycogenosis), and synthesizing triglycerides (lipogenesis). Table 4.1.1 summarizes some of the catabolic and anabolic pathways and their functions in energy metabolism.

***Table** 4.1.1: 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

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 and 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 produces 4 kcal/gm; fat produces 9 kcal/gm; and, alcohol produces 7 kcal/gm.

Some amino acids have the nitrogen removed and 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 entering the citric acid cycle as acetyl-CoA. In the presence of glucose, these two carbon units enter the citric acid cycle and are 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."

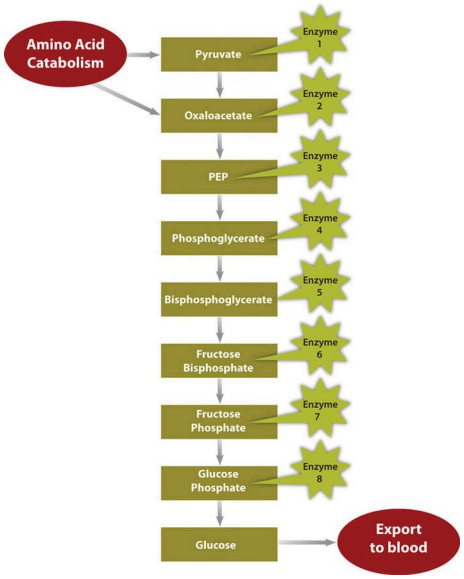


Figure 4.1.2: Metabolic Pathway of Gluconeogenesis

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 4.1.2). 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 among 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 "Nutrition and You" and the concept of the "thrifty gene."
2. Can an overweight person blame their excess weight on having a slower metabolism?

This page titled 4.1: Metabolism Overview is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.2: Energy and Calories

Skills to Develop

- 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.

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 an 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 number of Calories it contains, go to MyFood-a-pedia, a website maintained by the USDA. https://www.govloop.com/community/bl...0Gov%20Project.

Interactive 4.2.1

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 4.2.1, the protein content in one serving is 6 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 or 6 grams × 4 kilocalories/gram = 24 kilocalories from protein per container

(# kilocalories from protein ÷ total kilocalories per serving) × 100 or (24 ÷ 150) × 100 = 16 percent of calories in the container are from protein



Figure 4.2.1: 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 equations above

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?

This page titled 4.2: Energy and Calories is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.3: Balancing Energy Input with Energy Output

Skills to Develop

- 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 4.3.1.

Table 4.3.1: *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 the 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.

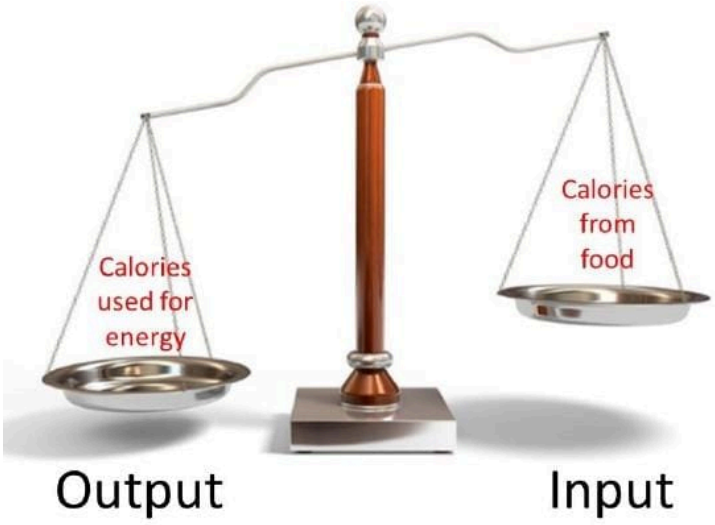


Figure 4.3.1: Energy is a balance between energy input and energy output. When one exceeds the other you will lose or gain weight.

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 sizes 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 urinate before measuring RMR. BMR is measured with no ambulatory movement.

Table 4.3.2: *Energy Breakdown of Organs*

Organ	Percent of Energy Expended
Liver	27
Brain	19
Heart	7
Kidneys	10

Organ	Percent of Energy Expended
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.

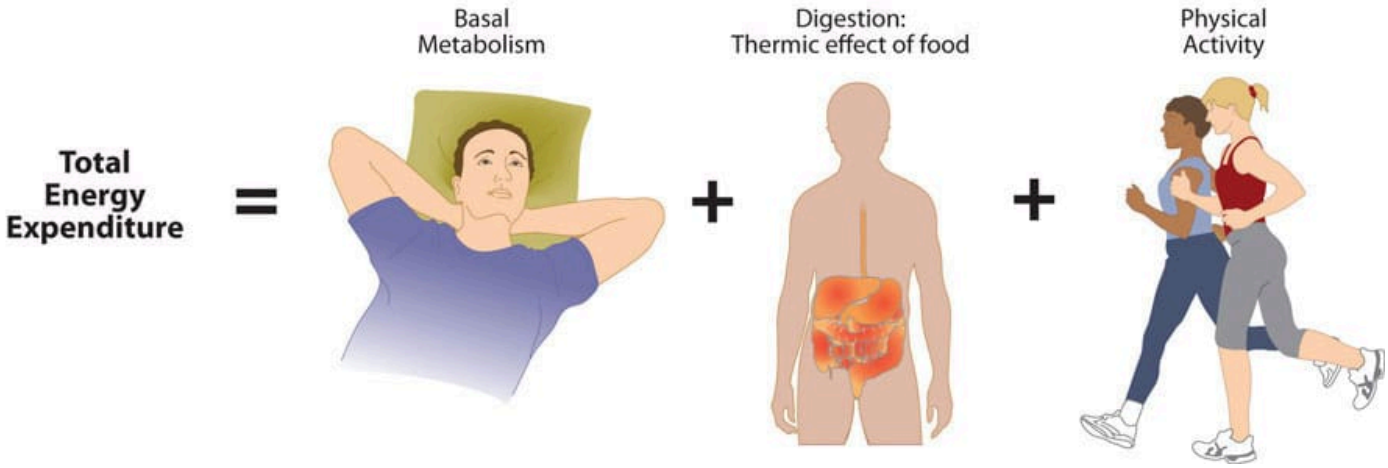


Figure 4.3.2: Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity.

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:

$$EER = 662 - [9.53 \times age(y)] + PA \times [15.91 \times wt(kg) + 5.39.6 \times ht(m)] \tag{4.3.1}$$

- Adult female:

$$EER = 354 - [6.91 \times age(y)] + PA \times [9.36 \times wt(kg) + 726 \times ht(m)] \tag{4.3.2}$$

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 4.2, 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 4.3.1

To begin your dietary assessment, go to MyPlate, which is available on the US Department of Agriculture (USDA) website: https://www.myplate.gov/.

Table 4.3.3: *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
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 4.3.4: *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

Sex	Age (years)	Sedentary	Moderately Active	Active
	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* provide a table (Table 4.5.4) that gives the estimated daily calorie needs for different age groups of males and females with various activity levels. The *2010 Dietary Guidelines* also state 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 4.3.5: *Acceptable Macronutrient Distribution Ranges*

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 4.3.1: 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 4.3.2).

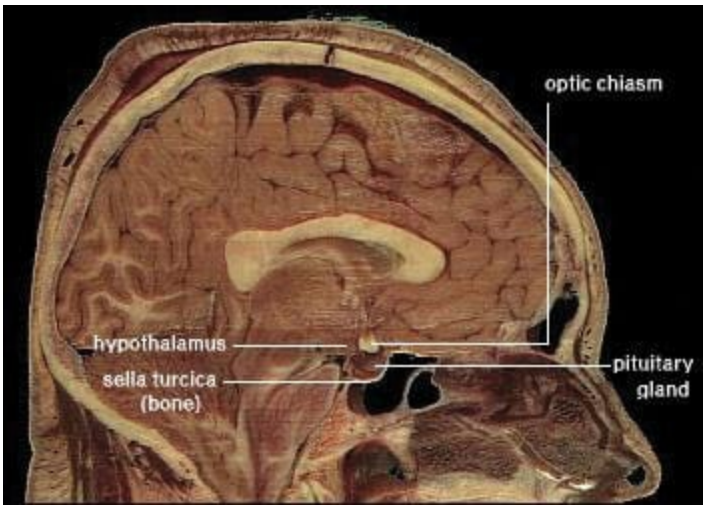


Figure 4.3.3: This is a scan of a brain. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety. Source: Diabesity, Sixth Framework Programme. “Novel Molecular Targets for Obesity and Type 2 Diabetes.” 2002-2006. www.diabesity.eu/.honours.htm.

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 plays 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 the 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.

Societal Influences

It is without a doubt that 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 food 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video 4.3.1**. 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 setpoint 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 4.3.1: 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/

This page titled 4.3: Balancing Energy Input with Energy Output is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.4: 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 4.4.1: *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 cell 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.

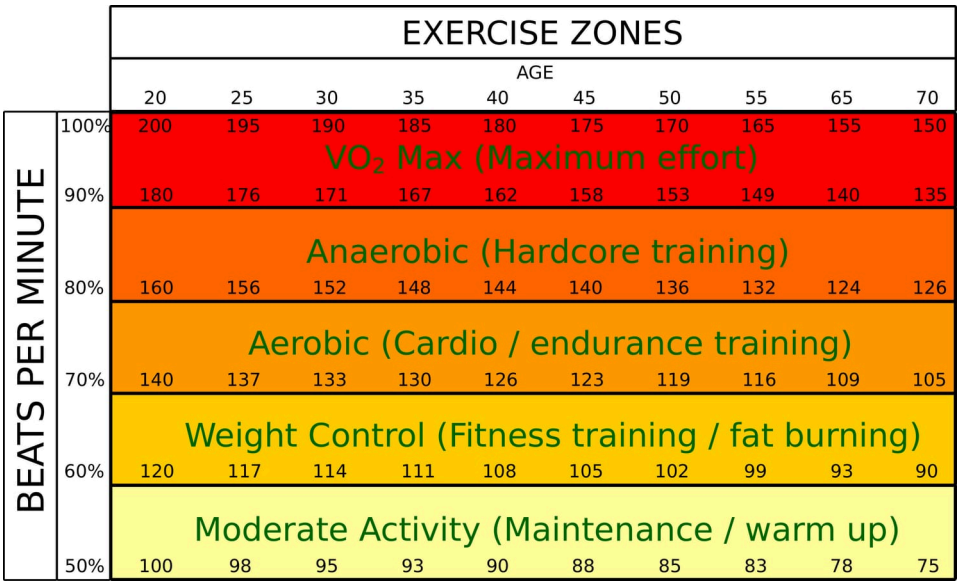


Figure 4.4.2: Fox and Haskell formula showing the split between aerobic (light orange) and anaerobic (dark orange) exercise and heart rate

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.

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 kettlebell 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 the 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 the 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 exercises 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 4.4.3: *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 4.4.1: *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

References

- *Sharon A. Plowman; Denise L. Smith (1 June 2007). Exercise Physiology for Health, Fitness, and Performance. Lippincott Williams & Wilkins. p. 61. ISBN 978-0-7817-8406-1. Retrieved 13 October 2011.*
- *Kenneth H. Cooper (1997). Can stress heal?. Thomas Nelson Inc. p. 40. ISBN 978-0-7852-8315-7. Retrieved 19 October 2011.*
- *William D. McArdle; Frank I. Katch; Victor L. Katch (2006). Essentials of exercise physiology. Lippincott Williams & Wilkins. p. 204. ISBN 978-0-7817-4991-6. Retrieved 13 October 2011.*
- *Cooper, Kenneth H. (1983) [1968]. Aerobics (revised, reissue ed.). Bantam Books. ISBN 0553274473.*
- *Netburn, Deborah (March 30, 2009), "Dr. Kenneth Cooper got a nation moving through aerobics", Los Angeles Times*
- *Wayne, Jake (14 June 2011). "Aerobic Vs. Anaerobic Fitness". LIVESTRONG.COM. Retrieved 21 April 2013.*
- Muscle as a secretory organ. Pedersen BK. American Physiological Society. Compr Physiol 3:1337-1362, 2013. http://www.inflammation-metabolism.dk/index.php?pageid=21&pmid=23897689
- *"Fat vs. carbohydrate metabolism during aerobic exercise".*
- *Matthew J Watt; et al. (June 2002). "Intramuscular triacylglycerol, glycogen and acetyl group metabolism during 4 h of moderate exercise in man". J Physiol **541** (Pt 3): 969–78. doi:10.1113/jphysiol.2002.018820. PMC 2290362. PMID 12068055.*
- *"Aerobic exercise: the health benefits". myDr. 11 January 2010. Retrieved 17 May 2016.*
- *"Cardiovascular fitness is linked to intelligence".*
- Snowling, N. J., & Hopkins, W. G. (2006). Effects of Different Modes of Exercise Training on Glucose Control and Risk Factors for Complications in Type 2 Diabetic Patients A meta-analysis. *Diabetes Care*, *29*(11), 518–2527. http://doi.org/10.2337/dc06-1317
- 'aerobic exercise', *Food and Fitness: A Dictionary of Diet and Exercise*, Michael Kent, Oxford University Press, 1997.
- *Hebestreit, Helge; Bar-Or, Oded (2008). The Young Athlete. Blackwell Publishing Ltd. p. 443. ISBN 978-1-4051-5647-9. Retrieved 29 July 2014.*
- *Bouchard, Claude; Ping An; Treva Rice; James S. Skinner; Jack H. Wilmore; Jacques Gagnon; Louis Perusse; Arthus S. Leon; D. C. Rao (1 September 1999). "Familial aggregation of VO(2max) response to exercise training: results from the HERITAGE Family Study". Journal of Applied Physiology **87** (3): 1003–1008. PMID 10484570. Retrieved 2007-07-17.*
- *Kolata, Gina (February 12, 2002). "Why Some People Won't Be Fit Despite Exercise". The New York Times. Retrieved*

2007-07-17.
- East Tennessee State University Thesis

References

- Cooper, Kenneth C. *The New Aerobics*. Eldora, Iowa: Prairie Wind.
- Donatelle, Rebecca J. *Health: The Basics*. 6th ed. San Francisco: Pearson Education, Inc. 2005.
- Exercite Glossary. *Definition: Aerobic Exercise*. Exercite Glossary Definition: Aerobic Exercise
- Hinkle, J. Scott. *School Children and Fitness: Aerobics for Life*. Ann Arbor, MI: ERIC
- Clearinghouse on Counseling and Personnel Services.
- Aberg MA, Pedersen NL, Torén K, Svartengren M, Bäckstrand B, Johnsson T, Cooper-Kuhn CM, Aberg ND, Nilsson M, & Kuhn HG. (2009) Cardiovascular fitness is associated with cognition in young adulthood. Proceedings of the National Academy of Sciences of the United States of America.
- Guiney, Hayley & Machado, Liana. Benefits of regular exercise for executive functioning in healthy populations. Psychon. Bull. Rev. 2013.
- Rendi, Maria, Szabo, Atila, Szabo, Tomas, Velenczei, Attila & Kovas, Arpad. Acute psychological benefits of aerobic exercise: A field study into the effects of exercise characteristics. Psychol, Health. Med. 2008.

Contributors and Attributions

- Wikipedia

This page titled 4.4: Aerobic Exercise is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.5: 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.

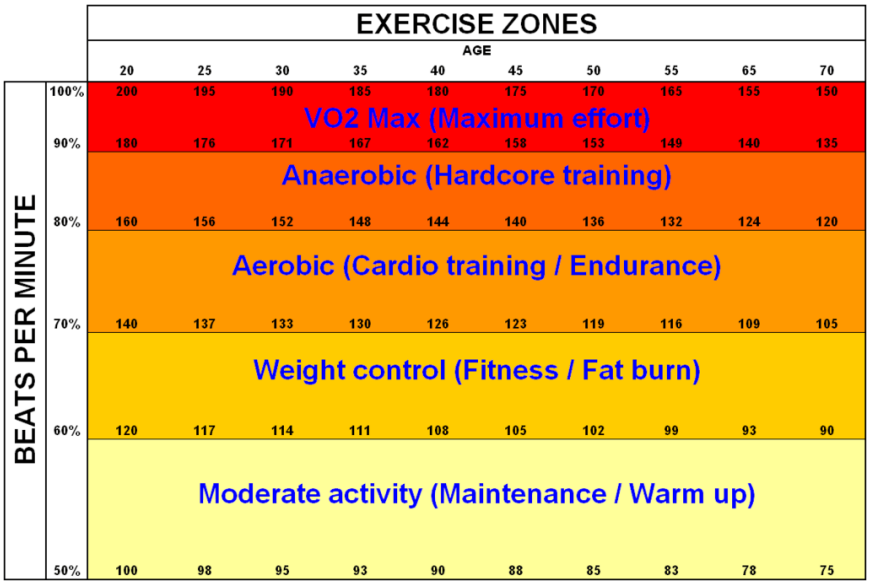


Figure 4.5.1: *Exercise work zones (Fox and Haskell formula between 20 and 70-year-old): VO2Max (red zone), anaerobic, aerobic, weight control and moderate activity. (CC BY-Sa 3.0; Morgoth666)*

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 that 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

References

- *Medbo, JI; Mohn, AC; Tabata, I; Bahr, R; Vaage, O; Sejersted, OM (January 1988). "Anaerobic capacity determined by maximal accumulated O2 deficit". Journal of Applied Physiology **64** (1): 50–60. Retrieved 14 May 2011.*
- *Scott, Christopher B (June 2005). "Contribution of anaerobic energy expenditure to whole body thermogenesis". Nutrition & Metabolism. 14 **2**. doi:10.1186/1743-7075-2-14. Retrieved 14 May 2011.*
- *Di Prampero, PE; G. Ferretti (Dec 1, 1999). "The energetics of anaerobic muscle metabolism" (PDF). Respiration Physiology **118** (2-3): 103–115. doi:10.1016/s0034-5687(99)00083-3.*
- *Scott, Christopher B (2008). A Primer for the Exercise and Nutrition Sciences: Thermodynamics, Bioenergetics, Metabolism. Humana Press. p. 166. ISBN 978-1-60327-382-4.*
- Robert Donatelli, *Sports-specific Rehabilitation*, p. 40, Elsevier, 2007 ISBN 0443066426
- *McMahon, Thomas A (1984). Muscles, Reflexes, and Locomotion. Princeton University Press. pp. 37–51. ISBN 0-691-02376-X.*

Contributors

- *Wikipedia*

This page titled 4.5: Anaerobic Exercise is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

4.6: 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. There are three energy macronutrients as you have learned - carbohydrate, fat, and protein. Carbohydrates 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 carbohydrates 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 of 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 carbohydrates (55% or greater) daily.

In the chapter on protein, you will learn 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 is required to build or maintain tissue. If carbohydrate is 55% of 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 carbohydrates 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 for 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 these 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.

Supplemental Reading

http://extension.colostate.edu/topic...athlete-9-362/

This page titled 4.6: Nutrients that are critical to athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5: CARBOHYDRATE BASICS - THE ATHLETE'S ENERGY POWERHOUSE

5.1: Introduction to Carbohydrates

5.2: A Closer Look at Carbohydrates

5.3: Digestion and Absorption of Carbohydrates

5.4: The Functions of Carbohydrates in the Body

5.5: Health Consequences and Benefits of High-Carbohydrate Diets

5.6: Carbohydrates and Personal Diet Choices

5.7: The Food Industry - Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

5.8: Glycemic Index

5.9: Glycemic Index and the Athlete

5.10: Paper - A Step Towards Personalized Sports Nutrition - Carbohydrate Intake During Exercise

This page titled 5: Carbohydrate Basics - The Athlete's Energy Powerhouse is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.1: Introduction to Carbohydrates

You likely eat grains every day—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 5.1.1

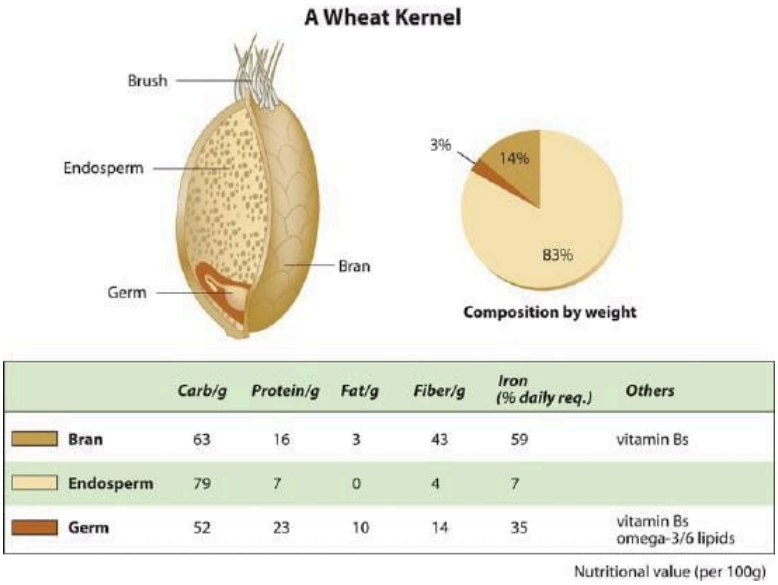
Watch the History of Bread: https://www.youtube.com/watch?v=oOjc4KZTWzg

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 5.1.1: The *2020 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 5.1.2: *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.

While wheat is one of the primary grains in the American diet, there are many other types of grains. Check out this website and see other types of grains you could add to your diet: https://wholegrainscouncil.org/whole-grains-101/whole-grains-z

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)

This page titled 5.1: Introduction to Carbohydrates is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.2: A Closer Look at Carbohydrates

Skills to Develop

- 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.

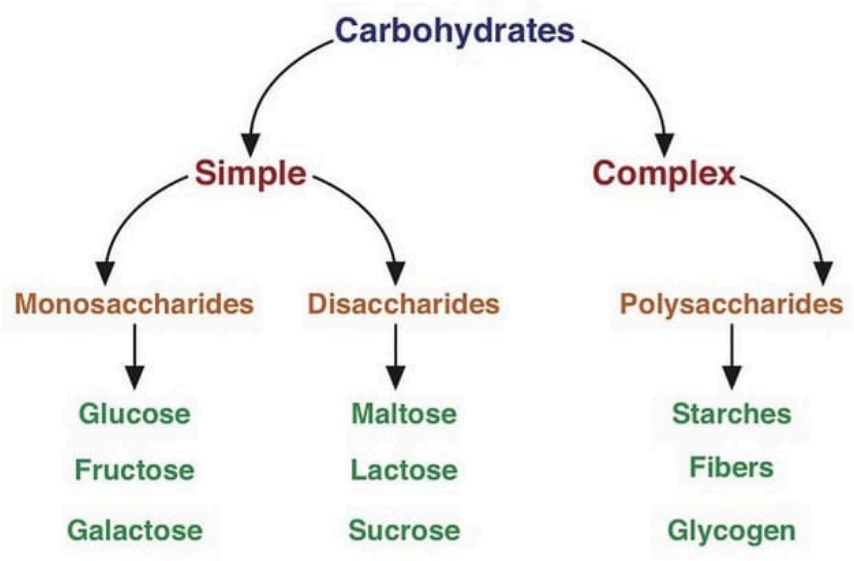


Figure 5.2.1: Carbohydrate Classification Scheme. Carbohydrates are broken down into the subgroups "fast-releasing" and "slow-releasing" carbohydrates. These subgroups are further categorized into mono-, di-, and polysaccharides.

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 monosaccharides and disaccharides. Slow-releasing carbohydrates are long chains of monosaccharides. (Figure 5.2.1).

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 5.2.2). 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 5.2.2). 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.

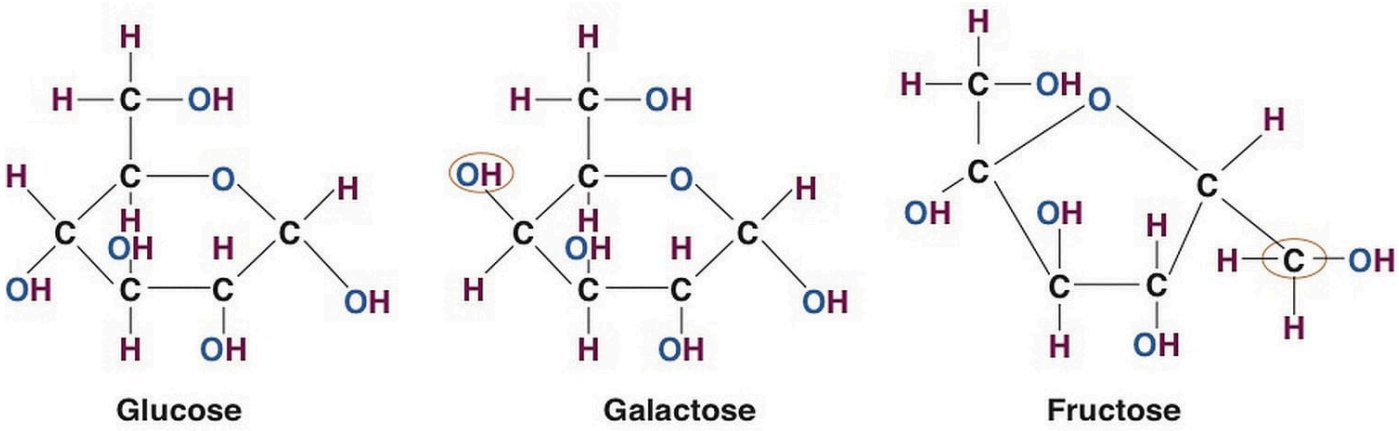


Figure 5.2.2: Structures of the Three Most Common Monosaccharides: Glucose, Galactose, and Fructose. Red circles indicate the structural differences between the three.

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 oppose 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.

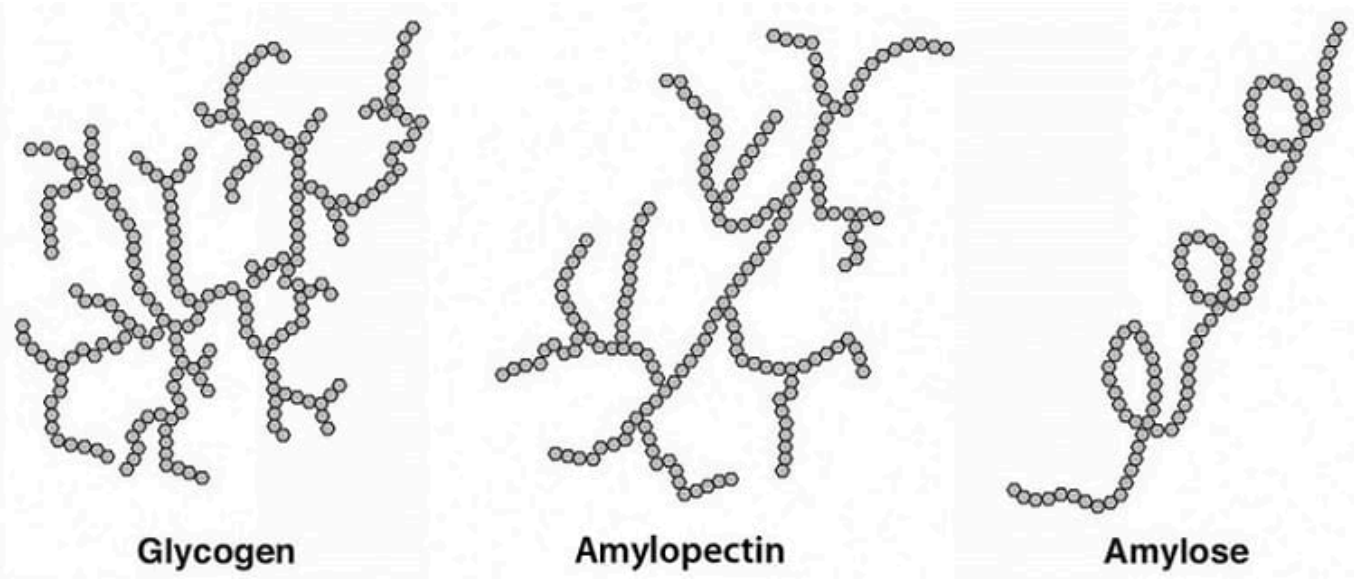


Figure 5.2.3: Structures of the Plant Starches and Glycogen

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 a 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

This page titled 5.2: A Closer Look at Carbohydrates is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.3: Digestion and Absorption of Carbohydrates

Skills to Develop

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

See Table 5.3.1 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 5.3.1**: Sweetness Comparison of Carbohydrates*

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

Carbohydrate	Sweetness (percentage of sucrose)
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.

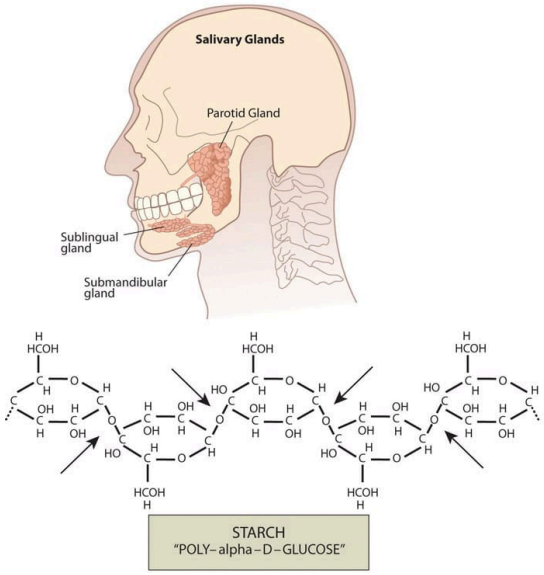


Figure 5.3.2: Salivary glands secrete salivary amylase, which begins the chemical breakdown of carbohydrates by breaking the bonds between monomeric sugar units.

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/diseases/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.

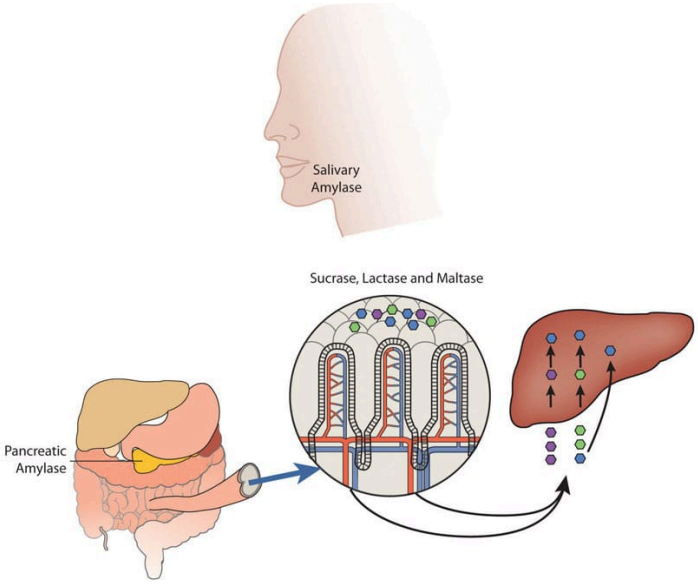


Figure 5.3.3: Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver.

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 they 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 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 5.3.4: 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.

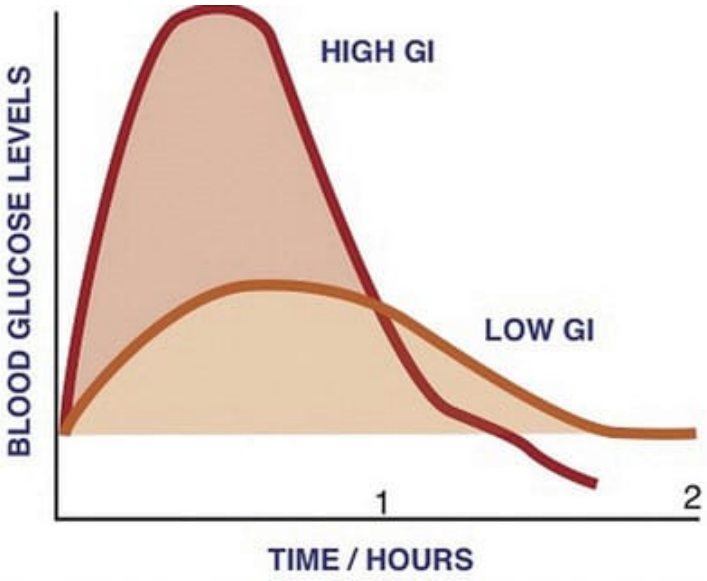


Figure 5.3.5: The glycemic index measures the effects of foods on blood glucose levels.

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 5.3.5).

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 5.3.2: *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

Foods	GI Value
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
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

Foods	GI Value
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 its 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 of 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 5.3.1: 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.

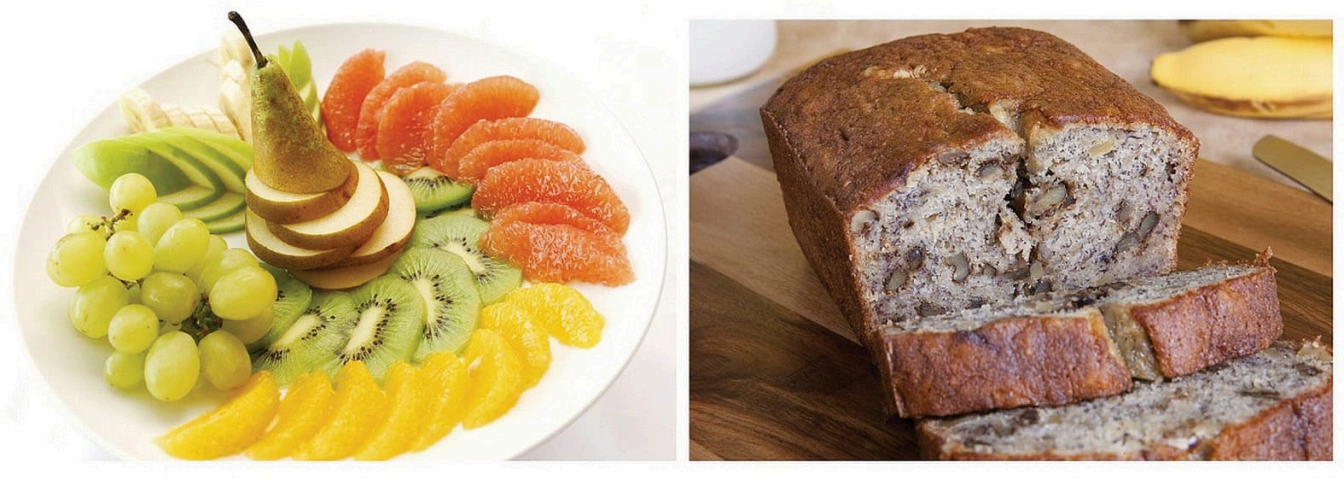


Figure 5.3.6: *Balance the high-GI foods at the Thanksgiving table with low-GI foods. © Shutterstock*

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 to 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.

This page titled 5.3: Digestion and Absorption of Carbohydrates is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.4: The Functions of Carbohydrates in the Body

Skills to Develop

- 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 a cell can use.

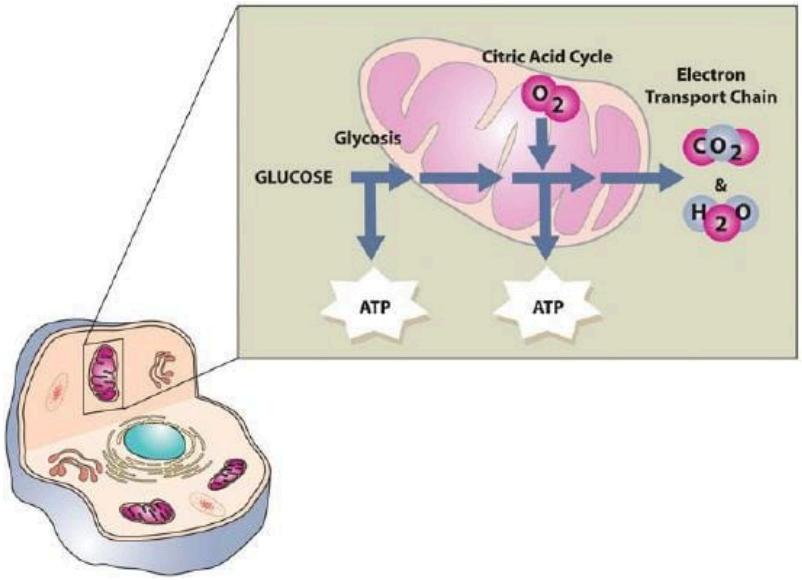


Figure 5.4.1: *Cellular respiration is the process by which energy is captured from glucose.*

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 5.4.2).

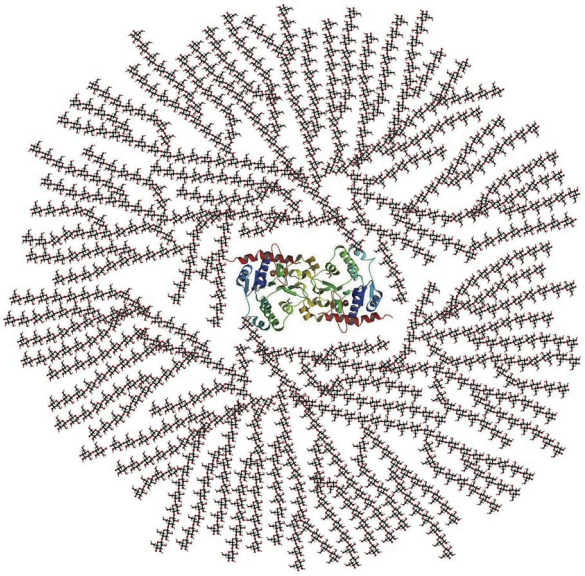


Figure 5.4.2: The structure of glycogen enables its rapid mobilization into free glucose to power cells.

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 mealtimes. 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 5.4.3). 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 to the fat pounds—a topic that will be discussed shortly.

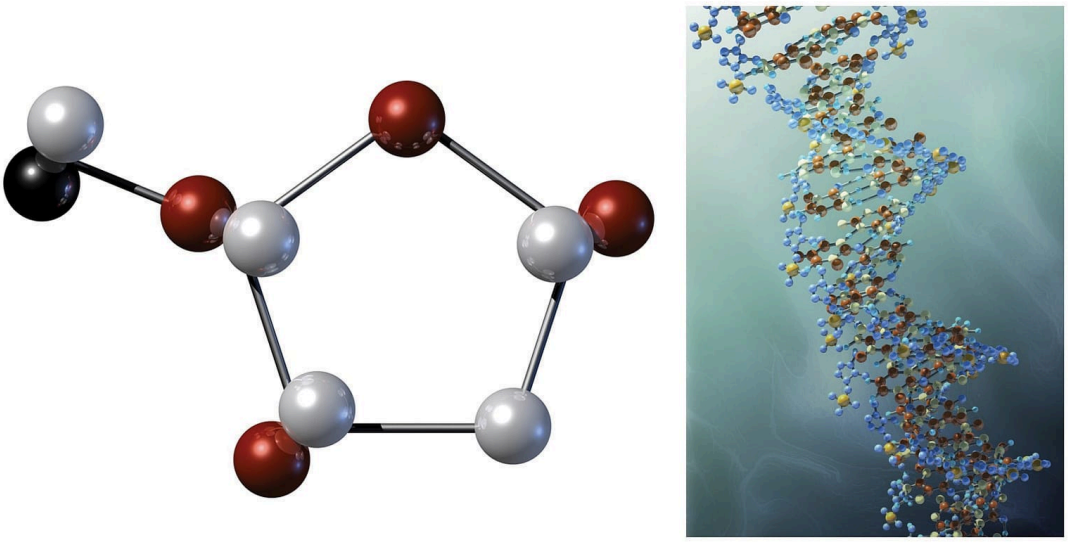


Figure 5.4.3: The sugar molecule deoxyribose is used to build the backbone of DNA.© Shutterstock

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 the 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 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 supporting 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 mealtimes. 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?

This page titled 5.4: The Functions of Carbohydrates in the Body is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.5: Health Consequences and Benefits of High-Carbohydrate Diets

Skills to Develop

- 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 report 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).

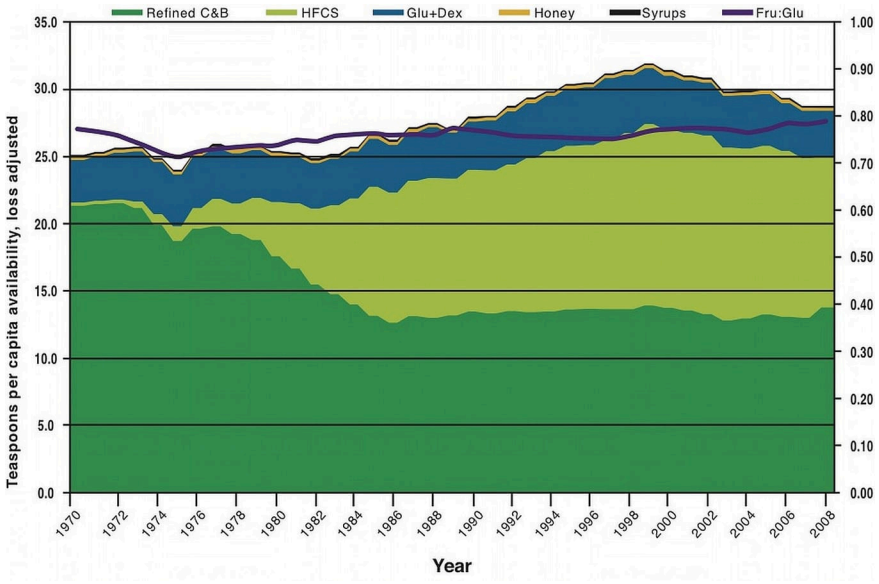


Figure 5.5.1: *Sugar Consumption (in Teaspoons) from Various Sources*

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 into 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 the 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 5.5.1

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.

https://fdc.nal.usda.gov/

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 5.5.2). 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 5.5.2: *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 5.5.2

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.

https://www.hsph.harvard.edu/nutritionsource/healthy-drinks/sugary-drinks/how-sweet-is-it/

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).

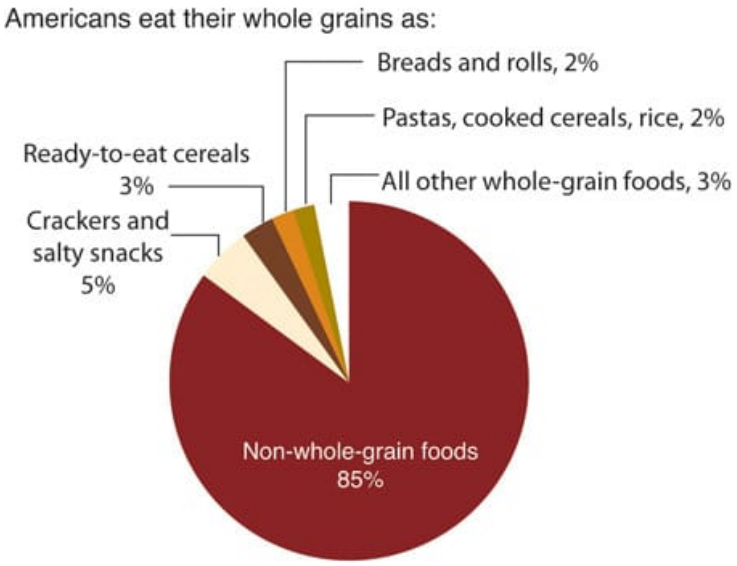


Figure 5.5.3: *Grain Consumption Statistics in America. Source: Economic Research Service. http://www.ers.usda.gov/data-products/commodity-consumption-by-population-characteristics/documentation.aspx.*

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 the 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/diseases/pubs/diverticulosis/. Ten to 25 percent of people who have diverticulosis go on to develop diverticulitis.National Digestive Diseases Information Clearinghouse, a service of the 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.

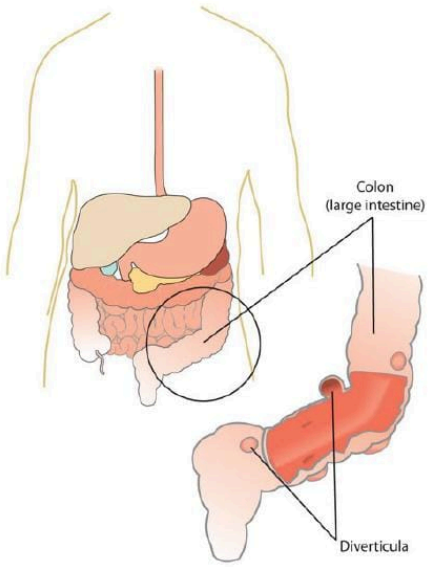


Figure 5.5.4: *Diverticulitis: A Disease of Fiber Deficiency*

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 to 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

This page titled 5.5: Health Consequences and Benefits of High-Carbohydrate Diets is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.6: Carbohydrates and Personal Diet Choices

Skills to Develop

- 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 5.6.1: *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 5.6.2 gives the specific amounts of carbohydrates, fiber, and added sugar in various foods.

Table 5.6.2: *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 5.6.1

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 cornflour. (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 5.6.3).

Table 5.6.3: *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 a 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 carbohydrates 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 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

This page titled 5.6: Carbohydrates and Personal Diet Choices is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.7: The Food Industry - Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

Skills to Develop

- 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 5.7.1: 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.

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 5.7.1: *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 5.7.1). 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 5.7.1: *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 decrease 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 on 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 has 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 with amino acids. When digested, it is broken down into 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 5.7.2.

Table 5.7.2: *Sweeteners*

Sweeteners with Trade Name	Calories	Source/ Origin	Consumer Recommendations	Controversial Issues	Product Uses
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 the potential to reach ADI if consuming many beverages, desserts, frozen desserts, and gums containing aspartame routinely.	Beverages, gelatin desserts, gums, fruit 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 were associated with bladder cancer in laboratory animals. In 1977, FDA proposed banning saccharin from use in food • protests launched by consumer & interest groups • warning labels listed on products about saccharin and cancer risk in animals until 2001 when studies concluded that it did not cause cancer in humans	General-purpose sweetener in all foods and beverages. Sold as Sweet 'n' Low in the United States; also found in cosmetics and pharmaceutical products.

Sweeteners with Trade Name	Calories	Source/ Origin	Consumer Recommendations	Controversial Issues	Product Uses
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 gum, powdered beverage mixes, non-dairy creamers, gelatins, puddings, instant teas, and coffees.
Cyclamates • Sugar Twin (Canada only)	0 kcal/g	Thirty times sweeter than sucrose. Discovered in 1937.	No ADI available.	1949, cyclamate was 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 is still pending for use in the United States since the ban. Canada and other countries use this type of sweetener.	Recommended as a substitute for table sugar for diabetics in the 1950s in baked goods.

Sweeteners with Trade Name	Calories	Source/ Origin	Consumer Recommendations	Controversial Issues	Product Uses
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-purpose sweetener, baked goods, beverages, gelatin desserts, frozen dairy desserts, canned fruits, salad dressings, dietary supplements; currently recommended as a replacement for table sugar and additive for diabetics.
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 health food stores as a dietary supplement.
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, cookies, cakes, pies, candy canes, ice cream, sorbets, and as a food preservative.

Sweeteners with Trade Name	Calories	Source/ Origin	Consumer Recommendations	Controversial Issues	Product Uses
Honey	3 kcal/g	Made from sucrose. Contains the 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.		Sweeteners in various foods and beverages such as sodas, teas, alcoholic beverages, and baked goods.
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, desserts, candies, jellies.
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 bulk and sweetness in the following sugar-free items: cookies, jams, jellies, chewing gum, candies, mints, pharmaceuticals, and oral health products.

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 incorporate 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 optimally 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)

This page titled 5.7: The Food Industry - Functional Attributes of Carbohydrates and the Use of Sugar Substitutes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

The following is taken from these sources and provides a general overview. The most authoritative source of information on this topic is the following website: http://www.glycemicindex.com/.

- https://en.Wikipedia.org/wiki/Glycemic_index
- https://www.gisymbol.com/about-glycemic-index/
- http://www.glycemicindex.com/

The **glycemic index** or **glycaemic index** (/glaɪˈsiːmɪk/;[1] **GI**) is a number associated with the carbohydrates in a particular type of food that indicates the effect of these carbohydrates on a person's blood glucose (also called blood sugar) level. A value of 100 represents the standard and is the response associated with an equivalent amount of pure glucose.[2]

The GI represents the rise in a person's blood sugar level two hours after consumption of the food. The glycemic effects of foods depend on a number of factors, such as the type of carbohydrate, physical entrapment of the carbohydrate molecules within the food (food matrix), fat and protein content of the food, and organic acids or their salts in the meal. The GI is useful for understanding how the body breaks down carbohydrates[3] and takes into account only the available carbohydrate (total carbohydrate minus fiber) in a food. The Glycemic index does not predict an individual's glycemic response to a food, but can be used as a tool to assess the insulin response burden of a food, averaged across a studied population. Individual responses vary greatly.[4]

The glycemic index is usually applied in the context of the quantity of the food and the amount of carbohydrate in the food that is actually consumed. A related measure, the glycemic load (GL),[5] factors this in by multiplying the glycemic index of the food in question by the carbohydrate content of the actual serving. Watermelon has a high glycemic index, but a low glycemic load for the quantity typically consumed.[6] Fructose, by contrast, has a low glycemic index but can have a high glycemic load if a large quantity is consumed.

GI tables are available that list many types of foods and their GIs (see http://www.glycemicindex.com/). Some tables also include the serving size and the glycemic load of the food per serving.[3]

Figure 5.8.1 Graph describing blood sugar change after a meal.

A practical limitation of the glycemic index is that it does not measure insulin production due to rises in blood sugar. As a result, two foods could have the same glycemic index, but produce different amounts of insulin. Likewise, two foods could have the same glycemic load but cause different insulin responses. Furthermore, both the glycemic index and glycemic load measurements are defined by the carbohydrate content of food. For example, when eating steak, which has no carbohydrate content but provides a high protein intake, up to 50% of that protein can be converted to glucose when there is little to no carbohydrate consumed with it.[7] But because it contains no carbohydrate itself, steak cannot have a glycemic index. For some food comparisons, the "insulin index" may be more useful.

Accuracy

Glycemic index charts often give only one value per food, but variations are possible due to

- **ripeness** (riper fruits contain more sugars increasing GI)
- **cooking methods** (the more cooked, or overcooked, a food, the more its cellular structure is broken, with a tendency for it to digest quickly and raise GI more)
- **processing** (*e.g.*, flour has a higher GI than the whole grain from which it is ground as grinding breaks the grain's protective layers) and the length of storage. Potatoes are a notable example, ranging from moderate to very high GI even within the same variety.[8][9]

More importantly, the glycemic response is different from one person to another, and also in the same person from day to day, depending on blood glucose levels, insulin resistance, and other factors.[9] [4]

The glycemic index only indicates the impact on glucose level two hours after eating the food. People with diabetes have elevated levels for four hours or longer after eating certain foods.[9]

Determining the GI of a Food

Foods with carbohydrates that break down quickly during digestion and release glucose rapidly into the bloodstream tend to have a high GI; foods with carbohydrates that break down more slowly, releasing glucose more gradually into the bloodstream, tend to have a low GI. The concept was developed by Dr. David J. Jenkins and colleagues[10] in 1980–1981 at the University of Toronto in their research to find out which foods were best for people with diabetes. A lower glycemic index suggests slower rates of digestion and absorption of the foods' carbohydrates and can also indicate greater extraction from the liver and periphery of the products of carbohydrate digestion. A lower glycemic response usually equates to a lower insulin demand but not always, and can improve long-term blood glucose control[11] and blood lipids. The insulin index is also useful for providing a direct measure of the insulin response to a food.

The glycemic index of a food is defined as the incremental area under the two-hour blood glucose response curve (AUC) following a 12-hour fast and ingestion of a food with a certain quantity of available carbohydrate (usually 50 g). The AUC of the test food is divided by the AUC of the standard (either glucose or white bread, giving two different definitions) and multiplied by 100. The average GI value is calculated from data collected from 10 human subjects. Both the standard and test food must contain an equal amount of available carbohydrates. The result gives a relative ranking for each tested food.[2][12]

The current validated methods use glucose as the reference food, giving it a glycemic index value of 100 by definition. This has the advantages of being universal and producing maximum GI values of approximately 100. White bread can also be used as a reference food, giving a different set of GI values (if white bread = 100, then glucose ≈ 140). For people whose staple carbohydrate source is white bread, this has the advantage of conveying directly whether replacement of the dietary staple with a different food would result in a faster or slower blood glucose response. A disadvantage of this system is that the reference food is not well-defined, because there is no universal standard for the carbohydrate content of white bread.

Classification

GI values can be interpreted intuitively as percentages on an absolute scale and are commonly interpreted as follows:

Table 5.8.1 Glycemic index ranges.

Classification	GI range[13]	Examples[13]
Low GI	55 or less	fructose; beans (black, pinto, kidney, lentil, peanut, chickpea); small seeds (sunflower, flax, pumpkin, poppy, sesame, hemp); walnuts, cashews, most whole intact grains (durum/spelt/kamut wheat, millet, oat, rye, rice, barley); most vegetables, most sweet fruits (peaches, strawberries, mangos); tagatose; mushrooms; chilis
Medium GI	56–69	white sugar or sucrose, not intact whole wheat or enriched wheat, pita bread, basmati rice, unpeeled boiled potato, grape juice, raisins, prunes, pumpernickel bread, cranberry juice,[14] regular ice cream, banana, sweet potato[15]
High GI	70 and above	glucose (dextrose, grape sugar), high fructose corn syrup, white bread (only wheat endosperm), most white rice (only rice endosperm), corn flakes, extruded breakfast cereals, maltose, maltodextrins, white potato (83).

A low-GI food will cause blood glucose levels to increase more slowly and steadily, which leads to more suitable postprandial (after meal) blood glucose readings. A high-GI food causes a more rapid rise in blood glucose level and is suitable for energy recovery after exercise or for a person experiencing hypoglycemia.

The glycemic effect of foods depends on a number of factors, such as the type of starch (amylose versus amylopectin), physical entrapment of the starch molecules within the food, fat and protein content of the food, and organic acids or their salts in the meal – adding vinegar, for example, will lower the GI.[16] The presence of fat or soluble dietary fiber can slow the gastric emptying rate, thus lowering the GI. In general, coarse, grainy breads with higher amounts of fiber have a lower GI value than white breads.[17]However, most breads made with 100% whole wheat or wholemeal flour have a GI not very different from endosperm only (white) bread.[18] Many brown breads are treated with enzymes to soften the crust, which makes the starch more accessible

(high GI).

While adding fat or protein will lower the glycemic response to a meal, the relative differences remain. That is, with or without additions, there is still a higher blood glucose curve after a high-GI bread than after a low-GI bread such as pumpernickel.

Fruits and vegetables tend to have a low glycemic index. The glycemic index can be applied only to foods where the test relies on subjects consuming an amount of food containing 50 g of available carbohydrate.[*citation needed*] But many fruits and vegetables (not potatoes, sweet potatoes, corn) contain less than 50 g of available carbohydrate per typical serving. Carrots were originally and incorrectly reported as having a high GI.[19] Alcoholic beverages have been reported to have low GI values; however, beer was initially reported to have a moderate GI due to the presence of maltose. This has been refuted by brewing industry professionals, who say that all maltose sugar is consumed in the brewing process and that packaged beer has little to no maltose present. Recent studies have shown that the consumption of an alcoholic drink prior to a meal reduces the GI of the meal by approximately 15%.[20] Moderate alcohol consumption more than 12 hours prior to a test does not affect the GI.[21]

Many modern diets rely on the glycemic index, including the South Beach Diet, Transitions by Market America, and NutriSystem Nourish Diet.[22] However, others have pointed out that foods generally considered to be unhealthy can have a low glycemic index, for instance, chocolate cake (GI 38), ice cream (37), or pure fructose (19), whereas foods like potatoes and rice have GIs around 100 but are commonly eaten in some countries with low rates of diabetes.[15]

Weight Control

Dietary replacement of saturated fats by carbohydrates with a low glycemic index may be beneficial for weight control, whereas substitution with refined, high glycemic index carbohydrates is not.[23] A Cochrane review found that the adoption of low glycemic index (or load) diets by people who are overweight or obese leads to more weight loss (and better fat control) than the use of diets involving higher glycemic index/load or other strategies.[24] Benefits were apparent even with low glycemic index/load diets that allow people to eat as much as they like.[24] The authors of the review concluded that "Lowering the glycaemic load of the diet appears to be an effective method of promoting weight loss and improving lipid profiles and can be simply incorporated into a person's lifestyle."[24]

In the clinical management of obesity, diets based on a low glycemic index/load appear to provide better glycemic and inflammatory control than ones based on a high glycemic index/load (and therefore could potentially be more effective in preventing obesity-related diseases).[25] In overweight and obese children, adoption of low glycemic index/load diets may not lead to weight loss but might potentially provide other benefits.[26]

Disease Prevention

Several lines of recent [1999] scientific evidence have shown that individuals who followed a low-GI diet over many years were at a significantly lower risk for developing both type 2 diabetes, coronary heart disease, and age-related macular degeneration than others.[27] High blood glucose levels or repeated glycemic "spikes" following a meal can promote these diseases by increasing systemic glycative stress, other oxidative stress to the vasculature, and also by the direct increase in insulin level.[28] The glycative stress sets up a vicious cycle of systemic protein glycation, compromised protein editing capacity involving the ubiquitin proteolytic pathway and autophagic pathways, leading to enhanced accumulation of glycated and other obsolete proteins.[29]

Postprandial hyperglycemia is a risk factor associated with diabetes. A 1998 study shows that it also presents an increased risk for atherosclerosis in the non-diabetic population[30] and that high GI diets, high blood-sugar levels more generally,[31] and diabetes[32]are related to kidney disease as well.

Conversely, there are areas such as Peru and Asia where people eat high-glycemic index foods such as potatoes and high-GI rice without a high level of obesity or diabetes.[*citation needed*] The high consumption of legumes in South America and fresh fruit and vegetables in Asia likely lowers the glycemic effect in these individuals.[*citation needed*] The mixing of high- and low-GI carbohydrates produces moderate GI values.[*citation needed*]

A study from the University of Sydney in Australia suggests that having a breakfast of white bread and sugar-rich cereals, over time, can make a person susceptible to diabetes, heart disease, and even cancer.[33]

A study published in 2007 in the American Journal of Clinical Nutrition found that age-related adult macular degeneration (AMD), which leads to blindness, is 42% higher among people with a high-GI diet, and concluded that eating a lower-GI diet would eliminate 20% of AMD cases.[34]

The American Diabetes Association supports the glycemic index but warns that the total amount of carbohydrates in the food is still the strongest and most important indicator and that everyone should make their own custom method that works best for them.[35][36]

The International Life Sciences Institute concluded in 2011 that because there are many different ways of lowering glycemic response, not all of which have the same effects on health, "It is becoming evident that modifying the glycemic response of the diet should not be seen as a stand-alone strategy but rather as an element of an overall balanced diet and lifestyle."[37]

A systematic review of a few human trials examined the potential of a low GI diet to improve pregnancy outcomes. Potential benefits were still seen despite no groundbreaking findings in maternal glycemia or pregnancy outcomes. In this regard, more women under a low GI diet achieved the target treatment goal for the postprandial glycemic level and reduced their need for insulin treatment. A low GI diet can also provide greater benefits to overweight and obese women. Interestingly, intervention at an early stage of pregnancy has shown a tendency to lower birth weight and birth centile in infants born to women with GDM.[38]

Other Factors

Depending on quantities, the number of grams of carbohydrate in a food can have a bigger impact on blood sugar levels than the glycemic index does. Consuming less dietary energy, losing weight, and carbohydrate counting can be better for lowering the blood sugar level.[9] Carbohydrates impact glucose levels most profoundly,[39] and two foods with the same carbohydrate content are, in general, comparable in their effects on blood sugar.[39] A food with a low glycemic index can have a high carbohydrate content or vice versa; this can be accounted for with the glycemic load (GL) where GL= GI% x grams of carbohydrate per serving (Louie JCY, *et al*., 2015]. Consuming carbohydrates with a low glycemic index and calculating carbohydrate intake would produce the most stable blood sugar levels.

Criticism and Alternatives

While the glycemic index of foods is used as a guide to the rise in blood glucose that should follow meals containing those foods, actual increases in blood glucose show considerable variability from person to person, even after consumption of identical meals.[4]This is in part because the glycemic index does not take into account other factors besides glycemic response, such as insulin response, which is measured by the insulin index and can be more appropriate in representing the effects of some food contents other than carbohydrates.[40] In particular, since it is based on the area under the curve of the glucose response over time from ingesting a subject food, the shape of the curve has no bearing on the corresponding GI value. The glucose response can rise to a high level and fall quickly, or rise less high but remain there for a longer time, and have the same area under the curve. For subjects with type 1 diabetes who do not have an insulin response, the rate of appearance of glucose after ingestion represents the absorption of the food itself. This glycemic response has been modeled,[41] where the model parameters for the food enable prediction of the continuous effect of the food over time on glucose values and not merely the ultimate effect that the GI represents.

Although the glycemic index provides some insights into the relative diabetic risk within specific food groups, it contains many counter-intuitive ratings. These include suggestions that bread generally has a higher glycemic ranking than sugar and that some potatoes are more glycemic than glucose. More significantly, studies such as that by Bazzano et al.[42] demonstrate a significant beneficial diabetic effect for fruit compared to a substantial detrimental impact for fruit juice despite these having similar "low GI" ratings.

From blood glucose curves presented by Brand-Miller et al.[43] the main distinguishing feature between average fruit and fruit juice blood glucose curves is the maximum slope of the leading edge of 4.38 $mmol \cdot L^{-1} \cdot h^{-1}$ for fruit and 6.71 $mmol \cdot L^{-1} \cdot h^{-1}$ for fruit juice. This raises the concept that the rate of increase in blood glucose may be a significant determinant, particularly when

comparing liquids to solids that release carbohydrates over time and therefore have an inherently greater area under the blood glucose curve.

This page titled 5.8: Glycemic Index is shared under a CC BY-SA 4.0 license and was authored, remixed, and/or curated by LibreTexts.

GI and its effect on athletic performance have been investigated for several decades. Currently, there is no consensus on whether consuming carbohydrates of a high or low GI improves endurance performance. For now, the athlete is encouraged to follow the carbohydrate recommendations and let their individual experience determine the use of high or low glycemic index foods and supplements before, during, and after exercise. The best advice is to consume "healthier" carbohydrates; i.e. whole grains and complex carbohydrates instead of added sugars. Here is a resource for implementing the GI with athletes: Glycemic Index and the Athlete.

This page titled 5.9: Glycemic Index and the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

5.10: Paper - A Step Towards Personalized Sports Nutrition - Carbohydrate Intake During Exercise

This article summarizes the current literature on carbohydrates and exercise.

Paper: A Step Towards Personalized Sports Nutrition: Carbohydrate Intake During Exercise: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4008807/

This page titled 5.10: Paper - A Step Towards Personalized Sports Nutrition - Carbohydrate Intake During Exercise is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6: LIPIDS BASICS - ANOTHER ENERGY SOURCE FOR THE ATHLETE

6.1: Introduction to Lipids

6.2: What Are Lipids?

6.3: How Lipids Work

6.4: Digestion and Absorption of Lipids

6.5: Understanding Blood Cholesterol

6.6: Balancing Your Diet with Lipids

6.7: Lipids and the Food Industry

6.8: Lipids and Disease

6.9: A Personal Choice about Lipids

6.10: Exercise and fat oxidation

This page titled 6: Lipids Basics - Another Energy Source for the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.1: Introduction to Lipids

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 6.1.1: 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

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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.

This page titled 6.1: Introduction to Lipids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.2: What Are Lipids?

Skills to Develop

- 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.

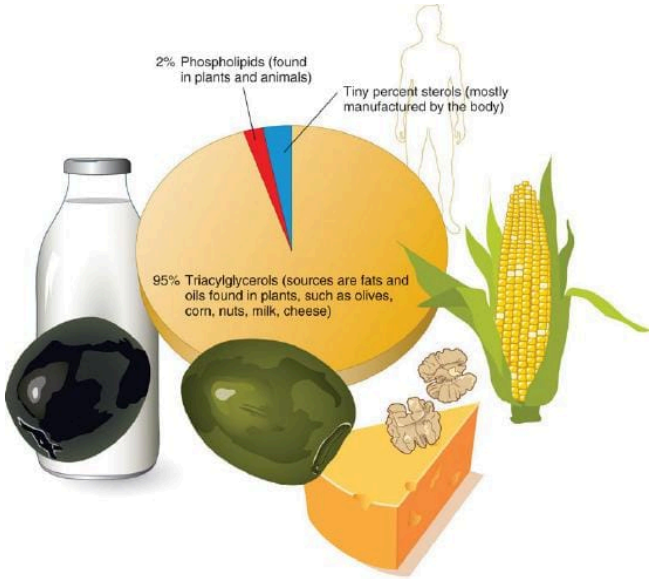


Figure 6.2.1: Types of Lipids

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 "Carbohydrates", 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 6.2.2: 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.

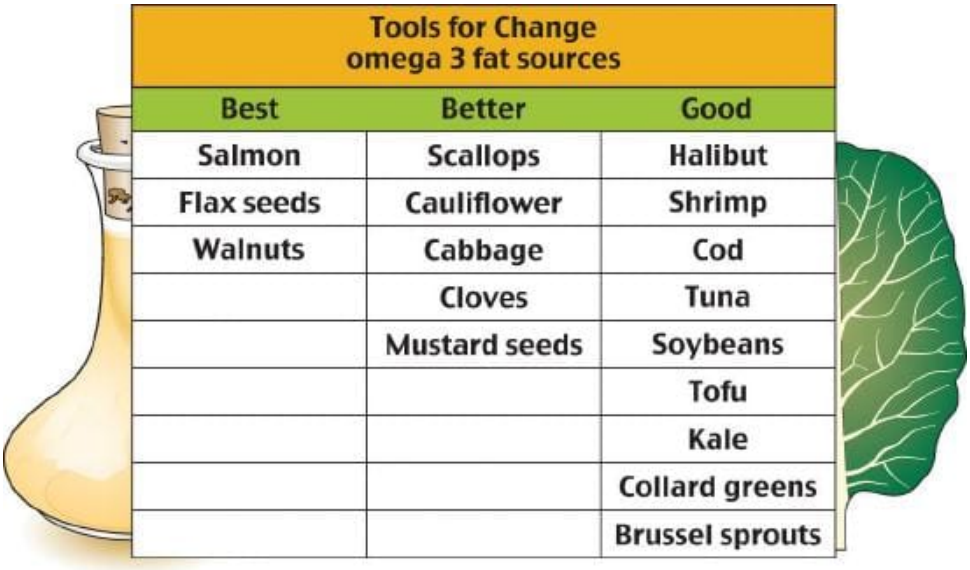


Figure 6.2.3: Food Sources of Fat-Soluble Vitamins

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 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 6.2.4: 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 the 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 the 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.

This page titled 6.2: What Are Lipids? is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.3: How Lipids Work

Skills to Develop

- 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.

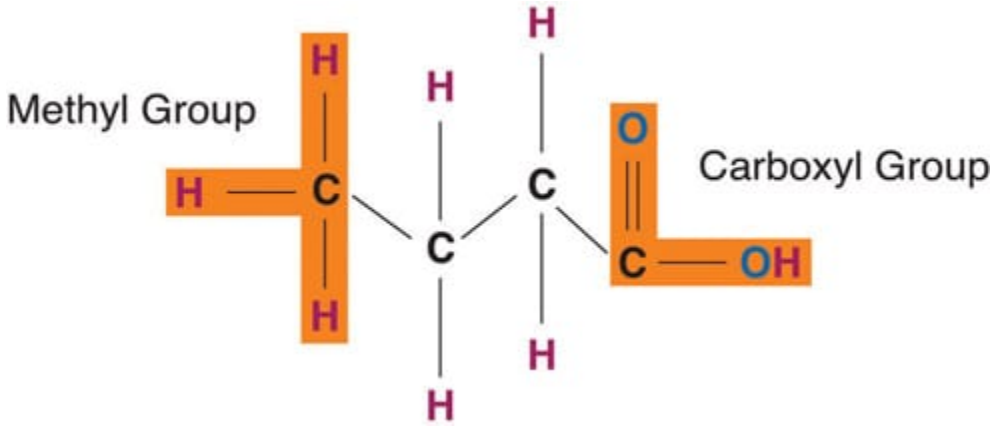


Figure 6.3.1: Structures of a Saturated, Monounsaturated, and Polyunsaturated Fat

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.

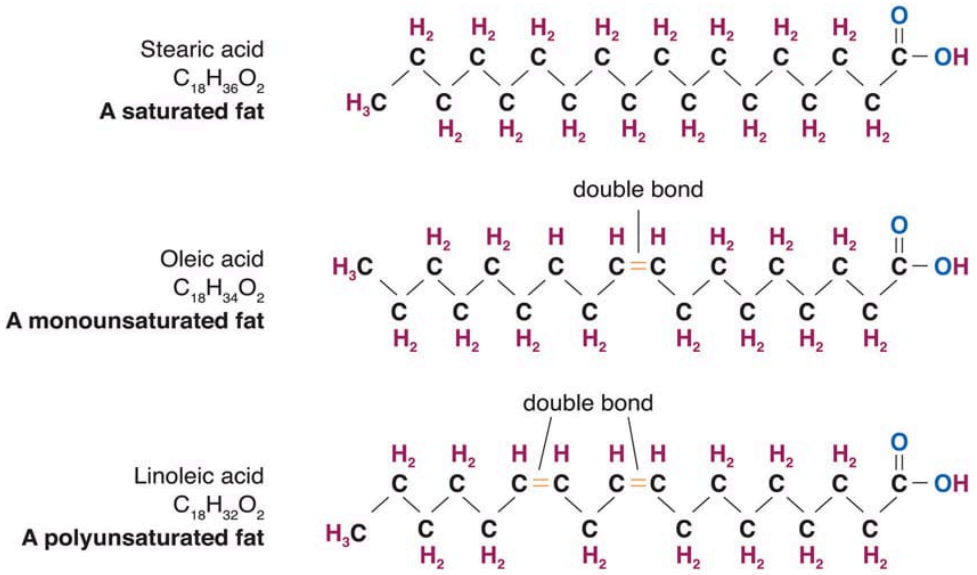


Figure 6.3.2: Chain structures of saturated fatty acids, monounsaturated, and polyunsaturated fatty acids

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; butterfat, 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 melting point temperature than 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 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 using 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 melts 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.

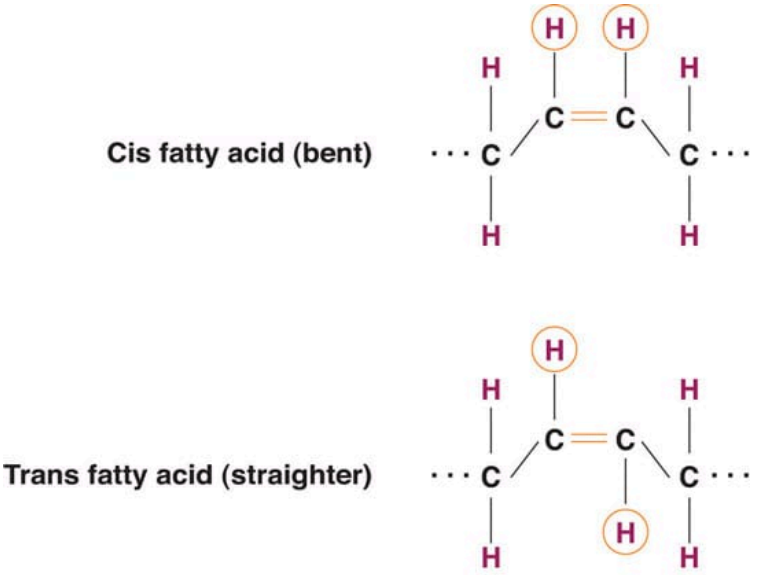


Figure 6.3.3: *Cis and trans double bonds.*

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 products. 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 effects 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.

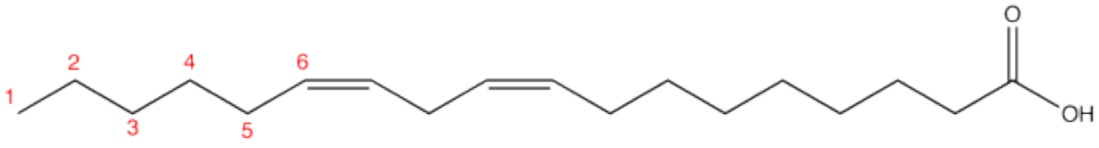
Nonessential and Essential Fatty Acids

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.

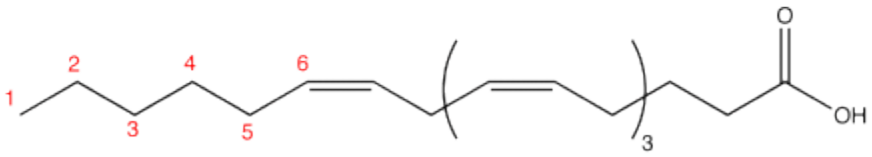
Essential fatty acids must be obtained from food. They fall into two categories—omega-3 and omega-6. The 3 and 6 refer to the position of the first carbon double bond and the omega refers to the methyl end of the chain. Omega-3 and omega-6 fatty acids are precursors to important compounds called eicosanoids. 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.



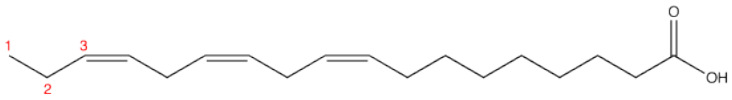
linoleic acid



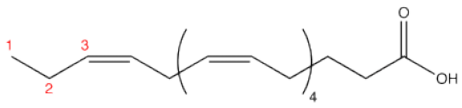
arachidonic acid

Figure 6.3.4: Omega-6 fatty acid showing the first doubly bonded carbon atom from the methyl group is the sixth carbon atom.

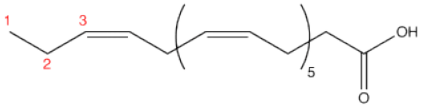
A small percent, about 17%, of dietary alpha-linolenic acid is converted to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Omega-3 fatty acids are involved in regulating a variety of processes including blood pressure, muscle contractions, blood clotting, immune cell production, and blood triglyceride.



linolenic acid



eicosopentaenoic acid (EPA)



docosahexaenoic acid (DHA)

***Figure 6.3.5**: Omega-3 fatty acids have their first double-bond the third carbon atom from the methyl group.*

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 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.

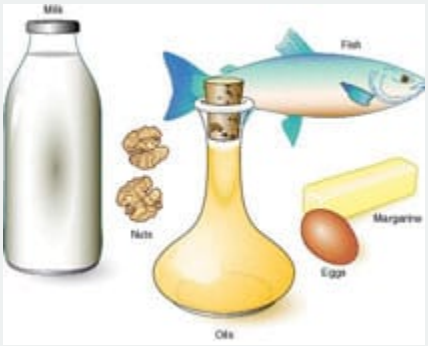


Figure 6.3.6: There are many sources of omega-3 foods.

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 the 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 lecithins 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 determine 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 the 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?

This page titled 6.3: How Lipids Work is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.4: Digestion and Absorption of Lipids

Skills to Develop

- 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.

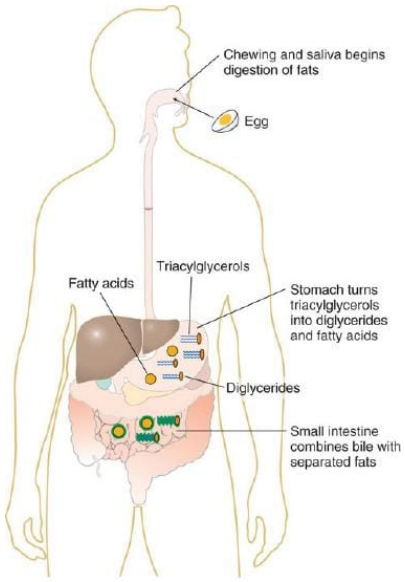


Figure 6.4.1: Lipid Digestion

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.

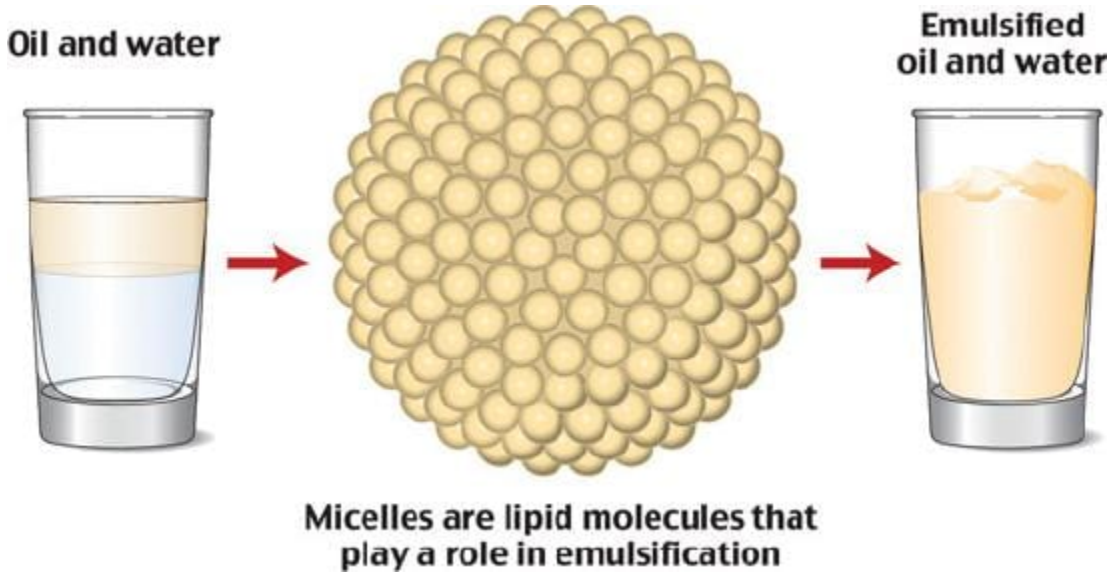


Figure 6.4.2: Fats can travel through the watery environment of the body due to the process of emulsification.

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.

Cholesterol is 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.

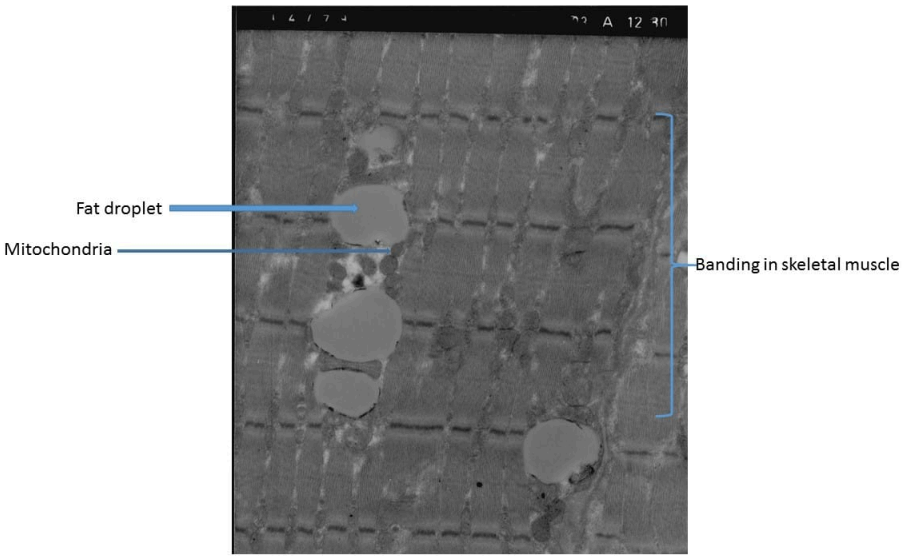


Figure 6.4.3: Adipocyte or fat cell within skeletal muscle.

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 burned 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 transforming 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 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 that 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.

This page titled 6.4: Digestion and Absorption of Lipids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.5: Understanding Blood Cholesterol

Skills to Develop

- 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 and 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.”

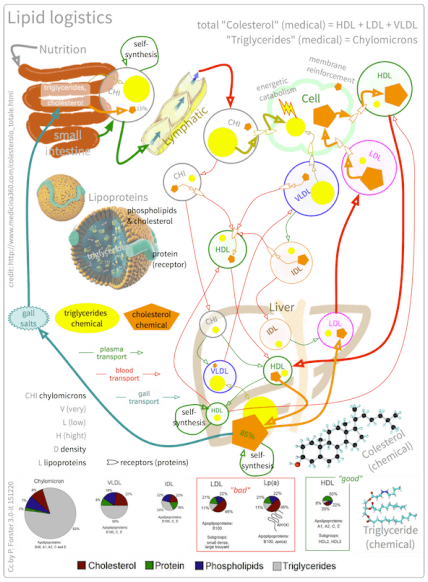


Figure 6.5.1 Formation of the major lipoproteins.

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 the 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, denser, 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 induce a chronic inflammatory effect throughout the body's vast network of vessels. This activity promotes atherosclerosis and significantly increases risk 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 the 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 raise 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 the blood.

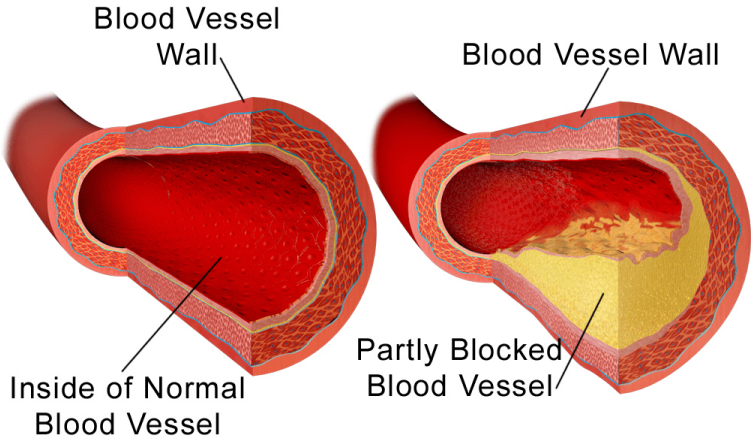


Figure 6.5.2: Illustration comparing a normal blood vessel and partially blocked vessel due to atherosclerotic plaque build-up. Plaque formation along arterial walls impedes blood flow and can create a thrombus, or stationary blood clot. from BruceBlaus (via Wikipedia). For a video of the process click 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 6.5.1: *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 margarine, 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 to 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

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video 6.5.1**: 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 risk 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?

This page titled 6.5: Understanding Blood Cholesterol is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.6: Balancing Your Diet with Lipids

Skills to Develop

- 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 the 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 6.6.1: 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) which 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 which 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 the 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.

This page titled 6.6: Balancing Your Diet with Lipids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.7: Lipids and the Food Industry

Skills to Develop

- 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 6.71 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 result 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 the 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 causes 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, and 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?

This page titled 6.7: Lipids and the Food Industry is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.8: Lipids and Disease

Skills to Develop

- 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 bradycardia), 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 6.8.1: *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 elevate 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 on 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 decreasing 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.

This page titled 6.8: Lipids and Disease is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.9: A Personal Choice about Lipids

Skills to Develop

- 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.

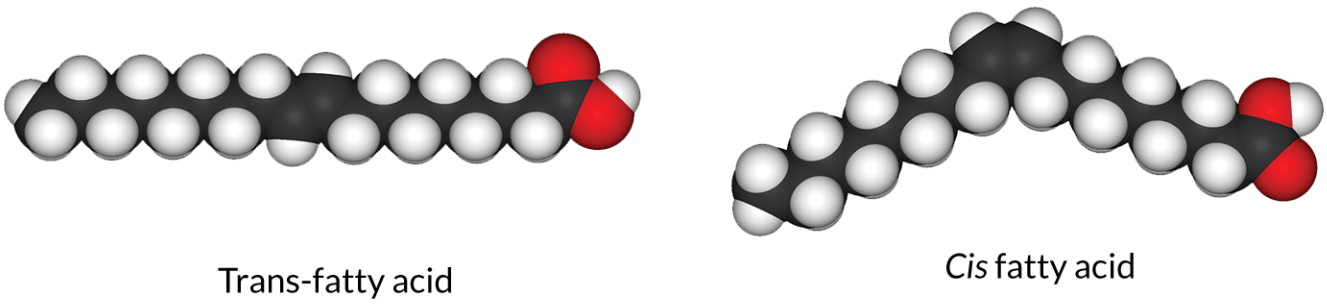


Figure 6.9.1: When a lipid molecule is unhydrogenated, the double bonds between the carbons keep it kinky and a liquid at room temperature. If that fat realigns into the trans formation, it gets straighter, forming up into a solid.

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 them 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?

This page titled 6.9: A Personal Choice about Lipids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

6.10: Exercise and fat oxidation

In the proceeding sections, you learned the basics about lipids. One of the fuels burned during exercise is fat/lipid and many things affect the amount of fat our muscle burns as a fuel. This blog introduces in simple language fat burning, What is FatMax?, while this article provides the scientific rationale: Paper: Understanding the factors that affect maximal fat oxidation: https://jissn.biomedcentral.com/arti...970-018-0207-1

This page titled 6.10: Exercise and fat oxidation is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7: PROTEIN BASICS - THE ATHLETE'S STRUCTURE BUILDER

Paper: International Society of Sports Nutrition Position Stand: Protein and Exercise https://jissn.biomedcentral.com/arti...970-017-0177-8



- Topic hierarchy

7.1: Chapter Introduction

7.2: Defining Protein

7.3: The Role of Proteins in Foods - Cooking and Denaturation

7.4: Protein Digestion, Absorption and Metabolism

7.5: Protein's Functions in the Body

7.6: Diseases Involving Proteins

7.7: Proteins, Diet, and Personal Choices

7.8: Protein and the Athlete

This page titled 7: Protein Basics - The Athlete's Structure Builder is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.1: 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 7.1.1 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 an 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.

This page titled 7.1: Chapter Introduction is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.2: Defining Protein

Skills to Develop

- 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 7.2.1 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; Laura Hale)

What Is Protein?

Proteins, simply put, are macromolecules composed of amino acids. Amino acids are commonly called protein 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, hydrogen, a nitrogen-containing *amino* group, and 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.

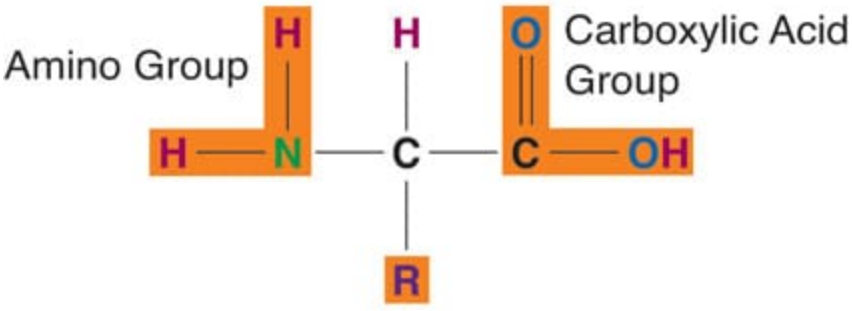


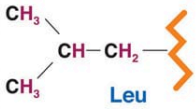
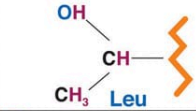
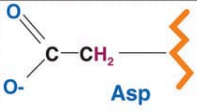
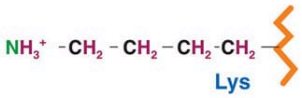
Figure 7.2.2: *Amino Acid Structure*

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 7.2.3: 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 7.2.1: *Essential and Nonessential Amino Acids*

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine*
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 are 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.

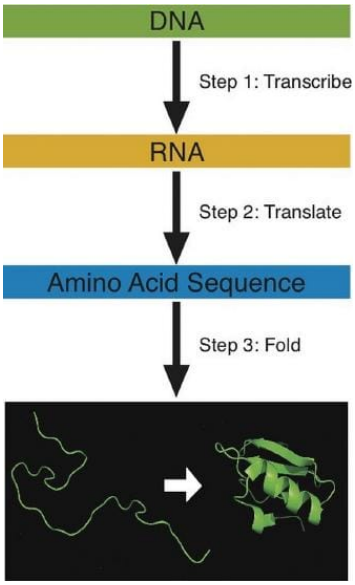


Figure 7.2.4: Building a protein involves three steps: transcription, translation, and folding.

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.

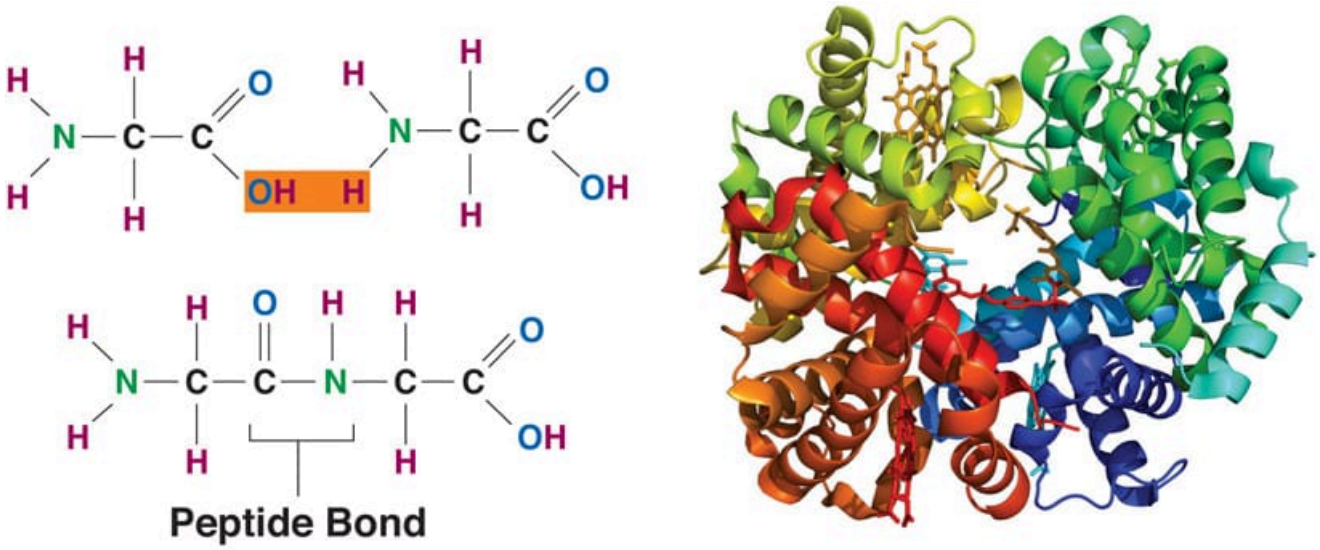


Figure 7.2.5: Connecting amino acids with peptide bonds builds proteins. In the process of translation, amino acids are sequentially strung along in a chain in a specific sequence that spontaneously folds into the correct protein shape.

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 a 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 a 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.

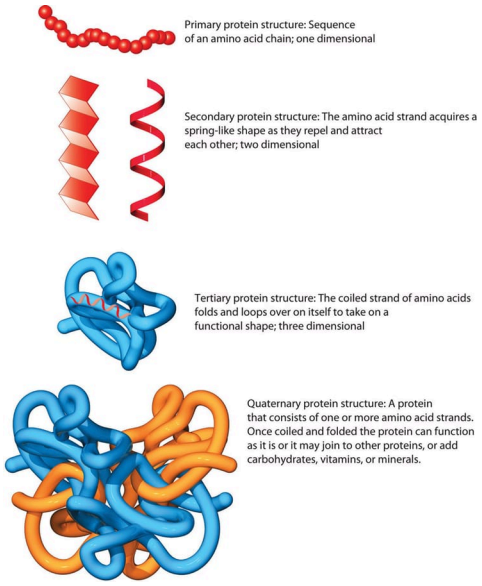


Figure 7.2.6: A protein has four different structural levels.

Video 7.1: From DNA to Protein

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 on 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?

This page titled 7.2: Defining Protein is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.3: The Role of Proteins in Foods - Cooking and Denaturation

Skills to Develop

- 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 7.3.1: 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 used 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).

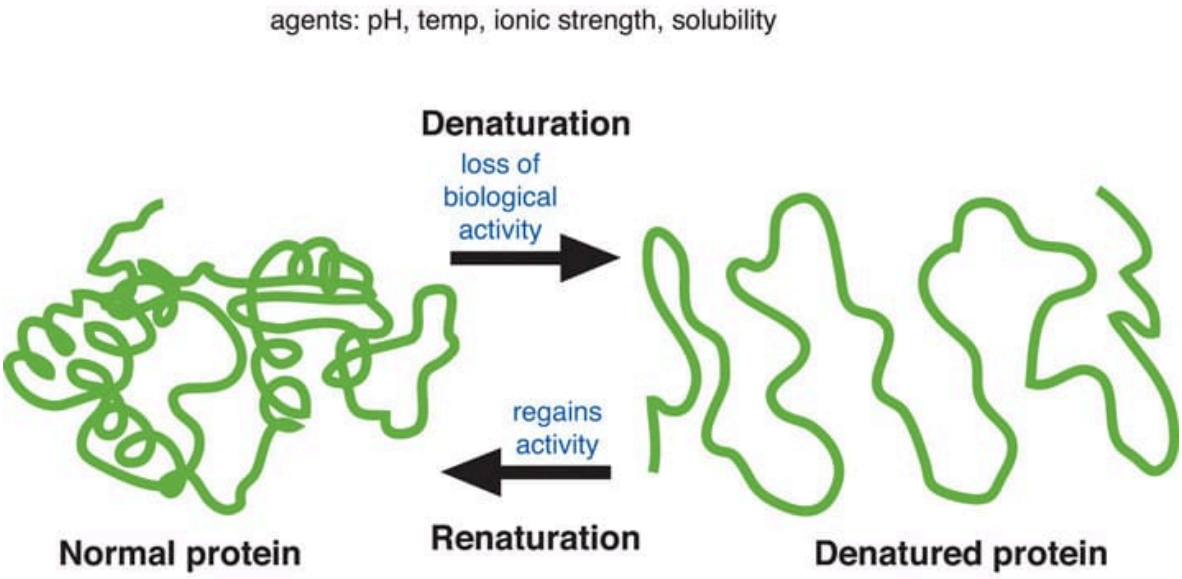


Figure 7.3.2: When a protein is exposed to a different environment, such as increased temperature, it unfolds into a single strand of amino acids.

Interactive 7.3.1: 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?

This page titled 7.3: The Role of Proteins in Foods - Cooking and Denaturation is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.4: Protein Digestion, Absorption and Metabolism

Skills to Develop

- 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 7.4.1: 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.

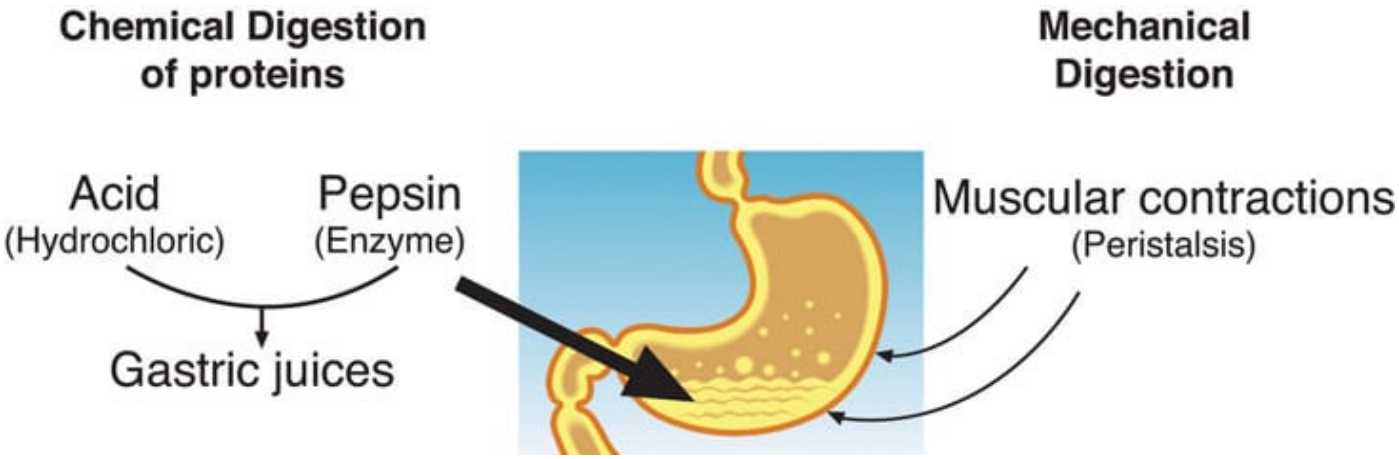


Figure 7.4.2: Protein digestion requires the chemical actions of gastric juice and the mechanical actions of the stomach.

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 your 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 bloodstream and are transported to the liver by the hepatic (liver) portal vein. This is known as 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 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 maintain 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).

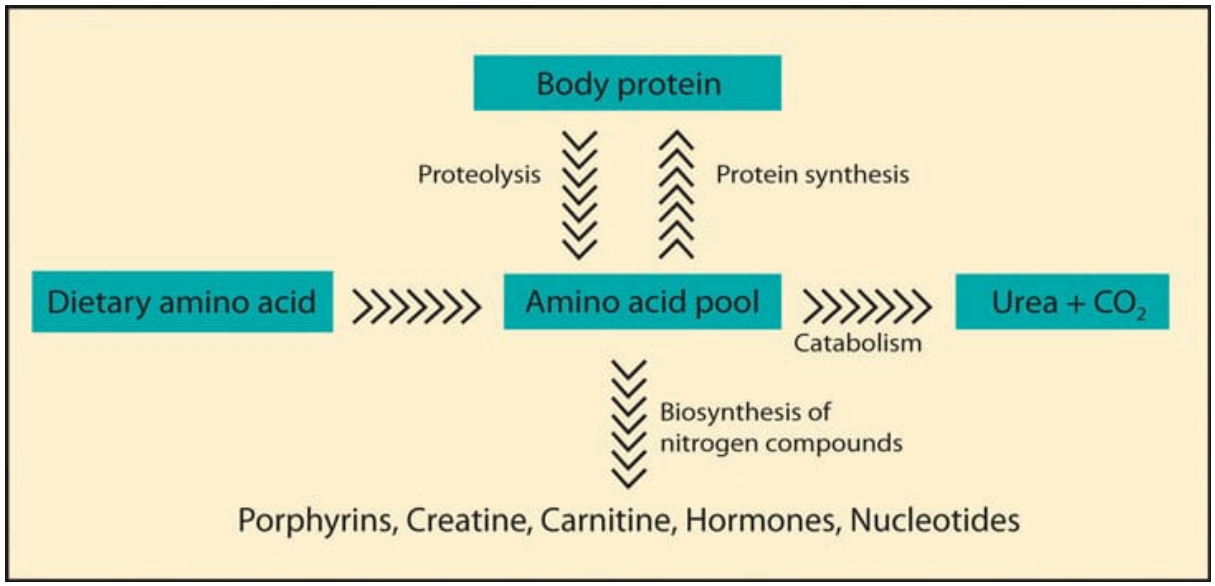


Figure 7.4.3: Amino acids in the cellular pool come from dietary protein and from the destruction of cellular proteins. The amino acids in this pool need to be replenished because amino acids are outsourced to make new proteins, energy, and other biological molecules.

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?

This page titled 7.4: Protein Digestion, Absorption and Metabolism is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.5: Protein's Functions in the Body

Skills to Develop

- 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.

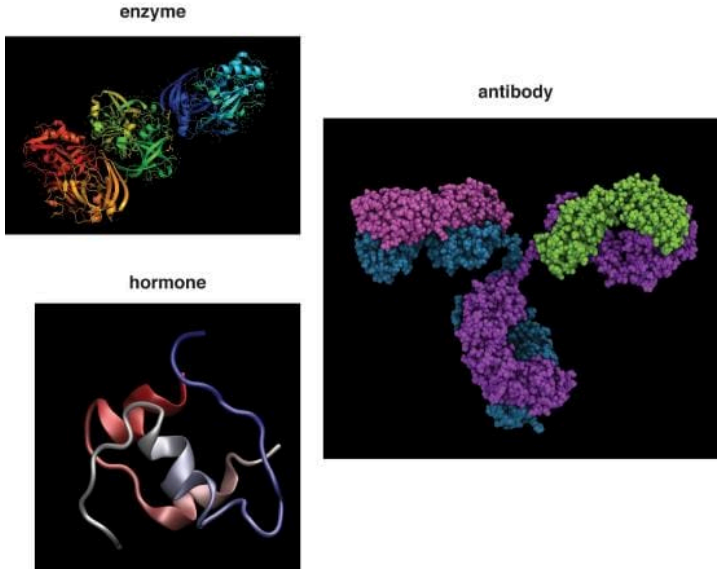


Figure 7.5.1: Proteins come in all sizes and shapes.

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.

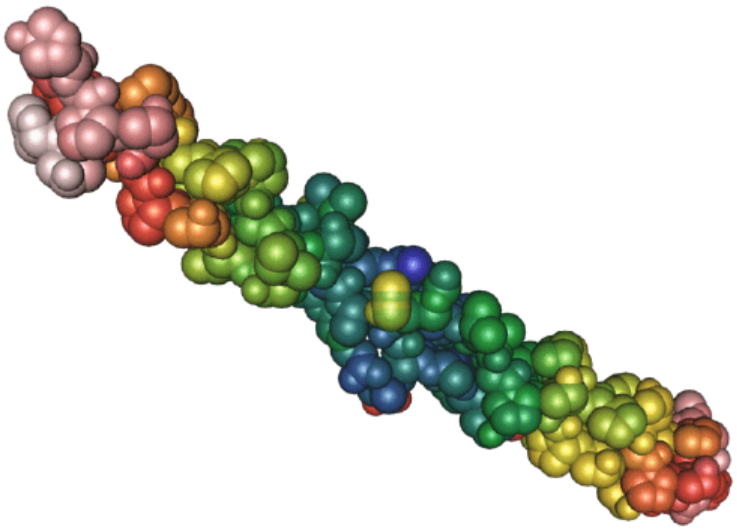


Figure 7.5.2: *Collagen: A strong protein made up of three intertwined peptides. (CC-SA-By; Nevit Dilmen).*

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 7.5.1: 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.

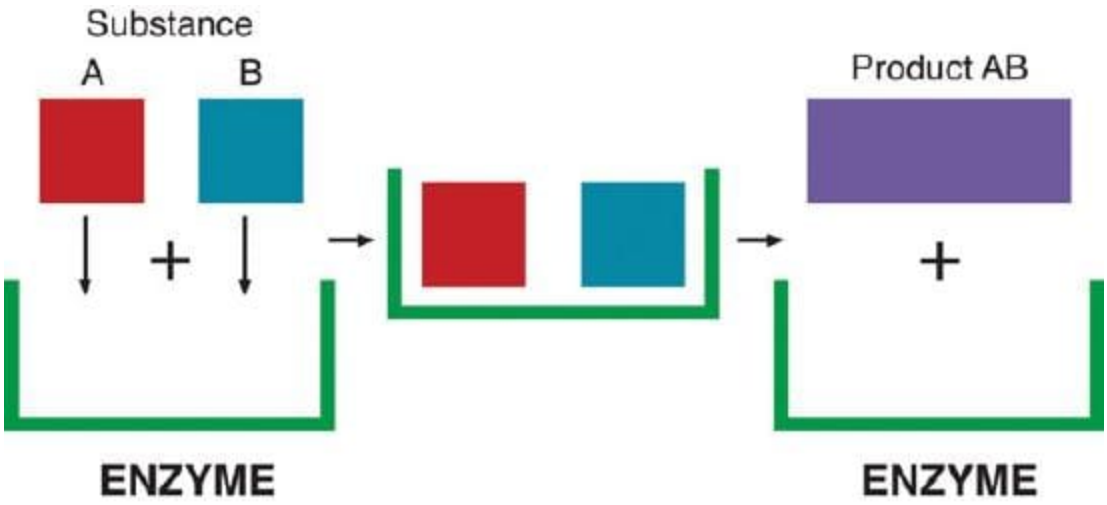


Figure 7.5.3: Enzymes are proteins. An enzyme's job is to provide a site for substances to chemically react and form a product and decrease the amount of energy and time it takes for this to happen.

Video 7.5.2: 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 at the extreme, but rather is minimized to preserve the status quo.

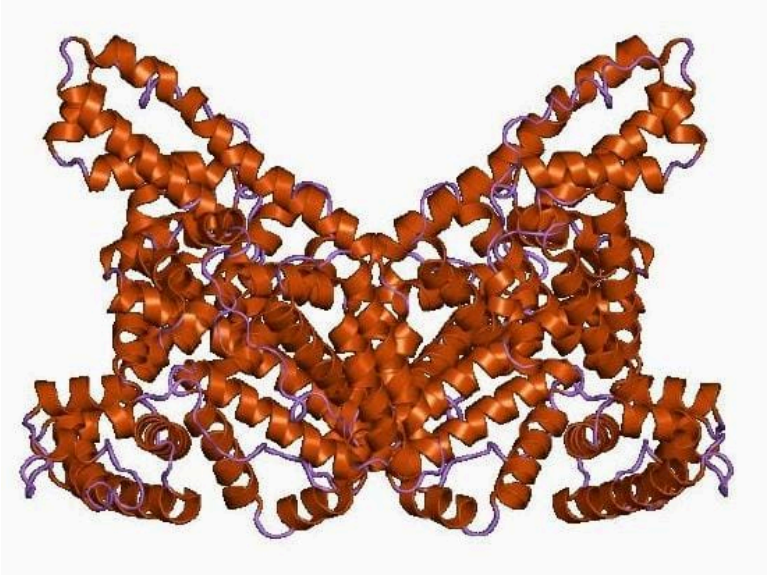


Figure 7.5.4: The butterfly-shaped protein, albumin, has many functions in the body including maintaining fluid and acid-base balance and transporting molecules. Cartoon representation of the molecular structure of protein registered with 1ao6 code. (Public Domain; Jawahar Swaminathan and MSD staff at 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 7.5.5).

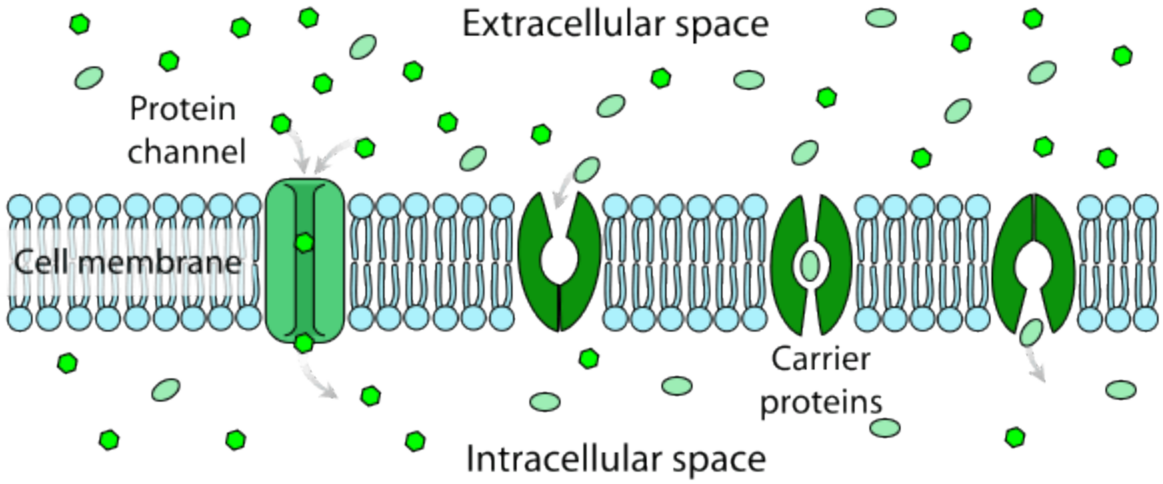


Figure 7.5.5: Molecules move in and out of cells through transport proteins, which are either channels or carriers. Facilitated diffusion in the cell membrane, showing ion channels (left) and carrier proteins (three on the right). (Public Domain; LadyofHats).

Protection

Earlier we discussed that the strong collagen fibers in the 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.

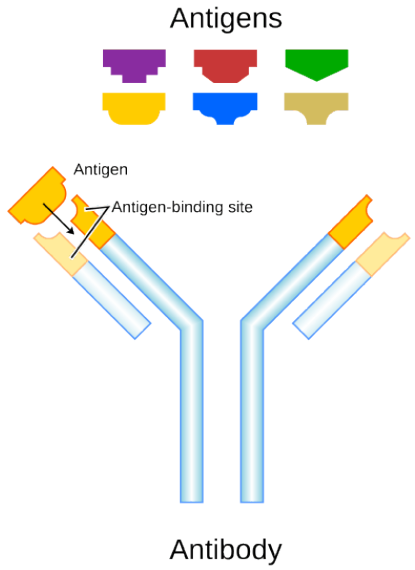


Figure 7.5.6: Proteins play a role in protecting the body against unwanted intruders. Antibodies surround and attack an influenza virus via "antigens" on their surface. Each antibody binds to a specific antigen; an interaction similar to a lock and key. (Public Domain; Fvasconcellos and USA government).

Video 7.5.3: 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, the 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 role in the immune system, what do you think might occur more frequently in a person whose diet is protein deficient?

This page titled 7.5: Protein's Functions in the Body is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.6: Diseases Involving Proteins

Skills to Develop

- 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.

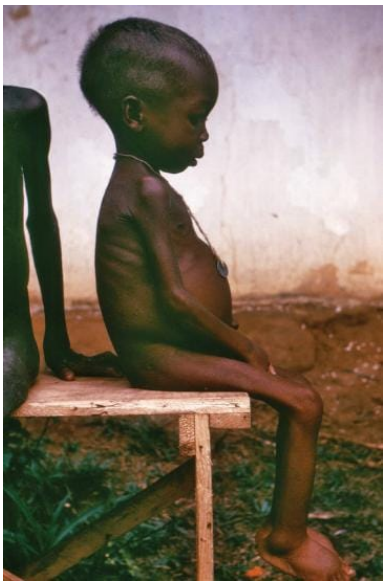


Figure 7.6.1: Kwashiorkor is a disease brought on by a severe dietary protein deficiency. Symptoms include edema of legs and feet, light-colored, thinning hair, anemia, a pot-belly, and shiny skin. (Public domain; Centers for Disease Control and Prevention).

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.

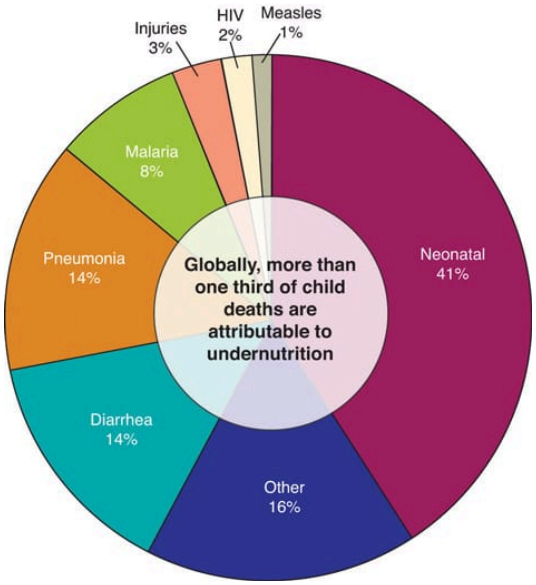


Figure 7.6.2: Causes of death for children under the age of five, worldwide.

Interactive 7.6.1

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 try the diet and stop only to 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, cause 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?

This page titled 7.6: Diseases Involving Proteins is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.7: Proteins, Diet, and Personal Choices

Skills to Develop

- 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 7.7.1: *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.

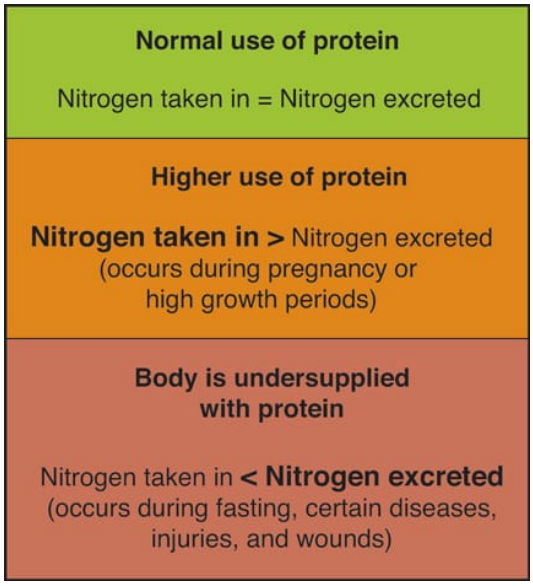


Figure 7.7.1: Nitrogen Balance

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 7.7.2: *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

Food	Protein Content (g)	Saturated Fat (g)	Cholesterol (mg)	Calories
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
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 7.7.1

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 to choose 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 7.7.2

The USDA manages the website myplate.gov. The site provides a lot of tips and information about protein-rich foods.
https://www.myplate.gov/eat-healthy/protein-foods

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 7.7.2). The only animal-based protein that is not complete is gelatin, which consists of the protein, collagen.



Figure 7.7.2: 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. See Table 7.7.4 for complementing protein sources the vegan way.

***Table 7.7.3**: 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 7.7.4: *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

Vegans 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 7.7.5: 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 7.7.6: *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 7.7.7: *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 analyses, 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 7.7.3

In addition to the information in Tables 7.7.6 and 7.7.7, this website 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 for vegetarian diets.

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. https://www.eatingwell.com/category/4304/vegetarian-meal-plans/

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 7.7.3: 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 7.7.8: *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 7.7.4

Visit "Nutrition 101, Eating for Exercise and Sports." This USDA site contains a wealth of nutritional information for active people.

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 7.7.4: 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.

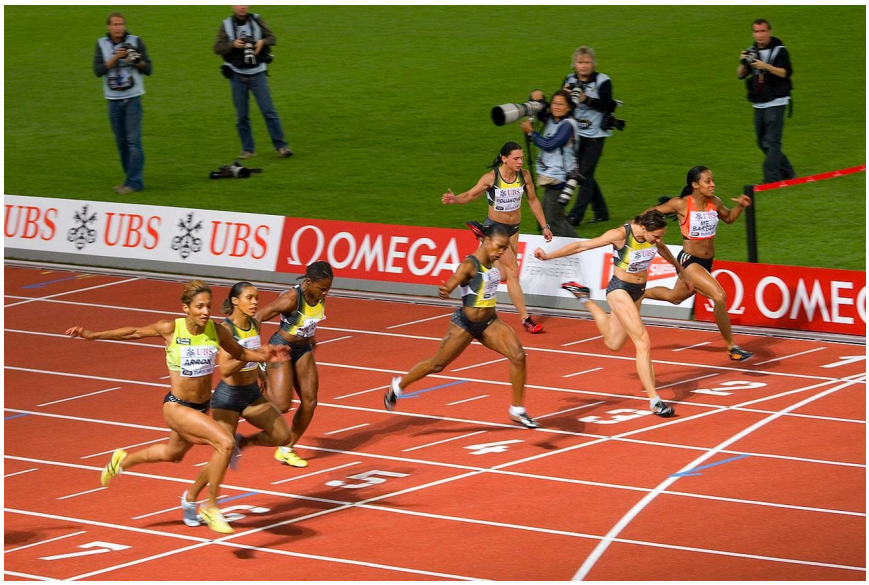


Figure 7.7.5: Many Olympic athletes have adopted a vegetarian diet which, when implemented effectively, supports a very active and athletic lifestyle. The finish of a women's 100 m race. (CC-SA-BY 3.0; Wikipedia/flickr)

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?

This page titled 7.7: Proteins, Diet, and Personal Choices is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

7.8: Protein and the Athlete

There are several organizations that take a position on nutrition for athletes. One such organization is the International Society of Sports Nutrition. Here is their position stand on protein and exercise: Position paper ISSN protein and exercise.

This page titled 7.8: Protein and the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8: VITAMIN AND MINERAL BASICS - METABOLIC REGULATORS

- Topic hierarchy

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

8.5: Bone Structure and Function

8.6: Bone Mineral Density is an Indicator of Bone Health

8.7: Micronutrients Essential for Bone Health - Calcium and Vitamin D

8.8: Deficiency, Supplementation, and Choices

8.9: Other Essential Micronutrients for Bone Health

8.10: Blood's Function in the Body and in Metabolism Support

8.11: Vitamins Important for Metabolism and for Blood Function and Renewal

8.12: Minerals Important for Blood Function and Renewal

8.13: Iron-Deficiency Anemia

8.14: Vitamins Important for Metabolism

8.15: Minerals Important for Metabolism and for Blood Function and Renewal

This page titled 8: Vitamin and Mineral Basics - Metabolic Regulators is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

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 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)

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 8.1.1: 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 an 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.

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 8.1.1

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 8.1.1: 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.

Template:HideTOC

This page titled 8.1: Chapter Introduction is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.2: Generation of Free Radicals in the Body

Skills to Develop

- 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 s*ingularly* 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.

Previously, 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 change, 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 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, and aids in regenerating vitamin E
Carotenoids	Free radical scavengers
Lipoic acid	Free radical scavenger, aids in the 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 their 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 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 the 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?

This page titled 8.2: Generation of Free Radicals in the Body is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.3: Antioxidant Micronutrients

Skills to Develop

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, bones, 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 are 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 of 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
Children (4–8 years)	25	650
***denotes Adequate Intake**		

Age Group	RDA Males and Females mg/day	UL
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, acting as a pro-oxidant, and giving 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

Food	Serving	Vitamin C (mg)
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 "Lipids" 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
***denotes Adequate Intake**		

Age Group	RDA Males and Females mg/day	UL
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 "Vitamin E Content of Various Foods" 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/.

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 take 1-2 years to manifest since it is 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 the vitamin, 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 the 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 prevent 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, and 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 as 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 a 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 between 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 enhances 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, especially flaxseed. 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 phytochemicals 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 functions, 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 those who eat food grown in areas where the soil levels of selenium are low, for example, in 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
Crabmeat	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 "Generation of Free Radicals in the Body" 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 about 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.

This page titled 8.3: Antioxidant Micronutrients is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.4: The Whole Nutrient Package versus Disease

Skills to Develop

- 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. Buoyed, 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 "Nutrients Important to Fluid and Electrolyte Balance" 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 you should be eating go to MyPlate.

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." https://www.hud.gov/sites/documents/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 Americans' 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." May 2022. https://www.cdc.gov/obesity/download...web_tag508.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, farmer's 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 the 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.

This page titled 8.4: The Whole Nutrient Package versus Disease is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.5: Bone Structure and Function

Skills to Develop

- 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 8.5.1*: 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 the 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.

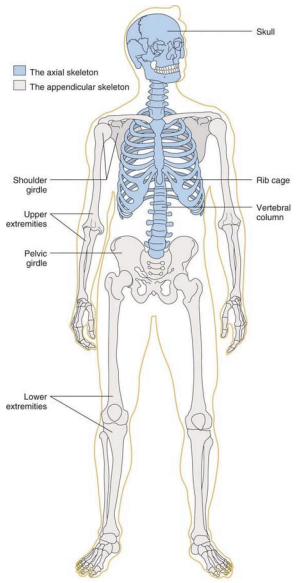


Figure 8.5.1: The human skeleton contains 206 bones. It is divided into two main parts, the axial and appendicular. © Networkgraphics

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 bones: 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 allow 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.

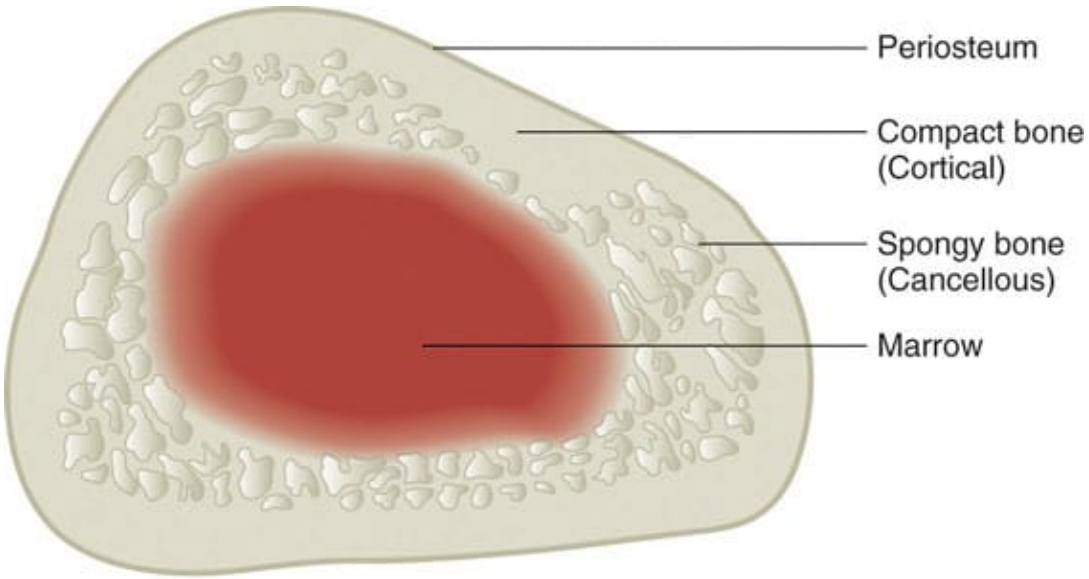


Figure 8.5.2: The Arrangement of Bone Tissues. Bone is composed of organized living tissues. © Networkgraphics

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. 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 8.5.2). 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 more dense 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 8.5.3). 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.

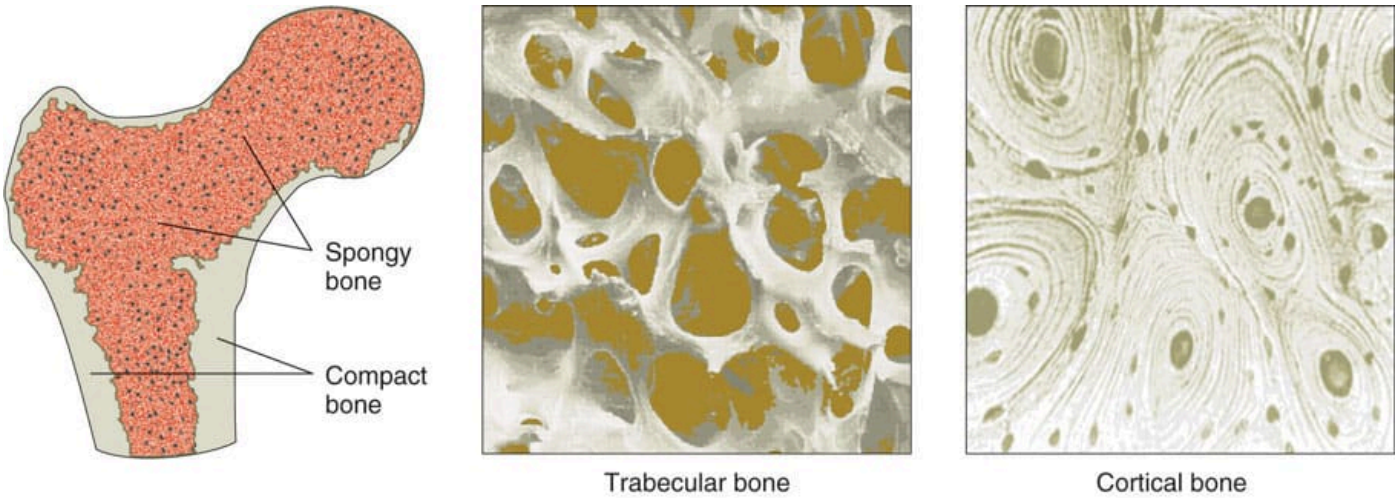


Figure 8.5.3: The two basic tissue types of bones are trabecular and cortical. Trabecular (spongy) and cortical (compact) bone tissues differ in their microarchitecture and porosity. © Networkgraphics

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. In adulthood, 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 8.5.2, 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 8.5.2*: Bone Modification. This video on bone remodeling demonstrates a bone's adaptability to mechanical stresses.*
https://www.youtube.com/watch?v=yENNqRJ2mu0

The first step in bone remodeling is osteocyte activation (Figure 8.5.4). 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.

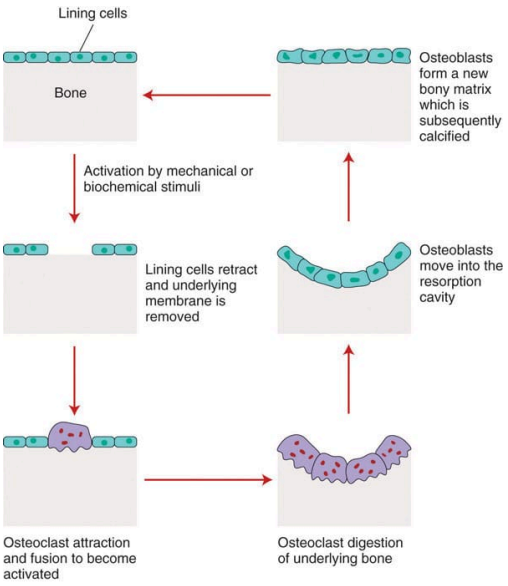


Figure 8.5.4*: Bone remodeling occurs in four steps: activation, osteoclast resorption, surface preparation, and building new bone tissue. © Networkgraphics*

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 that 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.

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?

This page titled 8.5: Bone Structure and Function is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.6: Bone Mineral Density is an Indicator of Bone Health

Skills to Develop

- 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 8.6.1). 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.

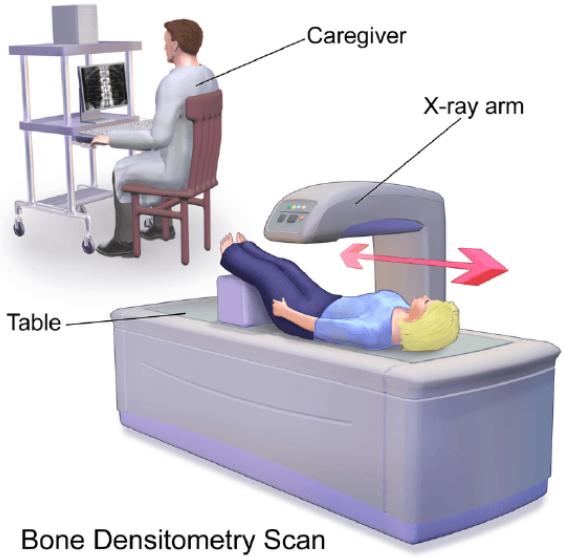


Figure 8.6.1: Bone Densitometry Scan. This image was donated by Blausen Medical. "Blausen gallery 2014". Wikiversity Journal of Medicine. DOI:10.15347/wjm/2014.010. ISSN 20018762.

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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video** 8.6.1**:** 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.

This page titled 8.6: Bone Mineral Density is an Indicator of Bone Health is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.7: Micronutrients Essential for Bone Health - Calcium and Vitamin D

Skills to Develop

- 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.

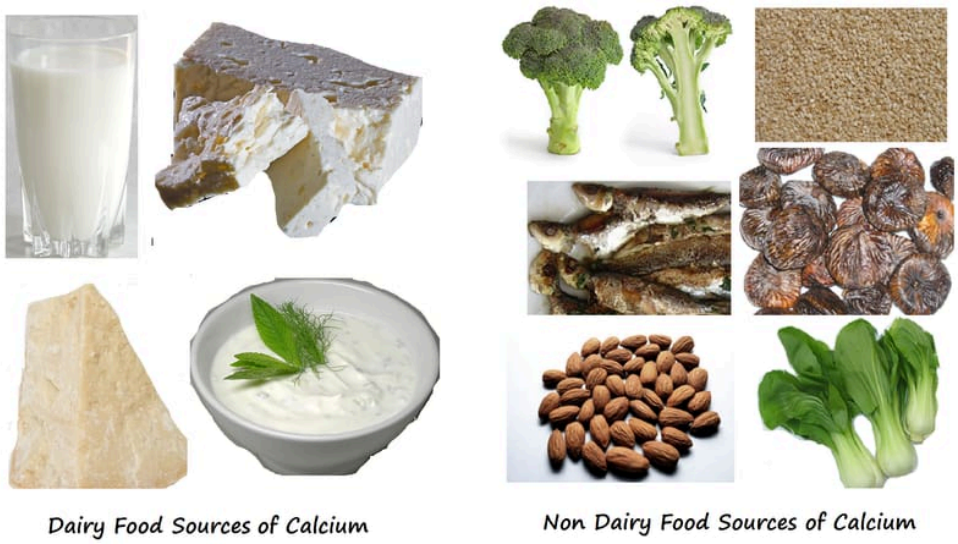


Figure 8.7.1: Calcium is an important mineral for multiple body functions. It is important to consume calcium-rich foods to sustain proper dietary intake of calcium. (CC BY-SA 4.0;'Brookepinsent)

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 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 (junctions 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.

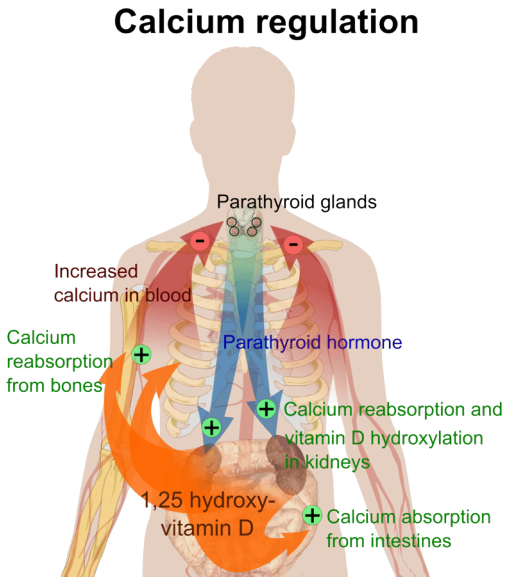


Figure 8.7.2: This is a typical negative feedback loop in which low calcium levels in the blood stimulate PTH release. PTH increases the movement of calcium from the bones, kidneys, and intestine to the blood with the help of activated vitamin D. The now higher calcium levels in the blood shut off further 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 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 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 by 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 other risk factors for cardiovascular diseases, 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 8.7.1: *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
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 8.7.3: 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 non-dairy 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 non-dairy 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 8.7.4: 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 8.7.2: *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 nigari, 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

Food, Standard Amount	Calcium (mg)	Calories
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 are 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).

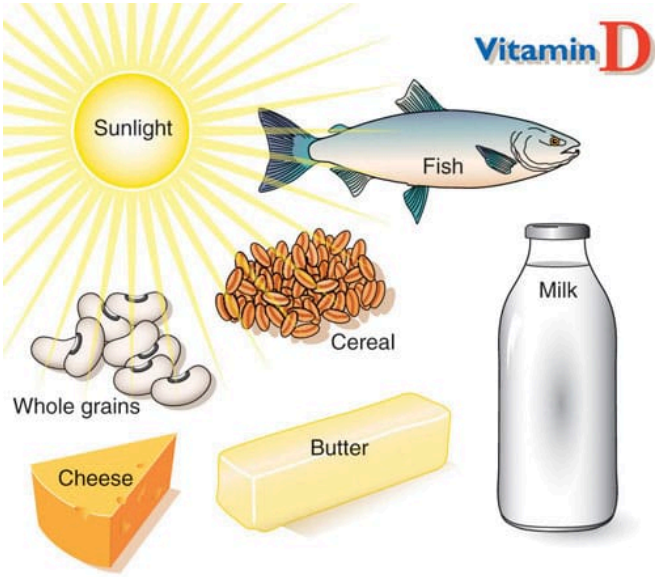


Figure 8.7.5: *Vitamin D Food Sources. © Networkgraphics*

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 casual exposure to the UVB rays in sunlight. For example, healthy light-skinned individuals can make sufficient vitamin D to meet the body's needs 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 is 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 8.7.1 Vitamin D Production in the Body

Visit this website to review the activation of vitamin D to calcitriol. http://www.vivo.colostate.edu/hbooks/pathphys/endocrine/otherendo/vitamind.html

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 nanograms 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.

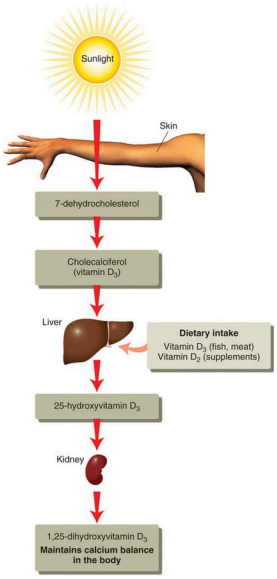


Figure 8.7.6: The Activation of Vitamin D to Calcitriol. © Networkgraphics

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 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.

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 8.7.3**: 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.

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 suggests vitamin D prevents the growth of certain cancers, blocks inflammatory pathways, reverses atherosclerosis, increases insulin secretion, 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 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 including 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 to 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)

This page titled 8.7: 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.

8.8: Deficiency, Supplementation, and Choices

Skills to Develop

- 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 8.8.1: 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 intake 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 "Micronutrients Essential for Bone Health: Calcium and Vitamin D" 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 8.8.2: 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 shells, 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 shells 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 shells 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 of 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 aged 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 8.8.3: 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 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 a need for caution when choosing different brands of calcium supplements. Oyster shells 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

This page titled 8.8: Deficiency, Supplementation, and Choices is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.9: Other Essential Micronutrients for Bone Health

Skills to Develop

- 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 to take one particular supplement. In Table 9.5.1, notice the important nutrients for bone health and good food sources for each.

Table 8.9.1: *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 fluoride)
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, chickpeas, liver, and artichoke

Micronutrient	Functional Role in Bone Health	Food Sources
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 8.9.2**: 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 8.9.3**: Calcium and Phosphorus Contents in 100 Grams of Certain Foods*

Foods	Calcium (mg)	Phosphorus (mg)
Dairy Products		

Foods	Calcium (mg)	Phosphorus (mg)
Buttermilk	116	89
Milk, nonfat	123	101
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		

Foods	Calcium (mg)	Phosphorus (mg)
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 8.9.1: For optimal magnesium intake, try consuming whole-grain breads and cereals. (Public domain; Peggy Greb, USDA ARS)

Table 8.9.4: *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 low blood calcium and potassium levels. Hypomagnesium is associated with the 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 8.9.5: *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
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 the 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 8.9.6: *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 promote 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 food to provide an adequate supply of these nutrients?

This page titled 8.9: Other Essential Micronutrients for Bone Health is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.10: Blood's Function in the Body and in Metabolism Support

Skills to Develop

- 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, and waste products like ammonia and urea, gases, enzymes, and hormones. You learned in Chapter 5 "Proteins" 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 "Nutrients Important to Fluid and Electrolyte Balance" 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 the 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video 8.10.1**: 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 the 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.

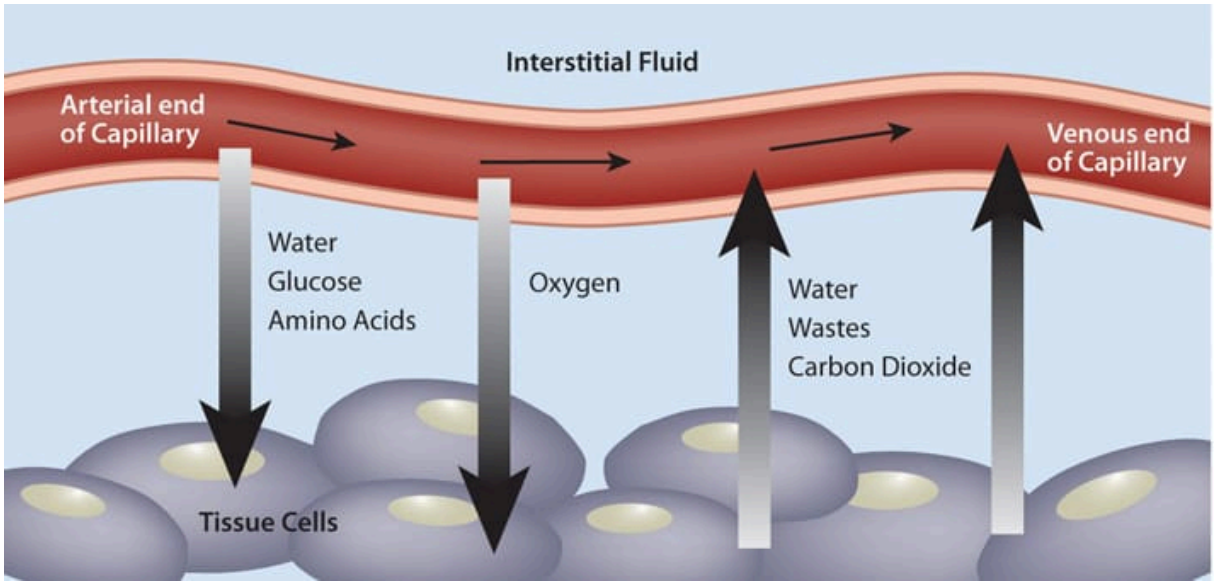


Figure 8.10.2: The Capillary Exchange: Nutrients In and Wastes Out

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 the 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 8.10.3: 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 the 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 aids in the diagnosis of disease risk and is indicative of overall health status. See Table 8.10.1 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 8.10.1: *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

Substance Measured	Indicates
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 8.10.1

Visit the websites of the National Heart, Lung, and Blood Institute and Lab Tests Online to find out more about 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 the 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 aids in the diagnosis of disease risk and is 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

This page titled 8.10: Blood's Function in the Body and in Metabolism Support is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.11: Vitamins Important for Metabolism and for Blood Function and Renewal

Skills to Develop

- 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.

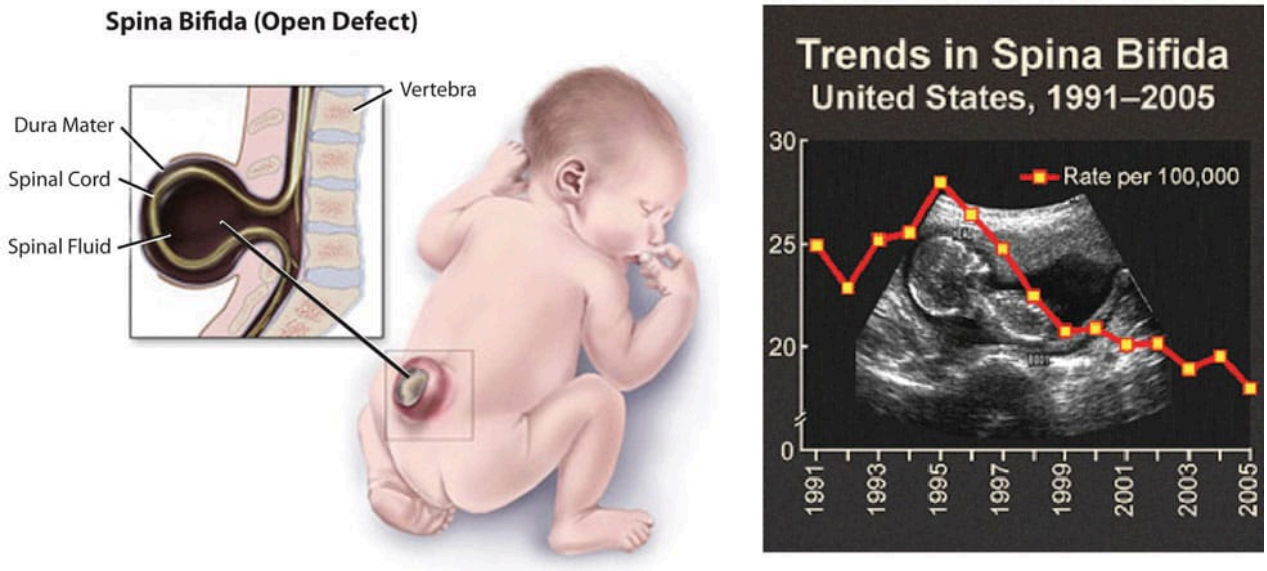


Figure 8.11.1: Spina bifida is a neural-tube defect that can have severe health consequences.

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 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 8.11.3 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 for 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 (ileum). 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 factors. 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} and their deficiency syndromes is given in Table 8.11.1.

Table 8.11.1: *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 8.11.1

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, ultraviolet 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 8.11.3.

***Table 8.11.2**: 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 8.11.3:** 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

Food	Micrograms per Serving	Percent Daily Value

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 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 circulate 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 8.11.1: *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 the 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 is 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 8.11.4*: 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

Food	Micrograms per Serving	Percent Daily Value
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.

This page titled 8.11: Vitamins Important for Metabolism and for Blood Function and Renewal is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.12: 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 8.12.2). 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 recycled from the continuous breakdown of red blood cells.

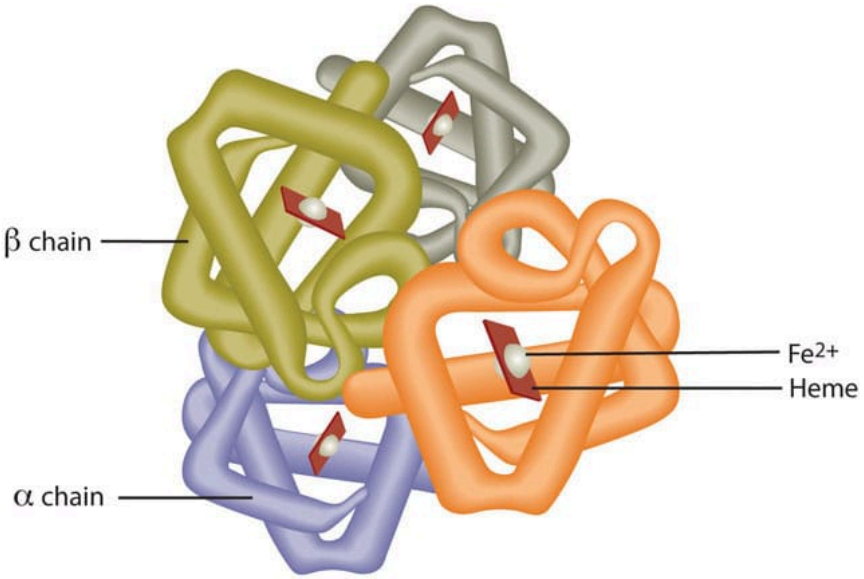


Figure 8.12.1: Hemoglobin is composed of four peptides. Each contains a heme group with iron in the center.

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 8.12.1"). 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video** 8.12.1**:** 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 "Iron-Deficiency Anemia".

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 "Nutrients Important As Antioxidants".

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 8.12.1: *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 is listed for adults in Table 8.12.2 "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 8.12.2: *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
	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.

This page titled 8.12: Minerals Important for Blood Function and Renewal is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.13: Iron-Deficiency Anemia

Skills to Develop

- 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 the 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 a late indicator of iron deficiency
- Erythrocyte protoporphyrin 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 RBCs.
- 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 needs; 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 the 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 improves 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. The first is the acidity of the food; the more acidic the food, the more iron will be released into the food. Second, the longer you leave the food to cook in iron cookware, the 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 8.13.1: *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 8.13.2***:*** *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 chronic diseases such as ulcers, inflammatory diseases, and cancer. Additionally, those who have recently suffered from traumatic blood loss, are frequent blood donors, 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 8.13.1***:*** *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 display symptoms similar to 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 an 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 8.13.1: 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 the 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.

This page titled 8.13: Iron-Deficiency Anemia is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.14: Vitamins Important for Metabolism

Skills to Develop

- 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 makeup 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 8.14.1). Coenzymes and cofactors are essential in catabolic pathways and play a role in many anabolic pathways too.

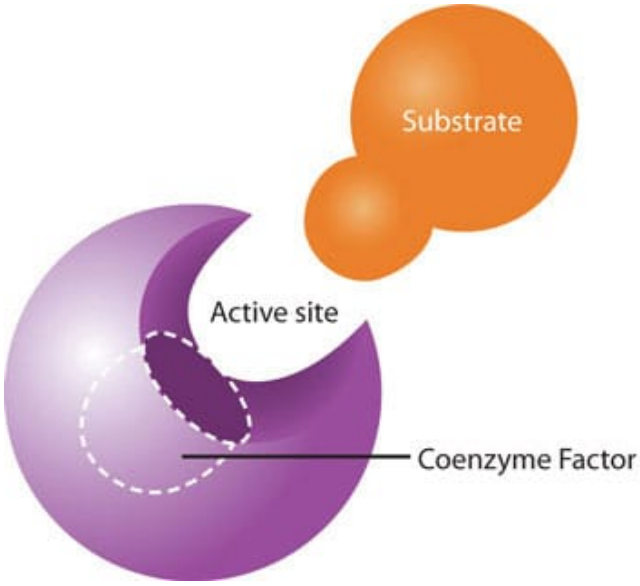


Figure 8.14.1: Coenzymes and cofactors are the particular vitamins or minerals required for enzymes to catalyze a specific reaction.

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 8.14.1). 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 helped 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 large 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 in 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 ingredient 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.

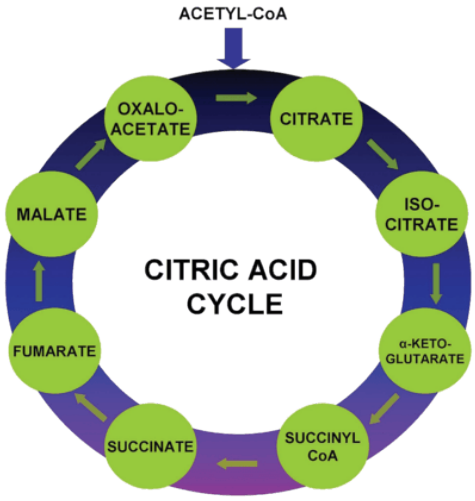


Figure 8.14.2: Vitamin B_5 makes up coenzyme A, which carries the carbons of glucose, fatty acids, and amino acids into the citric acid cycle as Acetyl-CoA.

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.

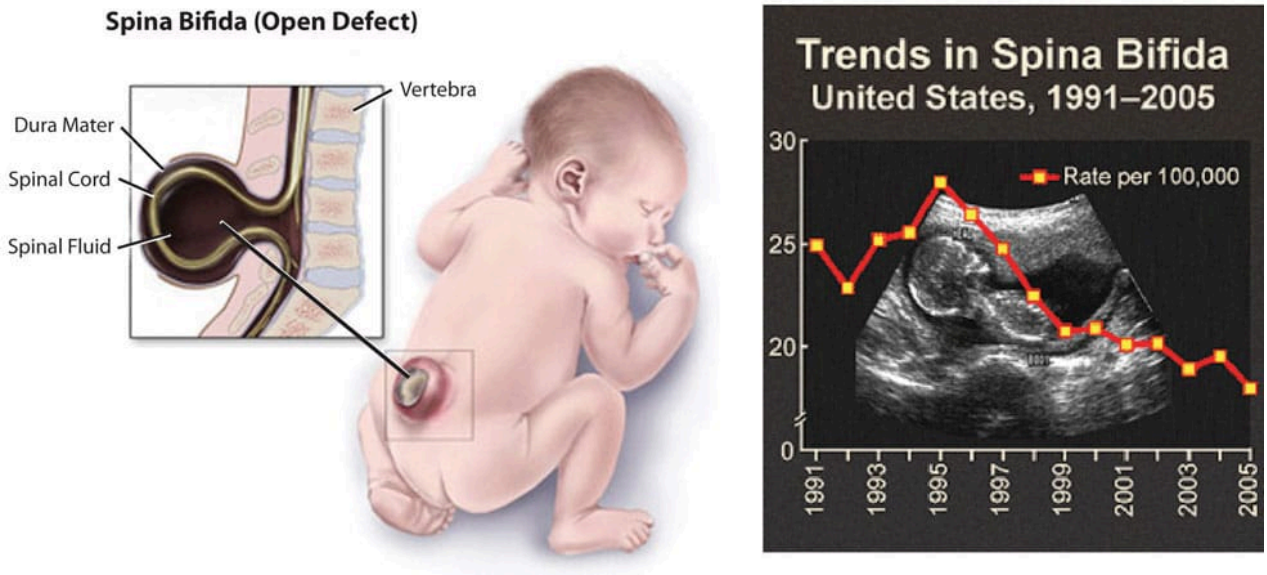


Figure 8.14.3: Spina bifida is a neural-tube defect that can have severe health consequences

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 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, 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 for 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 bloodstream 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 8.14.1.

Table 8.14.1***:*** *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_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 8.14.1). 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 8.14.1*: 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) are set by the IOM. The B vitamins are listed in Table 8.14.2, 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 on their website.

***Table** 8.14.2: 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 8.14.1

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 8.14.3 and 6.6 for good dietary sources of these micronutrients.

Table 8.14.3: *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 8.14.4: *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 the 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 is most highly concentrated in green leafy vegetables. See Table 8.14.5 for a list of dietary sources of vitamin K.

Table 8.14.5: *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.

This page titled 8.14: Vitamins Important for Metabolism is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

8.15: Minerals Important for Metabolism and for Blood Function and Renewal

This page titled 8.15: Minerals Important for Metabolism and for Blood Function and Renewal is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

9: FUELING THE ATHLETE



- Topic hierarchy

9.1: Fueling the Athlete

This page titled 9: Fueling the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

9.1: Fueling the Athlete

Providing the athlete with the right fuel at the right time is important. Here are several essential readings on this topic.

- The first paper is from the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine (2016). It is the position of these three organizations "that the performance of, and recovery from, sporting activities are enhanced by well-chosen nutrition strategies." Here is the link to this important position paper: www.eatrightpro.org/-/media/eatrightpro-files/practice/position-and-practice-papers/position-papers/nutritionathleticperf.pdf?la=en&hash=935E447EC7A3EA7DE5352F4F54F297FCFA8AC708 (Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Acad Nutr Diet. 2016 Mar;116(3):501-528. doi: 10.1016/j.jand.2015.12.006. Erratum in: J Acad Nutr Diet. 2017 Jan;117(1):146. PMID: 26920240.)
- Sports nutrition: A review of the latest guidelines for exercise sport nutrition from the American College of Sports Nutrition, the International Olympic Committee and the International Society for Sports Nutrition 2013): https://www.overvoedingengezondheid....19821-1-PB.pdf
- Selected Issues for Nutrition and the Athlete: A Team Physician Consensus Statement (2013): https://journals.lww.com/acsm-msse/F...te___A.21.aspx
- Role of nutrition in performance enhancement and post-exercise recovery (2015): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4540168/

This short article focuses on nutrition for basketball athletes after they have worked out. Many of the points made can be applied to other sports.

- Recovery Nutrition for the Basketball Athlete: http://www.gssiweb.org/en/sports-science-exchange/Article/sse-166-recovery-nutrition-for-the-basketball-athlete

Athletes may need to travel, so they need tips on eating for eating on the road. Here are two helpful sources from SCAN (Sports, Cardiovascular, and Wellness Nutrition Dietetics Practice Group)

- Eating on the Road (2009): http://www.eatright.org/~/media/eatr..._the_road.ashx
- Eating on the Road (2013): https://www.ncaa.org/sites/default/f...ct%20Sheet.pdf

This page titled 9.1: Fueling the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10: HYDRATION AND THERMOREGULATION FOR ATHLETES

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
10.8: Water Requirements and Fluid Balance During Exercise
10.9: Exertional Heat

This page titled 10: Hydration and Thermoregulation for Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.1: Chapter Introduction

Video 10.1.1: 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 are too high and send signals to the brain stimulating the conscious feeling to drink.



Figure 10.1.1: 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 to 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 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 10.1.1: 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)

This page titled 10.1: Chapter Introduction is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.2: Overview of Fluid and Electrolyte Balance

Skills to Develop

- Define osmosis.

The 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 to 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 the 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 10.2.1: 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 10.2.1) 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.

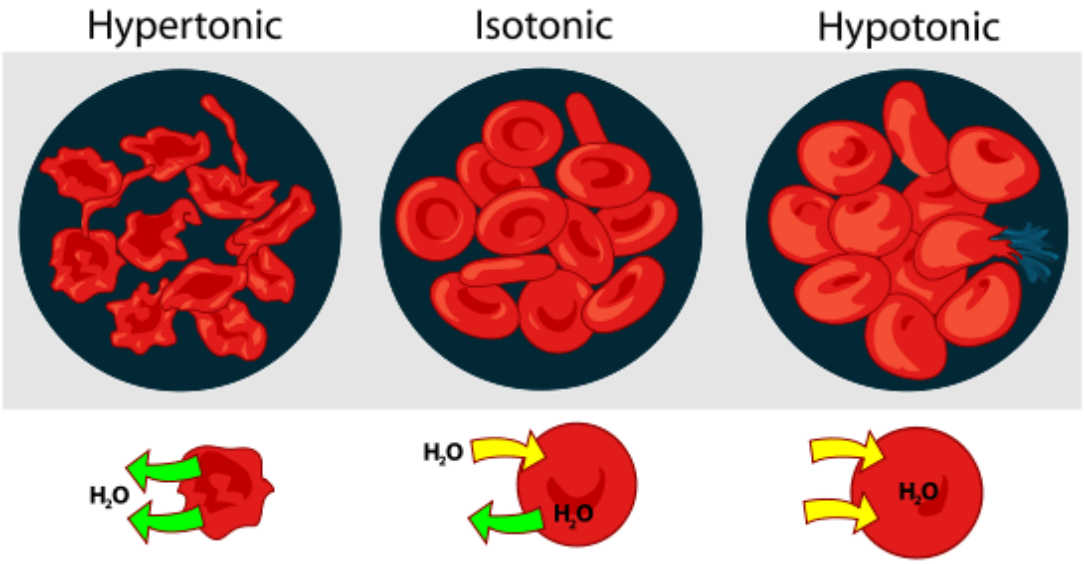


Figure 10.2.1: Cells maintain water volume by actively controlling electrolyte concentrations. Imaged used with permission (Public Domain; LadyofHats)

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 10.2.1). 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

- The human body is mostly water.
- The 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.

This page titled 10.2: Overview of Fluid and Electrolyte Balance is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.3: Water's Importance to Vitality

Skills to Develop

- Describe the four major functions of water in the human body

You get up in the morning, flush waste 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 10.3.1: 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 molecule's 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 the 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 is 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 humor, 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.

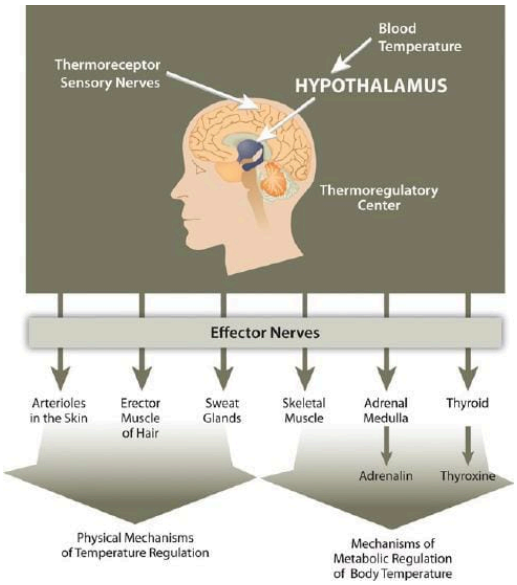


Figure 10.3.2: *Thermoregulation is the ability of an organism to maintain body temperature despite changing environmental temperatures.*

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?

This page titled 10.3: Water's Importance to Vitality is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.4: Regulation of Water Balance

Skills to Develop

- 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 systems. 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.

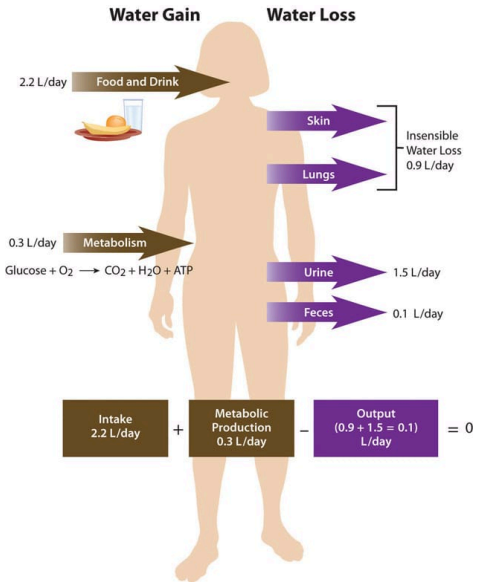


Figure 10.4.1: Daily Fluid Loss and Gain

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 10.4.1 for the range of water contents for selected food items. Beverages include water, tea, coffee, sodas, and juices.

***Table 10.4.1**: 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 are 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.

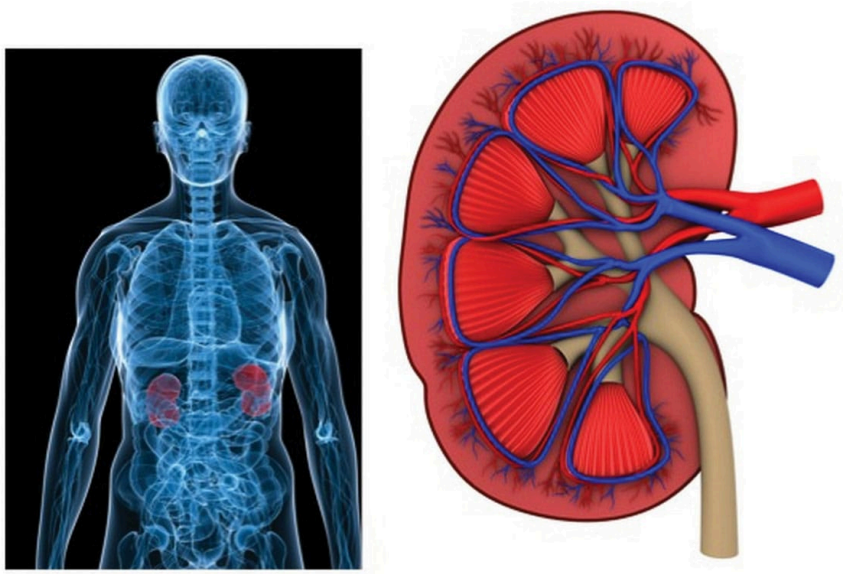


Figure 10.4.2: Kidneys. A primary function of the kidneys is to filter blood and remove wastes. They play a major role in fluid and electrolyte balance.© Thinkstock

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 restoring 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 the 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.

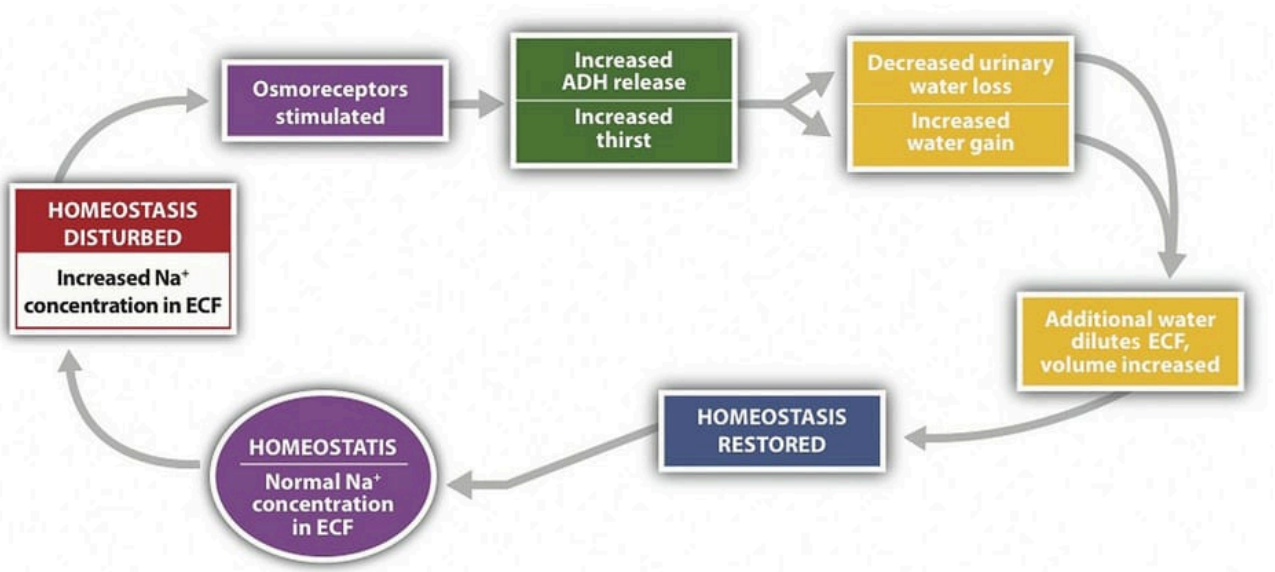


Figure 10.4.3: Sodium and fluid balance are intertwined.

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 the 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.

This page titled 10.4: Regulation of Water Balance is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.5: Electrolytes Important for Fluid Balance

Skills to Develop

- 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 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 a 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

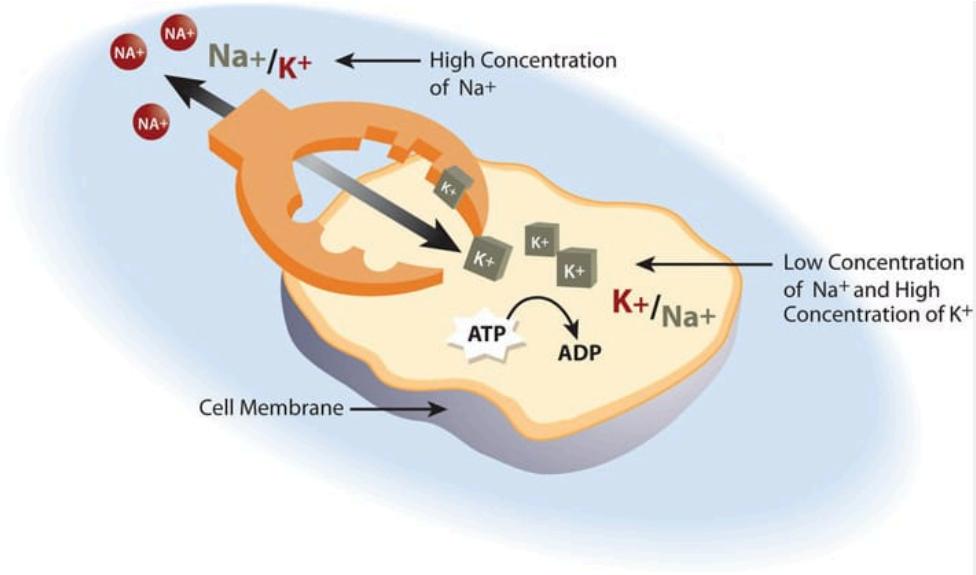


Figure 10.5.1: The sodium-potassium pump is the primary mechanism for cells to maintain water balance between themselves and their surrounding environment.

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 the 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, include nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death result.



Figure 10.5.2: 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 for 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) (Table 10.5.1) 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 10.5.1***:*** *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 10.5.2.

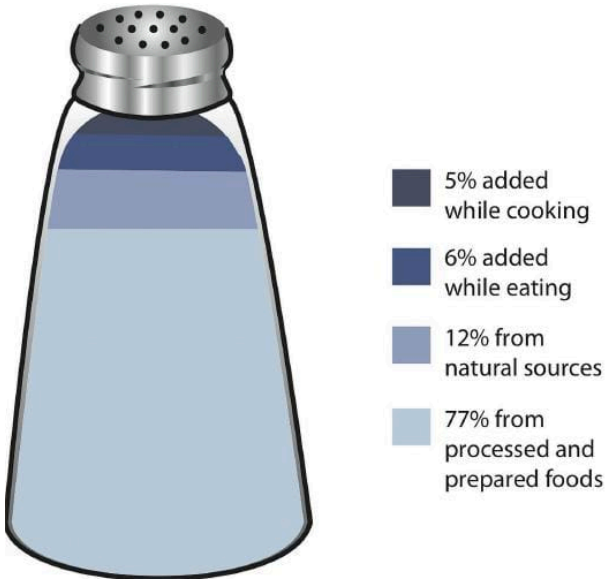


Figure 10.5.3: Dietary Sources of Sodium

Table 10.5.2***:*** *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
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

Food Group	Serving Size	Sodium (mg)
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.

https://fdc.nal.usda.gov/

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 10.5.4). 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.

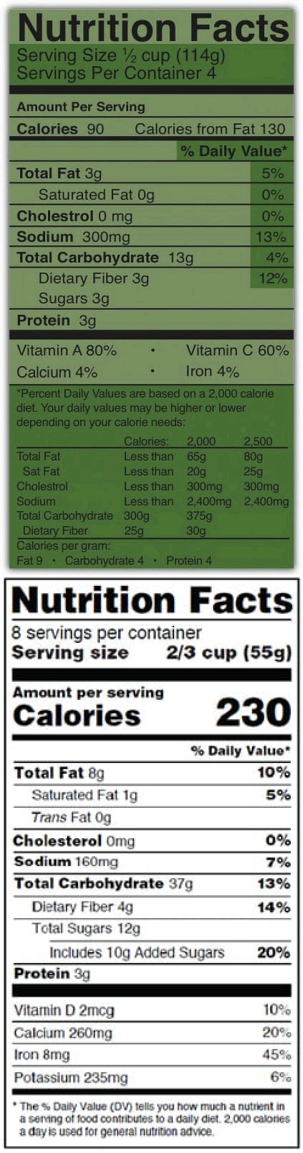


Figure 10.5.4: Sodium levels in milligrams is a required listing on a nutrition facts panel. The old nutrition facts panel is shown on the left and the new nutrition facts panel is shown on the right. Notice, both still require sodium.

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 10.5.3).

***Table** 10.5.3**:** 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
***Must also declare on the 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.**	

Claim	Meaning
“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 the 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.**	

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 10.5.5: 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 10.5.4 displays the sodium and potassium amounts in some salt substitutes.

***Table** 10.5.4**:** 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

Product	Serving Size	Sodium (mg)	Potassium (mg)
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.

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 10.5.5 for an AHA list of alternative food seasonings.

Table 10.5.5***:*** *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
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

Seasoning	Foods
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 10.5.5.

Table 10.5.5***:*** *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**, are toxic and also affect 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 males 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 10.5.6.

Table 10.5.6***:*** *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 10.5.4: High Potassium Foods

Here are foods high in potassium.(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 is 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 role 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

This page titled 10.5: Electrolytes Important for Fluid Balance is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.6: Consequences of Deficiency or Excess

Skills to Develop

- Summarize the following fluid and electrolyte imbalance disorders: dehydration, water intoxication, heatstroke, 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. Overhydration 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 10.6.1: Older people need to guard against dehydration by taking steps to drink more, especially when exercising. © Shutterstock

Heat Stroke

Heatstroke 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 a fast pulse. The elderly, infants, and athletes are the most at risk for heatstroke.

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 range is between 90/60 and 120/80 mmHg. Hypertension is the scientific term for high blood pressure and is 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 10.6.2: *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-cause 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 that 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 10.6.1

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 heatstroke.
- 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.

This page titled 10.6: Consequences of Deficiency or Excess is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.7: Water Concerns

Skills to Develop

- 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 10.7.1: 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 10.7.1).

Table 10.7.1***:*** *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

Beverage	Serving Size (oz)	Kilocalories
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
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 million 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.

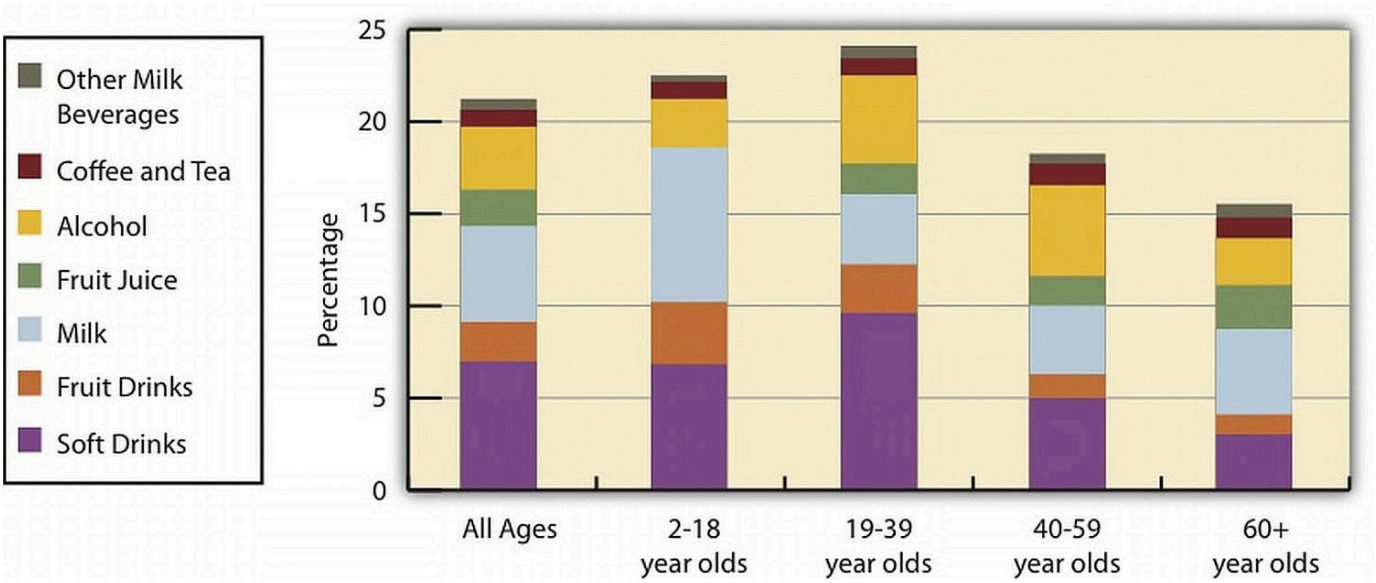


Figure 10.7.2: Percentage of Daily Caloric Intake from Beverage Groups. Source: University of North Carolina, Chapel Hill. US Beverage Guidance Council. "You Are What You Drink, and We Are Drinking Far Too Many Calories from Beverages!" Accessed November 6, 2012. http://www.cpc.unc.edu/projects/nutrans/policy/beverage/us-beverage-panel/.

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** 10.7.2: 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 10.7.1

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 10.7.1).

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 10.7.1*: The Water Treatment Process. Here is a brief video on how drinking water is treated.*

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.

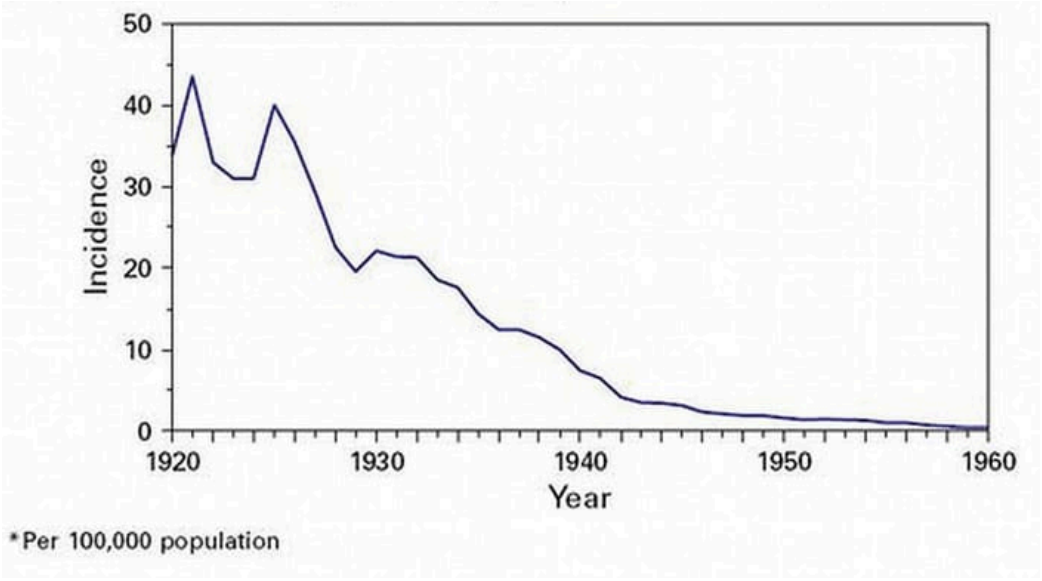


Figure 10.7.3***:*** *Deadly water-borne illnesses decreased to almost nonexistent levels in the United States after the implementation of water disinfection methods. Source: Image credit Robert Tauxe. Centers for Disease Control and Prevention. "Drinking Water Week." Reviewed May 17, 2012. http://www.cdc.gov/features/drinkingwater/graph.html.*

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 10.7.2

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 a 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 that 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 determine 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 10.7.4: The consumption of bottled water in the United States creates a mound of plastic waste. © Shutterstock

See Table 10.7.3 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 10.7.3***:*** *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
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 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 10.7.2*: Bottled Water versus Tap Water. Use this video to provoke discussion on tap water versus bottled water.*

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. Watch "Video 11.7.2" and debate the pros and cons of drinking tap water versus bottled water.
2. What is your favorite bottled water? Look up its source and treatment and compare your information with others in your class.

This page titled 10.7: Water Concerns is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.8: Water Requirements and Fluid Balance During Exercise

The National Athletic Trainers' Association has put out two position papers on this topic recently.

- Paper: National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active https://www.nata.org/sites/default/f...orAthletes.pdf
- Paper: National Athletic Trainers' Association Position Statement: Exertional Heat Illnesses: http://natajournals.org/doi/pdf/10.4085/1062-6050-50.9.07

This page titled 10.8: Water Requirements and Fluid Balance During Exercise is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

10.9: Exertional Heat

Paper: National Athletic Trainers' Association Position Statement: Exertional Heat Illness http://natajournals.org/doi/pdf/10.4...2-6050-50.9.07

This page titled 10.9: Exertional Heat is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

11: SPORTS DRIVEN NUTRITION

11.1: Sport Driven Nutrition

This page titled 11: Sports Driven Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

11.1: Sport Driven Nutrition

Here are two papers that summarize nutrition for particular sports.

Paper: Periodized Nutrition for Athletes, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5371625/
Paper: Nutrition for power sports: middle-distance running, track cycling, rowing, canoeing/kayaking, and swimming.
http://gssiweb.org/docs/default-sour...e-power-sports

This page titled 11.1: Sport Driven Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12: BODY COMPOSITION AND MAINTAINING, GAINING, AND LOSING WEIGHT

12.1: Introduction to Body Composition and Maintaining, Gaining, and Losing Weight
12.2: Too Little or Too Much Weight?
12.3: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution
12.4: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management
12.5: Methods to Detect Body Composition in Sports
12.6: Diets and Weight Loss for Athletes

This page titled 12: Body Composition and Maintaining, Gaining, and Losing Weight is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12.1: Introduction to Body Composition and Maintaining, Gaining, and Losing Weight

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 2017-2018 in the United States, 42.4 percent of adults and 19.3 percent of children were obese, a doubling and tripling of the numbers since 1980, respectively, while in Canada the obesity rate was 26.8 percent in 2018. 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?

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

***Video Link 12.1.1**: 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 without individuals, public health officials, or the 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 the 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 12.1.1

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 in 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)

This page titled 12.1: Introduction to Body Composition and Maintaining, Gaining, and Losing Weight is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12.2: Too Little or Too Much Weight?

Skills to Develop

- 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, have 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 12.2.1: Chinese Obesity: This video discusses 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 2017–March 2020:

- 41.9 percent of adults aged twenty years and over are obese
- 73.6 percent of adults aged twenty years and over are overweight (includes obese)
- 22.2 percent of adolescents age twelve to nineteen years are obese
- 20.7 percent of children age six to eleven years are obese
- 12.7 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 bodyweight), increased risk if surgery is needed, emotional disturbances and societal problems.

State Map of the Prevalence of Obesity in America

Visit https://www.cdc.gov/obesity/data/prevalence-maps.html#overall to see the obesity trends from 1985 to 2010. As you will see, the percentage of obese adults is 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 of death 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 which 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 being 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 being underweight effect 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 the 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 a 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 lower-than-normal body weight for the rest of their lives.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 12.2.2***:*** *What I Gained in Recovery from Anorexia. On a more positive note, watch this personal account of what can be gained from anorexia recovery.*

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.

This page titled 12.2: Too Little or Too Much Weight? is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

Skills to Develop

- 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 that 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 by 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.

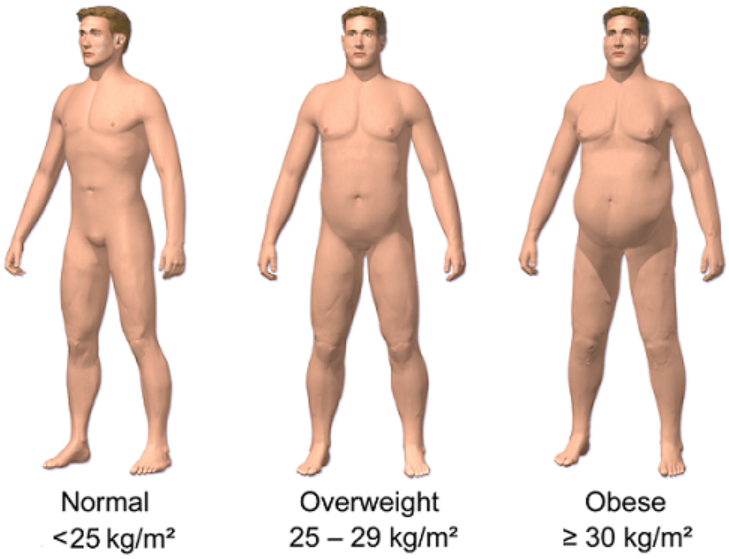


Figure 12.3.1: Obesity and BMI. (CC BY-SA 4.0; BruceBlaus).

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 BMIs 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.

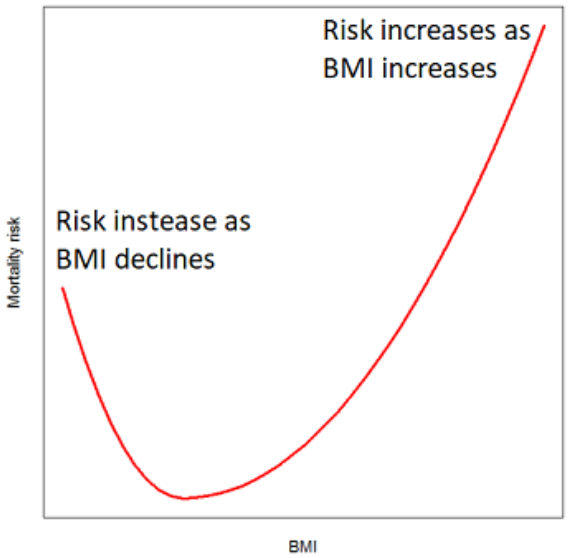


Figure 12.3.2: Mortality risk vs. BMI.

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

$$BMI = \frac{weight\ (kg)}{height\ (m)^2} \tag{11.2.1b}$$

Automatic BMI Calculators

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 12.3.1 or use a chart of weight and height to figure out your BMI.

Table** 12.3.1**: BMI Categories

Categories	BMI
Underweight	< 18.5
Normal weight	18.5–24.9
Overweight	25–29.9
Obese	> 30.0
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 non-invasive 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 for 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 are 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 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?

This page titled 12.3: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12.4: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management

Skills to Develop

- 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 interact with the other. For example, since the sequencing of 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 setpoint, 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 years 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 loss 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 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* offer 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. *2018 Physical Activity Guidelines for Americans*. 2018. Accessed October 8, 2011. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf

- 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. *2018 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf.

Table 12.4.1***:*** *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*. 2018. http://www.health.gov/paguidelines/.

Interactive 12.4.1

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: https://health.gov/our-work/nutrition-physical-activity/move-your-way-community-resources/partner-promotion-toolkit.

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 policymakers 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video Link 12.4.1: *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 expand, 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 were 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.

This page titled 12.4: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12.5: Methods to Detect Body Composition in Sports

Many athletes are concerned about their body image and composition. Here is a paper on body composition methods put forth by the working group on Body Composition Health and Performance under the International Olympic Committee Medical Commission.

> Paper: Current Status of Body Composition Assessment in Sport, https://link.springer.com/article/10...00000000-00000

Diets are the way people seek to change their body composition. There are many different types of diets and it is often confusing for the general public and practitioners to determine their appropriateness. This paper provides the scientific evidence in a systematic way on several of the more popular diets.

> Paper: International Society of Sports Nutrition Position Stand: Diets and Body Composition, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5470183/

This page titled 12.5: Methods to Detect Body Composition in Sports is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

12.6: Diets and Weight Loss for Athletes

Paper: International Society of Sports Nutrition Position Stand: Diets and Body Composition https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5470183/

This page titled 12.6: Diets and Weight Loss for Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

13: SUPPLEMENTS



- Topic hierarchy

13.1: Overview of Fitness Supplements and Steroids
13.2: IOC Statement on Supplements
13.3: Strength and Power Supplements
13.4: Whole Foods as Ergogenic Aids

This page titled 13: Supplements is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

13.1: Overview of Fitness Supplements and Steroids

- https://ods.od.nih.gov/factsheets/Ex...hProfessional/
- Quackwatch.org
- Natural Medicines database free on Kaiser Permanente website

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 the 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 damage, and experts say that Cahill is emblematic of 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, the death of 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 13.1.1: *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 the 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.

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.

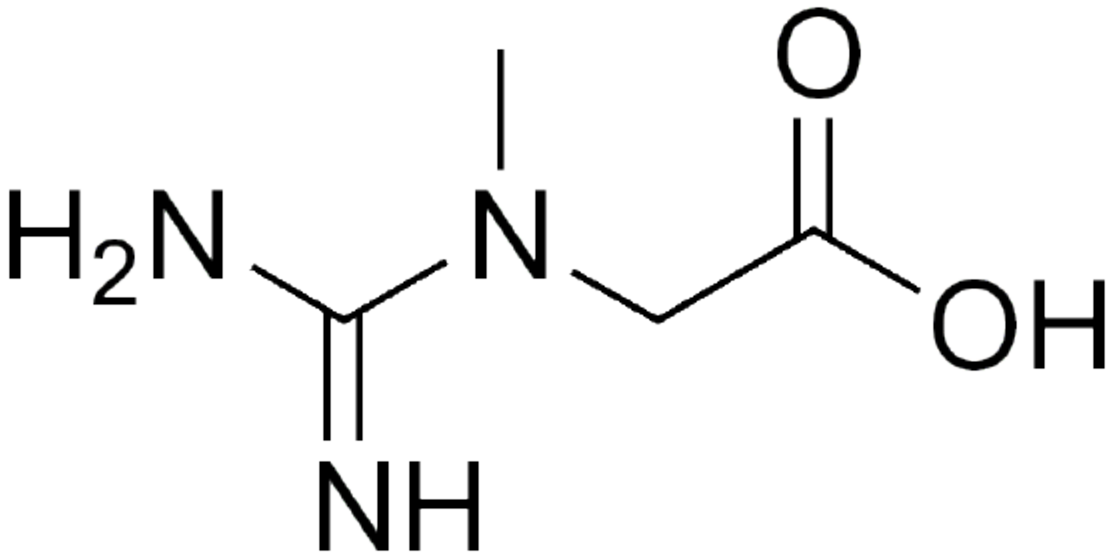


Figure 13.1.3: Skeletal formula of creatine

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 most 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 it's not only in beverages but also in some foods and medicine.

Table 13.1.1: *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

Beverage/Food	Milligrams
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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 13.1.1: *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 for 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.

The Bottom Line

Sports drinks consumed in excess by athletes or used by non-athletes simply are another source of added sugars, and thus extra calories, in the diet and provide no performance, exercise recovery, or health benefit.

Contributors and Attributions

- Wikipedia

This page titled 13.1: Overview of Fitness Supplements and Steroids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

13.2: IOC Statement on Supplements

The International Olympic Committee (IOC) Medical and Scientific Commission has recognized the important role that sound nutrition practices play in protecting good health and promoting the optimum performance of athletes. As part of its commitment to supporting the health and performance of athletes, it convened a meeting of experts in the field of dietary supplements to assess the evidence relating to the place of dietary supplements in the preparations of elite athletes. Particular focus was placed on their effects on athletes' health and performances, and the risk of contamination with substances that may be harmful to health or that may trigger an adverse analytical finding, leading to an anti-doping rule violation. The use of dietary supplements is widespread among elite athletes, as it is among the general population. The IOC concluded that:

- Diet significantly influences athletic performance, but the use of supplements does not compensate for poor food choices and an inadequate diet.
- Supplementation with essential nutrients may be beneficial if a specific nutrient deficiency is medically diagnosed and a food-based solution cannot be easily implemented.
- A few supplements, from the many thousands of different products on the market, may provide performance or health-related benefits for some athletes in some types of sports, when optimum training, nutrition, and recovery are already achieved.
- Quality assurance in supplement manufacture, storage, and distribution is sometimes not strictly enforced, leading to products that are of poor quality or contaminated.

Here is the complete statement from the IOC Medical and Scientific Consensus Meeting on Supplements: https://stillmed.olympic.org/media/D...hletes-eng.pdf

This page titled 13.2: IOC Statement on Supplements is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

13.3: Strength and Power Supplements

Strength and power supplements are dietary supplements commonly used by those involved in bodybuilding, weightlifting, mixed martial arts, and athletics for the purpose of facilitating an increase in lean body mass. The intent is to increase muscle, increase body weight, improve athletic performance, and for some sports, simultaneously decrease percent body fat so as to create better muscle definition.

Paper: Supplements for Strength-Power Athletes: https://journals.lww.com/nsca-scj/Fu...hletes.13.aspx

This page titled 13.3: Strength and Power Supplements is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

13.4: Whole Foods as Ergogenic Aids

So far, we have looked at isolate compounds as supplements or ergogenic aids. Many of these compounds are isolated from foods. In the last 20-30 years, scientists have demonstrated the powerful effects of foods as a whole instead of minimalizing to one particular isolated compound. Often several food constituents work together to produce the observed effect, so the food matrix is as important as the individual compound. If you look in the scientific literature, you will find many reports on the effect of whole food and athletic performance, for example, blueberries, bananas, chocolate milk, or sweet potatoes. The following blog provides a cursory overview of several whole foods to "whet your appetite." Do you have a favorite sports food? The best place to look for scientific evidence on its sports performance effect is PubMed. You may also find information in the Natural Medicine Database.

Blog: Ergogenic Foods for Performance and Health: http://blog.nasm.org/nutrition/ergog...rmance-health/

This page titled 13.4: Whole Foods as Ergogenic Aids is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

14: SELECTIVE TOPICS- ANEMIA

14.1: Case Study
14.2: Iron Supplementation and Performance

This page titled 14: Selective Topics- Anemia is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

14.1: Case Study

One of our selective topics is anemia which is not uncommon in athletes. Female distance runners have a higher risk of developing anemia and here is a case study that discusses iron deficiency for an athlete who runs cross-country.

> Paper: Case Report: Comprehensive Sports Medicine Treatment of an Athlete Who Runs Cross-Country and is Iron Deficient: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953317/

This page titled 14.1: Case Study is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

14.2: Iron Supplementation and Performance

Iron supplements are used to treat and prevent iron deficiency including iron deficiency anemia. For prevention, iron supplements are only recommended for those with poor absorption, heavy menstrual periods, pregnancy, hemodialysis, or a diet low in iron. Prevention may also be used in low birth weight babies. Iron supplements can be taken by mouth, injection into a vein, or injection into a muscle. While benefits may be seen in days, it can take months before iron levels return to normal.

There is debate amongst health care providers whether iron supplementation for elite athletes is necessary to prevent anemia. Here is an editorial that presents this controversy.

Paper: Sports anemia: facts or fiction? https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3417720/

This page titled 14.2: Iron Supplementation and Performance is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15: SELECTIVE TOPICS - ALCOHOL

15.1: Introduction to Alcohol
15.2: Alcohol Absorption and Metabolism
15.3: Pros and Cons of Drinking Alcohol
15.4: How Much to Drink?
15.5: Alcohol and the Athlete

This page titled 15: Selective Topics - Alcohol is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15.1: Introduction to Alcohol

Skills to Develop

- 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 (3). 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 (3). 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. However, recent studies suggest no level of alcohol is safe (5,6). 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 (4). Although drunkenness has pervaded many cultures, drinking in moderation has long been a mantra of multiple cultures with access to alcohol.



Figure 15.1.1: 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 15.1.1: 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.
3. Centers for Disease Control and Prevention. “Alcohol and Public Health.” Last updated March 5, 2012. http://www.cdc.gov/alcohol/
4. 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
5. GBD 2016 Alcohol Collaborators. **Alcohol use and burden for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016**. *The Lancet*, 2018; DOI: 10.1016/S0140-6736(18)31310-2
6. https://world-heart-federation.org/w...ef-Alcohol.pdf

This page titled 15.1: Introduction to Alcohol is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15.2: Alcohol Absorption and Metabolism

Skills to Develop

- 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 (15.2.1). 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 buildup are rapid heartbeat and hyperventilation. One-fifth of the alcohol absorbed is degraded by MEOS to acetaldehyde.

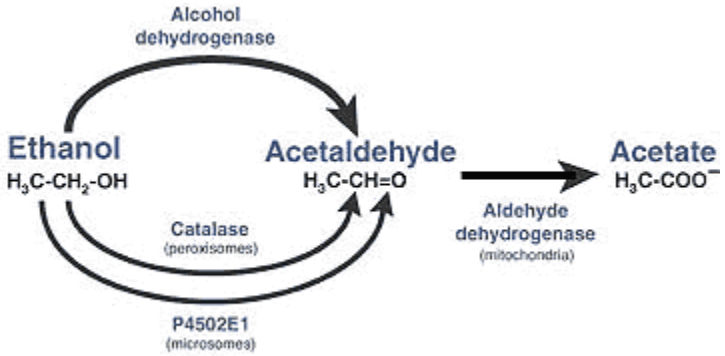


Figure 15.2.1: Break down of alcohol into acetaldehyde and acetate.

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 prevent 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.

This page titled 15.2: Alcohol Absorption and Metabolism is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15.3: Pros and Cons of Drinking Alcohol

Skills to Develop

- 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 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 although this data is now being questioned. Red wine has been the alcohol most studied, not other forms of alcohol. 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. One of the problems with these studies is they include sick quitters in the abstainers group imaking this group sicker. Sick quitters are individuals who decide to stop drinking because of a health problem. 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 contribute to their characteristic "skinniness" and multiple associated micronutrient deficiencies. The most common macronutrient 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 from 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 the 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.

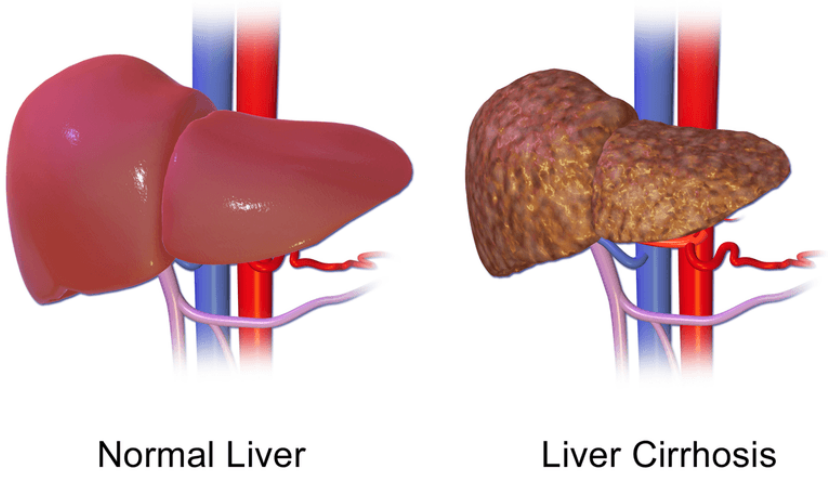


Figure 15.3.1: *Liver Cirrhosis. Excessive alcohol consumption causes the destruction of liver cells. In an attempt to repair itself, the liver initiates an inflammatory and reparation process causing scar tissue to form. In the liver's attempt to replace the dead cells, surviving liver cells multiply. 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 that 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.

This page titled 15.3: Pros and Cons of Drinking Alcohol is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15.4: How Much to Drink?

Skills to Develop

- 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 15.4.1***:*** *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 15.4.2 summarizes the mental and physical effects associated with different BAC levels.

Table 15.4.2: *Mental and Physical Effects of Different BAC Levels*

BAC Percent	Typical Effects
0.02	Some loss of judgment, altered mood, relaxation, increased body warmth
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 15.4.2: 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

This page titled 15.4: How Much to Drink? is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

15.5: Alcohol and the Athlete

Athletes will drink alcohol for a variety of reasons. What are the acute effects of alcohol on the athlete? The first paper identifies the acute effects of alcohol on athletic performance and provides an overview of that topic. The second paper provides an overview in lay language. The third source provides particle information on alcohol.

- Paper: Alcohol, Athletic Performance and Recovery: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3257708/
- Paper from the National Strength and Conditioning Association, The Effects of Alcohol on Athletic Performance: www.nsca.com/education/artic...c-performance/
- Paper from Sports, Cardiovascular and Wellness Nutrition Dietetic Practice Group on Alcohol and Athletic Performance: www.ncaa.org/sites/default/files/Alcohol%20and%20Athletic%20Performance%20Fact%20Sheet.pdf

This page titled 15.5: Alcohol and the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

16: SELECTIVE TOPICS - VEGETARIAN



- Topic hierarchy

16.1: Vegetarian Athletes

This page titled 16: Selective Topics - Vegetarian is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

16.1: Vegetarian Athletes

Vegetarian diets can be nutritionally adequate for athletes as long as you carefully plan meals that provide the right nutrients for your active needs. On average, carbs will take up half of a good athletic diet with the rest split between fat and protein. Carbohydrates can be found in vegetables, fruits, beans, and grains while protein can be found in beans. Some vegetarians may add dairy and eggs, although others prefer not to eat them. Planning meals with proper nutrition in mind and stocking your kitchen with staples will help you prepare vegetarian meals for athletes. Here is a paper that discusses practical advice for athletes that want to follow a vegan diet.

Vegan Diets: Practical Advice for Athletes and Exercisers: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5598028/

This page titled 16.1: Vegetarian Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17: SELECTIVE TOPICS - ATHLETIC NEEDS THROUGHOUT THE LIFESPAN

- Topic hierarchy

17.1: Childhood and Nutrition
17.2: Puberty and Nutrition
17.3: Older Adolescence and Nutrition
17.4: Young Adulthood and Nutrition
17.5: Pregnancy and Nutrition
17.6: Lactation
17.7: Nutrition and the Active Female
17.8: Elite Young Athletes
17.9: IOC Consensus on Youth Athletic Development
17.10: Masters Athletes
17.11: Nutrition and Exercise Guidance for the Pregnant Athlete

This page titled 17: Selective Topics - Athletic Needs throughout the Lifespan is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.1: Childhood and Nutrition

Skills to Develop

- 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. During the preschool years, children grow at a slower rate, their appetite may decrease, and their eating behaviors change. 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 17.1.1: 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. Changes in height and weight can be used to indicate long-term nutrition effects. 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 17.1.1 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 17.1.1: 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. Undernourished children can exhibit fatigue, increased susceptibility to infection, and/or be underweight. 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." 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, 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 March 5, 2012. http://healthyschoollunches.org/.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 17.1.1: *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 of 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 food intolerance, which does not involve an immune response. 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 the 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 the 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

This page titled 17.1: Childhood and Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.2: Puberty and Nutrition

Skills to Develop

- 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 its 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. It is not unusual for adolescents to skip meals, snack often, and eat out.

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 17.2.1: 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 needs, not body weight. From 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 in females because menstruation starts and in males due to an increase in muscle mass.

Table 17.2.1: *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.

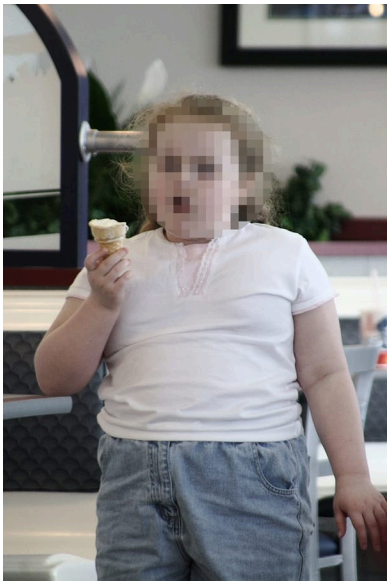


Figure 17.2.2: *A sedentary lifestyle along with a poor diet contributes to childhood obesity. (CC SA-By 2.5; Robert Lawton);*

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
- genetics
- TV watching or playing video games

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 to address problem behaviors, exercise counseling to increase physical activity, psychological support or therapy, family counseling, and family meal planning advice to decrease intake of high-fat, high-energy foods. 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 17.2.1: 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 *2018 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. "2018 Physical Activity Guidelines for Americans." Accessed May 11, 2022. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.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 on this website to discuss suggestions. https://www.myplate.gov/

This page titled 17.2: Puberty and Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.3: Older Adolescence and Nutrition

Skills to Develop

- 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 include 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

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 allow 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 17.3.1: *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 and 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, overprotective, 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 disorders. 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 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 heartbeat. 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.

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Video 17.3.1: 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/

This page titled 17.3: Older Adolescence and Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.4: Young Adulthood and Nutrition

Skills to Develop

- 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 17.4.1: 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. 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 does your intake of carbohydrates, proteins, and fats compare to the AMDR? What can you do to make changes and meet the nutritional recommendations?

This page titled 17.4: Young Adulthood and Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.5: Pregnancy and Nutrition

Skills to Develop

- 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 during 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. The time to focus on nutrition, though, is before conception, during the childbearing years, so she is in good nutritional status before she becomes pregnant. 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 (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 17.5.1: *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 17.5.1: 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 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 (the term for developing offspring after the eighth week of pregnancy), 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 for the 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. The fetus gains most of its body fat and mineral stores during the last part of the pregnancy. 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 more 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 in 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 17.5.2: 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 pregnancy. Taking a daily prenatal supplement or multivitamin 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 17.5.2: *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 in 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. 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 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 in 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 sharks, 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 17.5.3: 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 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 17.5.1: 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 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.

This page titled 17.5: Pregnancy and Nutrition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.6: Lactation

Learning Objectives

- Describe the structure of the lactating breast
- Summarize the process of lactation
- Explain how the composition of breast milk changes during the first days of lactation and in the course of a single feeding

Lactation is the process by which milk is synthesized and secreted from the mammary glands of the postpartum female breast in response to an infant sucking at the nipple. Breast milk provides ideal nutrition and passive immunity for the infant, encourages mild uterine contractions to return the uterus to its pre-pregnancy size (i.e., involution), and induces a substantial metabolic increase in the mother, consuming the fat reserves stored during pregnancy. Other benefits for the mother are less postpartum bleeding, weight loss, and keeping the mother's bones strong.

Structure of the Lactating Breast

Mammary glands are modified sweat glands. The non-pregnant and non-lactating female breast is composed primarily of adipose and collagenous tissue, with mammary glands making up a very minor proportion of breast volume. The mammary gland is composed of milk-transporting lactiferous ducts, which expand and branch extensively during pregnancy in response to estrogen, growth hormone, cortisol, and prolactin. Moreover, in response to progesterone, clusters of breast alveoli bud from the ducts and expand outward toward the chest wall. Breast alveoli are balloon-like structures lined with milk-secreting cuboidal cells, or lactocytes, that are surrounded by a net of contractile myoepithelial cells. Milk is secreted from the lactocytes, fills the alveoli, and is squeezed into the ducts. Clusters of alveoli that drain to a common duct are called lobules; the lactating female has 12–20 lobules organized radially around the nipple. Milk drains from lactiferous ducts into lactiferous sinuses that meet at 4 to 18 perforations in the nipple, called nipple pores. The small bumps of the areola (the darkened skin around the nipple) are called Montgomery glands. They secrete oil to cleanse the nipple opening and prevent chapping and cracking of the nipple during breastfeeding.

The Process of Lactation

The pituitary hormone **prolactin** is instrumental in the establishment and maintenance of breast milk supply. It also is important for the mobilization of maternal micronutrients for breast milk.

Near the fifth week of pregnancy, the level of circulating prolactin begins to increase, eventually rising to approximately 10–20 times the pre-pregnancy concentration. We noted earlier that, during pregnancy, prolactin and other hormones prepare the breasts anatomically for the secretion of milk. The level of prolactin plateaus in late pregnancy, at a level high enough to initiate milk production. However, estrogen, progesterone, and other placental hormones inhibit prolactin-mediated milk synthesis during pregnancy. It is not until the placenta is expelled that this inhibition is lifted and milk production commences.

After childbirth, the baseline prolactin level drops sharply, but it is restored for a 1-hour spike during each feeding to stimulate the production of milk for the next feeding. With each prolactin spike, estrogen and progesterone also increase slightly.

When the infant suckles, sensory nerve fibers in the areola trigger a neuroendocrine reflex that results in milk secretion from lactocytes into the alveoli. The posterior pituitary releases oxytocin, which stimulates myoepithelial cells to squeeze milk from the alveoli so it can drain into the lactiferous ducts, collect in the lactiferous sinuses, and discharge through the nipple pores. It takes less than 1 minute from the time when an infant begins suckling (the latent period) until milk is secreted (the let-down). Figure 17.6.1 summarizes the positive feedback loop of the **let-down reflex**.

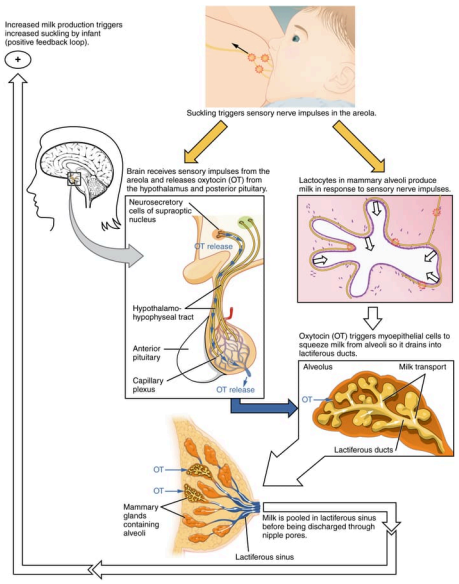


Figure 17.6.1: Let-Down Reflex. A positive feedback loop ensures continued milk production as long as the infant continues to breastfeed.

The prolactin-mediated synthesis of milk changes with time. Frequent milk removal by breastfeeding (or pumping) will maintain high circulating prolactin levels for several months. However, even with continued breastfeeding, baseline prolactin will decrease over time to its pre-pregnancy level. In addition to prolactin and oxytocin, growth hormone, cortisol, parathyroid hormone, and insulin contribute to lactation, in part by facilitating the transport of maternal amino acids, fatty acids, glucose, and calcium to the breast milk.

Changes in the Composition of Breast Milk

In the final weeks of pregnancy, the alveoli swell with colostrum, a thick, yellowish substance that is high in protein but contains less fat and glucose than mature breast milk (Table 17.6.1). Before childbirth, some women experience leakage of colostrum from the nipples. In contrast, mature breast milk does not leak during pregnancy and is not secreted until several days after childbirth.

**Cow's milk should never be given to an infant. Its composition is not suitable and its proteins are difficult for the infant to digest.*

Table 17.6.1

Compositions of Human Colostrum, Mature Breast Milk, and Cow's Milk (g/L)			
	Human colostrum	**Human breast milk**	**Cow's milk***
Total protein	23	11	31
Immunoglobulins	19	0.1	1
Fat	30	45	38
Lactose	57	71	47
Calcium	0.5	0.3	1.4
Phosphorus	0.16	0.14	0.90
Sodium	0.50	0.15	0.41

Colostrum is secreted during the first 48–72 hours postpartum. Only a small volume of colostrum is produced—approximately 3 ounces in a 24-hour period—but it is sufficient for the newborn in the first few days of life. Colostrum is rich with immunoglobulins, which confer gastrointestinal, and also likely systemic, immunity as the newborn adjusts to a nonsterile environment.

After about the third postpartum day, the mother secretes transitional milk that represents an intermediate between mature milk and colostrum. This is followed by mature milk from approximately postpartum day 10 (see Table). As you can see in the accompanying table, cow's milk is not a substitute for breast milk. It contains less lactose, less fat, and more protein and minerals. Moreover, the proteins in cow's milk are difficult for an infant's immature digestive system to metabolize and absorb.

The first few weeks of breastfeeding may involve leakage, soreness, and periods of milk engorgement as the relationship between milk supply and infant demand becomes established. Once this period is complete, the mother will produce approximately 1.5 liters of milk per day for a single infant, and more if she has twins or triplets. As the infant goes through growth spurts, the milk supply constantly adjusts to accommodate changes in demand. A woman can continue to lactate for years, but once breastfeeding is stopped for approximately 1 week, any remaining milk will be reabsorbed; in most cases, no more will be produced, even if suckling or pumping is resumed.

Mature milk changes from the beginning to the end of a feeding. The early milk, called **foremilk**, is watery, translucent, and rich in lactose and protein. Its purpose is to quench the infant's thirst. **Hindmilk** is delivered toward the end of a feeding. It is opaque, creamy, and rich in fat, and serves to satisfy the infant's appetite.

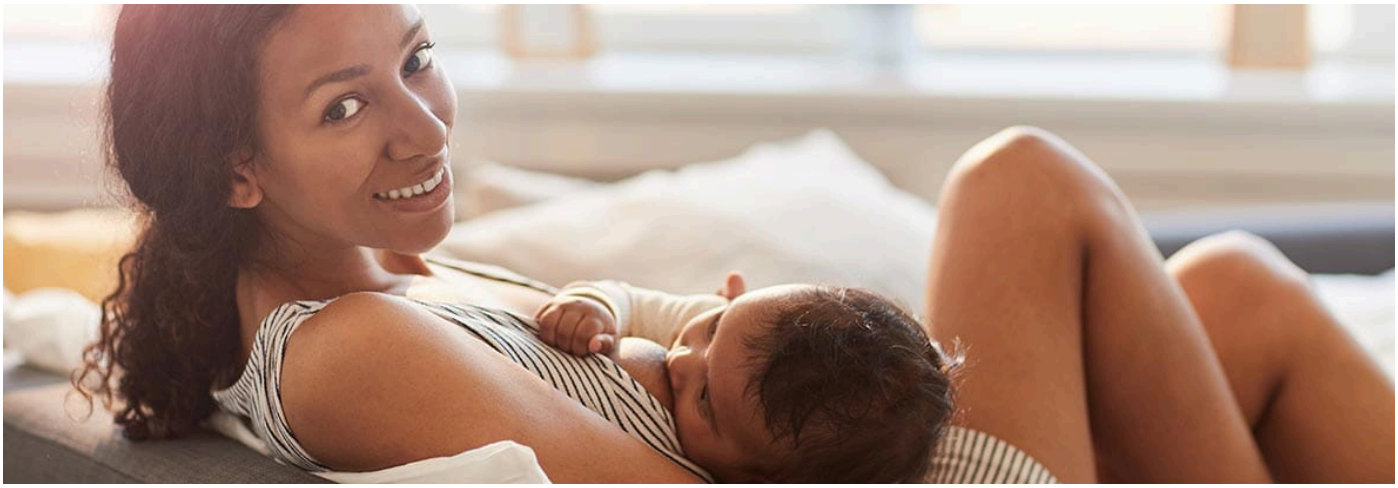
During the first days of a newborn's life, it is important for meconium to be cleared from the intestines and for bilirubin to be kept low in the circulation. Recall that bilirubin, a product of erythrocyte breakdown, is processed by the liver and secreted in bile. It enters the gastrointestinal tract and exits the body in the stool. Breast milk has laxative properties that help expel meconium from the intestines and clear bilirubin through the excretion of bile. A high concentration of bilirubin in the blood causes jaundice. Some degree of jaundice is normal in newborns, but a high level of bilirubin—which is neurotoxic—can cause brain damage. Newborns, who do not yet have a fully functional blood-brain barrier, are highly vulnerable to the bilirubin circulating in the blood. Indeed, hyperbilirubinemia, a high level of circulating bilirubin, is the most common condition requiring medical attention in newborns. Newborns with hyperbilirubinemia are treated with phototherapy because UV light helps to break down the bilirubin quickly.

Nutrition for Breastfeeding Mothers

Breastfeeding mothers have nutrient requirements similar to women in the third trimester of pregnancy. After all, they're continuing to provide nutrients for their babies through their milk, and milk production requires energy, macronutrients, micronutrients, and water. Breastfeeding women have a remarkable ability to make enough milk to meet their babies' nutrient needs even without an optimal diet, but eating well supports maternal health and energy levels during this demanding time.

Breastfeeding increases energy requirements by about 450 to 500 calories per day, part of which can be supplied by using adipose stored in pregnancy and part of which should be supplied from greater caloric intake. In general, breastfeeding mothers can eat a wide variety of foods, and they don't usually need to avoid or restrict any specific foods. However, as in pregnancy, they should continue to avoid high-mercury fish. Consuming low-mercury fish 2 to 3 times per week provides the omega-3 fatty acids DHA and EPA, which pass into breast milk and support brain and eye development for the breastfeeding infant.[1] There is no need to avoid common food allergens, such as peanut or dairy; avoiding these foods while breastfeeding has not been shown to reduce babies' chances of developing food allergies.[2] Sometimes women find that certain foods, such as garlic or spicy foods, are associated with fussiness or gas in their infants, and they may experiment with avoiding those foods. However, most infants don't have a problem tolerating these foods. In fact, flavors from the mother's diet pass into breast milk, so researchers hypothesize that when mothers eat a wide variety of foods and flavors while breastfeeding, their children grow up to be more adventurous eaters.[3]

In addition to consuming a nutrient-dense diet, obstetricians sometimes recommend that breastfeeding mothers continue taking a prenatal supplement to ensure that their micronutrient needs are met. Breastfeeding mothers should also be sure to drink plenty of fluids to support milk production.[1]



Similar to pregnancy, substances consumed by the breastfeeding mother can pass to the infant in her milk. However, how much passes into the milk depends on the type of substance and the timing of consumption relative to breastfeeding. For example, it's considered safe for a breastfeeding mother to have an alcoholic drink so long as she waits at least two hours before breastfeeding because, by that point, most of the alcohol will have cleared her bloodstream and will not pass into her milk. Caffeine lasts longer in the blood but is considered safe in moderation, with a limit of about 300 milligrams per day.[1] Cannabinoid, the chemicals found in cannabis, are fat-soluble and remain in a mother's bloodstream and body tissues for much longer. Tetrahydrocannabinol (THC), the main psychoactive chemical in cannabis, has been detected in breast milk as much as 6 weeks after a mother used cannabis.[4] Although it's not clear how these chemicals affect babies when consumed in breast milk, medical organizations agree it's best to avoid using cannabis while breastfeeding.

The National Institutes of Health's LactMed database is a great resource for information about the safety of drugs, medications, and supplements during breastfeeding.

Chapter Review

The lactating mother supplies all the hydration and nutrients that a growing infant needs for the first 4–6 months of life. During pregnancy, the body prepares for lactation by stimulating the growth and development of branching lactiferous ducts and alveoli lined with milk-secreting lactocytes, and by creating colostrum. These functions are attributable to the actions of several hormones, including prolactin. Following childbirth, suckling triggers oxytocin release, which stimulates myoepithelial cells to squeeze milk from alveoli. Breast milk then drains toward the nipple pores to be consumed by the infant. Colostrum, the milk produced in the first postpartum days, provides immunoglobulins that increase the newborn's immune defenses. Colostrum, transitional milk, and mature breast milk are ideally suited to each stage of the newborn's development, and breastfeeding helps the newborn's digestive system expel meconium and clear bilirubin. Mature milk changes from the beginning to the end of a feeding. Foremilk quenches the infant's thirst, whereas hindmilk satisfies the infant's appetite.

Review Questions

Q. Alveoli are connected to the lactiferous sinuses by _____.

A. lactocytes

B. lactiferous ducts

C. nipple pores

C. lobules

Answer: B

Q. How is colostrum most important to a newborn?

A. It helps boost the newborn's immune system.

B. It provides much needed fat.

C. It satisfies the newborn's thirst.

D. It satisfies the infant's appetite.

Answer: A

Q. Mature breast milk _____.

A. has more sodium than cow's milk

B. has more calcium than cow's milk

C. has more protein than cow's milk

D. has more fat than cow's milk

Answer: D

Critical Thinking Questions

Q. Describe the transit of breast milk from lactocytes to nipple pores.

A. Milk is secreted by lactocytes into alveoli. Suckling stimulates the contraction of myoepithelial cells that squeeze milk into lactiferous ducts. It then collects in lactiferous sinuses and is secreted through the nipple pores.

Q. A woman who stopped breastfeeding suddenly is experiencing breast engorgement and leakage, just like she did in the first few weeks of breastfeeding. Why?

A. It takes time to establish a balance between milk supply and milk demand. When breastfeeding stops abruptly, it takes time for the supply to fall. Excessive milk supply creates breast engorgement and leakage.

Glossary

colostrum
thick, yellowish substance secreted from a mother's breasts in the first postpartum days; rich in immunoglobulins

foremilk
watery, translucent breast milk that is secreted first during a feeding and is rich in lactose and protein; quenches the infant's thirst

hindmilk
opaque, creamy breast milk delivered toward the end of a feeding; rich in fat; satisfies the infant's appetite

lactation
process by which milk is synthesized and secreted from the mammary glands of the postpartum female breast in response to sucking at the nipple

let-down reflex
release of milk from the alveoli triggered by infant suckling

prolactin
pituitary hormone that establishes and maintains the supply of breast milk; also important for the mobilization of maternal micronutrients for breast milk

References:

- [1]CDC. (2020, February 10). *Diet considerations for breastfeeding mothers*. Centers for Disease Control and Prevention. https://www.cdc.gov/breastfeeding/breastfeeding-special-circumstances/diet-and-micronutrients/maternal-diet.html
- [2]Abrams, E. M., & Chan, E. S. (2019). It's Not Mom's Fault: Prenatal and Early Life Exposures that Do and Do Not Contribute to Food Allergy Development. Immunology and Allergy Clinics of North America, 39(4), 447–457. https://doi.org/10.1016/j.iac.2019.06.001
- [3]Forestell, C. A. (2017). Flavor Perception and Preference Development in Human Infants. Annals of Nutrition & Metabolism, 70 Suppl 3, 17–25. https://doi.org/10.1159/000478759
- [4]LactMed. (2020). Cannabis. In *Drugs and Lactation Database*. National Library of Medicine (US). http://www.ncbi.nlm.nih.gov/books/NBK501587/

Image Credits:

- "Breastfeeding mother and baby" by Centers for Disease Control and Prevention is in the Public Domain

This page titled 17.6: Lactation is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by OpenStax via source content that was edited to the style and standards of the LibreTexts platform.

- 11.3: Nutrition in Early Infancy by Alice Callahan, Heather Leonard, and Tamberly Powell is licensed CC BY-NC-SA 4.0.

17.7: Nutrition and the Active Female

The female athlete has energy and nutrient needs that are unique compared to male athletes. Here is a blog that discusses those special needs and measures that can be taken to prevent problems related to low or inappropriate nutrient intake.

Blog - The Female Athlete: Energy and Nutrition Issues: http://www.gssiweb.org/en/sports-sci...trition-issues

This page titled 17.7: Nutrition and the Active Female is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.8: Elite Young Athletes

Young athletes have different energy and nutrient requirements compared to their adult counterparts, in part, because the young athletes are still growing and maturing. This abstract captures briefly the unique nutritional needs of elite young athletes. Much more research is needed in this area.

Abstract: Nutrition and Elite Young Athletes: https://www.gssiweb.org/en-ca/Article/nutrition-and-elite-young-athletes

This page titled 17.8: Elite Young Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.9: IOC Consensus on Youth Athletic Development

The International Olympic Committee made a consensus statement on youth athletic development in 2015. While the consensus covers much more than nutrition, many of the concerns and topics discussed interplay with nutrition. Here is the paper that was published:

> Paper: International Olympic Committee consensus statement on youth athletic development: bjsm.bmj.com/content/49/13/843.long

This page titled 17.9: IOC Consensus on Youth Athletic Development is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.10: Masters Athletes

Master athlete is generally someone over 35 year of age who competes in track and field events and/or cross country. This paper better explains the Master athlete and review the current exercise and treatment recommendations.

> Paper: The Masters Athlete: A Review of Current Exercise and Treatment Recommendations: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4482301/

Here is a short summary of the nutrition needs of the master athlete. Not much is known, so one needs to make sure the nutrient needs of someone that age are meet and then increase needs for athletic performance.

> Blog: Physiological Changes and Nutrition for Masters Athletes: https://journals.lww.com/acsm-healthfitness/Fulltext/2010/01000/Physiological_Changes_and_Nutrition_for_Masters.11.aspx

This page titled 17.10: Masters Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

17.11: Nutrition and Exercise Guidance for the Pregnant Athlete

The effect of exercise on the fetus is described in this blog:

> Blog: Fitness Training for Pregnant Athletes: https://www.active.com/women/articles/fitness-training-for-pregnant-athletes-876109

bjsm.bmj.com/content/50/10/571.long

This page titled 17.11: Nutrition and Exercise Guidance for the Pregnant Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

18: SELECTIVE TOPICS - FEMALE ATHLETE TRIAD

The female athlete triad is a syndrome characterized by disordered eating that results in low energy availability, amenorrhoea/oligomenorrhoea, and decreased bone mineral density(osteoporosis and osteopenia) are present. Also called the Triad, it is commonly seen in females participating in sports that emphasize leanness or low body weight such as endurance running, gymnastics, ballet, swimming, diving, and figure skating. The syndrome can cause lifelong health consequences and potentially be fatal.

18.1: Female Athlete Triad

18.2: IOC New Definition

This page titled 18: Selective Topics - Female Athlete Triad is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

18.1: Female Athlete Triad

In 1992, an association between disordered eating, amenorrhea, and osteoporosis was observed in female athletes concerned about a lean physique. The phrase, female athlete triad, was coined and is now used to describe a syndrome in which eating disorders (or low energy availability), amenorrhoea/oligomenorrhoea, and decreased bone mineral density (osteoporosis and osteopenia) are present.

- Here is the position of the American College of Sports Medicine on the female athlete triad: https://insights.ovid.com/pubmed?pmid=17909417

This page titled 18.1: Female Athlete Triad is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

18.2: IOC New Definition

In 2005, the International Olympic Committee (IOC) defined the Female Athlete Triad (Triad) as "the combination of disordered eating (DE) and irregular menstrual cycles eventually leading to a decrease in endogenous oestrogen and other hormones, resulting in low bone mineral density "(BMD). Since then, it has become clear that the Triad's etiology is an imbalance between dietary energy intake and energy expenditure required for daily living activities, growth, and exercise that results in an energy deficiency relative to the balance between energy intake and energy output. The triad is not an interplay of amenorrhea, osteoporosis, and low energy availability. Instead, the relative energy deficiency drives the alterations in menstrual function and bone health. So, the IOC has come forward with a consensus statement to rename the female athlete triad, Relative Energy Deficiency in Sport (RED-S). Here is the first consensus statement published in 2014, and the additions published in 2015.

- Paper: The IOC consensus statement: Beyond the Female Athlete Triad-Relative Energy Deficiency in Sport (RED-S) bjsm.bmj.com/content/48/7/491.long
- Paper: Authors' 2015 additions to the IOC consensus statement: Relative Energy Deficiency in Sport (RED-S) bjsm.bmj.com/content/49/7/417.long

This page titled 18.2: IOC New Definition is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

19: SELECTIVE TOPICS - DIABETIC ATHLETE

Improvements in the management of diabetes mellitus in the twentieth century have made it possible for athletes to compete in sport at a professional level. While it is rare for professional athletes to have type 2 diabetes, a number of notable athletes have type 1. Literature on the management of diabetes in competitive sports focuses on the difficulties with balancing energy and insulin intake during periods of strenuous exercise.



-  Topic hierarchy

19.1: Looking More Closely at Diabetes

19.2: Diabetes and the Athlete

This page titled 19: Selective Topics - Diabetic Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

19.1: Looking More Closely at Diabetes

Skills to Develop

- 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, 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 19.1.1). 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.

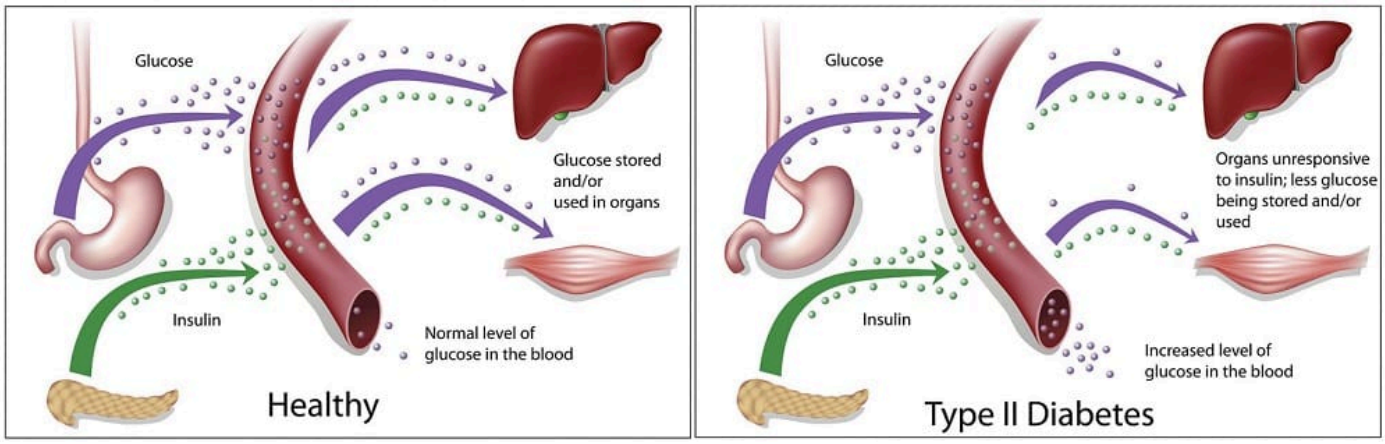


Figure 19.1.1: Type 2 diabetes is a metabolic disease characterized by high blood glucose levels. © Shutterstock

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 19.1.1: Do You Have High Blood Sugar?

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

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Having more than one risk factor for Type 2 diabetes substantially increases a person’s chances of 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 19.1.2). 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.

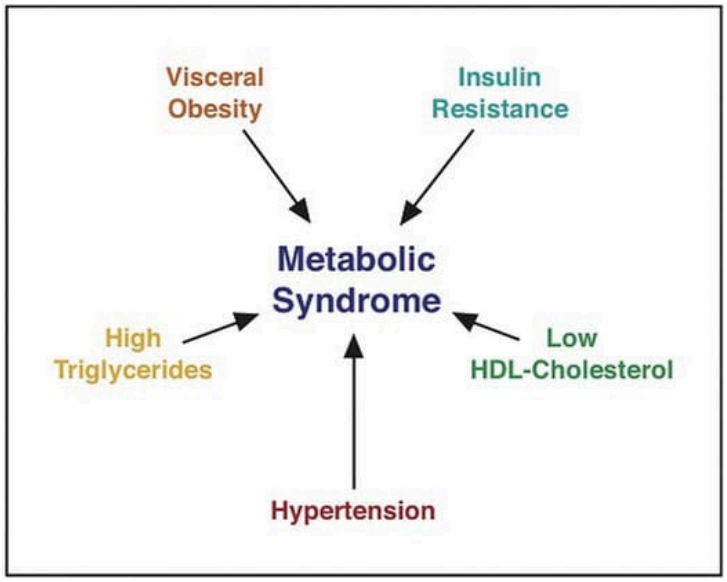


Figure 19.1.2: *Metabolic Syndrome: A Combination of Risk Factors Increasing the Chances for Chronic Disease*

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.

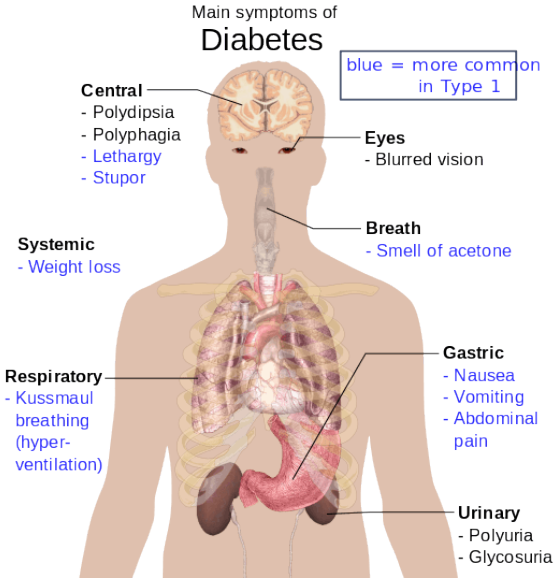


Figure 19.1.3: Overview of the most significant possible symptoms of diabetes. (Public domain; Mikael Häggström)

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 19.1.2: Diabetes and Associated Complications

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

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

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 improves 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 19.1.1

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?

This page titled 19.1: Looking More Closely at Diabetes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

19.2: Diabetes and the Athlete

This article focuses on physical activity and its impact on people with type 2 diabetes. Diabetic athletes should work with their healthcare providers to match their dietary needs with their medications.

- Paper: Exercise and Type 2 Diabetes: American College of Sports Medicine and the American Diabetes Association Joint Position Statement https://journals.lww.com/acsm-msse/F...ege_of.18.aspx

This article focuses on the dietary needs of type 1 diabetics. Much of what is discussed in this article is applicable to the type 2 diabetic athlete.

- Paper: Sports nutrition and diabetes: www.diapedia.org/management/8104958847/sports-nutrition-and-diabetes

This page titled 19.2: Diabetes and the Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

20: SELECTIVE TOPICS - DISABLED ATHLETE



- Topic hierarchy

20.1: Disabled Athlete

This page titled 20: Selective Topics - Disabled Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

20.1: Disabled Athlete

Paralympic athletes are highly competitive and need nutrition to maximize their performance but the energy and nutrient needs of this group have been poorly studied. Thus, they are forced to follow able-bodied recommendations which may not be appropriate. Here is one of very few scientific articles published on this topic.

- Paper: Evaluation of Dietary Intakes and Supplement Use in Paralympic Athletes, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5707738/

This page titled 20.1: Disabled Athlete is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

21: SELECTIVE TOPICS - NUTRITION FOR SPORTS INJURY



- Topic hierarchy

21.1: Nutrition for Sports Injury

This page titled 21: Selective Topics - Nutrition for Sports Injury is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

21.1: Nutrition for Sports Injury

An athlete may be injured and unable to play their sport. Nutrition is important to help that athlete recover quickly but wisely. The recovery period may involve a reduction in exercise or none at all but in either case, it is important that all the nutrients are supplied by their diet. Here is an article that will discuss nutrient needs during recovery from injuries.

Nutritional Support for Injuries Requiring Reduced Activity: http://gssiweb.org/en/sports-science...duced-activity

This page titled 21.1: Nutrition for Sports Injury is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

22: SELECTIVE TOPICS - NUTRITION CONSULTING

- Topic hierarchy

22.1: Nutrition Needs Analysis
22.2: Nutrition Consultation with Athletes
22.3: Scope of Practice for Exercise Professional

This page titled 22: Selective Topics - Nutrition Consulting is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

22.1: Nutrition Needs Analysis

Analyzing the needs of the athlete should be done by a qualified professional like the Registered Dietitian. The following section will provide a brief description of the steps the RD will take to determine the athlete's nutrition needs. This process will include determining the athlete's current body composition, weight and diet history, and current food intake. It may also include any current lab work and bone density if these are available.

Body composition: There are a variety of different ways to measure lean body mass or fat-free mass and fat mass. These techniques include: 1) anthropometrics, 2) underwater weighing, 3) DEXA, 4) Bodpod, 5) bioelectric impedance, 6) isotope dilution and 7) MRI to name a few but not all. Each has strengths and weaknesses. Here is an excellent review of the different methods for measuring body composition. Also, we discussed many of these techniques in a previous chapter.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2082845/

Body weight history: The athlete is asked to recall their body weight

Diet history: The athlete is asked to recall their food intake; this could be over a specific period of time and/or just foods in general. They may also be asked to recall what they ate the previous 24 hours.

There are a variety of different diet analysis programs available on the internet. Here are several resources for a few of the programs available:

1. This website provides a general review of a few programs available on the website. It lists Super Tracker which is no longer available (https://www.nal.usda.gov/fnic/software).

This page titled 22.1: Nutrition Needs Analysis is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

22.2: Nutrition Consultation with Athletes

Consultation and providing nutrition advice to the athlete must be left to the appropriate health care professional; an MD and RD should be involved. The goal is to provide the athlete with knowledge so obtaining good nutrition practice habits becomes second nature. The plan should be tailored to the specific athlete so it is easier for the athlete to make nutrition become a component of their training program. Again, certified personal trainers, conditioning coaches or professionals, athletic trainers, and strength coaches, need to be careful not to dispense medical nutrition information which is only allowed legally by the Registered Dietitian.

This page titled 22.2: Nutrition Consultation with Athletes is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

22.3: Scope of Practice for Exercise Professional

Who can provide nutrition advice? Most people can provide nutrition advice, to a degree. That is the good news but you need to be careful with the advice you provide. You cannot prescribe diets or supplements to treat medical or clinical conditions; prescribe diets to treat symptoms of medical and clinical conditions; or diagnose medical conditions. This reference discusses what you can and cannot do.

- Can personal trainers and health coaches give nutrition advice? https://www.precisionnutrition.com/c...trition-advice

This page titled 22.3: Scope of Practice for Exercise Professional is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

23: PUTTING IT ALL TOGETHER

- Topic hierarchy

23.1: Putting It All Together

This page titled 23: Putting It All Together is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

23.1: Putting It All Together

Nutrition is important for everyone, but it is essential for the athlete to succeed. As you have learned, the timing of nutrients before, during, and after exercise can make or break an exercise bout. Included in that are fluid needs; water is a nutrient too.

This page titled 23.1: Putting It All Together is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

INDEX

A

anaerobic exercise
4.5: Anaerobic Exercise

C

colostrum
17.6: Lactation

D

Dietary Toolkit
2.1: Dietary Toolkit

F

Female Athlete Triad
18.1: Female Athlete Triad

foremilk
17.6: Lactation

G

glycemic index
5.8: Glycemic Index

H

hindmilk
17.6: Lactation

L

lactation
17.6: Lactation

P

prolactin
17.6: Lactation

This page titled Index is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

GLOSSARY

S

Sample Word 1 | Sample Definition 1

This page titled Glossary is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.

DETAILED LICENSING

Overview

Title: APUS: Basic Foundation of Nutrition for Sports Performance (Byerley)

Webpages: 152

Applicable Restrictions: Noncommercial

All licenses found:

- CC BY-NC-SA 3.0: 98.7% (150 pages)
- Undeclared: 0.7% (1 page)
- CC BY-SA 4.0: 0.7% (1 page)

By Page

- APUS: Basic Foundation of Nutrition for Sports Performance (Byerley) - *CC BY-NC-SA 3.0*
  - Front Matter - *CC BY-NC-SA 3.0*
    - TitlePage - *CC BY-NC-SA 3.0*
    - InfoPage - *CC BY-NC-SA 3.0*
    - Table of Contents - *Undeclared*
    - Licensing - *CC BY-NC-SA 3.0*
  - 1: An Introduction to the Athlete's Nutrient and Diet Basics - *CC BY-NC-SA 3.0*
    - 1.1: Introduction - *CC BY-NC-SA 3.0*
    - 1.2: Introduction to Nutrition and Physical Fitness - *CC BY-NC-SA 3.0*
    - 1.3: Defining Nutrition, Health, and Disease - *CC BY-NC-SA 3.0*
    - 1.4: Basic Physiology of Exercise - *CC BY-NC-SA 3.0*
    - 1.5: The Broad Role of Nutritional Science - *CC BY-NC-SA 3.0*
    - 1.6: A Healthy Philosophy toward Food - *CC BY-NC-SA 3.0*
    - 1.7: What Are Nutrients? - *CC BY-NC-SA 3.0*
  - 2: The Athlete's Diet Basics and Tools - *CC BY-NC-SA 3.0*
    - 2.1: Dietary Toolkit - *CC BY-NC-SA 3.0*
    - 2.2: Nutritional Balance - Moderation and Variety - *CC BY-NC-SA 3.0*
    - 2.3: Understanding the Bigger Picture of Dietary Guidelines - *CC BY-NC-SA 3.0*
    - 2.4: National Goals for Nutrition and Health - Healthy People 2030 - *CC BY-NC-SA 3.0*
    - 2.5: Recommendations for Optimal Health - *CC BY-NC-SA 3.0*
    - 2.6: Understanding Dietary Reference Intakes - *CC BY-NC-SA 3.0*
    - 2.7: Discovering Nutrition Facts - *CC BY-NC-SA 3.0*
    - 2.8: When Enough is Enough - *CC BY-NC-SA 3.0*
  - 3: Digestion and Absorption - *CC BY-NC-SA 3.0*
    - 3.1: Introduction to Digestion and Absorption - *CC BY-NC-SA 3.0*
    - 3.2: The Basic Structural and Functional Unit of Life - The Cell - *CC BY-NC-SA 3.0*
    - 3.3: The Digestion and Absorption Process - *CC BY-NC-SA 3.0*
    - 3.4: Nutrients Are Essential for Organ Function - *CC BY-NC-SA 3.0*
    - 3.5: Gastrointestinal Tract and Your Health - *CC BY-NC-SA 3.0*
  - 4: Metabolism and Energy - *CC BY-NC-SA 3.0*
    - 4.1: Metabolism Overview - *CC BY-NC-SA 3.0*
    - 4.2: Energy and Calories - *CC BY-NC-SA 3.0*
    - 4.3: Balancing Energy Input with Energy Output - *CC BY-NC-SA 3.0*
    - 4.4: Aerobic Exercise - *CC BY-NC-SA 3.0*
    - 4.5: Anaerobic Exercise - *CC BY-NC-SA 3.0*
    - 4.6: Nutrients that are critical to athletes - *CC BY-NC-SA 3.0*
  - 5: Carbohydrate Basics - The Athlete's Energy Powerhouse - *CC BY-NC-SA 3.0*
    - 5.1: Introduction to Carbohydrates - *CC BY-NC-SA 3.0*
    - 5.2: A Closer Look at Carbohydrates - *CC BY-NC-SA 3.0*
    - 5.3: Digestion and Absorption of Carbohydrates - *CC BY-NC-SA 3.0*
    - 5.4: The Functions of Carbohydrates in the Body - *CC BY-NC-SA 3.0*
    - 5.5: Health Consequences and Benefits of High-Carbohydrate Diets - *CC BY-NC-SA 3.0*
    - 5.6: Carbohydrates and Personal Diet Choices - *CC BY-NC-SA 3.0*
    - 5.7: The Food Industry - Functional Attributes of Carbohydrates and the Use of Sugar Substitutes

- *CC BY-NC-SA 3.0*
    - 5.8: Glycemic Index - *CC BY-SA 4.0*
    - 5.9: Glycemic Index and the Athlete - *CC BY-NC-SA 3.0*
    - 5.10: Paper - A Step Towards Personalized Sports Nutrition - Carbohydrate Intake During Exercise - *CC BY-NC-SA 3.0*
- 6: Lipids Basics - Another Energy Source for the Athlete - *CC BY-NC-SA 3.0*
    - 6.1: Introduction to Lipids - *CC BY-NC-SA 3.0*
    - 6.2: What Are Lipids? - *CC BY-NC-SA 3.0*
    - 6.3: How Lipids Work - *CC BY-NC-SA 3.0*
    - 6.4: Digestion and Absorption of Lipids - *CC BY-NC-SA 3.0*
    - 6.5: Understanding Blood Cholesterol - *CC BY-NC-SA 3.0*
    - 6.6: Balancing Your Diet with Lipids - *CC BY-NC-SA 3.0*
    - 6.7: Lipids and the Food Industry - *CC BY-NC-SA 3.0*
    - 6.8: Lipids and Disease - *CC BY-NC-SA 3.0*
    - 6.9: A Personal Choice about Lipids - *CC BY-NC-SA 3.0*
    - 6.10: Exercise and fat oxidation - *CC BY-NC-SA 3.0*
- 7: Protein Basics - The Athlete's Structure Builder - *CC BY-NC-SA 3.0*
    - 7.1: Chapter Introduction - *CC BY-NC-SA 3.0*
    - 7.2: Defining Protein - *CC BY-NC-SA 3.0*
    - 7.3: The Role of Proteins in Foods - Cooking and Denaturation - *CC BY-NC-SA 3.0*
    - 7.4: Protein Digestion, Absorption and Metabolism - *CC BY-NC-SA 3.0*
    - 7.5: Protein's Functions in the Body - *CC BY-NC-SA 3.0*
    - 7.6: Diseases Involving Proteins - *CC BY-NC-SA 3.0*
    - 7.7: Proteins, Diet, and Personal Choices - *CC BY-NC-SA 3.0*
    - 7.8: Protein and the Athlete - *CC BY-NC-SA 3.0*
- 8: Vitamin and Mineral Basics - Metabolic Regulators - *CC BY-NC-SA 3.0*
    - 8.1: Chapter Introduction - *CC BY-NC-SA 3.0*
    - 8.2: Generation of Free Radicals in the Body - *CC BY-NC-SA 3.0*
    - 8.3: Antioxidant Micronutrients - *CC BY-NC-SA 3.0*
    - 8.4: The Whole Nutrient Package versus Disease - *CC BY-NC-SA 3.0*
    - 8.5: Bone Structure and Function - *CC BY-NC-SA 3.0*
    - 8.6: Bone Mineral Density is an Indicator of Bone Health - *CC BY-NC-SA 3.0*
    - 8.7: Micronutrients Essential for Bone Health - Calcium and Vitamin D - *CC BY-NC-SA 3.0*
    - 8.8: Deficiency, Supplementation, and Choices - *CC BY-NC-SA 3.0*
    - 8.9: Other Essential Micronutrients for Bone Health - *CC BY-NC-SA 3.0*
    - 8.10: Blood's Function in the Body and in Metabolism Support - *CC BY-NC-SA 3.0*
    - 8.11: Vitamins Important for Metabolism and for Blood Function and Renewal - *CC BY-NC-SA 3.0*
    - 8.12: Minerals Important for Blood Function and Renewal - *CC BY-NC-SA 3.0*
    - 8.13: Iron-Deficiency Anemia - *CC BY-NC-SA 3.0*
    - 8.14: Vitamins Important for Metabolism - *CC BY-NC-SA 3.0*
    - 8.15: Minerals Important for Metabolism and for Blood Function and Renewal - *CC BY-NC-SA 3.0*
- 9: Fueling the Athlete - *CC BY-NC-SA 3.0*
    - 9.1: Fueling the Athlete - *CC BY-NC-SA 3.0*
- 10: Hydration and Thermoregulation for Athletes - *CC BY-NC-SA 3.0*
    - 10.1: Chapter Introduction - *CC BY-NC-SA 3.0*
    - 10.2: Overview of Fluid and Electrolyte Balance - *CC BY-NC-SA 3.0*
    - 10.3: Water's Importance to Vitality - *CC BY-NC-SA 3.0*
    - 10.4: Regulation of Water Balance - *CC BY-NC-SA 3.0*
    - 10.5: Electrolytes Important for Fluid Balance - *CC BY-NC-SA 3.0*
    - 10.6: Consequences of Deficiency or Excess - *CC BY-NC-SA 3.0*
    - 10.7: Water Concerns - *CC BY-NC-SA 3.0*
    - 10.8: Water Requirements and Fluid Balance During Exercise - *CC BY-NC-SA 3.0*
    - 10.9: Exertional Heat - *CC BY-NC-SA 3.0*
- 11: Sports Driven Nutrition - *CC BY-NC-SA 3.0*
    - 11.1: Sport Driven Nutrition - *CC BY-NC-SA 3.0*
- 12: Body Composition and Maintaining, Gaining, and Losing Weight - *CC BY-NC-SA 3.0*
    - 12.1: Introduction to Body Composition and Maintaining, Gaining, and Losing Weight - *CC BY-NC-SA 3.0*
    - 12.2: Too Little or Too Much Weight? - *CC BY-NC-SA 3.0*
    - 12.3: Indicators of Health- Body Mass Index, Body Composition, and Fat Distribution - *CC BY-NC-SA 3.0*
    - 12.4: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management - *CC BY-NC-SA 3.0*
    - 12.5: Methods to Detect Body Composition in Sports - *CC BY-NC-SA 3.0*
    - 12.6: Diets and Weight Loss for Athletes - *CC BY-NC-SA 3.0*
- 13: Supplements - *CC BY-NC-SA 3.0*
    - 13.1: Overview of Fitness Supplements and Steroids - *CC BY-NC-SA 3.0*
    - 13.2: IOC Statement on Supplements - *CC BY-NC-SA 3.0*

- 13.3: Strength and Power Supplements - *CC BY-NC-SA 3.0*
- 13.4: Whole Foods as Ergogenic Aids - *CC BY-NC-SA 3.0*

◦ 14: Selective Topics- Anemia - *CC BY-NC-SA 3.0*
- 14.1: Case Study - *CC BY-NC-SA 3.0*
- 14.2: Iron Supplementation and Performance - *CC BY-NC-SA 3.0*

◦ 15: Selective Topics - Alcohol - *CC BY-NC-SA 3.0*
- 15.1: Introduction to Alcohol - *CC BY-NC-SA 3.0*
- 15.2: Alcohol Absorption and Metabolism - *CC BY-NC-SA 3.0*
- 15.3: Pros and Cons of Drinking Alcohol - *CC BY-NC-SA 3.0*
- 15.4: How Much to Drink? - *CC BY-NC-SA 3.0*
- 15.5: Alcohol and the Athlete - *CC BY-NC-SA 3.0*

◦ 16: Selective Topics - Vegetarian - *CC BY-NC-SA 3.0*
- 16.1: Vegetarian Athletes - *CC BY-NC-SA 3.0*

◦ 17: Selective Topics - Athletic Needs throughout the Lifespan - *CC BY-NC-SA 3.0*
- 17.1: Childhood and Nutrition - *CC BY-NC-SA 3.0*
- 17.2: Puberty and Nutrition - *CC BY-NC-SA 3.0*
- 17.3: Older Adolescence and Nutrition - *CC BY-NC-SA 3.0*
- 17.4: Young Adulthood and Nutrition - *CC BY-NC-SA 3.0*
- 17.5: Pregnancy and Nutrition - *CC BY-NC-SA 3.0*
- 17.6: Lactation - *CC BY-NC-SA 3.0*
- 17.7: Nutrition and the Active Female - *CC BY-NC-SA 3.0*
- 17.8: Elite Young Athletes - *CC BY-NC-SA 3.0*
- 17.9: IOC Consensus on Youth Athletic Development - *CC BY-NC-SA 3.0*
- 17.10: Masters Athletes - *CC BY-NC-SA 3.0*
- 17.11: Nutrition and Exercise Guidance for the Pregnant Athlete - *CC BY-NC-SA 3.0*

◦ 18: Selective Topics - Female Athlete Triad - *CC BY-NC-SA 3.0*
- 18.1: Female Athlete Triad - *CC BY-NC-SA 3.0*
- 18.2: IOC New Definition - *CC BY-NC-SA 3.0*

◦ 19: Selective Topics - Diabetic Athlete - *CC BY-NC-SA 3.0*
- 19.1: Looking More Closely at Diabetes - *CC BY-NC-SA 3.0*
- 19.2: Diabetes and the Athlete - *CC BY-NC-SA 3.0*

◦ 20: Selective Topics - Disabled Athlete - *CC BY-NC-SA 3.0*
- 20.1: Disabled Athlete - *CC BY-NC-SA 3.0*

◦ 21: Selective Topics - Nutrition for Sports Injury - *CC BY-NC-SA 3.0*
- 21.1: Nutrition for Sports Injury - *CC BY-NC-SA 3.0*

◦ 22: Selective Topics - Nutrition Consulting - *CC BY-NC-SA 3.0*
- 22.1: Nutrition Needs Analysis - *CC BY-NC-SA 3.0*
- 22.2: Nutrition Consultation with Athletes - *CC BY-NC-SA 3.0*
- 22.3: Scope of Practice for Exercise Professional - *CC BY-NC-SA 3.0*

◦ 23: Putting It All Together - *CC BY-NC-SA 3.0*
- 23.1: Putting It All Together - *CC BY-NC-SA 3.0*

◦ Back Matter - *CC BY-NC-SA 3.0*
- Index - *CC BY-NC-SA 3.0*
- Glossary - *CC BY-NC-SA 3.0*
- Detailed Licensing - *CC BY-NC-SA 3.0*

This page titled APUS: Basic Foundation of Nutrition for Sports Performance (Byerley) is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by LibreTexts.