NUTRI 300: NUTRITION



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SCC: Nutri 300 (Coppola)

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TABLE OF CONTENTS

Licensing

1: Nutrition and You

1.1: Defining Nutrition, Health, and Disease

1.2: What Are Nutrients?

1.3: The Broad Role of Nutritional Science

1.4: Health Factors and Their Impact

1.5: Serving Size

1.E: Nutrition and You (Exercises)

2: Achieving a Healthy Diet

2.1: Overview of Why we Need Recommendations for What to Eat and How Much

2.2: Why Nutrition is Critical for Health

2.3: What Constitutes a Healthy Diet?

2.4: Food Labels and How to Read Them

2.5: Trustworthy Sources of Information

2.6: My Plate - A Guide for Eating More Healthfully

2.7: Dietary Guidelines 2015-2020

2.8: National Goals for the Future

2.9: The Dietary Reference Intakes - How much of a Nutrient should we Consume?

2.E: Exercises

3: Nutrition and the Human Body

3.1: Chapter Introduction

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

3.3: Digestion and Absorption in the Gastrointestinal Tract (GI tract)

3.4: Nutrients Are Essential for Organ Function

3.5: Energy and Calories

3.6: Disorders That Can Compromise Health

3.E: Nutrition and the Human Body (Exercises)

4: Carbohydrates

4.1: Introduction to Carbohydrates

4.2: A Closer Look at Carbohydrates

4.3: Digestion and Absorption of Carbohydrates

4.4: The Functions of Carbohydrates in the Body

4.5: Looking Closely at Diabetes

4.6: Health Consequences and Benefits of High-Carbohydrate Diets

4.7: Carbohydrates and Personal Diet Choices

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

4.E: Carbohydrates (Exercises)

5: Lipids

5.1: Prelude to Lipids
5.2: What Are Lipids?
5.3: How Lipids Work
5.4: Digestion and Absorption of Lipids
5.5: Understanding Blood Cholesterol and Heart Attack Risk
5.6: Balancing Your Diet with Lipids
5.7: Lipids and the Food Industry
5.8: Lipids and Disease
5.9: A Personal Choice about Lipids
5.E: Lipids (Exercises)

6: Proteins

6.1: Prelude to Proteins
6.2: Defining Protein
6.3: The Role of Proteins in Foods- Cooking and Denaturation
6.4: Protein Digestion and Absorption
6.5: Protein's Functions in the Body
6.6: Diseases Involving Proteins
6.7: Proteins, Diet, and Personal Choices
6.E: Proteins (Exercises)

7: Vitamins

7.1: Vitamins- Basic Concepts

7.2: Fat Soluble Vitamins

7.2A: Vitamin A
7.2B: Vitamin D
7.2C: Vitamin E
7.2D: Vitamin K

7.3: Water Soluble Vitamins

7.3A: Vitamin B_1 (Thiamine)
7.3B: Vitamin B_2 (Riboflavin)
7.3C: Vitamin B_3 (Niacin)
7.3D: Vitamin B_5 (Pantothenic acid)
7.3E: Vitamin B_6 (Pyridoxine)
7.3F: Vitamin B_7 (Biotin)
7.3G: Vitamin B_9 (Folic acid)
7.3H: Vitamin B_{12} (Cobalamin)
7.3I: Vitamin C (Ascorbic acid)

8: Water and Minerals

8.1: Water

8.2: Minerals - Basic Concepts

8.3: Overview of Fluid and Electrolyte Balance

8.4: Water's Importance to Vitality

8.5: Regulation of Water Balance

8.6: Major Minerals

8.6A: Introduction to Major Minerals

8.6B: Calcium

8.6C: Phosphorus

8.6D: Sulfur

8.6E: Magnesium

8.6F: Sodium

8.6G: Chloride

8.6H: Potassium

8.7: Trace Minerals

8.7A: Prelude to Trace Minerals

8.7B: Iron

8.7C: Copper

8.7D: Zinc

8.7E: Iodine

8.7F: Chromium

8.7G: Manganese

8.7H: Molybdenum

8.7I: Fluoride

8.7J: Selenium

9: Energy Balance and Healthy Weight

9.1: Prelude to Energy Balance and Body Weight

9.2: Indicators of Health- Body Mass Index, Body Fat Content, and Fat Distribution

9.3: Balancing Energy Input with Energy Output

9.4: Too Little or Too Much Weight?

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

9.E: Energy Balance and Body Weight (Exercises)

10: Physical Fitness

10.1: Introduction to Nutrition and Physical Fitness

10.2: Aerobic Exercise

10.3: Anaerobic Exercise

10.4: Fitness Supplements and Steroids

10.5: How do my muscles get the Energy to perform work?

10.6: Nutrients that are critical to athletes
10.7: Creating your own fitness plan

11: Food Safety and the Future of our Food

11.1: Protecting Our Food
11.2: Microbes in Food
11.3: Foodborne Illness
11.4: Common Food-Borne Pathogens
11.5: Foodborne Illness and Food Safety
11.6: Food Preservation
11.7: Preparing for Disasters
11.8: Food Additives
11.9: Start Your Sustainable Future Today
11.10: Genetically Modified Foods (GMO's)

Index

Glossary

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1: NUTRITION AND YOU

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

1.1: Defining Nutrition, Health, and Disease

1.2: What Are Nutrients?

1.3: The Broad Role of Nutritional Science

1.4: Health Factors and Their Impact

1.5: Serving Size

1.E: Nutrition and You (Exercises)

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1.1: Defining Nutrition, Health, and Disease

Learning Objective

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

You and I are bombarded with images and messages about food everywhere we go. We see super models eating giant burgers, chefs battling to prepare meals, and the top places to burst your belly from consuming atomic chicken wings and deli sandwiches longer than a foot. There are also shows that feature bizarre foods from cultures around the world. How do you use the information from popular network food shows to build a nutritious meal? You don't—these shows are for entertainment. The construction of a nutritious meal requires learning about which foods are healthy and which foods are not-so-health, 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 text is designed to provide you with the information necessary to make sound nutritional choices that will optimize health and help prevent disease.



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How do you fill your plate?

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

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

Your ability to wake up, to think clearly, to communicate, to hope, to dream, to go to school, to gain knowledge, to go to work,

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

Interactive 1.1

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

Nutrition and Health and Disease

In 1946, the World Health Organization (WHO) defined health as “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.” 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.

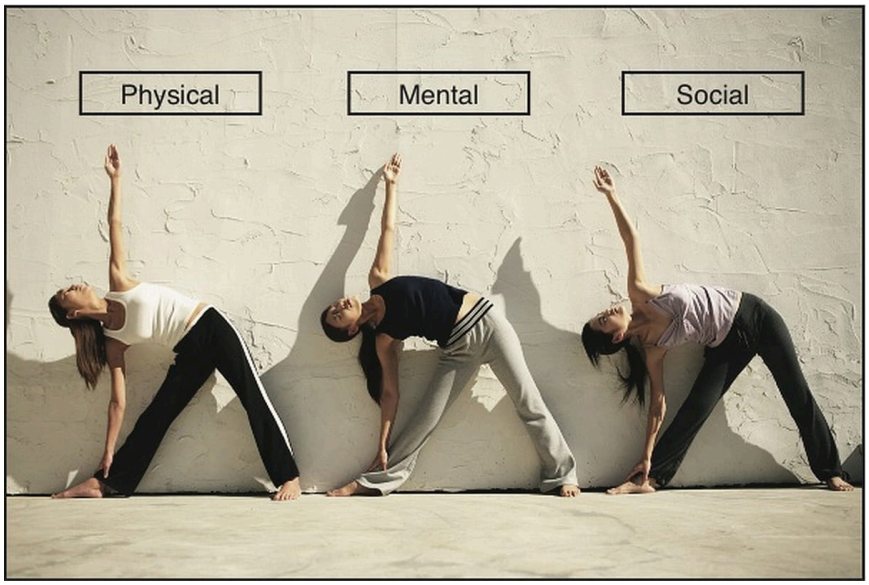


Figure 1.1.1: The Health Triangle. © Thinkstock

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

Public Health and Disease Prevention

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

Americans.

Although 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.

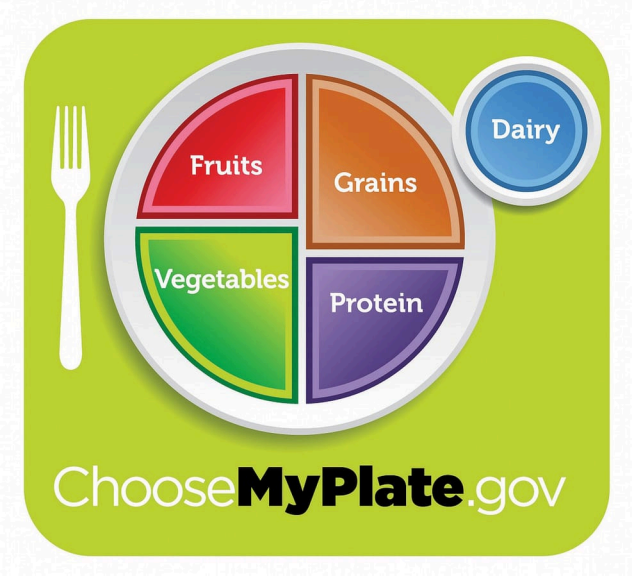


Figure 1.2: The Federal Government’s New and Improved Tool of Nutritional Communication

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

Key Takeaways

- Health is defined as “a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity.” World Health Organization.
- Disease is defined as any abnormal condition that affects the health of an organism, and is characterized by specific signs and symptoms.
- Disease affects all three aspects of the health triangle.
- Good nutrition provides a mechanism to promote health and prevent disease.

- Diet-related conditions and diseases include: obesity, Type 2 diabetes, cardiovascular disease, some cancers, and osteoporosis.
- It took until the 1980s for the US federal government to develop a diet-related public policy designed to equip Americans with the tools to change to a healthier diet.

Discussion Starters

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

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1.2: 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. The diet of most people contains a variety of foods: nuts, seeds, leafy green vegetables and more! The foods we eat contain nutrients. Nutrients are substances required by the body to perform its basic functions. Nutrients must be obtained from 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 fiber and antioxidants, some non-nutrients may be harmful to human health such as: preservatives, colorings, flavorings and pesticide residues.

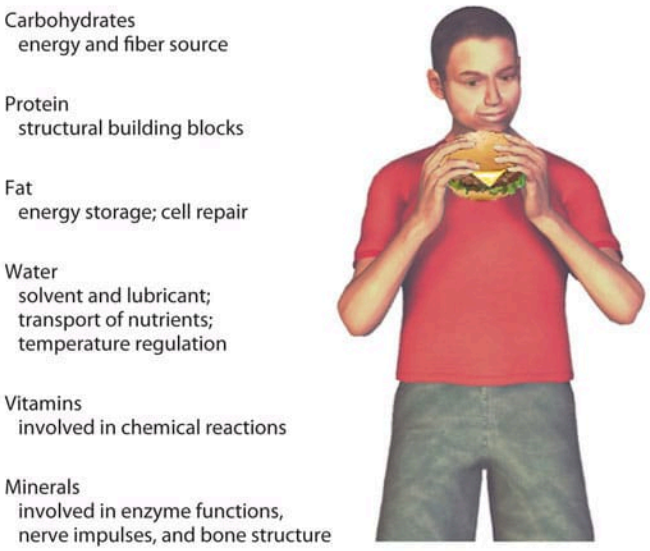


Figure 1.2.1: The Six Classes of Nutrients. Source: http://www.chemistry.wustl.edu/~edud.../vitamins.html.

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 generally NOT considered to be a nutrient. Alcohol (in the form of ethanol) provides about 7 Calories per gram.

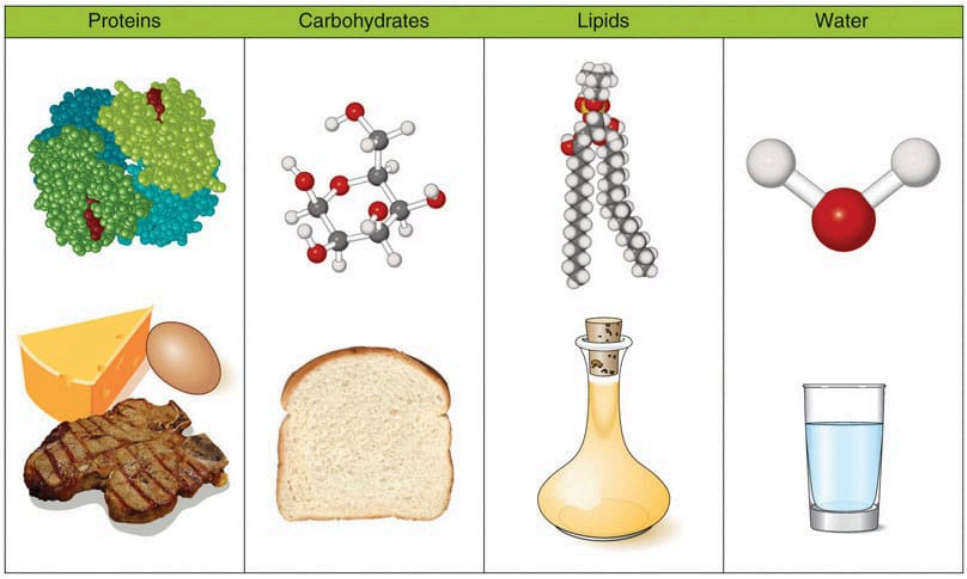


Figure 1.2.2: The Macronutrients: Carbohydrates, Lipids, Protein, and Water

Carbohydrates

When you eat a food that contains carbohydrate, 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 a Glucose linked together with a Fructose. Lactose is made of Glucose linked together with Galactose. 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!

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 to 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 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 generally not considered nutrients. Alcohol itself provides approximately 7 Calories for every gram consumed. In addition to alcohol, many alcoholic drinks contain carbohydrate 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 1.2.1 and 1.2.2 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 1.2.1: : Minerals and Their Major Functions

Minerals	Major Functions
Macro	
Sodium	Fluid balance, nerve transmission, muscle contraction
Chloride	Fluid balance, stomach acid production

Minerals	Major Functions
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 1.2.1: Vitamins and Their Major Functions

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

Vitamins	Major Functions
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 1.2.1). 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 1.2.1: 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 candy bar gives you quite a few Calories but not very many of the essential nutrients. We would say that the candy bar 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: What is a calorie? - Emma Bryce

One measurement of food quality is the amount of nutrients it contains relative to the amount of energy (Calories) it provides. High-quality foods are nutrient dense, meaning they contain lots of the nutrients relative to the amount of Calories they provide. Nutrient-dense foods are the opposite of "empty-calorie" foods such as carbonated sugary soft drinks, which provide many calories and very little, if any, other nutrients. Food quality is additionally associated with its taste, texture, appearance, microbial content, and how much consumers like it.

Food: A Better Source of Nutrients

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

Key Takeaways

- Foods contain nutrients that are essential for our bodies to function.
- Four of the 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 1.2.1.

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1.3: The Broad Role of Nutritional Science

Learning Objective

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

How to Determine the Health Effects of Food and Nutrients

Similar to the method by which a police detective finally charges a criminal with a crime, nutritional scientists discover the health effects of food and its nutrients by 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, the Greek word for violet. The following scientific record is some of what took place in order to conclude that iodine is a nutrient.

- **Observation.** Eating seaweed is a cure for goiter, a gross enlargement of the thyroid gland in the neck.
- **Hypothesis.** In 1813, Swiss physician Jean-Francois Coindet hypothesized that the seaweed contained iodine and he could use just iodine instead of seaweed to treat his patients.
- **Experimental test.** Coindet administered iodine tincture orally to his patients with goiter.
- **Interpret results.** Coindet's iodine treatment was successful.
- **Gathering more evidence.** Many other physicians contributed to the research on iodine deficiency and goiter.
- **Hypothesis.** French chemist Chatin proposed that the low iodine content in food and water of certain areas far away from the ocean were the primary cause of goiter and renounced the theory that goiter was the result of poor hygiene.
- **Experimental test.** In the late 1860s the program, "The stamping-out of goiter," started with people in several villages in France being given iodine tablets.
- **Results.** The program was effective and 80 percent of goitrous children were cured.
- **Hypothesis.** In 1918, Swiss doctor Bayard proposed iodizing salt as a good way to treat areas endemic with goiter.
- **Experimental test.** Iodized salt was transported by mules to a small village at the base of the Matterhorn where more than 75 percent of school children were goitrous. It was given to families to use for six months.
- **Results.** The iodized salt was beneficial in treating goiter in this remote population.
- **Experimental test.** Physician David Marine conducted the first experiment of treating goiter with iodized salt in America in Akron, Ohio.
- **Results.** This study conducted on over four-thousand school children found that iodized salt prevented goiter.
- **Conclusions.** Seven other studies similar to Marine's were conducted in Italy and Switzerland that also demonstrated the effectiveness of iodized salt in treating goiter. In 1924, US public health officials initiated the program of iodizing salt and started eliminating the scourge of goiterism. Today more than 70 percent of American households use iodized salt and many other countries have followed the same public health strategy to reduce the health consequences of iodine deficiency.

Evidence-Based Approach to Nutrition

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

"Systems for Evaluating Nutrition Research for Nutrition Care Guidelines: Do They Apply to Population Dietary Guidelines?" *J Am Diet Assoc* 103, no. 12, supplement 2 (December 2003): 34–41.

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

The Food and Nutrition Board of the Institute of Medicine, a nonprofit, nongovernmental organization, constructs its nutrient recommendations (i.e., Dietary Reference Intakes, or DRI) using an evidence-based approach to nutrition. The entire procedure for setting the DRI is documented and made available to the public. The same approach is used by the USDA and HHS, which are departments of the US federal government. The USDA and HHS websites are great tools for discovering ways to optimize health; however, it is important to gather nutrition information from multiple resources as there are often differences in opinion among various scientists and public health organizations. While the new *Dietary Guidelines*, published in 2015, have been well-received by some, there are nongovernmental public health organizations that are convinced that some pieces of the guidelines may be influenced by lobbying groups and/or the food industry. For example, the Harvard School of Public Health (HSPH) feels the government falls short by being "too lax on refined grains." The guidelines recommend getting at least *half* of grains from whole grains—according to the HSPH this still leaves too much consumption of refined grains.

For a list of reliable sources that advocate good nutrition to promote health and prevent disease using evidence-based science see Table 1.3.1. In subsequent sections, 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 1.3.1: Web Resources for Nutrition and Health

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

Organization	Website
The Academy of Nutrition and Dietetics	http://www.eatright.org/
Institute of Medicine: Food and Nutrition	www.iom.edu/Global/Topics/Food-Nutrition.aspx
Dietitians of Canada	http://www.dietitians.ca/

Types of Scientific Studies

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

Epidemiological studies are observational studies that look for health patterns and are often the front-line studies for public health. The CDC defines epidemiological studies as scientific investigations that define frequency, distribution, and patterns of health events in a population. Thus, these studies describe the occurrence and patterns of health events over time. The goal of an epidemiological study is to find factors associated with an increased risk for a health event, though these sometimes remain elusive. An example of an epidemiological study is the Framingham Heart Study, a project of the National Heart, Lung and Blood Institute and Boston University that has been ongoing since 1948. This study first examined the physical health and lifestyles of 5,209 men and women from the city of Framingham, Massachusetts and has now incorporated data from the children and grandchildren of the original participants. One of the seminal findings of this ambitious study was that higher cholesterol levels in the blood are a risk factor for heart disease. The Framingham Heart Study, a project of the National Heart, Lung, and Blood Institute and Boston University. “History of the Framingham Heart Study.” Epidemiological studies are a cornerstone for examining and evaluating public health and some of their advantages are that they can lead to the discovery of disease patterns and risk factors for diseases, and they can be used to predict future healthcare needs and provide information for the design of disease prevention strategies for entire populations. Some shortcomings of epidemiological studies are that investigators cannot control environments and lifestyles, a specific group of people studied may not be an accurate depiction of an entire population, and these types of scientific studies cannot directly determine if one variable causes another. Scientists regard epidemiological studies as a starting place for ideas about what types of lifestyle choice MAY contribute to a disease. They can show a correlation between two things happening but not whether one factor CAUSED the other. My favorite example of this is a thought experiment where a make-believe scientist observes (through epidemiological studies) that 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 scientist 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 treat high blood pressure. The attributes of high-quality clinical interventional trial studies are:

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

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

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

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

Other scientific studies used to provide supporting evidence for a hypothesis include laboratory studies conducted on animals or cells. An advantage of this type of study is that they typically do not cost as much as human studies and they require less time to conduct. Other advantages are that researchers have more control over the environment and the amount 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 are that researchers are not working with whole humans and thus the results may not be relevant. Nevertheless, well-conducted animal and cell studies that can be repeated by multiple researchers and obtain the same conclusion are definitely helpful in building the evidence to support a scientific hypothesis.

Evolving Science

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

Science can also be contentious even amongst experts that don’t have any conflicting financial interests. To see scientists debating over the nutritional guidelines, watch Video \({1{.}3{.}\eatSpaces{1} \endSpaces}\. Contentious science is actually a good thing as it forces researchers to be of high integrity, well-educated, well-trained, and dedicated. It also instigates public health policy makers to seek out multiple sources of evidence in order to support a new policy. 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

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Video 1.3.1: 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 make 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.

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 1.3.2: 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 1.3.1:. 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 1.3.1: 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 as a commonly accepted conclusion.
- Agreement of experts across multiple scientific disciplines is a necessity for recommending dietary changes to improve health and help to prevent disease.
- Science is always evolving as more and more information is collected.

Discussion Starters

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

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1.4: Health Factors and Their Impact

Learning Objective

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

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

Genetics

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



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

Now that we understand the map of the human genome, let's enter the fields of nutrigenomics and epigenetics. Recall that nutrigenomics is an emerging scientific discipline aimed at defining healthy genes and not-so-healthy genes and how nutrients affect them. Currently, scientists cannot change a person's DNA sequence. But they have discovered that chemical reactions in the body can turn genes "on" and "off," causing changes in the amounts and types of proteins expressed. Epigenetics is another rapidly advancing scientific field in which researchers study how chemical reactions turn genes "on" and "off" and the factors that influence the chemical reactions. Some of these factors are now known to be nutrients. Researchers at the Genetic

Science Learning Center at the University of Utah conducted an experiment in which some pregnant mice were fed a diet containing folate, choline, vitamin B_{12}, and betaine, and other pregnant mice were fed a diet that did not contain these nutrients and chemicals. Both groups of pregnant mice were also fed bisphenol A, a chemical in plastic, which alters DNA by inhibiting a specific chemical reaction. The mice born from the mother fed the supplemented diet were brown, thin, and healthy. The mice born from the mother fed the unsupplemented diet were yellow, fat, and unhealthy. This is a dramatic example of how nutrients change not the sequence of DNA, but which genes are expressed. These two mice look different, but have identical DNA sequences. Thus, not only do the things you eat determine your health, but so do the things your mother ate during pregnancy. Moreover, other studies have demonstrated what your dad ate—and what your grandmother ate while she was pregnant with your mother!—also can affect your gene expression and, consequently, your health. Does this make it OK for you to blame your mother and father for all of your shortcomings? No. Genetics are important in determining your health, but they are certainly not the only determinant.

Interactive 1.4.1

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

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

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

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

The Life Cycle

The life cycle of human beings originates from a fertilized egg, which develops into a fetus that is eventually born as a baby. A baby develops into a child, transitions through the wonderful phase of adolescence, becomes an adult, and then advances into old age and eventually death (Figure 1.4.1). The current average life expectancy in America is approaching eighty. To see how this compares with other countries, see Interactive 1.4.2.

Interactive 1.4.2: The World Bank

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

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

A person's stage of life influences their health and nutritional requirements. For example, when you are an adolescent, your bones grow quickly. More calcium, a bone-building nutrient, is required in the diet during this life stage than at other ages. As you get older, the aging process affects how your body functions. One effect of aging, apparently earlier in women than in men, is the deterioration of bone tissue. As a result, women over age fifty-one need more calcium in their diet than younger adult women. Another life-cycle stage, pregnancy, requires several adjustments to nutrition compared to nonpregnant women. It is recommended that a pregnant woman consume more protein than a nonpregnant woman to support growth and development,

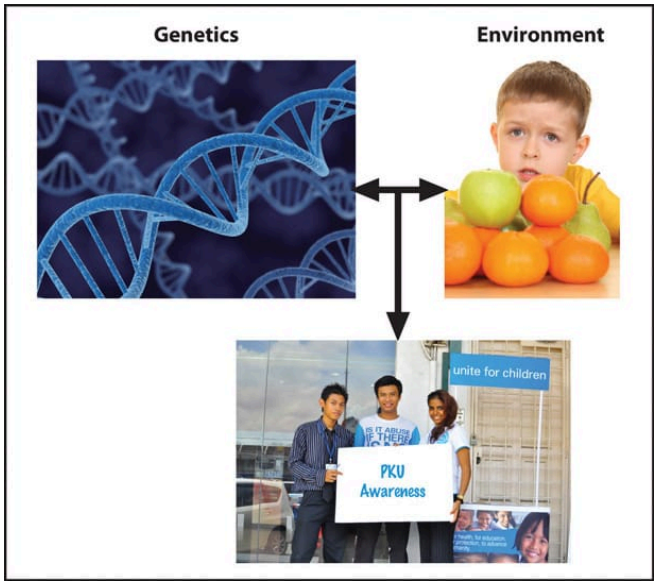
and to consume more of some vitamins, such as folate, to prevent certain birth defects. The USDA provides information on healthy diets for many different stages of the life cycle on their website. Healthy aging requires eating a diet that matches one's life stages to support the body's specific physiological requirements. What else is known to help a person age slowly and gracefully? Diets high in vegetables and fruits are associated with increased longevity and a decreased risk of many diseases.



Figure 1.4.1: The Life Cycle - The Forward March to Old Age and Ultimately Death. © Shutterstock

Environment

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



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

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

Socioeconomic Status

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

Interactive 1.4.3: CAUses of Death

To see the differences in causes of death for different sexes, races, and age groups, visit the website of Healthy People and compare the top ten causes of death for different populations (http://www.healthypeople.gov/2020/default.aspx).

Lifestyle

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

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

Interactive 1.4.4: Physical Activity Guidelines

Go to the HHS website to access the entire *2008 Physical Activity Guidelines for Americans* (https://health.gov/paguidelines/guidelines).

Recreational Drug Use

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

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

Sleeping Patterns

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

Interactive 1.4.5

Go to the HHS website and discover the many tools at your fingertips to live a healthier lifestyle. (www.healthfinder.gov/prevention/)

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

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

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

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

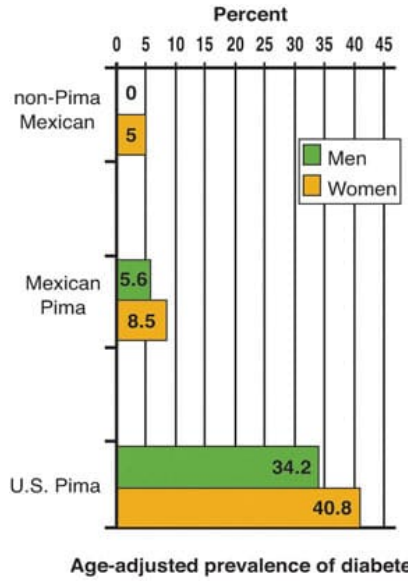


Figure 1.4.2: The Interplay of Nutrition, Genetics, Environment, and Lifestyle Affects Health. Pima Indians living in America are genetically similar to those who live in Mexico, but differences in their nutrition, environment, and lifestyle changes their health. Source: paleobioticslab.com/general-i...he-rest-of-us/.

Tools for Change

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

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

Personal Choice: The Challenge of Choosing Foods

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

Food also has psychological, cultural, and religious significance, so your personal choices of food affect your body, mind, and soul. The social implications of food have a great deal to do with what people eat, as well as how and when. Special events in individual lives—from birthdays to funerals—are commemorated with equally special foods. Being aware of these forces can help people make healthier food choices—and still honor the traditions and ties they hold dear. Typically, eating kosher food means a person is Jewish; eating fish on Fridays during Lent means a person is Catholic; fasting during the ninth month of the Islamic calendar means a person is Muslim. On New Year's Day, people from New England like to combine pork and sauerkraut as a way

to eat their way to luck. Several hundred miles away in the southern United States, people eat Hoppin' John, a favorite local dish made with black-eyed peas and pork, while fish is the "lucky" food of choice for Japanese Americans. National food traditions are carried to other countries when people immigrate. American cuisine would not be what it is today without the contributions of Italian, Chinese, Mexican, and other immigrants.

Factors that Drive Food Choices

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

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

Takeaways

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

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

Discussion Starters

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

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1.5: Serving Size

Learning Objectives

- Judge food portion sizes for adequacy.

Estimating Portion Size

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

The food industry makes following the *2010 Dietary Guidelines* a challenge. In many restaurants and eating establishments, portion sizes have increased, use of SoFAS has increased, and consequently the typical meal contains more calories than it used to. In addition, our sedentary lives make it difficult to expend enough calories during normal daily activities. In fact, more than one-third of adults are not physically active at all.

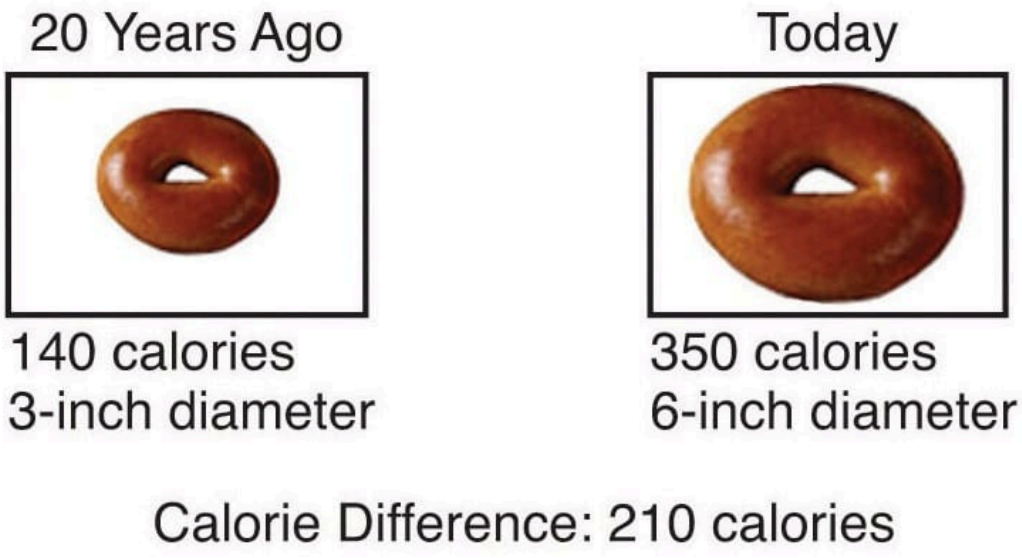


Figure 1.5.1: As food sizes and servings increase it is important to limit the portions of food consumed on a regular basis.

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 1.5.1 for some examples.American Cancer Society. “Controlling Portion Sizes.” Last revised January 12, 2012. http://www.cancer.org/Healthy/EatHealthyGetActive/TakeControlofYourWeight/controlling-portion-sizes.

Table 1.5.1: 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 1.5.1: 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

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

MyPlate Planner

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

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

Table 1.5.2: 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.

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1.E: Nutrition and You (Exercises)

Study Questions:

1. What does Essential mean?

2. What are the 6 classes of essential nutrients? Put a star by the MOST essential nutrient.

3. How many of the 6 classes of essential nutrients are present in the food you eat?

4. Which of the nutrients give you Calories?

5. If you ate a food that contained: 10 grams of Carbohydrate, 10 grams of Fat and 10 grams of Protein, how many Calories would that food contain (approximately)? *Hint: Use 4 Calories per gram of Carbohydrate, 9 Calories per gram of Fat and 4 Calories per gram of Protein*

6. Is Alcohol a nutrient? Does Alcohol give you Calories?

7. When it comes to nutrients, is it “the more the better”? Why or Why not?

8. Are there “good foods” and “bad foods”? Why or Why not?

9. What are “phytochemicals”?

10. What is meant by the term "serving size"? *For example, a "serving size" of potato chips is 1 ounce or about 15 chips.*

11. What is your opinion of the role of the federal government in promoting health and preventing disease in Americans?

Expand Your Knowledge

1. Conduct an assessment of your diet. Begin by recording what you eat every day, including snacks and beverages, in a journal. Then visit the website, myfitnesspal.com which has tools to help you assess your diet and exercise. Calculate how many Calories you are eating in a day compared to how many are suggested for you per day.
2. Conduct an informal survey of five of your friends and family members. Create a questionnaire with ten to fifteen questions pertaining to their perception of food, their favorite food shows, what restaurants they frequent, what they purchase from the grocery store each week, etc. Ask questions about their general eating habits and record the answers. Next, get a camera and take pictures of the insides of their refrigerators. What have you learned about their eating habits? What advice would you give them? Review all the material and put it together in a report. Be prepared to share your findings.
3. Define eight steps your community can take to build a more sustainable food system. Visit the websites of Toronto’s and California’s plans to help provide you with some good ideas to accomplish the challenge. Toronto’s plan for a sustainable food system: wx.toronto.ca/inter/health/fo...s%20report.pdf

   California’s plan for a sustainable food system: www.vividpicture.net/

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2: ACHIEVING A HEALTHY DIET

In Chapter 2, we explore the tools you can use to achieve a healthy diet, as well as important nutrition concepts like balance and moderation.

2.1: Overview of Why we Need Recommendations for What to Eat and How Much

2.2: Why Nutrition is Critical for Health

2.3: What Constitutes a Healthy Diet?

2.4: Food Labels and How to Read Them

2.5: Trustworthy Sources of Information

2.6: My Plate - A Guide for Eating More Healthfully

2.7: Dietary Guidelines 2015-2020

2.8: National Goals for the Future

2.9: The Dietary Reference Intakes - How much of a Nutrient should we Consume?

2.E: Exercises

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2.1: Overview of Why we Need Recommendations for What to Eat and How Much

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 fruit 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.



Figure 2.1.2: A key part of the former First Lady Michelle Obama’s healthy eating campaign is the new My Food Plate. Official portrait of First Lady Michelle Obama in the Green Room of the White House. Unfortunately from a nutrition perspective, regulations put in place to advance nutrition in school children's diets have been rolled back by the subsequent administration.

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

> 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.

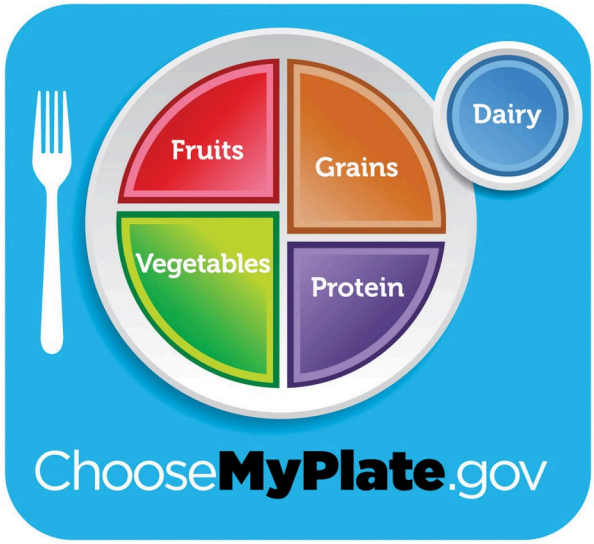


Figure 2.1.3: Today, the US government sets dietary guidelines that provide evidence-based nutrition information designed to improve the health of the population. Source: US Department of Agriculture.

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2.2: Why Nutrition is Critical for Health

Learning Objectives

- Explain why nutrition is important to health.

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

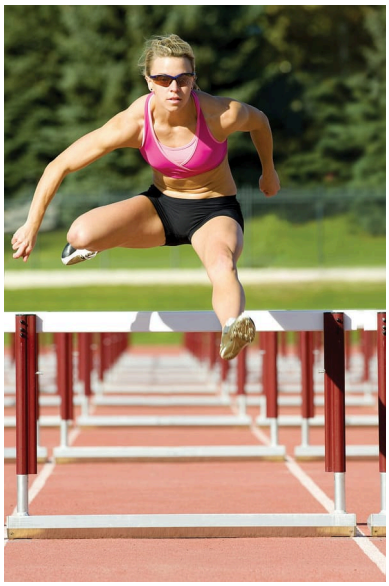


Figure 2.2.1: Nutrition provides the body with the nutrients it needs to perform all activities, from taking a breath to strenuous athletic activity. © Dreamstime

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.

Table 2.2.1: Why Nutrition Is Important to Health

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

Undernutrition, Overnutrition, and Malnutrition

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

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

Growth and Development

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



Figure 2.2.2: 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 2.2.3: Healing, a critical function of a healthy body, is facilitated by adequate nutrition.

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

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

Key Takeaways

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

Discussion Starter

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

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2.3: What Constitutes a Healthy Diet?

Learning Objectives

- Define the components of a healthful diet.

Achieving a Healthy Diet

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

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

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

Adequacy

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

Tools for Change

Does your diet contain nutrient-dense foods? Record your eating habits for one week. Note the sugary, fatty, and calorie-heavy foods you most often consume. Look at Table 2.3.1 to decide what you can substitute those foods with.

Table 2.3.1: 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 2.3.1: With careful planning, a balanced diet providing optimal nutrition can be achieved and maintained. © Shutterstock

Moderation

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

Calorie Control

Monitor food portions. For optimum weight maintenance, it is important to ensure that energy consumed from foods meets the energy expenditures required for body functions and activity. If not, the excess energy contributes to gradual, steady weight gain. In order to lose weight, you need to ensure that more calories are burned than consumed. Likewise, in order to gain weight, calories must be eaten in excess of what is expended daily. So what exactly is a Calorie anyway? Watch this YouTube Video called "What is a calorie? - Emma Bryce"

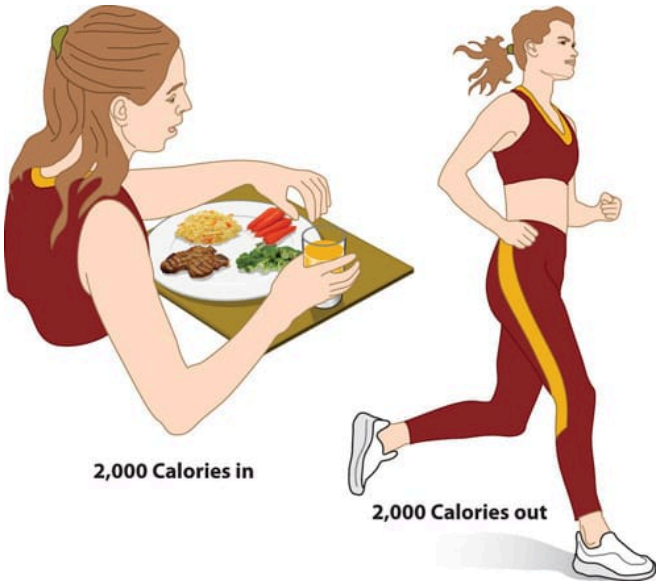


Figure 2.3.2: The number of calories consumed should always match the number of calories being expended by the body to maintain a healthy weight.© Networkgraphics

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 2.3.2: 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.				

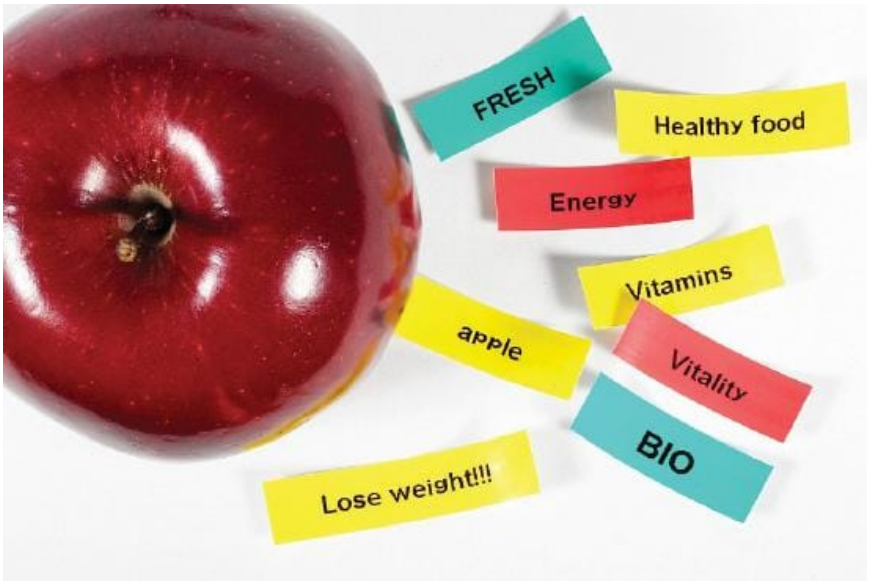


Figure 2.3.3: Scientific evidence confirms that a diet full of fresh whole foods reduces the risks for developing chronic disease and helps maintain a healthy weight. © Dreamstime

Video Link

Different Types of Grains: In this video, a registered dietitian discusses the benefits of eating whole grains. https://youtu.be/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.

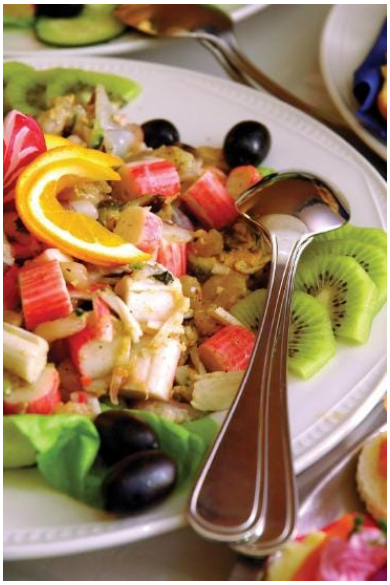


Figure 2.3.4: Widening your food palate will increase your intake of vital nutrients. © Dreamstime

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 2.3. Pick one that you have not tried before. Make a dish using this grain. Discuss with your classmates your experience eating this new food.

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2.4: Food Labels and How to Read Them

Learning Objectives

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

The Labels on Your Food

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

In the United States, the Nutrition Labeling and Education Act passed in 1990 and came into effect in 1994. In Canada, mandatory labeling came into effect in 2005. As a result, all packaged foods sold in the United States and Canada must have nutrition labels that accurately reflect the contents of the food products. There are several mandated nutrients and some optional ones that manufacturers or packagers include. Table 2.4.1 lists the mandatory and optional inclusions.

Table 2.4.1: Mandatory and Optional Inclusions on Nutrition Labels

Mandatory Inclusion	Optional Inclusion
Total Calories	Calories from saturated fats
Calories from fat	Polyunsaturated fat
Total fat	Monounsaturated fat
Saturated fat	Potassium
Cholesterol	Soluble fiber
Total carbohydrates	Sugar alcohol
Dietary fiber	Other carbohydrates
Sugars	Percent of vitamin A present as beta-carotene
Vitamins A and C	Other essential vitamins and minerals
Calcium	
Iron	
Source: US Food and Drug Administration. “Food Labeling Guide.” Last updated February 10, 2012. http://www.fda.gov.	

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 (US Food and Drug Administration. “Food Labeling & Nutrition”)

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/Cons...abelHighlights. 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: http://www.fda.gov/Food/LabelingNutrition/default.htm.

Interactive Link: The Food Label and You.

The FDA has prepared an Interactive Food Label that is packed with helpful information. http://www.accessdata.fda.gov/script...tionFactsLabel

Reading the Label

The first part of the Nutrition Facts panel gives you information on the serving size and how many servings are in the container. For example, a label on a box of crackers might tell you that twenty crackers equals 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. This helps you determine if the food is a good source of a particular nutrient or not. The Daily Value (DV) represents the recommended amount of a given nutrient based on the RDI of that nutrient in a 2,000-kilocalorie diet. The percentage of Daily Value (percent DV) represents the proportion of the total daily recommended amount that you will get from one serving of the food. For example, in the food label in Figure 2.4.1, the percent DV of calcium for one serving of macaroni-and-cheese is 20 percent, which means that one serving of macaroni and cheese provides 20 percent of the daily recommended calcium intake. Since the DV for calcium is 1,000 milligrams, the food producer determined the *percent* DV for calcium by taking the calcium content in milligrams in each serving, and dividing it by 1,000 milligrams, and then multiplying it by 100 to get it into percentage format. Whether you consume 2,000 calories per day or not you can still use the percent DV as a target reference.

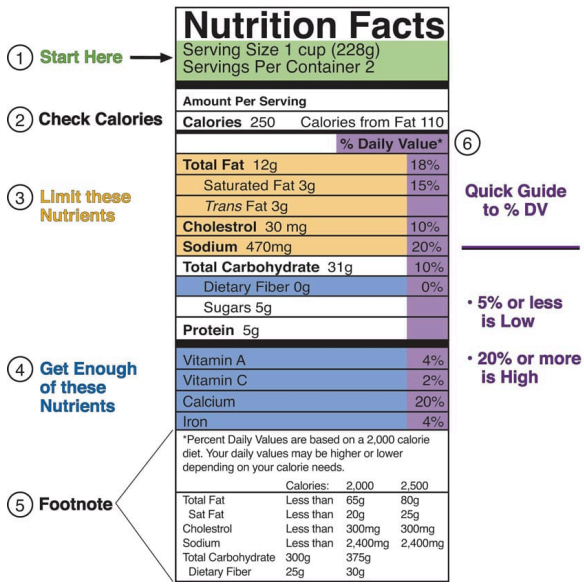


Figure 2.4.1: Determining Your Nutrient Allowances per Day. Pictured here is a sample label for macaroni and cheese. Source: FDA. “How to Understand and Use the Nutrition Facts Panel.” Last updated February 15, 2012. www.fda.gov/food/labelingnutr...078889.htm#dvs

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 of macaroni-and-cheese, 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 2.4.2: 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	65 g
Saturated fat	20 g
Cholesterol	300 mg
Sodium	2,400 mg
Potassium	3,500 mg
Total carbohydrate	300 g
Dietary fiber	25 g
Protein	50 g
Vitamin A	5,000 IU
Vitamin C	60 mg
Calcium	1,000 mg
Iron	18 mg
Vitamin D	400 IU
Vitamin E	30 IU
Vitamin K	80 micrograms µg
Thiamin	1.5 mg
Riboflavin	1.7 mg
Niacin	20 mg
Vitamin B_6	2 mg
Folate	400 µg
Vitamin B_{12}	6 µg
Biotin	300 µg
Pantothenic acid	10 mg
Phosphorus	1,000 mg
Iodine	150 µg
Magnesium	400 mg
Zinc	15 mg
Selenium	70 µg
Copper	2 mg
Manganese	2 mg
Chromium	120 µg
Molybdenum	75 µg
Chloride	3,400 mg
Source: FDA, www.fda.gov/Food/GuidanceComp.../ucm064928.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: www.fda.gov/Food/ResourcesFor.../ucm274593.htm

Video Link: How to Read Food Labels.

Pay attention to the fine print when grocery shopping. https://recipes.howstuffworks.com/fda-unveils-new-food-nutrition-labels.htm

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 2.4.3 for some examples.US Food and Drug Administration. "Additional Requirements for Nutrient Content Claims." Appendix B in *Food Labeling Guide* (October 2009).

Table 2.4.3: Common Label Terms Defined

Term	Explanation
Lean	Fewer than a set amount of grams of fat for that particular cut of meat
High	Contains more than 20% of the nutrient's DV
Good source	Contains 10 to 19% of nutrient's DV
Light/lite	Contains ⅓ fewer calories or 50% less fat; if more than half of calories come from fat, then fat content must be reduced by 50% or more
Organic	Contains 95% organic ingredients

Source: US Food and Drug Administration. "Food Labeling Guide." Last updated February 10, 2012. http://www.fda.gov.

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 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/food-labeling-nutrition/authorized-health-claims-meet-significant-scientific-agreement-ssa-standard

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."

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."

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 elseshere). 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 the amount of servings per container, the amount of calories per serving, and the amounts of certain nutrients.
- The percent DV is the percentage of the amount of the nutrient in the food in relationship to its recommended intake. It is a guide to help you determine if a food is a good or poor source of nutrients.
- To keep companies from making false claims, the FDA provides regulation for food manufacturers in putting labels on packages that promote health. Allergens must also be listed on food labels. Sometimes cross contamination does occur during packaging. Most food manufacturers voluntarily list this information. If you have a food allergy, it is best to avoid any product that has even had the possibility of coming in contact with a known allergen.

Discussion Starter

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

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2.5: Trustworthy Sources of Information

Skills to Develop

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

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



Right information or wrong information? How can you know? © Shutterstock

Using Eyes of Discernment

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

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

you drink enough of it to see any negative effects? Remember, if a headline professes a new remedy for a nutrition-related topic, it may well be a research-supported piece of news, but more often than not it is a sensational story designed to catch the attention of an unsuspecting consumer. Track down the original journal article to see if it really supports the conclusions being drawn in the news report.

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

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

Trustworthy Sources

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

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

Key Takeaways

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

Discussion Starter

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

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2.6: My Plate - A Guide for Eating More Healthfully

Learning Objectives

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

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

The Choose MyPlate program uses a tailored approach to give people the needed information to help design a healthy diet. The plate is divided according to the amount of food and nutrients you should consume for each meal. Each food group is identified with a different color, showing the food variety that all plates must have. Aside from educating people about the type of food that is best to support optimal health, the new food plan offers the advice that it is okay to enjoy food, just eat less of it.US Department of Agriculture. Accessed July 22, 2012. http://www.choosemyplate.gov/.

Video 2.6.1: Introducing the New Food Icon: MyPlate

This video provides an introduction to the new MyPlate food guide.

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

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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.

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

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.



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.



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

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

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

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

Discretionary Calories

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

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

Table 2.6.1: Sample Menu Plan Containing 2,000 Calories

Meal	Calories	Total Meal/Snack Calories
Breakfast		
1 scrambled egg	92	
with sliced mushrooms and spinach	7	
½ whole-wheat muffin	67	
1 tsp. margarine-like spread	15	
1 orange	65	
8 oz. low-sodium tomato juice	53	299
Snack		
6 oz. fat-free flavored yogurt	100	
with ½ c. raspberries	32	132
Lunch		
1 sandwich on pumpernickel bread	160	
with smoked turkey deli meat,	30	
4 slices tomato	14	
2 lettuce leaves	3	
1 tsp. mustard	3	
1 oz. baked potato chips	110	
½ c. blueberries, with 1 tsp. sugar	57	
8 oz. fat-free milk	90	467
Snack		
1 banana	105	
7 reduced-fat high-fiber crackers	120	225
Dinner		
1 c. Greek salad (tomatoes, cucumbers, feta)	150	
with 5 Greek olives,	45	
with 1.5 tsp. olive oil	60	
3 oz. grilled chicken breast	150	
½ c. steamed asparagus	20	
with 1 tsp. olive oil,	40	
with 1 tsp. sesame seeds	18	
½ c. cooked wild rice	83	
with ½ c. chopped kale	18	
1 whole-wheat dinner roll	4	
with 1 tsp. almond butter	33	691
(Total calories from all meals and snacks = 1,814)		
Discretionary calorie allowance: 186		

Healthy Eating Index

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

Key Takeaways

- The Food Pyramid has been replaced by MyPlate, a system that was designed to be easier to implement. The new MyPlate encourages all plates to be filled with fruits and vegetables (50 percent), protein (25 percent), and grains (25 percent). Half of daily grain intake should be from whole-grain sources. Dairy choices should be switched to low-fat or non-fat sources.
- A diet rich in fresh fruits and vegetables will help you lose and/or maintain weight, will lower your risk for stroke, heart disease, high blood pressure, Type 2 diabetes, and certain types of cancer, and will boost your overall health profile.
- By choosing nutrient-dense foods, you may have discretionary calories to "spend" at the end of the day.

Discussion Starter

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

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2.7: Dietary Guidelines 2015-2020

Learning Objectives

- Describe the major themes of the *2015-2020 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 intakes of caloric energy and eight essential nutrients. These were disseminated to officials responsible for food relief for armed forces and civilians supporting the war effort. Since 1980, the dietary guidelines have been reevaluated and updated every five years by the advisory committees of the US Department of Agriculture (USDA) and the US Department of Health and Human Services (HHS). 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.



Figure 2.7.1: Dietary guidelines help people to stay on a healthful track by drawing attention to the overall scope of their diet and lifestyle. © Dreamstime

Why Are Guidelines Needed?

Instituting nation-wide standard policies provides consistency across organizations and allows health-care workers, nutrition educators, school boards, and elder-care facilities to improve nutrition and subsequently the health of their respective populations. The 2015–2020 Dietary Guidelines is designed to help Americans eat a healthier diet. Intended for policymakers and health professionals, the 2015 edition of the Dietary Guidelines outlines how people can improve their overall eating patterns — the complete combination of foods and drinks in their diet. The free 2015 edition offers overarching themes about what constitutes a healthy diet, how to shift behaviors to make it possible to follow a healthful diet and a number of Key Recommendations with specific nutritional targets and dietary limits



Figure 2.7.2: The major theme of the *2010 Dietary Guidelines for Americans* is an adequate diet combined with proper exercise. © Dreamstime

Major Themes of the *2015 Dietary Guidelines*

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

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

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

How should you develop a healthy eating plan to best achieve your goals of losing weight, gaining weight, or maintaining weight? We will start with some basics and move on to healthy eating patterns. To provide further guidance, several key recommendations are provided. These should be applied in their entirety because of their interconnectedness.

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

A health heating pattern includes:

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

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

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

drinks per day for men - and only by adults of legal drinking age.

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

Foods and Food Components to Reduce

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

Table 2.7.1: A Little Less of These, Please

Dietary Constituent	Health Implications	Recommendations
Excess sodium	High blood pressure	Limit intake to 2,300 mg daily
Too much saturated fat	Cardiovascular disease	Limit intake to < 10 percent of total calories
Trans fats	Cardiovascular disease	Minimal, if any consumption
Excess cholesterol	Atherosclerosis	Limit intake to below 300 mg daily
SoFAS (solid fats and added sugars)	Obesity, Type 2 diabetes	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

The average person consumes 3,400 milligrams of sodium per day, mostly in the form of table salt. The *2010 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 that fat calories should be obtained by eating foods high in unsaturated fatty acids. Cholesterol intake should be decreased to below 300 milligrams per day and trans fatty acid consumption kept to a bare minimum. The *Dietary Guidelines* stresses the importance of limiting the consumption of foods with refined grains and added sugars, and introduce the new term, SoFAS, which is an acronym for *solid fats and added sugars*, both of which are to be avoided in a healthy diet plan.Nelson, J. and K. Zeratsky. “Dietary Guidelines Connect SoFAS and Weight Gain.” Mayo Clinic, *Nutrition-Wise* (blog). August 25, 2010. www.mayoclinic.com/health/die...elines/MY01417. Moreover, if alcohol is consumed, it should be consumed only in moderation, which for women it is not more than one drink per day and for men is not more than two drinks per day. The macronutrients protein, carbohydrates, and fats contribute considerably to total caloric intake. The IOM has made recommendations for different age groups on the percentage of total calories that should be obtained from each macronutrient class (Table 2.7.2).

Table 2.7.2: Recommendations for Macronutrient Intake As Percentage of Total Calories

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

Source: *2010 Dietary Guidelines*.

Foods and Nutrients to Increase

The typical American diet lacks sufficient amounts of vegetables, fruits, whole grains, and high-calcium foods, causing concern for deficiencies in certain nutrients important for maintaining health. The *2010 Dietary Guidelines* provide the following suggestions on food choices to achieve a healthier diet:

1. Eat a variety of vegetables, especially dark green, red, and orange vegetables.
2. Choose at least half of your grains consumed from whole-grain foods.

3. For dairy products, eat the low-fat versions.
4. Don't get your protein only from red meats; choose instead seafood, poultry, eggs, beans, peas, nuts, seeds, and soy products.
5. Replace butter with oils.
6. Choose foods dense in the nutrients potassium, calcium, and vitamin D.
7. Increase intake of dietary fiber.

Building Healthy Eating Patterns

The *2010 Dietary Guidelines* recommend that people make an effort to reduce their caloric consumption, reduce the intake of nutrient-poor foods, and increase the intake of nutrient-dense foods. To accomplish these tasks it is necessary to incorporate moderation and variety. The goal is not only choosing specific foods for your diet, but also the development of a healthy eating pattern. Several studies provide good evidence that certain dietary patterns increase overall health and decrease the risk of chronic disease. The Dietary Approaches to Stop Hypertension trial, or DASH, reports that men and women who consumed more than eight servings per day of fruits and vegetables had lower blood pressures than a control group that consumed under four servings per day of fruits and vegetables.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 (January 2001): 3–10. http://www.nejm.org/doi/full/10.1056/NEJM200101043440101. Other studies investigating the benefits of the DASH diet have also found it to be protective against cardiovascular disease and decrease overall mortality. Another well-known diet is the Mediterranean diet. In general, the Mediterranean diet is described as one that emphasizes fruits, vegetables, whole grains, and nuts, and olive oil as a replacement for butter. Few meats and high-fat dairy products are eaten. Observational studies have linked the Mediterranean diet to reduced cardiovascular disease and decreased mortality. Vegetarian diets, which emphasize many of the same foods as the DASH and Mediterranean diets have also been linked to a decrease in incidences of some chronic diseases.



Figure 2.7.3: Fresh vegetables and olive oil are examples of foods emphasized in the DASH and Mediterranean diets. © Thinkstock

Key Takeaways

- US dietary guidelines are based on evolving scientific evidence and are updated every five years. The goals of the *2015-2020 Dietary Guidelines* are to prevent nutrient inadequacy, promote health, reduce chronic disease, and decrease the prevalence of overweight and obesity.
- To have a healthy eating pattern, reduce the intake of sodium, saturated and trans fats, cholesterol, added sugars, and refined grains. Increase the consumption of fruits, vegetables, low-fat dairy products, dietary fiber, and oils.
- Healthy eating patterns prevent chronic disease and provide nutrient adequacy.

Discussion Starter

1. Discuss with your classmates suggestions from the *2015-2020 Dietary Guidelines* that you should incorporate into your diet. How can you align your personal dietary goals with these recommendations?

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2.8: National Goals for the Future

Learning Objectives

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

The Healthy People 2020 program, launched in 2010, is a ten-year national program instituted by the US government with objectives aimed toward improving the health of all Americans. Similar to the *2010 Dietary Guidelines*, it has been established to promote longer lives free of preventable disease, disability, injury, and premature death. With a revived intent on identifying, measuring, tracking, and reducing health disparities through a "determinants of health approach," Healthy People 2020 will strive to create the social and physical environments that promote good health for all and to promote quality of life, healthy development, and healthy behaviors across all life stages. This means that the understanding of what makes and keeps people healthy is consistently refined. The determinants of health approach reflects the evidence from outside factors that greatly affect the health of individuals.US Department of Health and Human Services. "About Healthy People." Last updated March 29, 2012. http://www.healthypeople.gov/2020/about/default.aspx It takes into consideration the circumstances in which people are born, live, work, and age. It also reflects the conditions that shape their circumstances such as money, power, and resources at the local, national, and global levels. Social determinants of health are primarily accountable for the lack of fair health opportunities and the unjust differences in health status that exist within and between countries.World Health Organization. "Social Determinants of Health." © 2012. http://www.who.int/social_determinants/en/.

Video 2.8.1: Preparing for the Next Decade

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

Helping People Make Healthy Choices

It is not just ourselves, the food industry, and federal government that shape 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 USDA and the 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 2.8.1: 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. As a result of the recent financial crisis in America the number of people who struggle to have enough to eat is rising and approaching fifty million. 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...1116001598.html.

Video 2.8.2: Determinants of Health

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Determinants of Health Approach in Healthy People 2020 (click to see video)

Goals for Nutrition and Weight Status

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



Figure 2.8.2: One of the ways that Healthy People 2020 strives to promote good health and nutrition is by bringing together multiple agencies and groups dedicated to achieving the Healthy People 2020 nationwide objectives. © Shutterstock

Healthy People 2020 has defined their mission as:

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

Healthy People 2020 has set key recommendations as follows:

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



Figure 2.8.3: Consuming nutrient-dense foods and limiting portion sizes of food will contribute to weight management. Avoiding excessive amounts of anything allows room for many food types in the diet. © Dreamstime

Tools for Change

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

Benefits of Following the Healthy People 2020 Goals

Nutrition and weight status are important to children's growth and development. In addition, healthy eating habits will decrease risks for developing chronic health conditions such as obesity, malnutrition, anemia, cardiovascular disease, high blood pressure, dyslipidemia (poor lipid profiles), Type 2 diabetes, osteoporosis, dental disease, constipation, diverticular disease, and certain types of cancer.

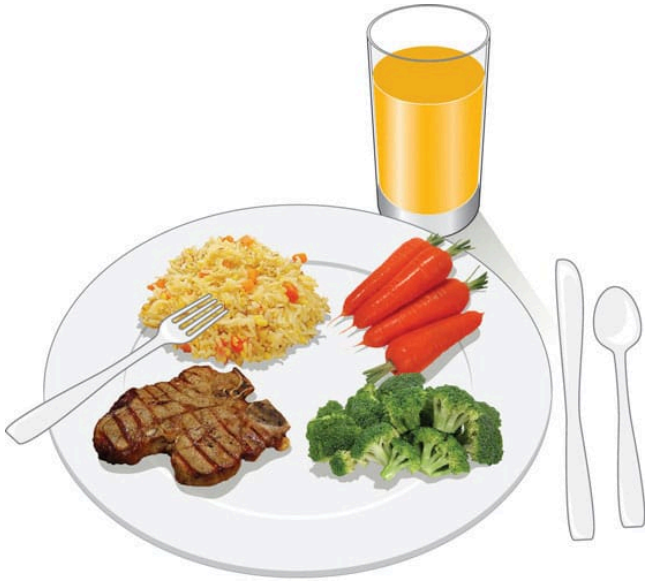


Figure 2.8.4: Following the *2015 Dietary Guidelines* will promote nutrition, weight loss, and weight maintenance as well as the reduction of chronic disease. © Networkgraphics

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

Objectives Related to the Healthy People 2020 Goals

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

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

chronic disease, improving bone health, decreasing body fat, and preventing an early death.

Video 2.8.3: 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

This video provides a short overview of leading an active life versus a sedentary life.

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



Figure 2.8.5: Healthy children will lead to a healthy adult population with less disease, lower healthcare costs, and increased longevity. © Shutterstock

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

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

Key Takeaways

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

Discussion Starters

1. Think of fun ways to increase physical activity in your life. Think small but frequent and think about things you can incorporate easily in your regular daily activities.
2. Review some of the Healthy People 2020 nutrition and physical activity program objectives. What objectives would you like to see enacted in your community? Why is this important to you? http://www.healthypeople.gov/2020

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2.9: The Dietary Reference Intakes - How much of a Nutrient should we Consume?

Learning Objectives

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

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

Dietary Reference Intakes: A Brief Overview

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

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

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

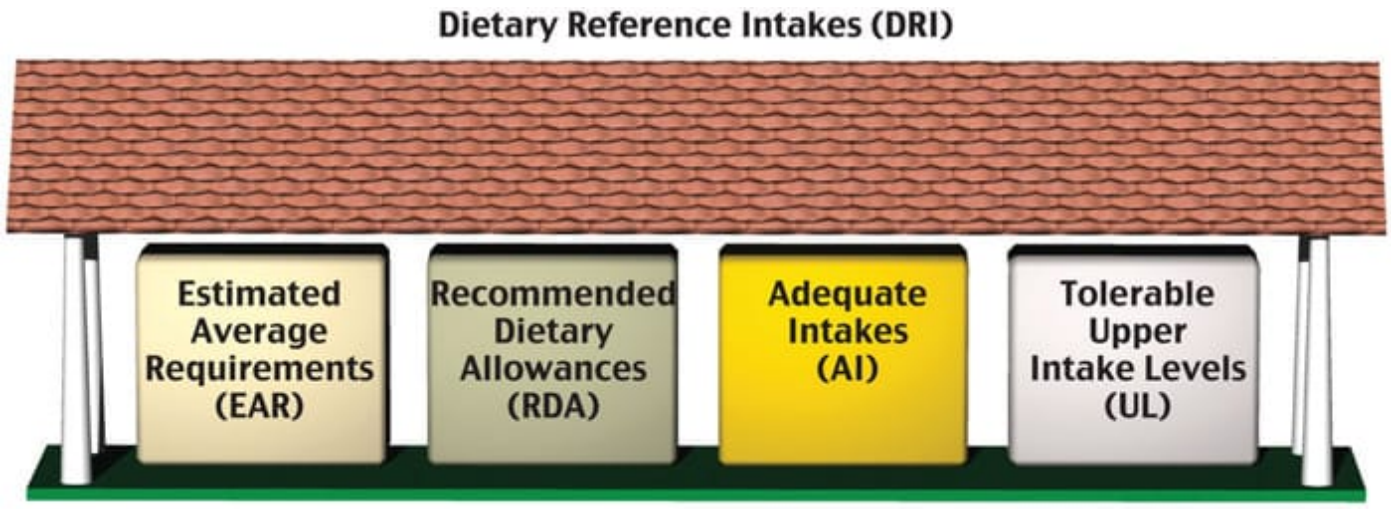


Figure 2.9.1: The DRIs are inclusive of all four reference values. © Networkgraphics

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

Determining Dietary Reference Intakes

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

1. **Estimated Average Requirements.** 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.** 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.

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.** 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 for 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.** 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.

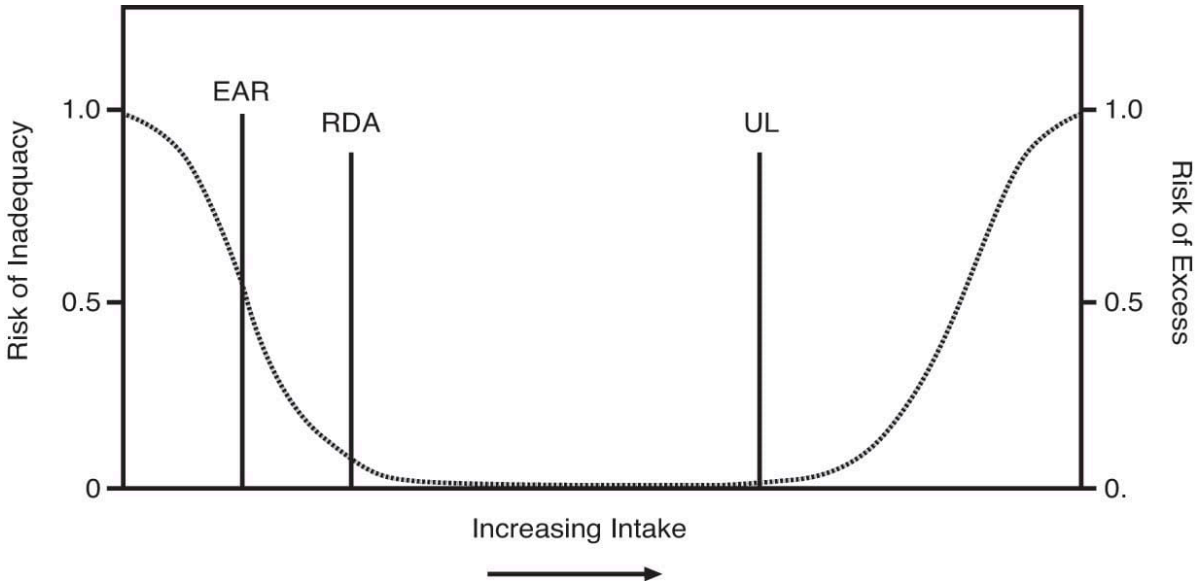


Figure 2.9.2: DRI Graph. This graph illustrates the risks of nutrient inadequacy and nutrient excess as we move from a low intake of a nutrient to a high intake. Starting on the left side of the graph, you can see that when you have a very low intake of a nutrient, your risk of nutrient deficiency is 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.** 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 2.7: 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
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.

Key Takeaways

- Nutrient-intake recommendations set for healthy people living in the United States and Canada are known as Dietary Reference Intakes.
- The DRIs includes the AI, EAR, RDA, and UL for micronutrients and the AMDR ranges for energy-yielding macronutrients. The

DRI provide a set of standards for researchers and government policy-makers, and specifies nutrient consumption guidelines for individuals.

Discussion Starter

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

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2.E: Exercises

It's Your Turn

1. What are the dietary reference intakes (DRI's)? What are they for? There used to only be one

   reference intake, the RDA, why are there so many now?

2. Define each of the following in everyday language:

   A. Estimated Average Requirements (EAR)

   *Why DON'T we use this one as the recommended amount people should eat daily?

   B. Recommended Dietary Allowances (RDA)

   *Why DO we use this one as the recommended amount people should eat daily?

   C. Adequate Intakes (AI)

   D. Tolerable Upper Intake Levels (UL)

   *Should we strive to reach the UL for a nutrient every day?6. Using Food Labels (use food label image below):

3. Select a packaged food and find the "Nutrition Facts" panel. Then answer the following questions A. How many Calories are there in 1 serving of this food?
   B. Look at the "Total Fat" and the "Saturated Fat". Is the Saturated fat PART of the Total Fat?
   C. What does the % Daily Value mean? For example, if it says that for every 1 serving of this food I get 2% Daily Value of Vitamin C. What does that mean?

Apply It

1. You have been hired to write a two-page article for a weekly magazine about why nutrition is important to health. Using simple terms and a good supply of photographs, create your article. Be prepared to share your project with the class.
2. Record a food diary this week. At the end of the week, circle the foods that contain SoFAS. Next to each food, write a substitute food to replace it. Record a food diary next week. Be sure to eat the substitute foods you have selected to replace the foods that contained the SoFAS.
3. Search the Internet for sites that claim to give you nutritional advice. Check to see who sponsors the sites and if the site is trying to sell you a product or service. Compare the information found on the sites to those recommended in this text. What similarities do you notice? What differences do you notice?

Expand Your Knowledge

1. You have just been hired at the local Boys and Girls club in an inner city neighborhood that happens to have a large high school drop-out rate. You have been put in charge of creating physical and nutritional opportunities for the community. Your goal for the first quarter is to enroll one hundred students in an exercise/nutrition program. You must develop two programs.
   - Define each program and state its objectives
   - Describe the ways in which the program will benefit participants
   - List ways in which you will encourage enrollment
   - Create a marketing flyer for each program
2. You are planning a big meal for a surprise graduation party for your friend. You expect fifty guests to attend. Using the information you have learned regarding healthy eating and food portions, plan a healthful meal. Determine how much protein, vegetables, fruits, and starch you will need to purchase to feed everyone comfortably. Write down a detailed list so that you can shop and prepare your budget accordingly. Share your results with the class.

3. You are a Registered Dietitian who has been asked to help a vegan patient adjust their eating habits to get more nutrients from their diet and halt unwanted weight loss. Develop a week's worth of meals to help this person have balance in their diet.

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3: NUTRITION AND THE HUMAN BODY

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

3.1: Chapter Introduction

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

3.3: Digestion and Absorption in the Gastrointestinal Tract (GI tract)

3.4: Nutrients Are Essential for Organ Function

3.5: Energy and Calories

3.6: Disorders That Can Compromise Health

3.E: Nutrition and the Human Body (Exercises)

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3.1: Chapter Introduction

Big take away

- Eat your way to health.

"Let food be thy medicine and medicine be thy food." These words, espoused by 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."



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

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

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

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

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

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

You Decide

Will you eat your way to health with probiotic foods?

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

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

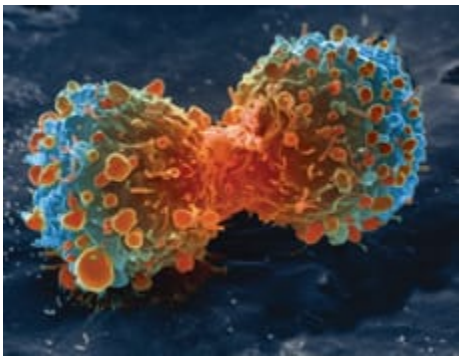
Learning Objectives

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

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

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

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



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

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

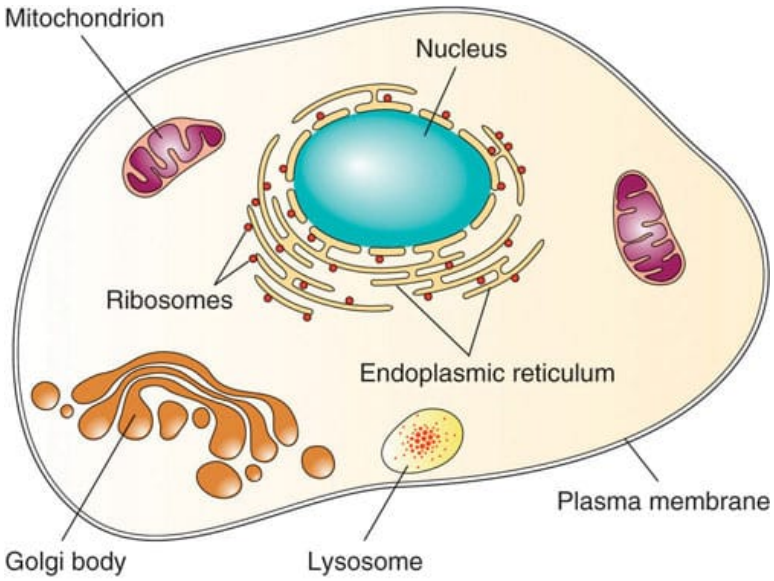


Figure 3.2.1: The cell is structurally and functionally complex.

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 3.1: 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 the 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

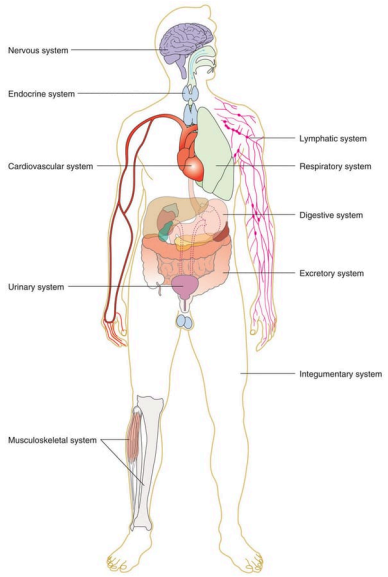


Figure 3.2.2: Organ Systems in the Human Body © Networkgraphics

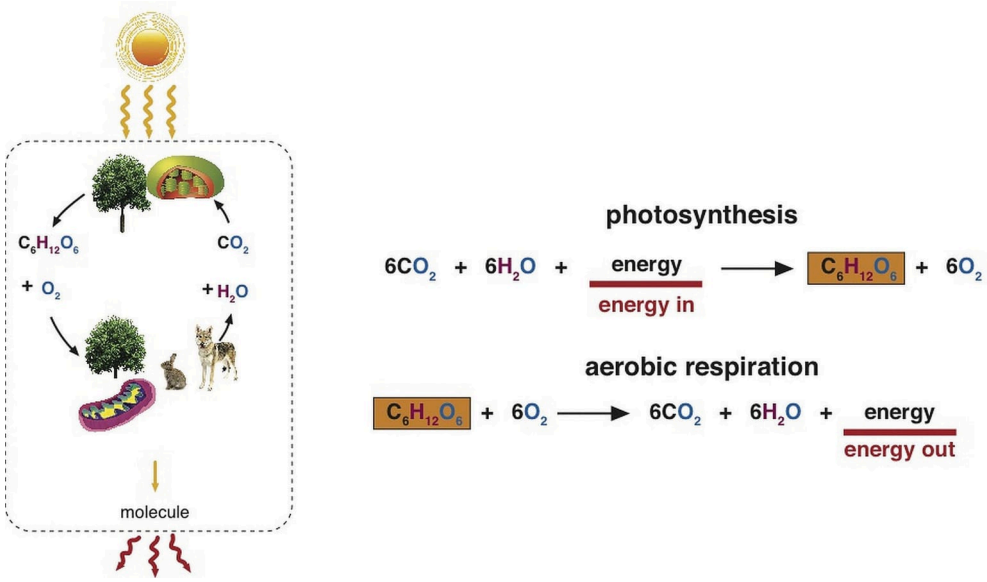
An Organism Requires Energy and Nutrient Input

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

Nutrient and Energy Flow

Energy is stored in a nutrient's chemical bonds. Energy comes from sunlight, which plants then capture and, via photosynthesis, use it to transform carbon dioxide in the air into the molecule, glucose. When the glucose bonds are broken, energy is released. Bacteria, plants, and animals (including humans) harvest the energy in glucose via a biological process called cellular respiration. In this process the chemical energy of glucose is transformed into cellular energy in the form of the molecule, adenosine triphosphate (ATP). Cellular respiration requires oxygen (aerobic) and it is provided as a waste product of photosynthesis. The

waste products of cellular respiration are carbon dioxide (CO_2) and water, which plants use to conduct photosynthesis again. Thus, energy is constantly cycling between plants and animals. As energy is consumed nutrients are recycled within it.



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

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

Key Takeaways

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

Discussion Starter

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

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3.3: Digestion and Absorption in the Gastrointestinal Tract (GI tract)

Learning Objectives

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

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

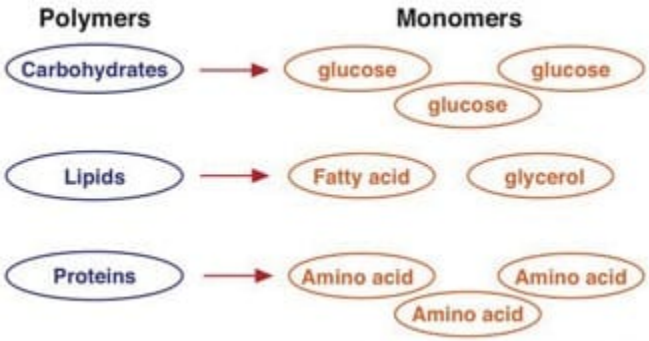


Figure 3.3.1: The Digestion Process. Digestion converts the food we eat into smaller particles, which will be processed into energy or used as building blocks

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" or a "catabolic reaction". 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 3.3.2). 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. Theses enzymes are secreted by the salivary glands, stomach, pancreas, and small intestine. Mechanical breakdown starts with mastication (chewing) in the mouth. Teeth crush and grind large food particles, while saliva initiates the chemical breakdown of food and enables its movement downward. The slippery mass of partially broken-down food is called bolus, which moves down the digestive tract as you swallow. Swallowing may seem voluntary at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins.

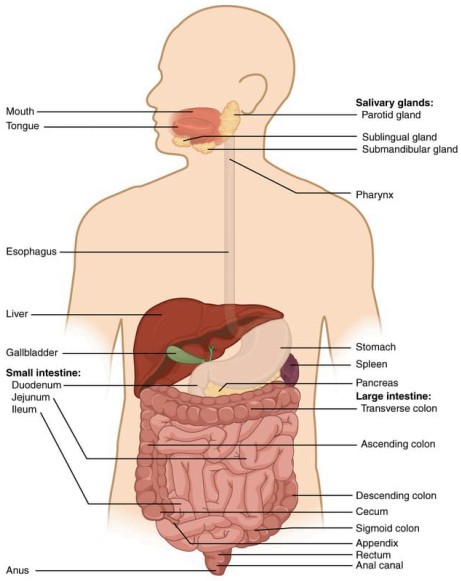


Figure 3.3.2: Components of the Human Digestive System. All digestive organs play integral roles in the life-sustaining process of digestion. (CC BY 3.0; OpenStax).

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

From the Stomach to the Small Intestine

When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. Chyme is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. Cells in the stomach also secrete hydrochloric acid and the enzyme pepsin, that chemically breaks down food into smaller molecules. 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.

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

Video 3.3.2: the food machine - great endoscopic images, xray and ultrasound images of food being digested (pretty graphic). Great visuals! Also talks about energy from food

The small intestine is divided into three structural parts: the duodenum (the top), the jejunum (the middle), and the ileum (the last part). Once the chyme enters the duodenum (the first segment of the small intestine), three accessory (or helper) organs: liver, pancreas and gallbladder are stimulated to release juices that aid in digestion. The pancreas secretes up to 1.5 liters of pancreatic juice through a duct into the duodenum per day. This fluid consists mostly of water, but it also contains bicarbonate ions that neutralize the acidity of the stomach-derived chyme and enzymes that further 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 gall bladder. 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).

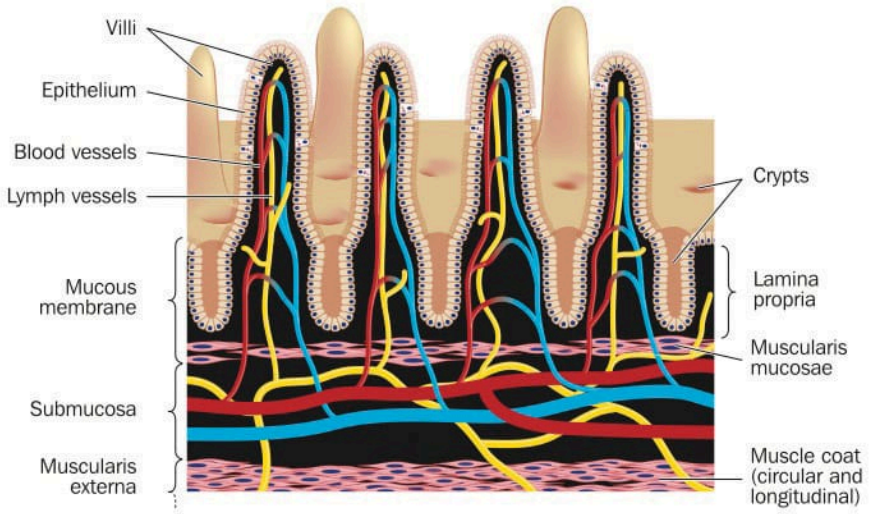


Figure 3.3.3: The way the small intestine is structured gives it a huge surface area to maximize nutrient absorption. The surface area is increased by folds, villi, and microvilli. Digested nutrients are absorbed into either capillaries or lymphatic vessels contained within each microvilli. © Shutterstock

The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The surface area of the small intestine increases by multiple levels of folding. The internal tissue of the small intestine is covered in villi, which are tiny finger-like projections that are covered with even smaller projections, called microvilli (Figure 3.3.1). The digested nutrients pass through the absorptive cells of the intestine via diffusion or special transport proteins. Nutrients that are water soluble (dissolve in water) like amino acids and monosaccharides (sugars) are transported from the intestinal cells into capillaries (blood), but the fat soluble nutrients like fatty acids, fat-soluble vitamins, and other lipids are transported first through lymphatic vessels (lymph), 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. 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 millilters 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 be 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.

Kefir

There has been significant talk about pre- and probiotic foods in the mainstream media. The World Health Organization defines probiotics as live bacteria that confer beneficial health effects on their host. They are sometimes called “friendly bacteria.” The most common bacteria labeled as probiotic is lactic acid bacteria (lactobacilli). They are added as live cultures to certain fermented foods such as yogurt. Prebiotics are indigestible foods, primarily soluble fibers, that stimulate the growth of certain strains of bacteria in the large intestine and provide health benefits to the host. A review article in the June 2008 issue of the *Journal of Nutrition* concludes that there is 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 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.



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 3.3.3: 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

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 accomplish 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/up...ate0905c.shtml

   https://ods.od.nih.gov/factsheets/Probiotics-HealthProfessional/

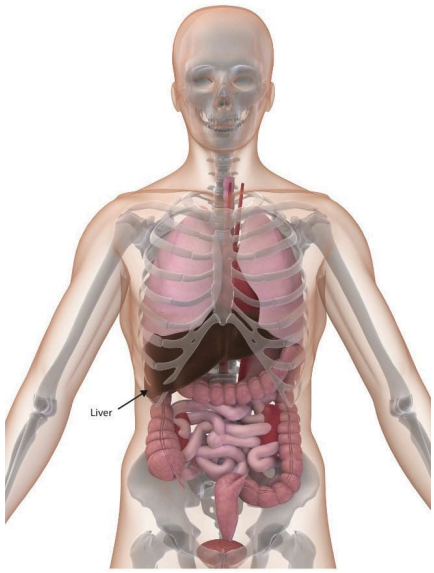
This page titled 3.3: Digestion and Absorption in the Gastrointestinal Tract (GI tract) is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by Anonymous.

3.4: Nutrients Are Essential for Organ Function

Learning Objectives

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

When the digestive system has broken down food to its nutrient components they are ready to get absorbed. Absorption is the movement of the nutrient molecules from the digestive tract into the blood or lymph. If the absorbed nutrient is water soluble it will be absorbed into the blood and if the nutrient is fat soluble it will be packaged into a special transport package, called a chylomicron, and absorbed into the lymph. For water soluble nutrients, the first stop is the liver. The liver has the ability to store some nutrients, send some nutrients on to other parts of the body and/or change some nutrients into other molecules the body needs! Fat soluble nutrients, because they are absorbed into the lymph and only later spill into the blood, travel first to the heart but eventually they too will end up at the liver.



The liver is the checkpoint for metabolic activity. © Shutterstock

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 is 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 (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.

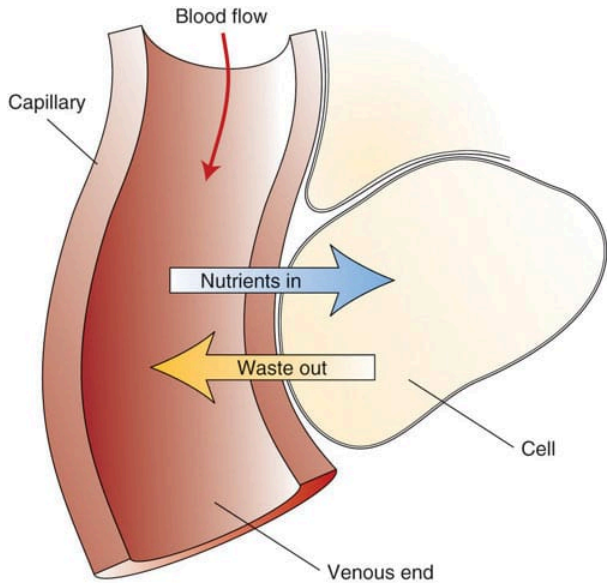
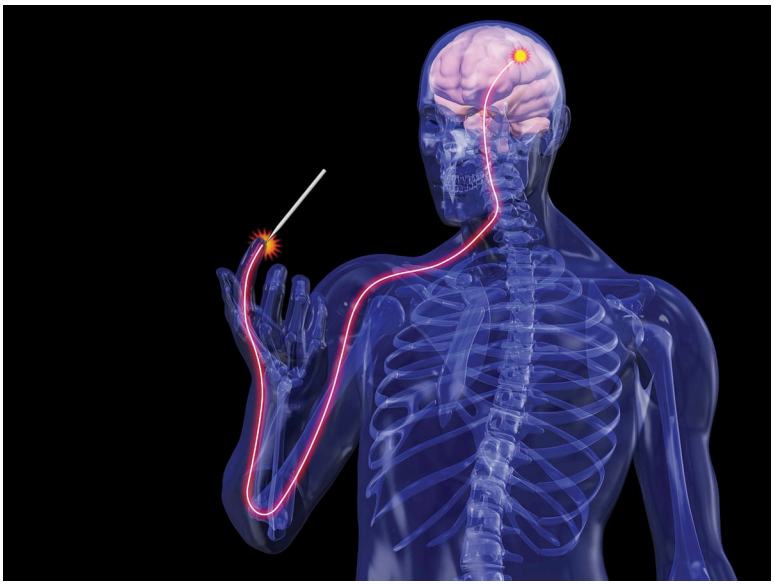


Figure 3.4.1: The Circulatory System: The circulatory system transports nutrients to all cells and carries wastes out.

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.



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

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

The Muscular System

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

“Hitting the Wall” or “Bonking”

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



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. (Public Domain; Vzach).

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 that people who have Type 2 diabetes are at increased risk for cardiovascular disease, kidney disease, nerve damage, and eye disease.

Tools for Change

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

The Immune System

The immune system is comprised of several types of white blood cells that circulate in the blood and lymph. Their jobs are to seek, recruit, attack, and destroy foreign invaders, such as bacteria and viruses. Other less realized components of the immune system are the skin (which acts as a barricade), mucus (which traps and entangles microorganisms), and even the bacteria in the large intestine (which prevent the colonization of bad bacteria in the gut). Immune system functions are completely dependent on dietary nutrients. In fact, malnutrition is the leading cause of immune-system deficiency worldwide. When immune system functions are inadequate there is a marked increase in the chance of getting an infection. Children in many poor, developing countries have protein- and/or energy-deficient diets that are causative of two different syndromes, kwashiokors 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 for infection and death. Zinc deficiency results in suppression of the immune system's barrier functions by damaging skin cells; it is also associated with a decrease in the number of circulating white blood cells. A review of several studies in the journal *Pediatrics* concluded that zinc supplements administered to children under age five for longer than three months significantly reduces the incidence and severity of diarrhea and respiratory illnesses.Aggarwal R., MD, DM, J. Sentz, MPH and M. A. Miller, MD. "Role of Zinc Administration in Prevention of Childhood Diarrhea and Respiratory Illnesses: A Meta-Analysis." *Pediatrics* 119, no. 6 (2007): 1120–30. doi: 10.1542/peds.2006–3481. Zinc supplementation has also been found to be therapeutically beneficial for the treatment of leprosy, tuberculosis, pneumonia, and the common cold. Equally important to remember is that multiple studies show that it is best to obtain your minerals and vitamins from eating a variety of healthy foods.

Tools for Change

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



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

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

Key Takeaways

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

Interactive 3.1

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/statisti...tes_slides.htm

Discussion Starter

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

website.

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

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

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

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

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

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

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3.5: Energy and Calories

Learning Objectives

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

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

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

Some basic forms of energy are:

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

The Calorie Is a Unit of Energy

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

Estimating Caloric Content

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

Calculating the number of Calories in commercially prepared food is made fairly easy since the total number of Calories in a serving of a particular food is listed on the Nutrition Facts panel. If you wanted to know the number of Calories in the breakfast you consumed this morning just add up the number of Calories in each food. For example, if you ate one serving of yogurt that contained 150 Calories, on which you sprinkled one half of a cup of low-fat granola cereal that contained 209 Calories, and drank

a glass of orange juice that contained 100 Calories, the total number of Calories you consumed at breakfast is 150 + 209 + 100 = 459 Calories. If you do not have a Nutrition Facts panel for a certain food, such as a half cup of blueberries, and want to find out the amount of Calories it contains, go to MyFood-a-pedia, a website maintained by the USDA.

Interactive 3.2: Fooducate

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+.

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 3.7, the protein content in one serving is 7 grams. Protein yields 4 kilocalories per gram. The number of kilocalories from protein is calculated by using the following equation:

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

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

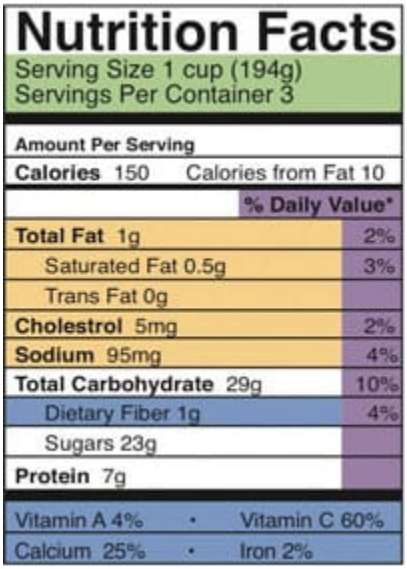


Figure 3.5.1: A Nutrition Facts Panel for Yogurt: Because the total number of kilocalories in each serving of yogurt is 150, the percent of energy obtained from protein is calculated by using the following equation:

Key Takeaways

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

Discussion Starter

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

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3.6: Disorders That Can Compromise Health

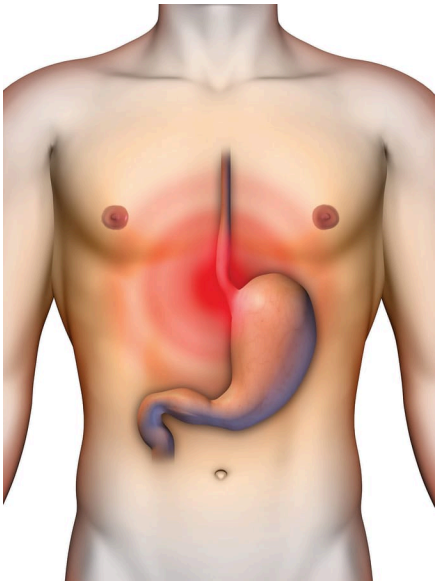
Learning Objectives

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

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

Gastroesophageal Reflux Disease

Gastroesophageal reflux disease (GERD) is a persistent form of acid reflux that occurs more than two times per week. Acid reflux occurs when the acidic contents of the stomach leak backward into the esophagus and cause irritation. It is estimated that GERD affects 25 to 35 percent of the US population. An analysis of several studies published in the August 2005 issue of *Annals of Internal Medicine* concludes that GERD is much more prevalent in people who are obese.Hampel, H. MD, PhD, N. S. Abraham, MD, MSc(Epi) and H. B. El-Serag, MD, MPH. "Meta-Analysis: Obesity and the Risk for 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.



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

Additional Facts about GERD

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

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

Irritable Bowel Syndome

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.

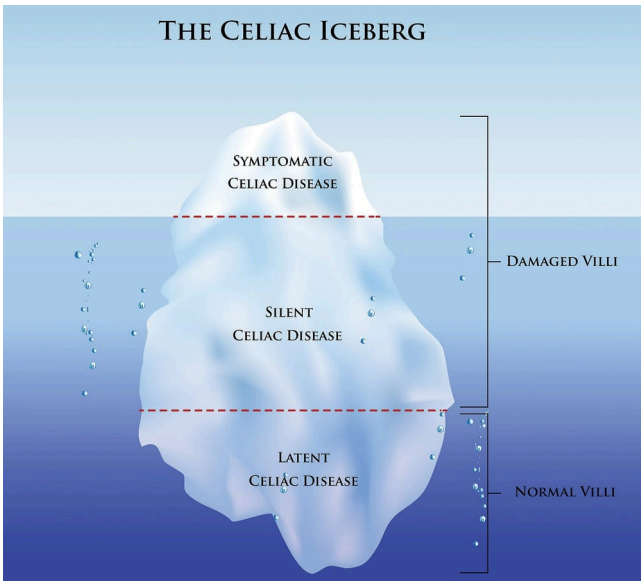


Figure 3.6.1: Celiac: Not everyone with celiac is diagnosed—many have “silent” or “latent” celiac disease. © Shutterstock

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

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

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

Food Allergies

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



Many people with food allergies experience skin rashes after eating an allergenic food. © Shutterstock

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

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

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

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

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

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

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 functioning of the organ systems and decrease health.
- Food allergies affect roughly twelve million Americans, with symptoms that range from mild to deadly. Proper diagnosis leads to better management of food allergies and sensitivities.

Discussion Starter

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

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3.E: Nutrition and the Human Body (Exercises)

It's Your Turn

1. Summarize the organization of the human body in a flow chart.
2. Determine how many calories you ate of a particular food yesterday and calculate the percent of calories that came from carbohydrates, protein, and fat.
3. Watch the video on celiac disease at https://www.youtube.com/watch?v=GnI6R5xN3nA and summarize how this ailment leads to decreased nutrient absorption.

Apply It

1. Draw a flow chart that summarizes the steps of digestion that take place in each organ of the digestive system.
2. Calculate the calories derived from protein, fats, and carbohydrates from five different foods you often eat.
3. After watching the video on GERD, list the potential consequences of GERD.

   Understanding GERD video

Expand Your Knowledge

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

   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.

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

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

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4: CARBOHYDRATES

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

4.1: Introduction to Carbohydrates

4.2: A Closer Look at Carbohydrates

4.3: Digestion and Absorption of Carbohydrates

4.4: The Functions of Carbohydrates in the Body

4.5: Looking Closely at Diabetes

4.6: Health Consequences and Benefits of High-Carbohydrate Diets

4.7: Carbohydrates and Personal Diet Choices

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

4.E: Carbohydrates (Exercises)

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4.1: 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.

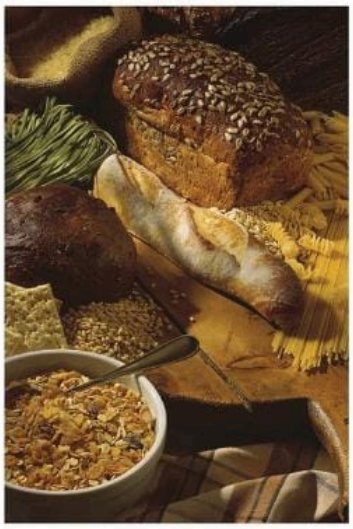
Video 4.1

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

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

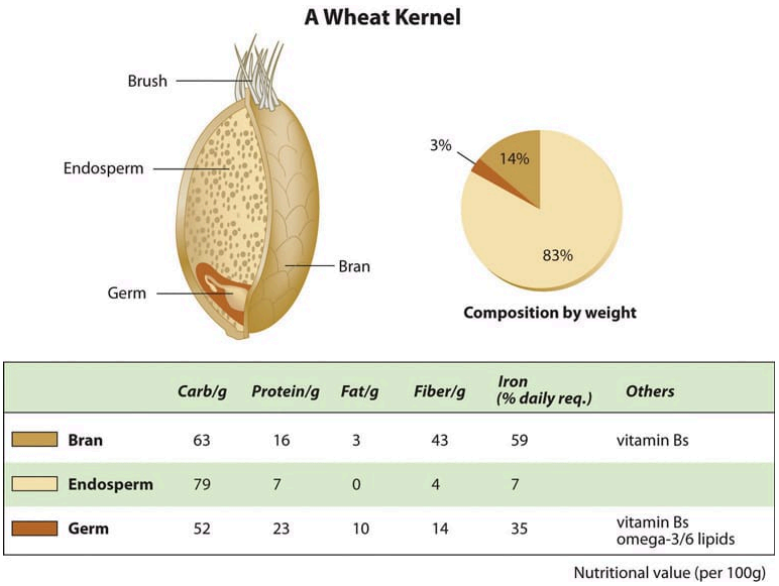
In ancient times whole grains were cracked open using quern stones that required hours of hand labor. As technology slowly advanced, the quern stone was modified into the millstone. It wasn't until the advent of water wheels that human labor to produce grains was reduced. About 2,500 years ago the Romans 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.





The *2010 Dietary Guidelines* recommend that half of all grains in your diet come from whole 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)

Wheat kernel anatomy and composition.

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

You Decide

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

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

nutritional punch from various carbohydrates in your diet.

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

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

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4.2: A Closer Look at Carbohydrates

Learning Objectives

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

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

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

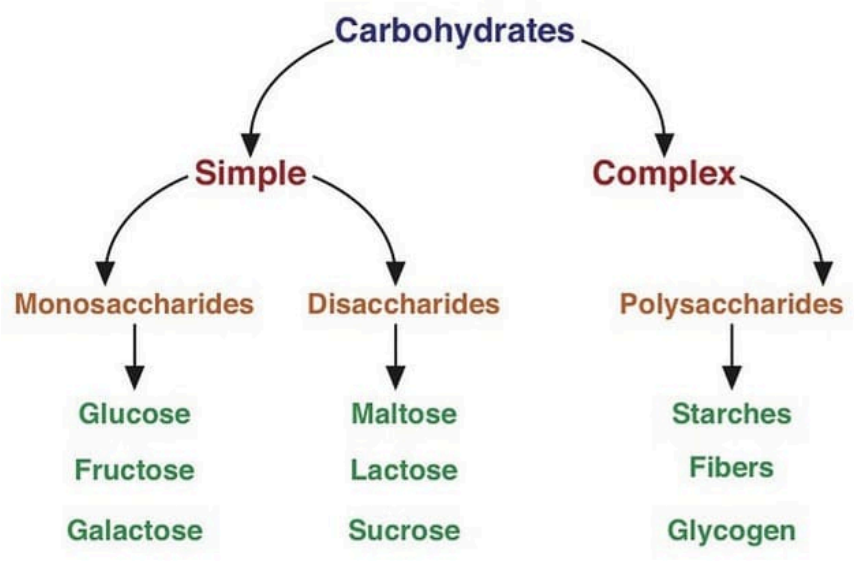


Figure 4.2.1: Carbohydrate Classification Scheme. Carbohydrates are broken down into the subgroups "fast-releasing" and "slow-releasing" carbohydrates. These subgroups are further categorized into mono-, di-, and polysaccharides.

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, the most abundant carbohydrate in the human body, has six carbon atoms, twelve hydrogen atoms, and six oxygen atoms. The chemical formula for glucose is written as $C_6H_{12}O_6$. Synonymous with the term carbohydrate is the Greek word "saccharide," which means sugar. The simplest unit of a carbohydrate is a monosaccharide. Carbohydrates are broadly classified into two subgroups, "fast-releasing" and "slow-releasing." Fast-releasing carbohydrates are further grouped into the monosaccharides and dissacharides. Slow-releasing carbohydrates are long chains of monosaccharides. (Figure 4.2.1).

Fast-Releasing Carbohydrates

Fast-releasing carbohydrates are also known more simply as "sugars." Fast-releasing carbohydrates are grouped as either monosaccharides or dissacharides. Monosaccharides include glucose, fructose, and galactose, and the dissacharides 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 4.2.2). This small structural alteration causes galactose to be less stable than glucose. As a result, the liver rapidly converts it to glucose. Most absorbed galactose is utilized for energy production in cells after its conversion to glucose. (Galactose is one of two simple sugars that are bound together to make up the sugar found in milk. It is later freed during the digestion process.)

Fructose also has the same chemical formula as glucose but differs in its chemical structure, as the ring structure contains only five carbons and not six (Figure 4.2.2). Fructose, in contrast to glucose, is not an energy source for other cells in the body. Mostly found in fruits, honey, and sugarcane, fructose is one of the most common monosaccharides in nature. It is also found in soft drinks, cereals, and other products sweetened with high fructose corn syrup.

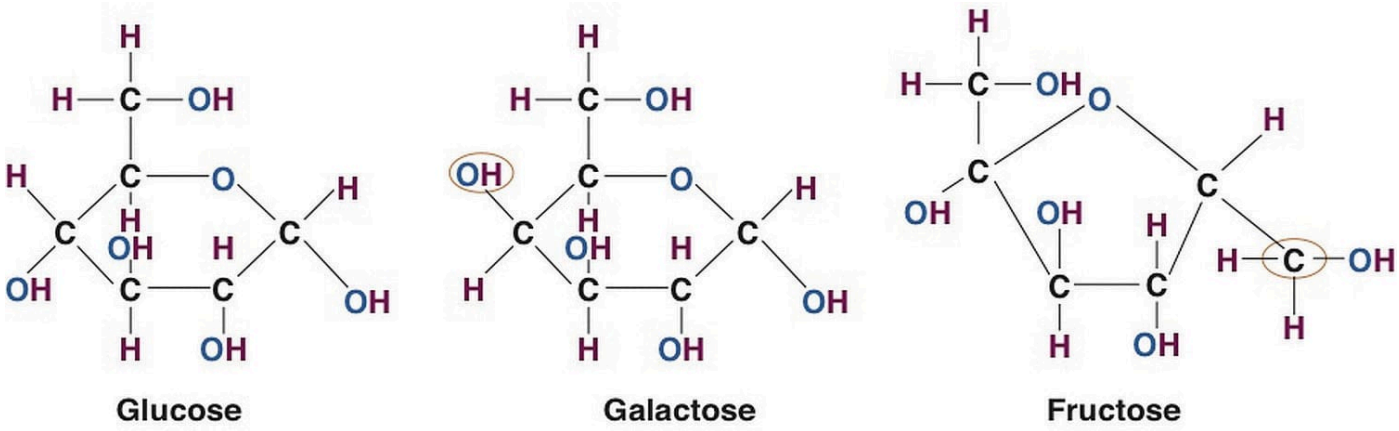


Figure 4.2.2: Structures of the Three Most Common Monosaccharides: Glucose, Galactose, and Fructose. Red circles indicate the structural differences between the three.

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 as table sugar.) Sugar alcohols are often used in place of table sugar to sweeten foods as they are incompletely digested and absorbed, and therefore less caloric. The bacteria in your mouth opposes them, hence sugar alcohols do not cause tooth decay. Interestingly, the sensation of “coolness” that occurs when chewing gum that contains sugar alcohols comes from them dissolving in the mouth, a chemical reaction that requires heat from the inside of the mouth.

Disaccharides

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

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

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 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 amylopectine) 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.

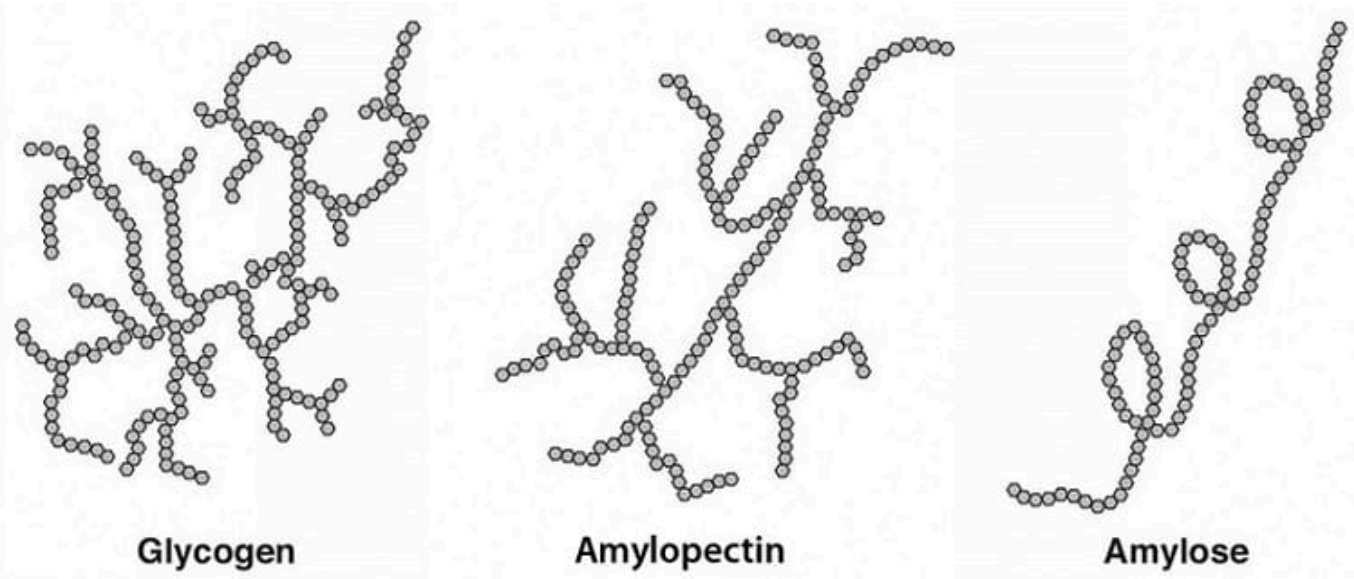


Figure 4.2.3: Structures of the Plant Starches and Glycogen

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. Some examples of soluble fibers are inulin, pectin, and guar gum and they are found in peas, beans, oats, barley, and rye. Cellulose and lignin are insoluble fibers and a few dietary sources of them 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.

Key Takeaways

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

Discussion Starters

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

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4.3: Digestion and Absorption of Carbohydrates

Learning Objectives

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

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



Figure 4.3.1: Blueberry pancakes. *Whole grains provide satisfaction from the beginning to the end of the digestion process. (CC-SA-BY-2.0;* jeffreyw)

See Table 4.3.1 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 4.3.1: 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/course...bohydrates.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 mechanical breakdown is ongoing—the strong peristaltic contractions of the stomach mix the carbohydrates into the more uniform mixture of chyme.

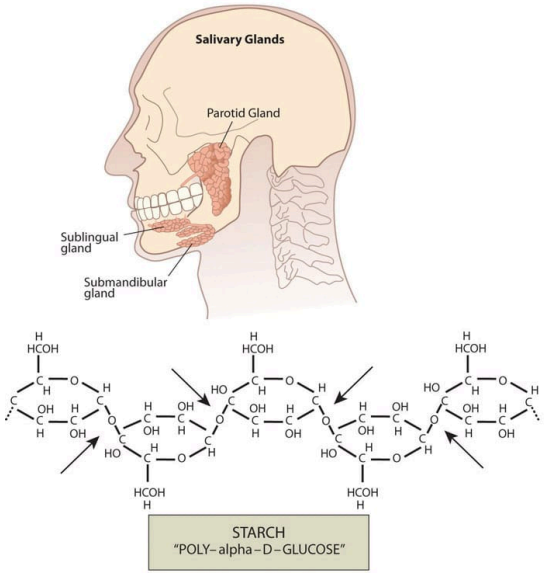


Figure 4.3.2: Salivary glands secrete salivary amylase, which begins the chemical breakdown of carbohydrates by breaking the bonds between monomeric sugar units.

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/ddise...seintolerance/. 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. 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.

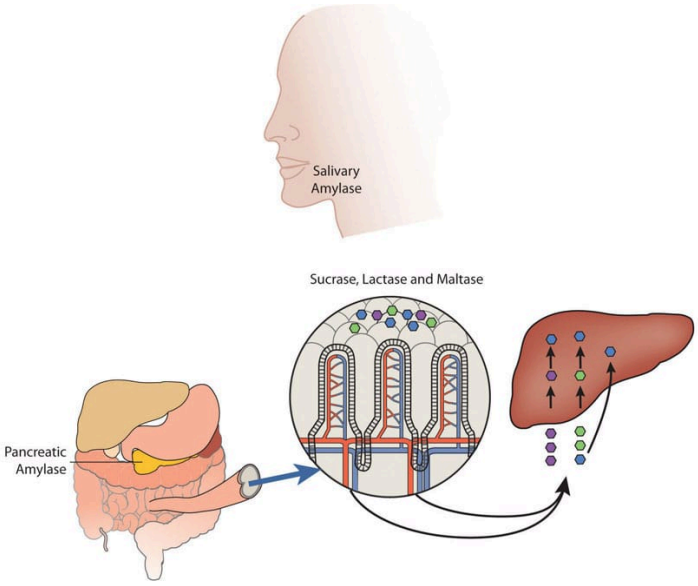


Figure 4.3.3: Carbohydrate digestion begins in the mouth and is most extensive in the small intestine. The resultant monosaccharides are absorbed into the bloodstream and transported to the liver.

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 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 to the insides of cells and to use it 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 increases, glucose levels decrease in the blood. Glucagon-secreting cells in the pancreas sense the drop in glucose and, in response, release glucagon into the blood. Glucagon communicates to the cells in the body to stop using all the glucose. More specifically, it signals the liver to break down glycogen and release the stored glucose into the blood, so that glucose levels stay within the target range and all cells get the needed fuel to function properly.

Leftover Carbohydrates: The Large Intestine

Almost all of the carbohydrates, except for dietary fiber and resistant starches, are efficiently digested and absorbed into the body. Some of the remaining indigestible carbohydrates are broken down by enzymes released by bacteria in the large intestine. The products of bacterial digestion of these slow-releasing carbohydrates are short-chain fatty acids and some gases. The short-chain fatty acids are either used by the bacteria to make energy and grow, are eliminated in the feces, or are absorbed into cells of the colon, with a small amount being transported to the liver. Colonic cells use the short-chain fatty acids to support some of their functions. The liver can also metabolize the short-chain fatty acids into cellular energy. The yield of energy from dietary fiber is about 2 kilocalories per gram for humans, but is highly dependent upon the fiber type, with soluble fibers and resistant starches yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other carbohydrate types (simple sugars, many starches) the rise in blood glucose after eating them is less, and slower. These physiological attributes of high-fiber foods (i.e. whole grains) are linked to a decrease in weight gain and reduced risk of chronic diseases, such as Type 2 diabetes and cardiovascular disease.

A Carbohydrate Feast



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 maximization of glycogen stores and all the excess glucose, protein, and lipids are stored as fat.

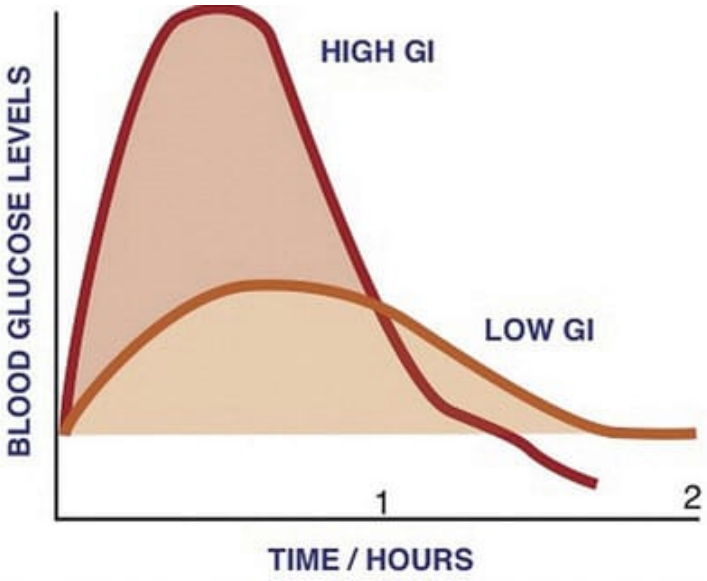


Figure 4.3.4: The glycemic index measures the effects of foods on blood-glucose levels.

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 4.3.4).

Glycemic Index

The glycemic responses of various foods have been measured and then ranked in comparison to a reference food, usually a slice of white bread 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 neither as much nor 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 4.3.2: 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/.	

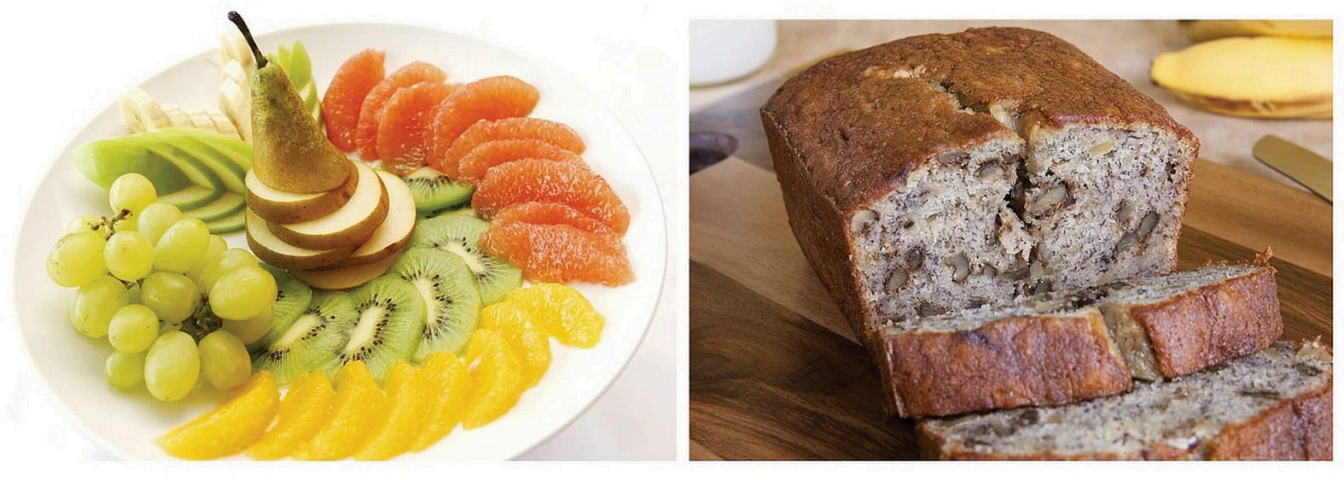
The carbohydrate type within a food affects the GI, but so does its fat and fiber content (which reduce the GI). Increased fat and fiber in foods increases the time required for digestion and delays the rate of gastric emptying into the small intestine. Processing and cooking additionally affect a food's GI by increasing their digestibility. Advancements in the technologies of food processing and the high consumer demand for convenient, precooked foods in the United States have created foods that are digested and absorbed more rapidly, independent of the fiber content. Modern breakfast cereals, breads, pastas, and many prepared foods have a high GI. In contrast, most raw foods have a lower GI. (However, the more ripened a fruit or vegetable is, the higher its GI.) Table 4.2 provides the GI for various foods. The GI can be used as a guide for choosing healthier carbohydrate choices but has some limitations. One is that the GI does not take into account the amount of carbohydrates in a portion of food, only the type of carbohydrate. Another is that combining low- and high-GI foods changes the GI for the meal. Also, some nutrient-dense foods have higher GIs than less nutritious food. (For instance, oatmeal has a higher GI than chocolate because the fat content of chocolate is higher.) Lastly, meats and fats do not have a GI since they do not contain carbohydrates.

Interactive 4.1: 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.



Balance the high-GI foods at the Thanksgiving table with low-GI foods. © Shutterstock

Key Takeaways

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

Discussion Starters

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

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4.4: The Functions of Carbohydrates in the Body

Learning Objectives

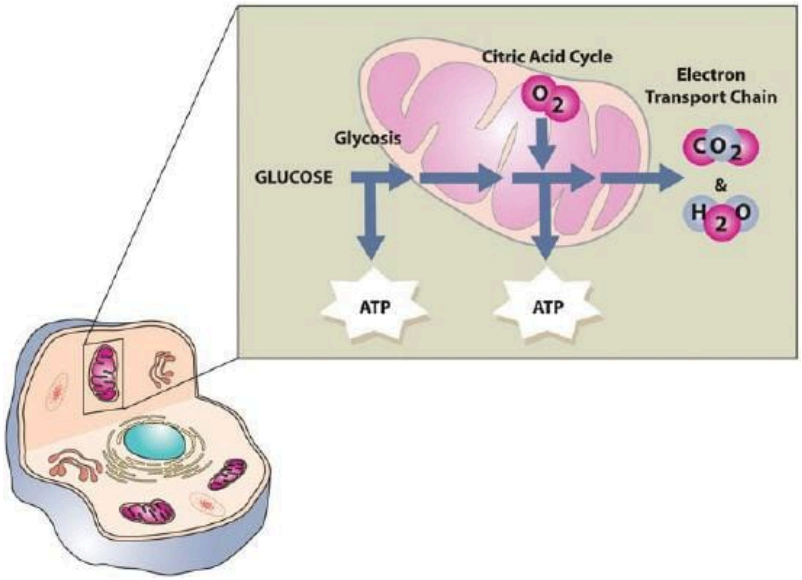
- List four primary functions of carbohydrates in the human body

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

Energy Production

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

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



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 4.4.1).

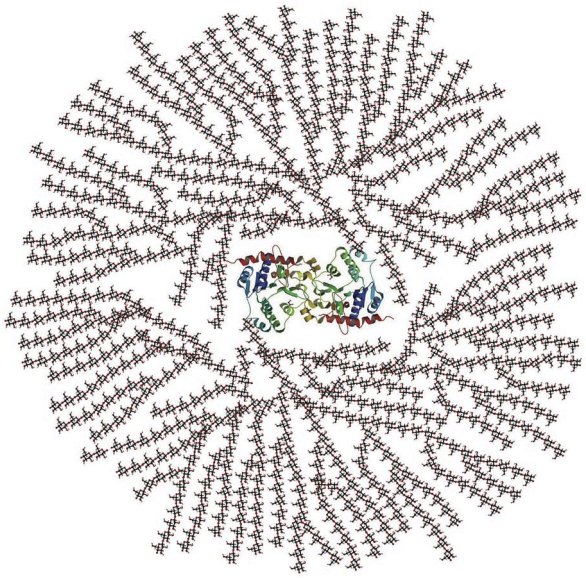


Figure 4.4.1: *The structure of glycogen enables its rapid mobilization into free glucose to power cells.*

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

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

Building Macromolecules

Although most absorbed glucose is used to make energy, some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP (Figure 4.4.2). Glucose is additionally utilized to make the molecule NADPH, which is important for protection against oxidative stress and is used in many other chemical reactions in the body. If all of the energy, glycogen-storing capacity, and building needs of the body are met, excess glucose can be used to make fat. This is why a diet too high in carbohydrates and calories can add on the fat pounds—a topic that will be discussed shortly.

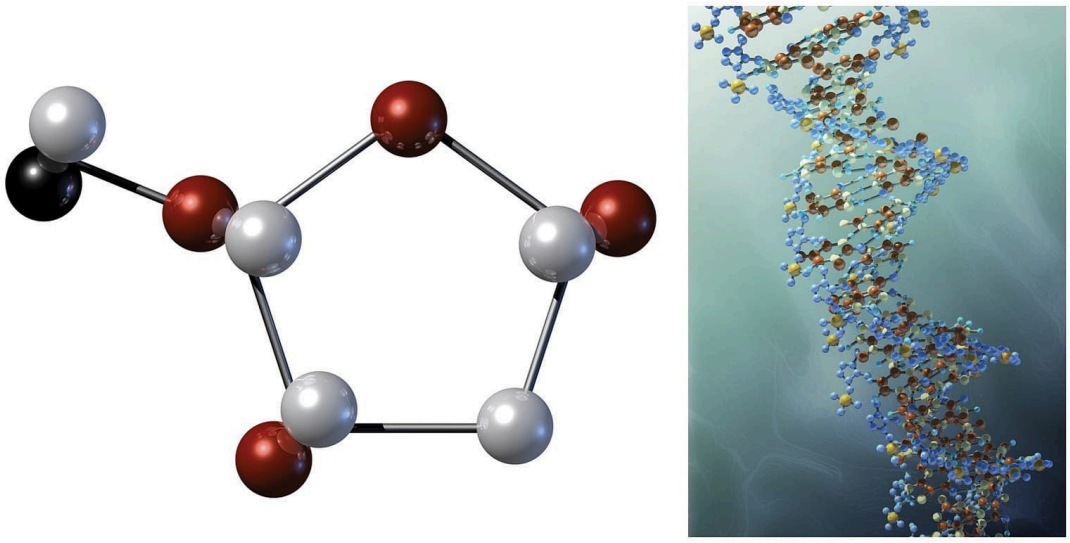


Figure 4.4.2: *The sugar molecule deoxyribose is used to build the backbone of DNA.© Shutterstock*

Sparing Protein

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

Lipid Metabolism

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

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

Key Takeaways

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

Discussion Starters

1. Discuss two reasons it is essential to include carbohydrates in your diet.

2. Why is it necessary for the body to spare protein?

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4.5: Looking Closely at Diabetes

Learning Objectives

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

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

Type 1 Diabetes

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

A person with Type 1 diabetes usually has a rapid onset of symptoms that include hunger, excessive thirst and urination, and rapid weight loss. Because the main function of glucose is to provide energy for the body, when insulin is no longer present there is no message sent to cells to take up glucose from the blood. Instead, cells use fat and proteins to make energy, resulting in weight loss. If Type 1 diabetes goes untreated individuals with the disease will develop a life-threatening condition called ketoacidosis. This condition occurs when the body uses fats and not glucose to make energy, resulting in a build-up of ketone bodies in the blood. It is a severe form of ketosis with symptoms of vomiting, dehydration, rapid breathing, and confusion and eventually coma and death. Upon insulin injection these severe symptoms are treated and death is avoided. Unfortunately, while insulin injection prevents death, it is not considered a cure. Type 1 diabetics are advised to count the carbohydrates they eat, to consume low glycemic index foods, and to monitor blood sugar levels. These guidelines are aimed at preventing large fluctuations in blood glucose. 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 4.5.1). In brief, cells in the body have become resistant to insulin and no longer receive the full physiological message of insulin to take up glucose from the blood. Thus, similar to patients with Type 1 diabetes, those with Type 2 diabetes also have high blood-glucose levels.

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

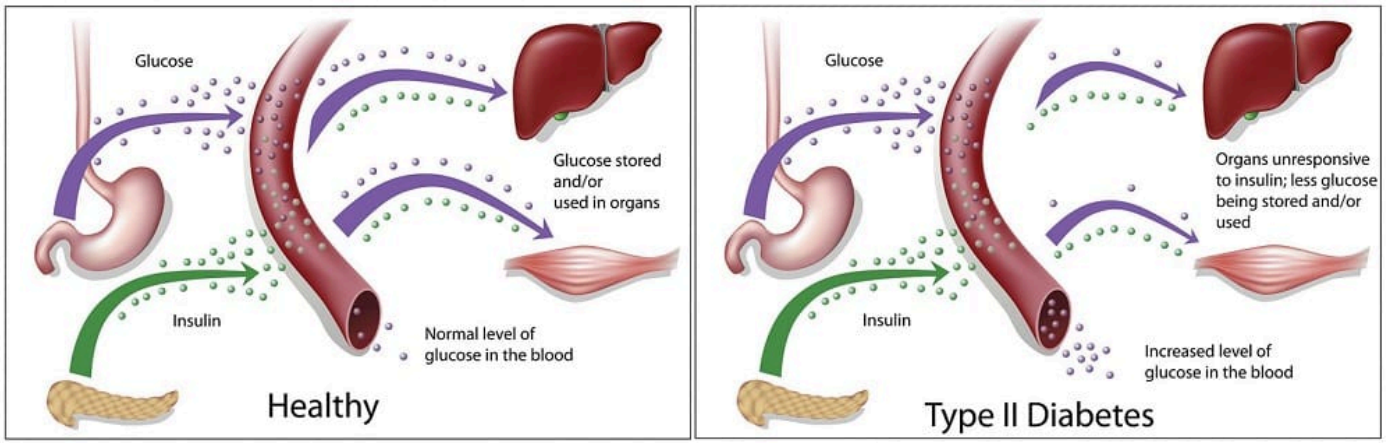


Figure 4.5.1: Type 2 diabetes is a metabolic disease characterized by high blood-glucose levels. © Shutterstock

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

Video 4.5.1: 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 for developing the disease. Metabolic syndrome refers to a medical condition in which people have three or more risk factors for Type 2 diabetes and cardiovascular disease (Figure 4.5.2). According to the International Diabetes Federation (IDF) people are diagnosed with this syndrome if they have central (abdominal) obesity and any two of the following health parameters: triglycerides greater than 150 mg/dL; high density lipoproteins (HDL) lower than 40 mg/dL; systolic blood pressure above 100 mmHg, or diastolic above 85 mmHg; fasting blood-glucose levels greater than 100 mg/dL.International Diabetes Federation. "The IDF Consensus Worldwide Definition of the Metabolic Syndrome." Accessed September 30, 2011. www.idf.org/webdata/docs/IDF_..._def_final.pdf.

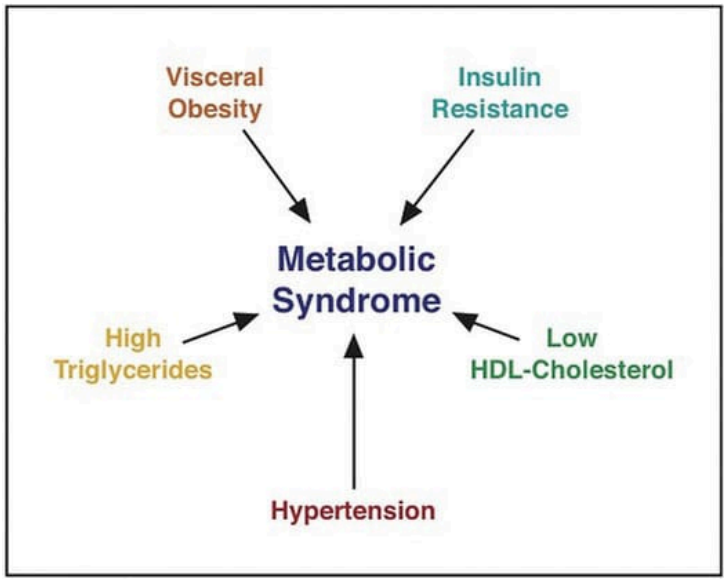
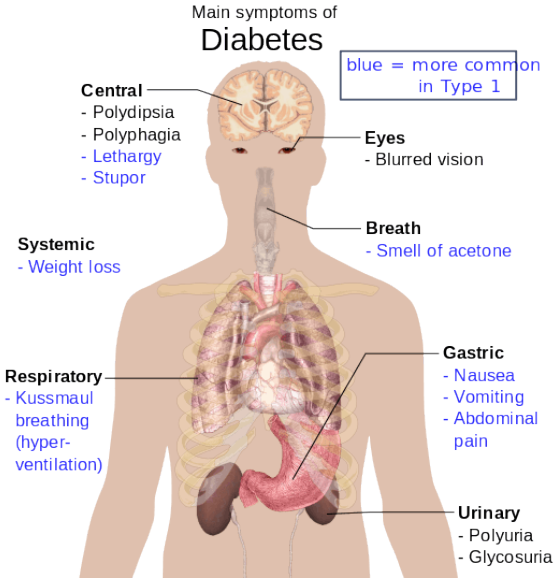


Figure 4.5.2***:*** *Metabolic Syndrome: A Combination of Risk Factors Increasing the Chances for Chronic Disease*

The IDF estimates that between 20 and 25 percent of adults worldwide have metabolic syndrome. Studies vary, but people with metabolic syndrome have between a 9 and 30 times greater chance for 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_..._def_final.pdf.



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. 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 4.5.2: 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. Inviduals with reactive hypoglycemia have some symptoms of hypoglycemia. Symptoms are caused by a higher than normal increase in blood-insulin levels. This rapidly decreases blood-glucose levels to a level below what is required for proper brain function.



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

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

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

Interactive 4.5.1

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

Key Takeaways

- Diabetes is a disease of insulin deficiency and glucose oversufficiency. Like other diseases, genetics, nutrition, environment, and lifestyle are all involved in determining a person’s risk for developing diabetes.
- Type 1 diabetes was once a death sentence, but now can be treated with insulin injections. However, insulin injections do not cure the disease, and diabetics can suffer many disease complications. Diabetes complications can be relieved by strictly

managing blood-glucose levels, adhering to a healthy diet, and increasing physical activity.
- The incidence of Type 2 diabetes has more than doubled in America in the past thirty years and the rise is partly attributed to the increase in obesity. The front-line approach for treating Type 2 diabetes includes eating a healthy diet and increasing physical activity.
- The long-term health consequences of diabetes are severe. They are the result of chronically high glucose concentrations in the blood and other metabolic abnormalities such as high blood-lipid levels.

Discussion Starters

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

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4.6: Health Consequences and Benefits of High-Carbohydrate Diets

Learning Objectives

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

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

Added Sugars

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

Currently, nutrition labels do not distinguish between added and naturally occurring sugars and give only the total sugar content, making it difficult for consumers to determine their consumption of added sugars. Results from a survey of forty-two thousand Americans reports that in 2008 the average intake of added sugars is 15 percent of total calories, a drop from 18 percent of total calories in 2000.Welsh J. A. et al. "Consumption of Added Sugars Is Decreasing in the United States." *Am J Clin Nutr* 94, no. 3 (2011): 726–34. http://www.ncbi.nlm.nih.gov/pubmed/21753067. This is still above the recommended intake of less than 10 percent of total calories. The US Department of Agriculture (USDA) reports that sugar consumption in the American diet in 2008 was, on average, 28 teaspoons per day (Figure 4.6.1).

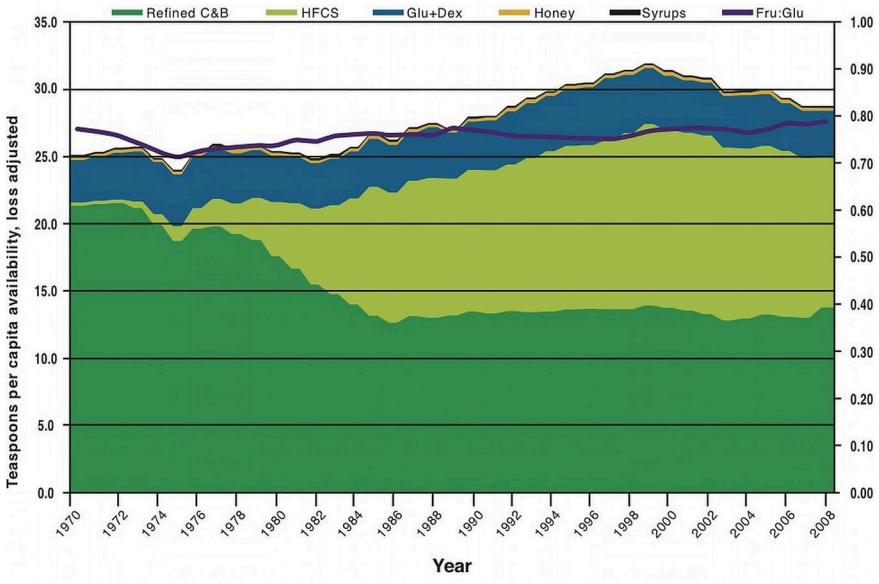


Figure 4.6.1: Sugar Consumption (in Teaspoons) from Various Sources

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

To understand the magnitude of the health problem in the United States consider this—in the United States approximately 130 million adults are overweight, and 30 percent of them are considered obese. The obesity epidemic has reached young adults and children and will markedly affect the prevalence of serious health consequences in adulthood. Health consequences linked to being overweight or obese include Type 2 diabetes, cardiovascular disease, arthritis, depression, and some cancers. An infatuation with sugary foods and refined grains likely contributes to the epidemic proportion of people who are overweight or obese in this country, but so do the consumption of high-calorie foods that contain too much saturated fat and the sedentary lifestyle of most Americans. There is much disagreement over whether high-carbohydrate diets increase weight-gain and disease risk, especially when calories are not significantly higher between compared diets. Many scientific studies demonstrate positive correlations between diets high in added sugars with weight gain and disease risk, but some others do not show a significant relationship. In regard to refined grains, there are no studies that show consumption of refined grains increases weight gain or disease risk. What is clear, however, is that getting more of your carbohydrates from dietary sources containing whole grains instead of refined grains stimulates weight loss and reduces disease risk.

A major source of added sugars in the American diet is soft drinks. There is consistent scientific evidence that consuming sugary soft drinks increases weight gain and disease risk. An analysis of over thirty studies in the *American Journal of Clinical Nutrition* concluded that there is much evidence to indicate higher consumption of sugar-sweetened beverages is linked with weight gain and obesity.Malik, V. S., M. B. Schulze, and F. B. Hu. “Intake of Sugar-Sweetened Beverages and Weight Gain: A Systematic Review.” *Am J Clin Nutr* 84, no. 2 (2006): 274–88. 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 HealthTakes Aim at Sugar and Salt.” Accessed September 30, 2011. www.hsph.harvard.edu/news/hph...-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 are not tied to positive nutrients such as in sugary drinks, candies, cakes, and cookies.
- Focus on calories in certain food categories such as beverages and confections, and encourage consumption of positive nutrients and foods such as cereals and low-fat or fat-free dairy products.Van Horn, L. et al. “Added Sugars and Health.” Research reviewed at the AHA Added Sugars Conference, 2010. *Circulation* 122 (2010): 2470–90. doi: 10.1161/CIR.0b013e3181ffdcb0.

The Most Notorious Sugar

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

Some scientists, public health personnel, and healthcare providers believe that fructose is the cause of the obesity epidemic and its associated health consequences. The majority of their evidence stems from the observation that since the early 1970s the number of overweight or obese Americans has dramatically increased and so has the consumption of foods containing HFCS. However, as discussed, so has the consumption of added sugars in general. Animal studies that fuel the fructose opponents show fructose is not used to produce energy in the body; instead it is mostly converted to fat in the liver—potentially contributing to insulin resistance and the development of Type 2 diabetes. Additionally, fructose does not stimulate the release of certain appetite-suppressing hormones, like insulin, as glucose does. Thus, a diet high in fructose could potentially stimulate fat deposition and weight gain.

In human studies, excessive fructose intake has sometimes been associated with weight gain, but results are inconsistent.

Moderate fructose intake is not associated with weight gain at all. Moreover, other studies show that some fructose in the diet actually improves glucose metabolism especially in people with Type 2 diabetes.Elliott, S. S. et al. “Fructose, Weight Gain, and the Insulin Resistance Syndrome.” *Am J Clin Nutr* 76, no. 5 (2002): 911–22. 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 4.6.1

The USDA is in the process of developing a database on the added sugars in many different foods and has made the information accessible. You might be frightened by what you discover when perusing it. For instance, one 6-ounce container (170 grams) of flavored yogurt contains 20 grams (5 teaspoons) of added sugars.

http://www.ars.usda.gov/SP2UserFiles/Place/12354500/Data/Add_Sug/addsug01.pdf

Oral Disease

Oral health refers not only to healthy teeth and gums, but also to the health of all the supporting tissues in the mouth such as ligaments, nerves, jawbone, chewing muscles, and salivary glands. Over ten years ago the Surgeon General produced its first report dedicated to oral health, stating that oral health and health in general are not separate entities.Surgeon General. “National Call to Action to Promote Oral Health.” Accessed September 30, 2011. www.surgeongeneral.gov/librar...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 4.6.2). Gums are also damaged by bacteria produced by acids, leading to gingivitis (characterized by inflamed and bleeding gums). Saliva is actually a natural mouthwash that neutralizes the acids and aids in building up teeth that have been damaged.



Figure 4.6.2*: Gingivitis. One way to prevent gingivitis and subsequent tooth decay is to lower consumption of sugary drinks.Gingivitis before (top) and after (bottom) a thorough mechanical debridement of the teeth. (Public domain).*

According to Healthy People 2010, 23 percent of US children have cavities by the age of four, and by second grade, one-half of all children in this country have at least one cavity.Continuing MCH Education in Oral Health. “Oral Health and Health Care.” Accessed September 30, 2011. http://ccnmtl.columbia.edu/projects/otm/index.html. Cavities are an epidemic health problem in

the United States and are associated with poor diet, but other contributors include poor dental hygiene and the inaccessibility to regular oral health care. A review in *Academic Pediatrics* reports that “frequent consumption of fast-releasing carbohydrates, primarily in the form of dietary sugars, is significantly associated with increased dental caries risk.”Mobley C., PhD, et al. “The Contribution of Dietary Factors to Dental Caries and Disparities in Caries.” Acad Pediatr 9, no. 6 (2009): 410–14. doi: 10.1016/j.acap.2009.09.008. In regards to sugary soft drinks, the American Dental Association says that drinking sugary soft drinks increases the risk of decay formation.American Dental Association. “Diet and Oral Health.” Accessed September 30, 2011. www.ada.org/2984.aspx#eatoothdecay.

Interactive 4.6.2

The Harvard School of Public Health *Nutrition Source* has developed a guide called “How Sweet Is It?” that notes the calories and sugar contents of many popular beverages. Visit the site to determine drinks that are better for your oral and overall health.

http://www.hsph.harvard.edu/nutritionsource/files/how-sweet-is-it-color.pdf

Tools for Change

Save your teeth and gums and choose to drink a beverage that does not contain excess added sugars. An idea: brew some raspberry tea, add some sparkling mineral water, a raspberry or two, some ice, and a mint leaf. Then sit back and refresh.

Do Low-Carbohydrate Diets Affect Health?

Since the early 1990s, marketers of low-carbohydrate diets have bombarded us with the idea that eating fewer carbohydrates promotes weight loss and that these diets are superior to others in their effects on weight loss and overall health. The most famous of these low-carbohydrate diets is the Atkin’s diet. Others include the “South Beach” diet, the “Zone” diet, and the “Earth” diet. Despite the claims these diets make, there is little scientific evidence to support that low-carbohydrate diets are significantly better than other diets in promoting long-term weight loss. A study in *The Nutritional Journal* concluded that all diets, (independent of carbohydrate, fat, and protein content) that incorporated an exercise regimen significantly decreased weight and waist circumference in obese women.Kerksick, C. M. et al. “Changes in Weight Loss, Body Composition, and Cardiovascular Disease Risk after Altering Macronutrient Distributions During a Regular Exercise Program in Obese Women.” *J Nutr* 9, no. 59 (2010). doi: 10.1186/1475-2891-9-59. Some studies do provide evidence that in comparison to other diets, low-carbohydrate diets improve insulin levels and other risk factors for Type 2 diabetes and cardiovascular disease. The overall scientific consensus is that consuming fewer calories in a balanced diet will promote health and stimulate weight loss, with significantly better results achieved when combined with regular exercise.

Health Benefits of Whole Grains in the Diet

While excessive consumption of fast-releasing carbohydrates is potentially bad for your health, consuming more slow-releasing carbohydrates is extremely beneficial to health. There is a wealth of scientific evidence supporting that replacing refined grains with whole grains decreases the risk for obesity, Type 2 diabetes, and cardiovascular disease. Whole grains are great dietary sources of fiber, vitamins, minerals, healthy fats, and a vast amount of beneficial plant chemicals, all of which contribute to the effects of whole grains on health. Americans typically do not consume the recommended amount of whole grains, which is 50 percent or more of grains from whole grains (Figure 4.6.3).

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 can help you feel full, so you’ll be satisfied with less calories” American Heart Association. “Whole Grains, Refined Grains and Dietary Fiber"

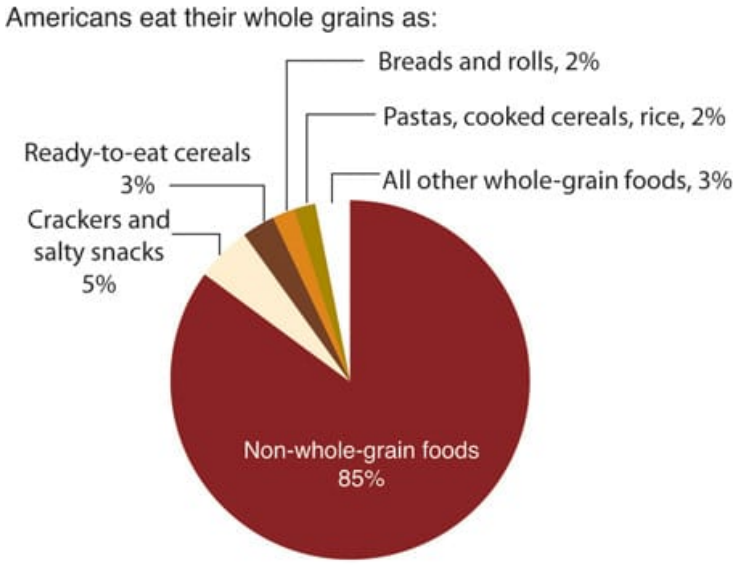


Figure 4.6.3: Grain Consumption Statistics in America. Source: Economic Research Service. http://www.ers.usda.gov/data-products/commodity-consumption-by-population-characteristics/documentation.aspx.

Colon Health

A substantial health benefit of whole grain foods is that fiber actively supports digestion and optimizes colon health. (This can be more specifically attributed to the insoluble fiber content of whole grains.) There is good evidence supporting that insoluble fiber prevents the irritating problem of constipation and the development of diverticulosis and diverticulitis. Diverticulosis is a benign condition characterized by out-pocketings of the colon. Diverticulitis occurs when the out-pocketings in the lining of the colon become inflamed. Interestingly, diverticulitis did not make its medical debut until the early 1900s, and in 1971 was defined as a deficiency of whole-grain fiber. According to the National Digestive Diseases Information Clearinghouse, 10 percent of Americans over the age of forty have diverticulosis, and 50 percent of people over the age of sixty have the disorder.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. “Diverticulosis and Diverticulitis.” *NIH Publication No. 08-1163* (July 2008). digestive.niddk.nih.gov/ddise...iverticulosis/. Ten to 25 percent of people who have diverticulosis go on to develop diverticulitis.National Digestive Diseases Information Clearinghouse, a service of National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health. “Diverticulosis and Diverticulitis.” *NIH Publication No. 08-1163* (July 2008). Symptoms include lower abdominal pain, nausea, and alternating between constipation and diarrhea.

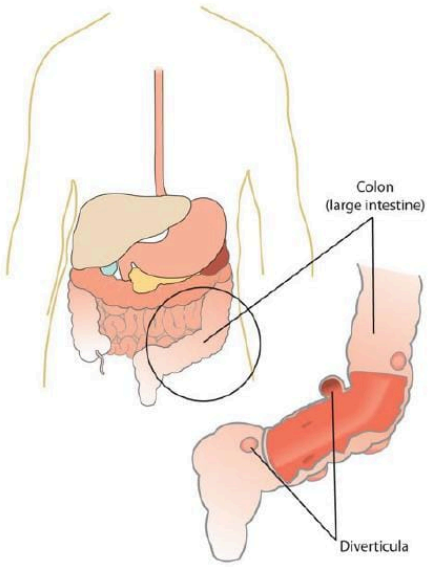


Figure 4.6.4***:*** *Diverticulitis: A Disease of Fiber Deficiency*

The chances of developing diverticulosis can be reduced with fiber intake because of what the breakdown products of the fiber do for the colon. The bacterial breakdown of fiber in the large intestine releases short-chain fatty acids. These molecules have been found to nourish colonic cells, inhibit colonic inflammation, and stimulate the immune system (thereby providing protection of the colon from harmful substances). Additionally, the bacterial indigestible fiber, mostly insoluble, increases stool bulk and softness increasing transit time in the large intestine and facilitating feces elimination. One phenomenon of consuming foods high in fiber is increased gas, since the byproducts of bacterial digestion of fiber are gases.

Some studies have found a link between high dietary-fiber intake and a decreased risk for colon cancer. However an analysis of several studies, published in the *Journal of the American Medical Association* in 2005, did not find that dietary-fiber intake was associated with a reduction in colon cancer risk.Park, Y. et al. “Dietary Fiber Intake and Risk of Colorectal Cancer.” *JAMA* 294, no. 22 (2005): 2849–57. doi: 10.1001/jama.294.22.2849. There is some evidence that specific fiber types (such as inulin) may protect against colon cancer, but more studies are needed to conclusively determine how certain fiber types (and at what dose) inhibit colon cancer development.

Key Takeaways

- Whole grain dietary sources stimulate weight loss and reduce disease risk. Excessive high fructose consumption has been shown to cause weight gain. A primary source of added sugars in the American diet is sugary soft drinks.
- While excessive consumption of some fast-releasing carbohydrates and refined grains is potentially bad for your health, consuming whole grains made up of nutrient-dense slow-releasing carbohydrates is extremely beneficial to health.

Discussion Starters

1. Have a debate in your classroom on the USDA restriction on the sale of carbonated beverages in schools. Find out more information on this topic by reading “Soft Drinks and School-Age Children: Trends, Effects, Solutions,” developed by the North Carolina School Nutrition Action Committee.

   nepc.colorado.edu/files/CERU-0203-41-OWI.pdf

2. Learn about the “Australian Paradox:” How decreased sugar consumption paralleled increased rates of overweight and obese people. Read the study and have a classroom debate over the weight of evidence that supports that diets high in added sugars actually increase weight gain.

   http://www.mdpi.com/2072-6643/3/4/491/pdf

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4.7: Carbohydrates and Personal Diet Choices

Learning Objectives

- Define the Acceptable Macronutrient Distribution Range for carbohydrates, the Adequate Intake for fiber, and recommended intake of added sugars.
- List five foods that are good sources of slow-releasing carbohydrates.
- Identify three to five foods high in fiber and carbohydrates from whole, unrefined sources.

In this chapter, you learned what carbohydrates are, the different types of carbohydrates in your diet, and that excess consumption of some types of carbohydrates cause disease while others decrease disease risk. Now that we know the benefits of eating the right carbohydrate, we will examine exactly how much should be eaten to promote health and prevent disease.

How Many Carbohydrates Does a Person Need?

The Food and Nutrition Board of IOM has set the Recommended Dietary Allowance (RDA) of carbohydrates for children and adults at 130 grams per day. This is the average minimum amount the brain requires to function properly. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrates is between 45 and 65 percent. This means that on a 2,000 kilocalorie diet, a person should consume between 225 and 325 grams of carbohydrate each day. According to the IOM not more than 25 percent of total calories consumed should come from added sugars. The World Health Organization and the AHA recommend much lower intakes of added sugars—10 percent or less of total calories consumed. The IOM has also set Adequate Intakes for dietary fiber, which are 38 and 25 grams for men and women, respectively. The recommendations for dietary fiber are based upon the intake levels known to prevent against heart disease.

Table 4.7.1: Dietary Reference Intakes for Carbohydrates and Fiber

Carbohydrate Type	RDA (g/day)	AMDR (% calories)
Total Carbohydrates	130	45–65
Added Sugars		< 25
Fiber	38 (men),* 25 (women)*	
*** denotes Adequate Intake**		

Dietary Sources of Carbohydrates

Carbohydrates are contained in all five food groups: grains, fruits, vegetables, meats, and beans (only in some processed meats and beans), and dairy products. Fast-releasing carbohydrates are more prevalent in fruits, fruit juices, and dairy products, while slow-releasing carbohydrates are more plentiful in starchy vegetables, beans, and whole grains. Fast-releasing carbohydrates are also found in large amounts in processed foods, soft drinks, and sweets. On average, a serving of fruits, whole grains, or starches contains 15 grams of carbohydrates. A serving of dairy contains about 12 grams of carbohydrates, and a serving of vegetables contains about 5 grams of carbohydrates. Table 4.7.2 gives the specific amounts of carbohydrates, fiber, and added sugar of various foods.

Table 4.7.2: Carbohydrates in Foods (grams/serving)

Foods	Total Carbohydrates	Sugars	Fiber	Added Sugars
Apple	19 (1 medium)	19.00	4.4	0
Banana	27 (1 medium)	14.40	3.1	0
Lentils	40 (1 c.)	3.50	16.0	0
Snap beans	8.7 (1 c.)	1.60	4.0	0

Foods	Total Carbohydrates	Sugars	Fiber	Added Sugars
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. www.nal.usda.gov/fnic/foodcomp/search/, and US Department of Agriculture. "Database for the Added Sugars Content of Selected Foods." February 2006. 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 4.7.1

This interactive USDA tool allows you to enter the foods and serving size of what you're eating and find out the whole nutrient package.

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

Understanding Carbohydrates from Product Information

While nutrition facts labels aid in determining the amount of carbohydrates you eat, they do not help in determining whether a food is refined or not. The ingredients list provides some help in this regard. It identifies all of the food's ingredients in order of concentration, with the most concentrated ingredient first. When choosing between two breads, pick the one that lists whole wheat (not wheat flour) as the first ingredient, and avoid those with other flour ingredients, such as white flour or corn flour. (Enriched wheat flour refers to white flour with added vitamins.) Eat less of products that list HFCS and other sugars such as sucrose, honey, dextrose, and cane sugar in the first five ingredients. If you want to eat less processed foods then, in general,

stay away from products with long ingredient lists. On the front of food and beverages the manufacturers may include claims such as “sugar-free,” “reduced sugar,” “high fiber,” etc.. The Nutrition and Labeling Act of 1990 has defined for the food industry and consumers what these labels mean (Table 4.7.3).

Table 4.7.3: Food Labels Pertaining to Carbohydrates

Label	Meaning
Sugar-free	Contains less than 0.5 grams of sugar per serving
Reduced sugar	Contains 25 percent less sugar than similar product
Less sugar	Contains 25 percent less sugar than similar product, and was not altered by processing to become so
No sugars added	No sugars added during processing
High fiber	Contains at least 20 percent of daily value of fiber in each serving
A good source of fiber	Contains between 10 and 19 percent of the daily value of fiber per serving
More fiber	Contains 10 percent or more of the daily value of fiber per serving

Source: US Food and Drug Administration. “Appendix A: Definitions of Nutrient Claims.” *Guidance for Industry: A Food Labeling Guide*. September 1994. Last revised October 2009. www.fda.gov/Food/GuidanceComp.../ucm064911.htm.

In addition, the FDA permits foods that contain whole oats (which contain soluble fiber) to make the health claim on the package that the food reduces the risk of coronary heart disease. The FDA no longer permits Cheerios to make the claim that by eating their cereal “you can lower your cholesterol four percent in six weeks.”

The Bottom Line

Read the labels and ingredient lists of foods to determine your carbohydrate intake and know the types of carbohydrate you consume.

Personal Choices

Carbohydrates are in most foods so you have a great variety of choices with which to meet the carbohydrates recommendations for a healthy diet. The *2015-2020 Dietary Guidelines* recommends eating more unrefined carbohydrates and more fiber, and reducing consumption of foods that are high in added sugars. To accomplish these recommendations use some or all of the following suggestions:

- Get more daily carbohydrate servings from whole grains by eating a whole-grain cereal for breakfast, using whole-grain bread to make a sandwich for lunch, and eating a serving of beans and/or nuts with dinner.
- Make sure to get at least three servings (or more) of all the grains you eat as whole grains every day. A serving of whole grains is equal to one slice of whole-wheat bread, one ounce of whole-grain cereal, and one-half cup of cooked cereal, brown rice, or whole-wheat pasta.
- Food products made with cornmeal use the whole grain so choose tortillas, corn cereals, and corn breads with cornmeal listed as the first ingredient.
- When baking, substitute whole-wheat flour or other whole-grain flour for some of the refined white flour.
- If you like bread at dinner, choose a whole-grain muffin over a Kaiser roll or baguette.
- Add beans, nuts, or seeds to salad—they add texture and taste.
- Choose whole-grain pastas and brown rice, cook al dente, and add some beans and vegetables in equal portions.
- Change it up a bit and experience the taste and satisfaction of other whole grains such as barley, quinoa, and bulgur.
- Eat snacks high in fiber, such as almonds, pistachios, raisins, and air-popped popcorn.
- Add an artichoke and green peas to your dinner plate more often.
- Calm your “sweet tooth” by eating fruits, such as berries or an apple.
- Replace sugary soft drinks with seltzer water, tea, or a small amount of 100 percent fruit juice added to water or soda water.

Key Takeaways

- The National Academy of Medicine 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, legumes (peas and beans) and dairy products.
- The *2015-2020 Dietary Guidelines* recommends eating more slow-releasing carbohydrates and more fiber, and reducing consumption of foods that are high in added sugars. This involves choosing carbohydrate sources that are nutrient-dense, with more essential nutrients per calorie of energy.

Discussion Starters

1. Are you getting the recommended amount of dietary fiber in your diet?
2. Read the following article from the Mayo clinic "Added Sugars: Don't get sabotaged by sweeteners". Identify the added sugars you typically consume and discuss some of the “surprises” that you discover with your classmates.

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

Learning Objectives

- Discuss the usefulness (or lack thereof) of consuming foods containing sugar substitutes

In the food industry, both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes, including increased sweetness, viscosity, bulk, coating ability, solubility, consistency, texture, body, and browning capacity. The differences in chemical structure between the different carbohydrates confer their varied functional uses in foods. Starches, gums, and pectins are used as thickening agents in making jam, cakes, cookies, noodles, canned products, imitation cheeses, and a variety of other foods. Molecular gastronomists use slow-releasing carbohydrates, such as alginate, to give shape and texture to their fascinating food creations (Video 4.8.1). Adding fiber to foods increases bulk. Simple sugars are used not only for adding sweetness, but also to add texture, consistency, and browning. In ice cream, the combination of sucrose and corn syrup imparts sweetness as well as a glossy appearance and smooth texture. Added sugars include white, brown, and raw sugar, corn syrup, HFCS, malt and maple syrups, liquid fructose, honey, molasses, agave nectar, and crystal dextrose.

Video 4.8.1: Ferran Adrian Demonstrates Alginates

Watch this video to see how molecular gastronomist Ferran Adrian uses the polysaccharide alginate to give shape and texture to olive puree.

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.

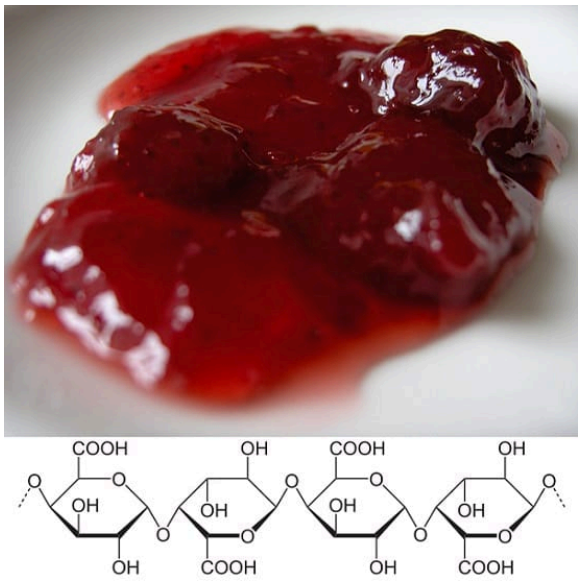


Figure 4.8.1: Pectin (a carbohydrate) is added to jam to give it its consistency. (bottom) This drawing depicts a pectin molecule. These molecules combine to form the network responsible for making jelly. (CC BY-SA 3.0; PatríciaR).

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 4.8.1). Artificial sweeteners and Stevia are not digested or absorbed in significant amounts and therefore are not a significant source of calories in the diet. Sugar alcohols are somewhat digested and absorbed and, on average, contribute about half of the calories as sucrose (4 kilocalories/gram). These attributes make sugar substitutes attractive for many people—especially those who want to lose weight and/or better manage their blood-glucose levels.

Table 4.8.1: Sweetness Comparison of Sugar Substitutes

Sweetener	Trade Names	Times that of Sucrose
Saccharine	“Sweet-N-Lo”	600.0
Aspartame	“NutraSweet,” “Equal”	180.0–220.0
Acesulfame-K	“Sunette”	200.0
Neotame		7,000.0–13,000.0
Sucralose	“Splenda”	600.0
Stevia		250.0–300.0
Xylitol		0.8
Mannitol		0.5
Sorbitol		0.6
Erythritol		1.0

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, or gum disease, or promotes tooth remineralization.

There is limited scientific evidence that consuming products with artificial sweeteners decreases weight. In fact, some studies suggest the intense sweetness of these products increases appetite for sweet foods and may lead to increased weight gain. Also, there is very limited evidence that suggests artificial sweeteners lower blood-glucose levels. Additionally, many foods and beverages containing artificial sweeteners and sugar alcohols are still empty-calorie foods (i.e. chewing sugarless gum or drinking diet soda pop) are not going to better your blood-glucose levels or your health.

Health Concerns

The most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion. Since the introduction of sugar substitutes to the food and beverage markets, the public has expressed concern about their safety. The health concerns of sugar substitutes originally stemmed from scientific studies, which were misinterpreted by both scientists and the public.

In the early 1970s scientific studies were published that demonstrated that high doses of saccharine caused bladder tumors in rats. This information fueled the still-ongoing debate of the health consequences of all artificial sweeteners. In actuality, the results from the early studies were completely irrelevant to humans. The large doses (2.5 percent of diet) of saccharine caused a pellet to form in the rat’s bladder. That pellet chronically irritated the bladder wall, eventually resulting in tumor development. Since this study, scientific investigation in rats, monkeys, and humans have not found any relationship between saccharine consumption and bladder cancer. In 2000, saccharin was removed from the US National Toxicology Program’s list of potential carcinogens.National Cancer Institute. “Artificial Sweeteners and Cancer.” Accessed September 30, 2011. http://www.cancer.gov/cancertopics/factsheet/Risk/artificial-sweeteners.

There have been health concerns over other artificial sweeteners, most notably aspartame (sold under the trade names of NutraSweet and Equal). The first misconception regarding aspartame was that it was linked with an increase in the incidence of brain tumors in the United States. It was subsequently discovered that the increase in brain tumors started eight years prior to the introduction of aspartame to the market. Today, aspartame is accused of causing brain damage, autism, emotional disorders, and a myriad of other disorders and diseases. Some even believe aspartame is part of a governmental conspiracy to make people dumber. The reality is there is no good scientific evidence backing any of these accusations, and that aspartame has been the most scientifically tested food additive. It is approved for use as an artificial sweetener in over ninety countries.

Aspartame is made by joining aspartic acid and phenylalanine to amino acids. When digested, it is broken down to aspartic acid, phenylalanine, and methanol. People who have the rare genetic disorder phenylketonuria (PKU) have to avoid products containing aspartame. Individuals who have PKU do not have a functional enzyme that converts phenylalanine to the amino acid tyrosine. This causes a build-up of phenylalanine and its metabolic products in the body. If PKU is not treated, the build-up of phenylalanine causes progressive brain damage and seizures. The FDA requires products that contain aspartame to state on the product label, “Phenylketonurics: Contains Phenylalanine.” For more details on sugar substitutes please refer to Table 4.8.1.

Table 4.8.3: 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 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 associated with bladder cancer in laboratory animals. In 1977, FDA proposed banning saccharin from use in food • protest launched by consumer & interest groups • warning label listed on products about saccharin and cancer risk in animals until 2001 when studies concluded that it did not cause cancer in humans	General purpose sweetener in all foods and beverages. Sold as Sweet 'n' Low in 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). Structure is very similar to saccharin's. 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. Body cannot digest it. ***Can be used in cooking.**		Chewing gum, powdered beverage mixes, nondairy 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 approved by FDA for use. Cyclamate was classified as GRAS (Generally Recognized As Safe) until 1970 when it was removed from GRAS status and banned from use in all food and beverage products within the United States on the basis of one study that indicated it caused bladder cancer in rats. Approval still pending for use in the United States since the ban. Canada and other countries use this type of sweetener.	Recommended as a substitute for table sugar for diabetics in 1950s, baked goods.

Sweeteners with Trade Name	Calories	Source/ Origin	Consumer Recommendations	Controversial Issues	Product Uses
Sucralose • Splenda	1 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 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 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 • Sorbital • 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, pharmaceutical 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/foodingredie.../ucm094211.htm.

The FDA additionally has established ADIs for artificial sweeteners. The ADIs are the maximum amount in milligrams per kilogram of body weight considered safe to consume daily (mg/kg bw/day) and incorporates a large safety factor. The following list contains the artificial sweeteners approved for use in foods and beverages in the United States, and their ADIs:

- **Acesulfame potassium (Sunett, Sweet One).** ADI = 15 mg/kg bw/day
- **Aspartame (Equal, NutraSweet).** ADI = 50 mg/kg bw/day
- **Neotame.** ADI = 18 mg/kg bw/day
- **Saccharin (SugarTwin, Sweet'N Low).** ADI = 5 mg/kg bw/day
- **Sucralose (Splenda).** ADI = 5 mg/kg bw/day

Carbohydrates in a Kernel

Referring back to the wheat kernel mentioned at the opening of this chapter, recall that all components of the wheat kernel are required in order to build an optimal healthy diet. The endosperm provides the carbohydrates, and the bran and germ contain the majority of protein, vitamins, minerals, and fiber. Eating foods made with whole grains provides a better nutritional punch for your health. Once whole grains are processed and refined, enrichment in only a few of these removed nutrients does not offset the gain from consuming whole-grain products. Other dietary sources of carbohydrates that maximize nutrient uptake are vegetables, fruits, beans, and low-fat dairy products. To avoid compromising your health, do not consume excessive amounts of carbohydrate foods that contain added sugars, or that are high in sodium and saturated fat. Processed foods contain all of these ingredients in an unwelcome nutrient package that negatively impacts health. Sugar substitutes provide one avenue of decreasing the intake of fast-releasing carbohydrates, but there are others. Know that consumer demand for healthy carbohydrate choices is on the rise, so in the future you can expect decreased prices, more variety of whole-grain products, and less added sugars.

The Bottom Line

Choose more slow-releasing carbohydrates, eat more fiber, and reduce consumption of foods high in added sugars.

Key Takeaways

- In the food industry both fast-releasing and slow-releasing carbohydrates are utilized to give foods a wide spectrum of functional attributes. The differences in chemical structure between the different carbohydrates confer their many different functional uses in foods.
- Due to the health consequences of consuming too many added sugars, sugar substitutes are widely used in many foods and beverages.
- Consuming foods and beverages containing sugar substitutes may benefit health by reducing the consumption of simple sugars, which are higher in calories, cause tooth decay, and are potentially linked to chronic disease. However, the most common side effect of consuming products containing sugar substitutes is gastrointestinal upset, a result of their incomplete digestion.
- Prior to introducing any new artificial sweetener into foods it is rigorously tested and must be legally approved by the FDA.

Discussion Starters

1. Conduct a taste test of sugar and its substitutes. What do your taste buds tell you? Do you prefer foods with sugar substitutes or the real thing?

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4.E: Carbohydrates (Exercises)

It's Your Turn

1. List four functions of carbohydrates in the body.
2. List sources of carbohydrate in the diet. Which ones are healthy? Which ones are not healthy?
3. Count the carbohydrates you consume in a day by following the steps for carbohydrate counting. Is your intake within the recommended range?
4. Determine your daily fiber intake and whether your diet supplies the amount of fiber recommended to promote health and prevent disease. What are the roles of soluble and insoluble fiber?
5. List the benefits of a higher carbohydrate diet. What could be concerns?

Apply It

1. Conduct a dietary assessment of the Glycemic Index of foods in three of your dinners. To aid in this process peruse the website, http://www.gilisting.com/. Plan a dinner menu that balances the Glycemic Index of the entire meal.
2. Conduct an experiment in the classroom that evaluates the sweetness and taste of sugar substitutes. Try them in pure form by putting a small amount on your finger. Record the results from you and your classmates and make a sweetness and taste comparison chart.

Expand Your Knowledge

1. Draw a flow chart that incorporates the concept of negative feedback in the regulation of blood glucose levels.
2. Visit the website of the CDC (https://www.cdc.gov/diabetes/data/index.html) and record the estimates of obesity, physical inactivity, and Type 2 diabetes in the county you live in. Make a list of five ways to curb the trends of obesity, physical inactivity, and Type 2 diabetes in your county.

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5: LIPIDS

In this chapter, we look at the types, structure, and roles of lipids, and we explain the different types of cholesterol in the blood. We also explore topics of interest such as omega-3 and omega-6 fatty acids and trans fats.

5.1: Prelude to Lipids

5.2: What Are Lipids?

5.3: How Lipids Work

5.4: Digestion and Absorption of Lipids

5.5: Understanding Blood Cholesterol and Heart Attack Risk

5.6: Balancing Your Diet with Lipids

5.7: Lipids and the Food Industry

5.8: Lipids and Disease

5.9: A Personal Choice about Lipids

5.E: Lipids (Exercises)

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5.1: Prelude 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 5.1.1: 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

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These findings were supported by a later study in 1972, when the Greenland Inuit first caught the attention of Dr. H. O. Bang from Aalborg University in Denmark. He noted that although the Inuit consumed massive amounts of fatty ocean fish, which are packed with omega-3s, none of the Inuit tested showed signs of heart disease. In addition, there was significantly less evidence of joint disease and skin disease than found in Western countries. Further research led Bang and his associate, Dyerberg, to conclude that the omega-3 fatty acids (docosahexaenoic acid, or DHA, and eicosapentaenoic acid, or EPA) present in the diet offer significant health benefits:Bang, H.O. and J. Dyerberg. "Fatty Acid Composition of the Plasma Lipids in Greenland Eskimos." *Am J Clin Nutr* 28 (1975): 958–66.

- **Heart disease.** Further research supports Bang and Dyerberg's finding and shows DHA and EPA to be beneficial to heart health and human development. EPA and DHA tend to reduce blood pressure, prevent blood-clot formation (thereby reducing the risk of stroke), and protect against irregular heartbeats.
- **Inflammation and autoimmune diseases.** According to research published in the *Journal of the American College of Nutrition*, animal experiments and clinical intervention studies indicate that omega-3 fatty acids have anti-inflammatory properties.Sears, B. "Anti-Inflammatory Diets for Obesity and Diabetes." *J Am Coll Nutr* 21 (2008). The low incidence of autoimmune and inflammatory disorders such as psoriasis, asthma, and Type 1 diabetes and the complete absence of multiple sclerosis has been observed and studied in the Inuit population in Greenland.Brzezinski, A. "Review." *Gastroenterol Hepatol* 3, no. 10 (2007): 787–88. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3104160/. Subsequent studies concur with these findings and it is believed that omega-3 fats play an important role in the prevention and treatment of coronary artery disease, high blood pressure, arthritis, other inflammatory and autoimmune disorders, and cancer.Simopoulos, A. "Omega-3 Fatty Acids in Inflammation and Autoimmune Diseases." *J Am Coll Nutr* 21, no. 6 (2002): 495–505. http://www.jacn.org/content/21/6/495.full.
- **Brain health.** Omega-3 fats play an important role in maintaining mental health and are crucial for brain function. Omega-3 fatty acids may provide benefits such as expanding learning and memory capacities. Early evidence suggests that the consumption of omega-3 fats is essential for synaptic transmission in the brain. Furthermore, omega-3 fats seem to be most effective when obtained from foods rather than from supplements.

You Decide

What sources of omega-3 fatty acids would you include in your diet and why?

As you read further, you will learn the different types of fats, their essential roles in the body, and the potential health consequences and benefits of diets rich in particular lipids. You will be better equipped to decide the best way to get your nutritional punch from various fats in your diet.

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5.2: What Are Lipids?

Learning Objectives

- Explain the role of lipids in overall health.

Lipids are important fats that serve different roles in the human body. A common misconception is that fat is simply fattening. However, fat is probably the reason we are all here. Throughout history, there have been many instances when food was scarce. Our ability to store excess caloric energy as fat for future usage allowed us to continue as a species during these times of famine. So, normal fat reserves are a signal that metabolic processes are efficient and a person is healthy.

Lipids are a family of organic compounds that are mostly insoluble in water. Composed of fats and oils, lipids are molecules that yield high energy and have a chemical composition mainly of carbon, hydrogen, and oxygen. Lipids perform three primary biological functions within the body: they serve as structural components of cell membranes, function as energy storehouses, and function as important signaling molecules.

The three main types of lipids are triacylglycerols, 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.

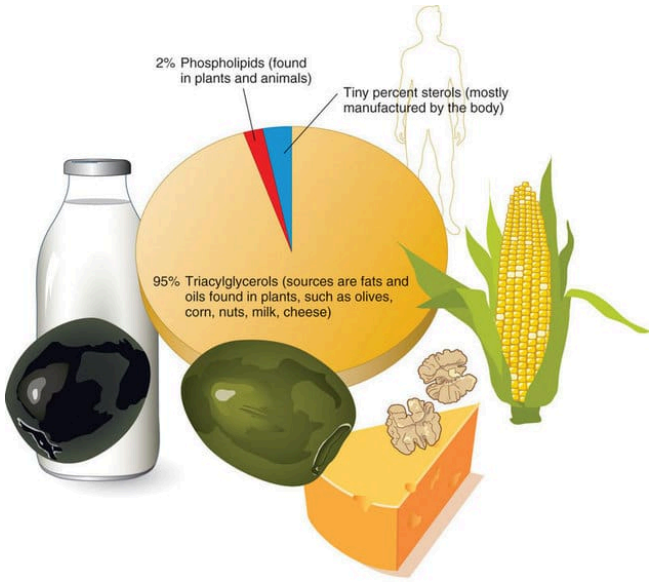


Figure 5.2.1: Types of Lipids

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 previously, 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 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.

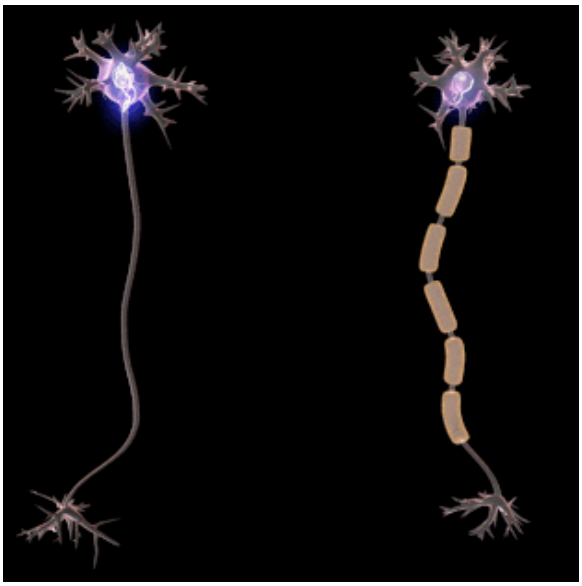


Figure 5.2.2: Lipids serve as signaling molecules; they are catalysts of electrical impulse activity within the brain. Nerve response in myelinated neurons (covered with a myelin coating on right that is 70% lipids in dry mass) propagate faster than in unmyelinated neurons (left). (CC BY 4.0; Dr. Jana).

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.

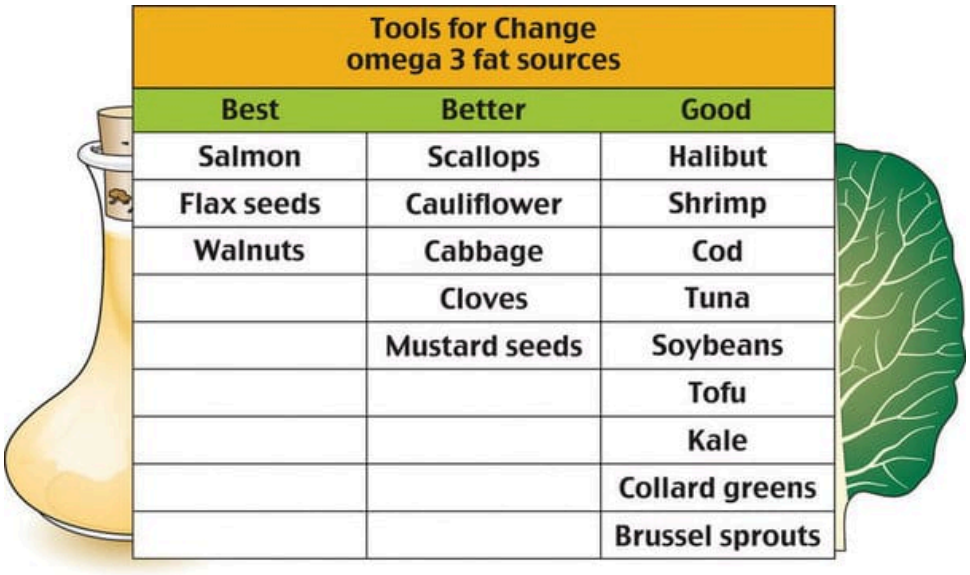


Figure 5.2.3: Food Sources for Fat Soluble Vitamins

Note that removing the lipid elements from food also takes away the food's fat-soluble vitamin content. When products such as grain and dairy are processed, these essential nutrients are lost. Manufacturers replace these nutrients through a process called enrichment.

Tools for Change

Remember, fat-soluble nutrients require fat for effective absorption. For your next snack, look for foods that contain vitamins A, D, E, and K. Do these foods also contain fat that will help you absorb them? If not, think of ways to add a bit of healthy fat to aid in their absorption.

Role of Lipids in Food: High Energy Source

Fat-rich foods naturally have a high caloric density. Foods that are high in fat contain more calories than foods high in protein

or carbohydrates. As a result, high-fat foods are a convenient source of energy. For example, 1 gram of fat or oil provides 9 kilocalories of energy, compared with 4 kilocalories found in 1 gram of carbohydrate or protein. Depending on the level of physical activity and on nutritional needs, fat requirements vary greatly from person to person. When energy needs are high, the body welcomes the high-caloric density of fats. For instance, infants and growing children require proper amounts of fat to support normal growth and development. If an infant or child is given a low-fat diet for an extended period, growth and development will not progress normally. Other individuals with high-energy needs are athletes, people who have physically demanding jobs, and those recuperating from illness.



Figure 5.2.4: Athletes have high-energy requirements. Caitlin Sinclair at IGSSA Swimming Carnival 2010. (Public Domain; MLC School)

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. Fat also adds texture to food. Baked foods are supple and moist. Frying foods locks in flavor and lessens cooking time. How long does it take you to recall the smell of your favorite food cooking? What would a meal be without that savory aroma to delight your senses and heighten your preparedness for eating a meal?

Fat plays another valuable role in nutrition. Fat contributes to satiety, or the sensation of fullness. When fatty foods are swallowed the body responds by enabling the processes controlling digestion to retard the movement of food along the digestive tract, thus promoting an overall sense of fullness. Oftentimes before the feeling of fullness arrives, people overindulge in fat-rich foods, finding the delectable taste irresistible. Indeed, the very things that make fat-rich foods attractive also make them a hindrance to maintaining a healthful diet.

Tools for Change

While fats provide delicious smells, tastes, and textures to our foods, they also provide numerous calories. To allow your body to experience the satiety effect of the fat before you overindulge, try savoring rich foods. Eating slowly will allow you to both fully enjoy the experience and be sated with a smaller portion. Remember to take your time. Drink water in between bites or eat a lower fat food before and after a higher fat food. The lower-fat foods will provide bulk, but fewer calories.

Key Takeaways

- Lipids include triacylglycerols, phospholipids, and sterols.
- Triacylglycerols, the most common lipid, comprise most body fat and are described as fats and oils in food.
- Excess energy from food is stored as adipose tissue in the body.
- Fats are critical for maintaining body temperature, cushioning vital organs, regulating hormones, transmitting nerve impulses, and storing memory.
- Lipids transport fat-soluble nutrients and phytochemicals and promote bioavailability of these compounds.
- Fat is a convenient source of energy for people with high-energy requirements.
- Fat provides double the energy per gram than protein or carbohydrates, enhances the smell and flavor of food, and promotes satiety.

Discussion Starters

- Discuss the role of lipids in our diet and their critical functions in the body.
- Explain the importance of fats to the bioavailability of other nutrients.
- Discuss the role of fats as an energy source for the body.

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5.3: How Lipids Work

Learning Objectives

- Explain how the structure of each lipid impacts its function as it relates to health and disease.
- Compare and contrast the structure of the following types of fats: triacylglycerols (monounsaturated, polyunsaturated, omega-3, and omega-6), phospholipids, and sterols.
- Explain how the fatty acids you consume relate to the fatty-acid composition of your body fat.

Lipids are unique organic compounds, each serving key roles and performing specific functions within the body. As we discuss the various types of lipids (triacylglycerols, phospholipids, and sterols) in further detail, we will compare their structures and functions and examine their impact on human health.

Triacylglycerols Structure and Functions

Triacylglycerols are the main form of lipid found in the body and in the diet. Fatty acids and glycerol are the building blocks of triacylglycerols. Glycerol is a thick, smooth, syrupy compound that is often used in the food industry. To form a triacylglycerol, a glycerol molecule is joined by three fatty acid chains. Triacylglycerols contain varying mixtures of fatty acids.

Fatty Acids

Fatty acids determine if the compound is solid or liquid at room temperature. Fatty acids consist of a carboxylic acid (–OOH) group on one end of a carbon chain and a methyl group ($–CH_3$) on the other end. Fatty acids can differ from one another in two important ways—carbon chain length and degree of saturation.

It's All in the Chain

Fatty acids have different chain lengths and different compositions. Foods have fatty acids with chain lengths between four and twenty-four carbons and most of them contain an even number of carbon atoms. When the carbon chain length is shorter, the melting point of the fatty acid becomes lower—and the fatty acid becomes more liquid.

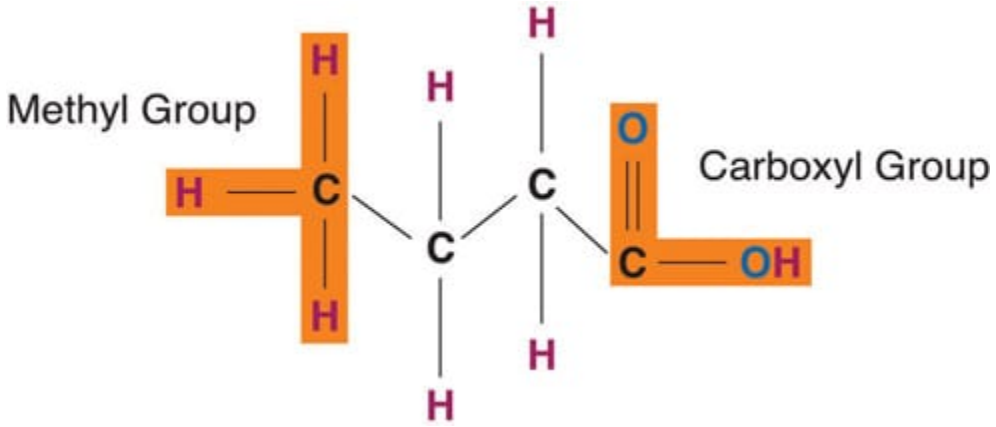


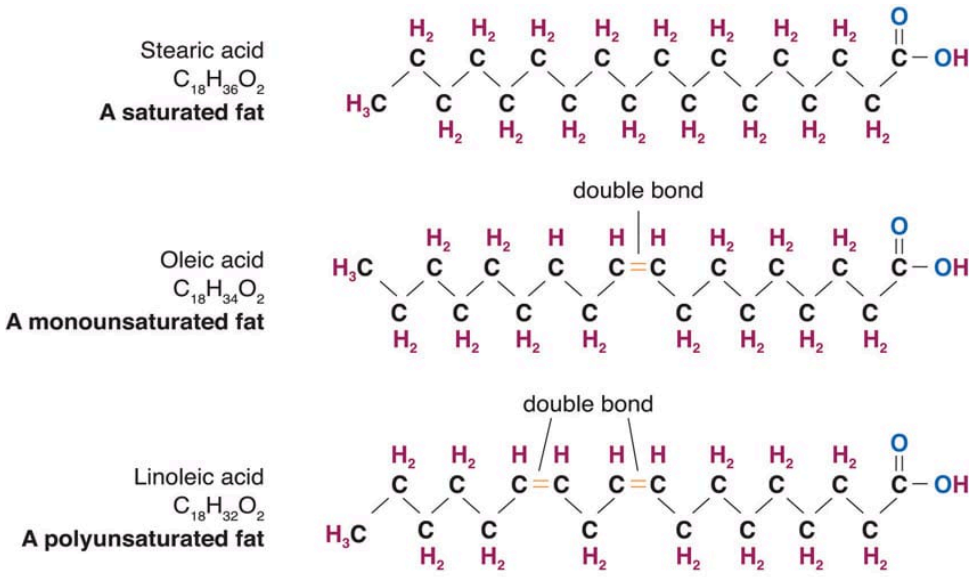
Figure 5.3.1: Structures of a Saturated, Monounsaturated, and Polyunsaturated Fat

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 for 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.



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. 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.

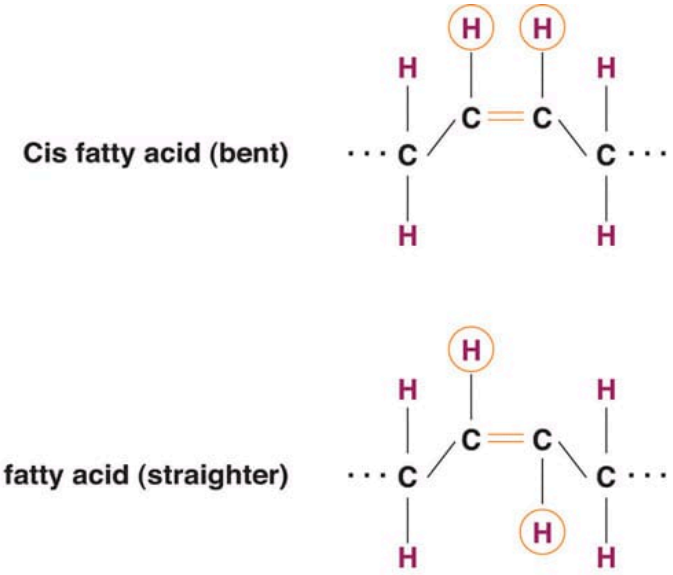
Knowing the connection between chain length, degree of saturation, and the state of the fatty acid (solid or liquid) is important for making food choices. If you decide to limit or redirect your intake of fat products, then choosing unsaturated fat is more beneficial than choosing a saturated fat. This choice is easy enough to make because unsaturated fats tend to be liquid at room temperature (for example, olive oil) whereas saturated fats tend to be solid at room temperature (for example, butter). Avocados are rich in unsaturated fats. Most vegetable and fish oils contain high quantities of polyunsaturated fats. Olive oil and canola oil are also rich in monounsaturated fats. Conversely, tropical oils are an exception to this rule in that they are liquid at room temperature yet high in saturated fat. Palm oil (often used in food processing) is highly saturated and has been proven to raise blood cholesterol. Shortening, margarine, and commercially prepared products (in general) report to use only vegetable-derived fats in their processing. But even so, much of the fat they use may be in the saturated and trans fat categories.

Cis or Trans Fatty Acids?

The introduction of a carbon double bond in a carbon chain, as in an unsaturated fatty acid, can result in different structures for the same fatty acid composition. When the hydrogen atoms are bonded to the same side of the carbon chain, it is called a cis fatty acid. Because the hydrogen atoms are on the same side, the carbon chain has a bent structure. 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). 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/nutritio...ry/#references.



Interestingly, some naturally occurring trans fats do not pose the same health risks as their artificially engineered counterparts. These trans fats are found in ruminant animals such as cows, sheep, and goats, resulting in trans fatty acids being present in our meat, milk, and other dairy product supply. Reports from the US Department of Agriculture (USDA) indicate that these trans fats comprise 15 to 20 percent of the total trans-fat intake in our diet. While we know that trans fats are not exactly harmless, it seems that any negative effect 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 nonessential 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 nonessential fatty acids doesn’t mean unimportant; the classification is based solely on the ability of the body to synthesize the fatty acid.

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.

Essential fatty acids play an important role in the life and death of cardiac cells, immune system function, and blood pressure regulation. Docosahexaenoic acid (DHA) is an omega-3 essential fatty acid shown to play important roles in synaptic transmission in the brain during fetal development.

Some excellent sources of omega-3 and omega-6 essential fatty acids are fish, flaxseed oil, hemp, walnuts, and leafy vegetables. Because these essential fatty acids are easily accessible, essential fatty acid deficiency is extremely rare.

Tools for Change

It is important to strike a proper balance between omega-3 and omega-6 fats in your diet. Research suggests that a diet that is too high in omega-6 fats distorts the balance of proinflammatory agents, promoting chronic inflammation and causing the potential for health problems such as asthma, arthritis, allergies, or diabetes. Omega-6 fats compete with omega-3 fats for enzymes and will actually replace omega-3 fats. The typical western diet is characterized by an excessive consumption of foods high in omega-6 fatty acids. To gain proper balance between the two, increase your omega-3 fat intake by eating more fatty fish or other sources of omega-3 fatty acids at least two times per week.



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).

In the body phospholipids bind together to form cell membranes. The amphiphilic nature of phospholipids governs their function as components of cell membranes. The phospholipids form a double layer in cell membranes, thus effectively protecting the inside of the cell from the outside environment while at the same time allowing for transport of fat and water through the membrane.

Phospholipids are 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 somewhat separate within 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 lecithin, such as its ability to lower blood cholesterol and aid with weight loss. There are several lecithin supplements on the market broadcasting these claims. However, as the body can make most phospholipids, it is not necessary to consume them in a pill. The body makes all of the lecithin that it needs.

Sterols

Sterols have a very different structure from triacylglycerols and phospholipids. Most sterols do not contain any fatty acids but rather multiring structures. They are complex molecules that contain interlinking rings of carbon atoms, with side chains of carbon, hydrogen, and oxygen attached. 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 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, and the sex hormones, progesterone, testosterone, and estrogens. 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.

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 excess accumulation of it in the blood. Like lecithin, the body can synthesize cholesterol.

Key Takeaways

- Three fatty acids combine with one glycerol to make a triacylglycerol, the body's storage form of fat.
- The carbon chain in fatty acids can be saturated (filled with hydrogen), monounsaturated (with one point of unsaturation and possessing one carbon-carbon double bond), or polyunsaturated (with more than one point of unsaturation and possessing two or more double-carbon bonds)
- The structure and length of a fatty acid determines whether it is solid or liquid at room temperature.
- Essential fatty acids cannot be synthesized by the body and must be included in the diet. Omega-3 and omega-6 fatty acids have opposing functions and must be consumed in proper balance to promote health.
- Fatty acids in food influence the composition of fatty acids in the body.
- Phospholipids are diglycerides with a phosphate-nitrogen group in place of the third fatty-acid chain. They are ideal emulsifiers as they keep oil and water mixed.
- Sterols contain a multiring structure. Cholesterol serves important body functions such as vitamin D and hormone synthesis and is important in cell membrane and brain structure.

Discussion Starters

1. List the oils, snacks, spreads, or sauces in your home. Do they contain saturated or unsaturated fatty acids?
2. Name the characteristic that differentiates a triacylglycerol from a phospholipid. Describe the properties of phospholipids. Discuss their role in forming cell membranes. Explain their role as an emulsifier.
3. Think about your favorite restaurant and the food you like to order there. What type of fatty acids does a typical meal that you eat there have? Discuss the health benefits and possible drawbacks. What foods would you add to enhance your meal? What foods should you consider avoiding?

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5.4: Digestion and Absorption of Lipids

Learning Objectives

- Summarize the steps in lipid digestion and absorption.
- Explain how lipids are used for energy and stored in the body.

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-based, how does the body break down fat and make it available for the various functions it must perform in the human body?

From the Mouth to the Stomach

The first step in the digestion of triacylglycerols and phospholipids begins in the mouth as lipids encounter saliva. Next, the physical action of chewing coupled with the action of emulsifiers enables the digestive enzymes to do their tasks. The enzyme lingual lipase, along with a small amount of phospholipid as an emulsifier, initiates the process of digestion. 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.

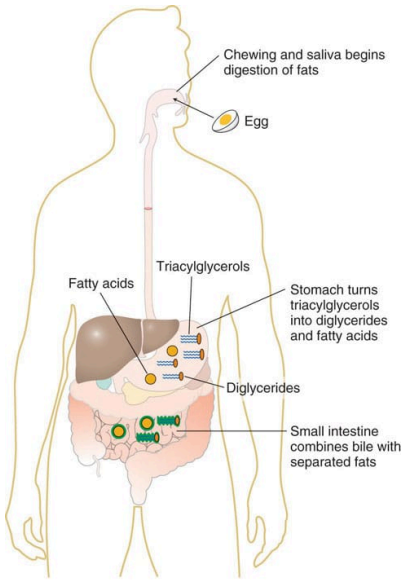


Figure 5.4.1: Lipid Digestion

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 sever 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 mucous 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.

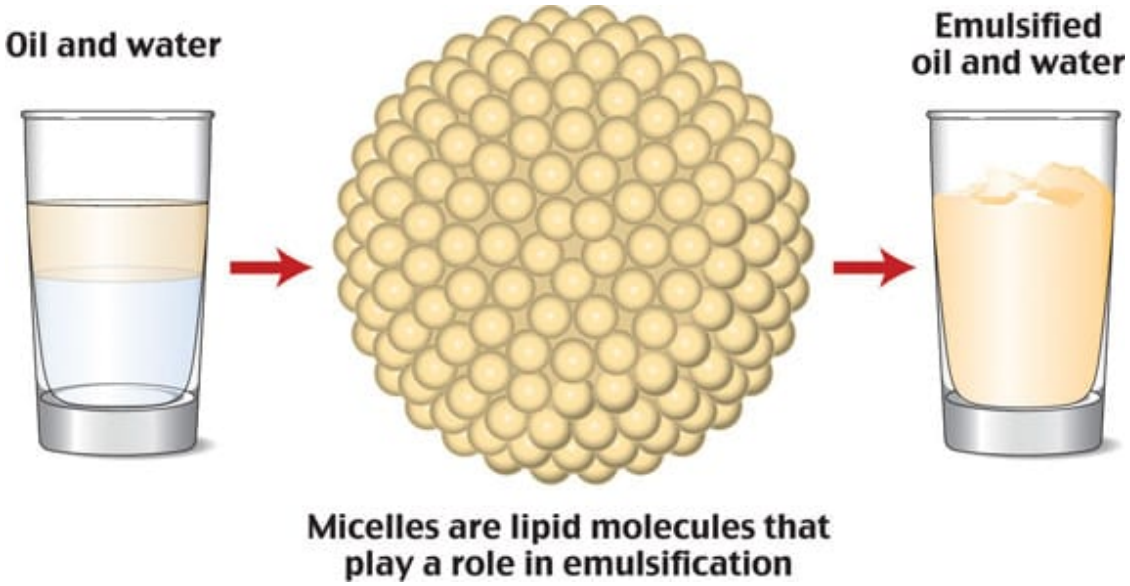


Figure 5.4.2: Fats can travel through the watery environment of the body due to the process of emulsion.

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 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.

Cholesterols are poorly absorbed when compared to phospholipids and triacylglycerols. Cholesterol absorption is aided by an increase in dietary fat components and is hindered by high fiber content. This is the reason that a high intake of fiber is recommended to decrease blood cholesterol. Foods high in fiber such as fresh fruits, vegetables, and oats can bind bile salts and cholesterol, preventing their absorption and carrying them out of the colon.

If fats are not absorbed properly as is seen in some medical conditions, a person's stool will contain high amounts of fat. If fat malabsorption persists the condition is known as steatorrhea. Steatorrhea can result from diseases that affect absorption, such as Crohn's disease and cystic fibrosis.

The Truth about Storing and Using Body Fat

Before the prepackaged food industry, fitness centers, and weight-loss programs, our ancestors worked hard to even locate a meal. They made plans, not for losing those last ten pounds to fit into a bathing suit for vacation, but rather for finding food. Today, this is why we can go long periods without eating, whether we are sick with a vanished appetite, our physical activity level has increased, or there is simply no food available. Our bodies reserve fuel for a rainy day.

One way the body stores fat involves the body transforms carbohydrates into glycogen that is in turn stored in the muscles for energy. When the muscles reach their capacity for glycogen storage, the excess is returned to the liver, where it is converted into triacylglycerols and then stored as fat.

In a similar manner, much of the triacylglycerols the body receives from food is transported to fat storehouses within the body

if not used for producing energy. The chylomicrons are responsible for shuttling the triacylglycerols to various locations such as the muscles, breasts, external layers under the skin, and internal fat layers of the abdomen, thighs, and buttocks where they are stored by the body in adipose tissue for future use. How is this accomplished? Recall that chylomicrons are large lipoproteins that contain a triacylglycerol and fatty-acid core. Capillary walls contain an enzyme called lipoprotein-lipase that dismantles the triacylglycerols in the lipoproteins into fatty acids and glycerol, thus enabling these to enter into the adipose cells. Once inside the adipose cells, the fatty acids and glycerol are reassembled into triacylglycerols and stored for later use. Muscle cells may also take up the fatty acids and use them for muscular work and generating energy. When a person's energy requirements exceed the amount of available fuel presented from a recent meal or extended physical activity has exhausted glycogen energy reserves, fat reserves are retrieved for energy utilization.

As the body calls for additional energy, the adipose tissue responds by dismantling its triacylglycerols and dispensing glycerol and fatty acids directly into the blood. Upon receipt of these substances the energy-hungry cells break them down further into tiny fragments. These fragments go through a series of chemical reactions that yield energy, carbon dioxide, and water.

Key Takeaways

- In the stomach fat is separated from other food substances. In the small intestines bile emulsifies fats while enzymes digest them. The intestinal cells absorb the fats.
- Long-chain fatty acids form a large lipoprotein structure called a chylomicron that transports fats through the lymph system.
- Chylomicrons are formed in the intestinal cells and carry lipids from the digestive tract into circulation.
- Short- and medium-fatty chains can be absorbed directly into the bloodstream from the intestinal microvillus because they are water-soluble.
- Cholesterol absorption is hindered by foods high in fiber.
- When energy supplies are low the body utilizes its stored fat reserves for energy.

Discussion Starters

- Explain the role of emulsifiers in fat digestion.
- Name the part of the digestive system where most fat digestion and absorption occurs.
- Describe the role of bile salts in the digestion of triacylglycerols and phospholipids.
- Define chylomicron.
- Explain how fiber-rich foods affect cholesterol absorption.
- Discuss the body's processes for using energy.

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5.5: Understanding Blood Cholesterol and Heart Attack Risk

Learning Objectives

- Compare and contrast the roles of LDLs and HDLs in your body.
- Explain the purpose of a blood lipid profile and identify healthy ranges.

You may have heard of the abbreviations LDL and HDL with respect to heart health. These abbreviations refer to low-density lipoprotein (LDL) and high-density lipoprotein (HDL), respectively. Lipoproteins are characterized by size, density, and composition. As the size of the lipoprotein increases, the density decreases. This means that HDL is smaller than LDL. Why are they referred to as “good” and “bad” cholesterol? What should you know about these lipoproteins?

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 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 travelling 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 from the liver to tissue throughout the body. LDLs are comprised of very small amounts of triacylglycerols, and house over 50 percent cholesterol and cholesterol esters. 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.”

Contrasting LDL and HDL

Heart attack and atherosclerosis are conditions often caused by cholesterol that has accumulated and thickened in the walls of arteries. HDLs and LDLs are directly connected to these life-threatening ailments. By comparing and contrasting the roles each of these lipoproteins serves in the health of heart and blood vessels, you will be able to construct and evaluate a plan of action for your personal health. Consider the following lipoprotein facts:

- **LDL/HDL composition**. LDL is approximately 25 percent protein and 75 percent cholesterol and other fats. LDL is bigger (yet lighter) and richer in cholesterol than HDL. HDL is 50 percent protein and 50 percent cholesterol and other fats. HDL is smaller, more dense, and richer in protein.
- **LDL/HDL function**. LDLs carry cholesterol into cells for normal usage, but LDLs can also deposit cholesterol into the walls of blood vessels, which can lead to harmful disease. HDLs scavenge excess cholesterol from the cells, tissues, and blood

vessels and deliver these back to the liver, where these are either reused or excreted.

- **LDL/HDL and inflammation**. LDLs carry lipids that are proinflammatory and may contribute to heart disease. HDLs transport lipids that are anti-inflammatory and may reduce the occurrence of heart disease.
- **LDL/HDL warnings**. High LDL values warn of increased health risks for heart disease, while high HDL values indicate a reduced risk for heart disease.
- **Oxidized LDL**. LDLs become more dangerous when oxidized. Oxidation is defined as the loss of electrons between two substances via a chemical reaction. If an LDL oxidation occurs, the oxidized LDL is left unstable. Oxidized LDL can speed up the process of plaque formation in the arteries. It is believed to hasten the deposition of cholesterol into the arterial walls and to induce a chronic inflammatory effect throughout the body's vast network of vessels. This activity promotes atherosclerosis and significantly increases risks for heart attack or stroke.

Blood Cholesterol Recommendations

For healthy total blood cholesterol, the desired range you would want to maintain is under 200 mg/dL. More specifically, when looking at individual lipid profiles, a low amount of LDL and a high amount of HDL prevents excess buildup of cholesterol in the arteries and wards off potential health hazards. An LDL level of less than 100 milligrams per deciliter is ideal while an LDL level above 160 milligrams per deciliter would be considered high. In contrast, a low value of HDL is a telltale sign that a person is living with major risks for disease. Values of less than 40 milligrams per deciliter for men and 50 milligrams per deciliter for women mark a risk factor for developing heart disease. In short, elevated LDL blood lipid profiles indicate an increased risk of heart attack, while elevated HDL blood lipid profiles indicate a reduced risk.

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.") 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.

Tools for Change

Being conscious of the need to reduce cholesterol means limiting the consumption of saturated fats and trans fats. Remember that saturated fats found in some meat, whole-fat dairy products, and tropical oils elevate your total cholesterol. Trans fats, such as the ones often found in margarines, processed cookies, pastries, crackers, fried foods, and snack foods also elevate your cholesterol levels. Read and select from the following suggestions as you plan ahead:

- Soluble fiber reduces cholesterol absorption in the bloodstream. Try eating more oatmeal, oat bran, kidney beans, apples, pears, citrus fruits, barley, and prunes.
- Fatty fish are heart-healthy due to high levels of omega-3 fatty acids that reduce inflammation and lower cholesterol levels. Consume mackerel, lake trout, herring, sardines, tuna, salmon, and halibut. Grilling or baking is best to avoid unhealthy trans fats that could be added from frying oil.
- Walnuts, almonds, peanuts, hazelnuts, pecans, some pine nuts, and pistachios all contain high levels of unsaturated fatty acids that aid in lowering LDL. Make sure the nuts are raw and unsalted. Avoid sugary or salty nuts. One ounce each day is a good amount.
- Olive oil contains a strong mix of antioxidants and monounsaturated fat, and may lower LDL while leaving HDL intact. Two tablespoons per day in place of less healthy saturated fats may contribute to these heart-healthy effects without adding extra calories. Extra virgin olive oil promises a greater effect, as the oil is minimally processed and contains more heart-healthy antioxidants.

Testing Your Lipid Profile

The danger of consuming foods rich in cholesterol and saturated and trans fats cannot be overemphasized. Regular testing can provide the foreknowledge necessary to take action to help prevent any life-threatening events.

Current guidelines recommend testing for anyone over age twenty. If there is 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/publ...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

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Video 5.5.1: What happens during a heart attack? Krishna Sudhir (https://youtu.be/3_PYnWVoUzM). Approximately seven million people around the world die from heart attacks every year. And cardiovascular disease, which causes heart attacks and other problems like strokes, is the world's leading killer. So what causes a heart attack? Krishna Sudhir examines the leading causes and treatments of this deadly disease.

Key Takeaways

- Some of the major lipoproteins are VLDL, IDL, LDL, and HDL.
- VLDL delivers triacylglycerols and other lipids to the body's tissues and slowly becomes IDL. The liver uses IDL to create LDL, the main transporter of cholesterol.
- LDL, or "bad" cholesterol, has low protein composition and high cholesterol content. High levels of LDL have been shown to increase the risks for heart disease.
- HDL or "good'' cholesterol has a larger proportion of protein and a small cholesterol composition. HDL scavenges excess cholesterol and returns it to the liver for reuse or disposal. A high level of HDL reduces the risk for heart disease.
- It is important to maintain a healthy lipid profile with values as recommended by the NIH in order to minimize the risk of heart disease. Consuming omega-3 fatty acids can help maintain a healthy blood lipid profile.

Discussion Starters

1. Summarize the roles of LDL and HDL. Explain why LDL is termed "bad" cholesterol and why HDL is termed "good" cholesterol.
2. Explain oxidation and how it affects LDL and contributes to heart disease.
3. Describe the procedure and blood test for testing your lipid profile.
4. Recall the desired lipid values set out by the NIH. Identify the desired total cholesterol, LDL, HDL, VLDL, and triacylglycerol values.
5. How has learning this information affected your motivation to eat a more healthy diet?

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5.6: Balancing Your Diet with Lipids

Learning Objectives

- Describe the current recommended intake levels for lipids.
- Recognize sources of saturated and unsaturated fats, essential fatty acids, and trans fats.
- Discuss the functions of essential fatty acids, such as omega-3, and where to find them in foods.

You may reason that if some fats are healthier than other fats, why not consume as much healthy fat as desired? Remember, everything in moderation. As we review the established guidelines for daily fat intake, the importance of balancing fat consumption with proper fat sources will be explained.

Recommended Fat Intake

The acceptable macronutrient distribution range (AMDR) from the Dietary Reference Intake Committee for adult fat consumption is as follows: USDA Dietary Reference Intakes for Macronutrients.

- 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 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. “Fish and Omega-3 Fatty Acids”. These more appropriate dietary choices will allow for enjoyment of a wide variety of foods while providing the body with the recommended levels of fat from healthier sources. Evaluate the following sources of fat in your overall dietary pattern:

- **Monounsaturated fat.** This type of fat is found in plant oils. Common sources are nuts (almonds, cashews, pecans, peanuts, and walnuts) and nut products, avocados, extra virgin olive oil, sesame oil, high oleic safflower oil, sunflower oil, and canola oil.
- **Polyunsaturated fat.** This type of fat is found mainly in plant-based foods, oils, and fish. Common sources are nuts (walnuts, hazel nuts, pecans, almonds, and peanuts), soybean oil, corn oil, safflower oil, flaxseed oil, canola oil, and fish (trout, herring, and salmon).
- **Saturated fat.** This fat is found in animal products, dairy products, 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 (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 5.6.1: 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, linolenic acid and linoleic acid.

- **Omega-3 Fatty Acids.** At the helm of the omega-3 fatty acid family is linolenic acid. From this fatty acid, the body can make eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Linolenic acid is found in nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed. EPA and DHA are found abundantly in fatty fish.
- **Omega-6 Fatty Acids.** At the helm of the omega-6 fatty acid family is linoleic acid. Like linolenic acid, the body uses linoleic acid to make other important substances such as arachidonic acid (ARA) that is used to make eicosanoids. Recall that eicosanoids perform critical roles in the body as they affect a broad spectrum of functions. The word *eicosanoid* originates from the Greek word *eicosa*, meaning twenty, because this hormone is derived from ARA that is twenty carbon atoms in length. Eicosanoids affect the synthesis of all other body hormones and control all body systems, such as the central nervous system and the immune system. Among the many functions eicosanoids serve in the body, their primary function is to regulate inflammation. Without these hormones the body would not be able to heal wounds, fight infections, or fight off illness each time a foreign germ presented itself. Eicosanoids work together with the body's immune and inflammation processes to play a major role in several important body functions, such as circulation, respiration, and muscle movement.

Attain the Omega-3 and Omega-6 Balance

As our food choices evolve, the sources of omega-6 fatty acids in our diets are increasing at a much faster rate than sources of omega-3 fatty acids. Omega-3s are plentiful in diets of nonprocessed foods where grazing animals and foraging chickens roam free, eating grass, clover, alfalfa, and grass-dwelling insects. In contrast, today's western diets are bombarded with sources of omega-6. For example, we have oils derived from seeds and nuts and from the meat of animals that are fed grain. Vegetable oils used in fast-food preparations, most snack-foods, cookies, crackers, and sweet treats are also loaded with omega-6 fatty acids. Also, our bodies synthesize eicosanoids from omega-6 fatty acids and these tend to increase inflammation, blood clotting, and cell proliferation, while the hormones synthesized from omega-3 fatty acids have just the opposite effect.

While omega-6 fatty acids are essential, they can be harmful when they are out of balance with omega-3 fatty acids. Omega-6 fats are required only in small quantities. Researchers believe that when omega-6 fats are out of balance with omega-3 fats in the diet they diminish the effects of omega-3 fats and their benefits. This imbalance may elevate the risks for allergies, arthritis, asthma, coronary heart disease, diabetes, and many types of cancer, autoimmunity, and neurodegenerative diseases, all of which are believed to originate from some form of inflammation in the body. The recommendations for the ratio of omega-3 to omega-6 fatty acids vary from 5:1 to 10:1.

What does this mean for you? If your diet is low in omega-3 fats to begin with, then most of your essential fatty acids are from omega-6s. Stop. Do not set up a proinflammatory environment. Attaining proper balance between omega-3 fatty acids and omega-6 fatty acids means learning to make healthy choices and replacing bad fats with good ones that promote health and well-being.

Key Takeaways

- The recommended fat intake for adults is 20–35 percent of your total caloric intake. Saturated fat must be less than 10 percent of your total caloric intake, and lowering this to 7 percent can further reduce the risks for heart disease. Trans fat should be less than 1 percent of total caloric intake.
- Nuts, seeds, whole grains, legumes, and vegetable oil such as soybean, canola, and flaxseed are excellent sources of monounsaturated and polyunsaturated fats.
- The polyunsaturated fatty acids linolenic and linoleic acids are used by the body to make substances that carry out many vital functions in the body.
- The omega-3 fatty-acid family includes linolenic acid, EPA, and DHA. The omega-6 fatty-acid family includes linoleic acid and ARA. DHA and ARA play crucial roles in brain and eye development. EPA and DHA found in fatty fish play important roles in inflammation reduction and disease prevention.
- Many people consume too many omega-6 fatty acids and not enough omega-3 fatty acids. Omega-3 fats and omega-6 fats are precursors to hormones that have opposing properties. A proper balance between both must be obtained to avoid health problems.

Discussion Starters

1. State the recommended intake of total fat, as well as saturated versus unsaturated fat, in the diet.
2. List sources of monounsaturated and polyunsaturated fats.
3. Summarize the important functions of essential fatty acids in the human body.
4. Explain why it is necessary to maintain a proper balance between omega-3 fat and omega-6 fat intake.
5. Record a food diary for one week. What foods do you most often consume? What type of fat dominates your diet? How can you alter your eating habits to promote better health? Outline steps you can take to replace saturated and trans fat in your diet.

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5.7: Lipids and the Food Industry

Learning Objectives

- Discuss reasons oils are hydrogenated and describe this process.
- Describe the health effects of trans fats.

What is the first thing that comes to mind when you read ingredients such as “partially hydrogenated oil” and “hydrogenated oil” on a food label? Do you think of heart disease, heart health, or atherosclerosis? Most people probably do not. As we uncover what hydrogenation is and why manufacturers use it, you will be better equipped to adhere to healthier dietary choices and promote your heart health.

Hydrogenation: The Good Gone Bad?

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 (Figure 5.7.1). Hydrogenation is the process of adding hydrogen to unsaturated fatty-acid chains, so that the hydrogen atoms are connected to the points of saturation and results in a more saturated fatty acid. Liquid oils that once contained more unsaturated fatty acids become semisolid or solid (upon complete hydrogenation) and behave like saturated fats. Oils initially contain polyunsaturated fatty acids. When the process of hydrogenation is not complete, for example, not all carbon double bonds have been saturated the end result is a partially hydrogenated oil. The resulting oil is not fully solid. Total hydrogenation makes the oil very hard and virtually unusable. Some newer products are now using fully hydrogenated oil combined with nonhydrogenated vegetable oils to create a usable fat.

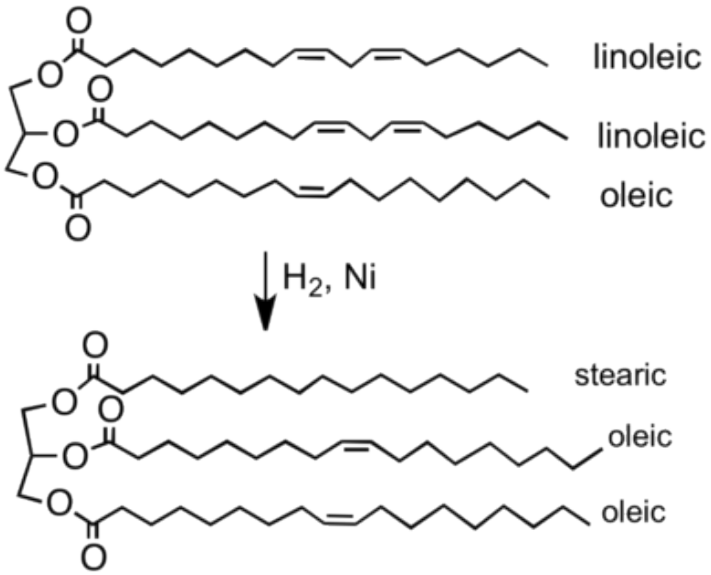


Figure 5.7.1: Partial hydrogenation of a typical plant oil to a typical component of margarine. Most of the C=C double bonds are removed in this process, which elevates the melting point of the product. (CC BY-SA 2.0; Smokefoot).

Manufacturers favor hydrogenation as a way to prevent oxidation of oils and ensure longer shelf life. Partially hydrogenated vegetable oils are used in the fast food and processed food industries because they impart the desired texture and crispness to baked and fried foods. Partially hydrogenated vegetable oils are more resistant to breakdown from extremely hot cooking temperatures. Because hydrogenated oils have a high *smoking point* they are very well suited for frying. In addition, processed

vegetable oils are cheaper than fats obtained from animal sources, making them a popular choice for the food industry.

Trans fatty acids occur in small amounts in nature, mostly in dairy products. However, the trans fats that are used by the food industry are produced from the hydrogenation process. Trans fats are a result of the partial hydrogenation of unsaturated fatty acids, which cause them to have a trans configuration, rather than the naturally occurring cis configuration.

Health Implications of Trans Fats

No trans fats! Zero trans fats! We see these advertisements on a regular basis. So widespread is the concern over the issue that restaurants, food manufacturers, and even fast-food establishments proudly tout either the absence or the reduction of these fats within their products. Amid the growing awareness that trans fats may not be good for you, let's get right to the heart of the matter. Why are trans fats so bad?

Processing naturally occurring fats to modify their texture from liquid to semisolid and solid forms results in the development of trans fats, which have been linked to an increased risk for heart disease. Trans fats are used in many processed foods such as cookies, cakes, chips, doughnuts, and snack foods to give them their crispy texture and increased shelf life. However, because trans fats can behave like saturated fats, the body processes them as if they were saturated fats. Consuming large amounts of trans fats has been associated with tissue inflammation throughout the body, insulin resistance in some people, weight gain, and digestive troubles. In addition, the hydrogenation process robs the person of the benefits of consuming the original oil because hydrogenation destroys omega-3 and omega-6 fatty acids. The AHA states that, like saturated fats, trans fats raise LDL "bad cholesterol," but unlike saturated fats, trans fats lower HDL "good cholesterol." The AHA advises limiting trans-fat consumption to less than 1 percent.

How can you benefit from this information? When selecting your foods, steer clear of anything that says "hydrogenated," "fractionally hydrogenated," or "partially hydrogenated," and read food labels in the following categories carefully:

- cookies, crackers, cakes, muffins, pie crusts, pizza dough, and breads
- stick margarines and vegetable shortening
- premixed cake mixes, pancake mixes, and drink mixes
- fried foods and hard taco shells
- snack foods (such as chips), candy, and frozen dinners

Choose brands that don't use trans fats and that are low in saturated fats.

Dietary-Fat Substitutes

In response to the rising awareness and concern over the consumption of trans fat, various fat replacers have been developed. Fat substitutes aim to mimic the richness, taste, and smooth feel of fat without the same caloric content as fat. The carbohydrate-based replacers tend to bind water and thus dilute calories. 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.

Tools for Change

One classic cinnamon roll can have 5 grams of trans fat, which is quite high for a single snack. Foods such as pastries, frozen bakery goods, cookies, chips, popcorn, and crackers contain trans fat and often have their nutrient contents listed for a very small serving size—much smaller than what people normally consume—which can easily lead you to eat many "servings." Labeling laws allow foods containing trans fat to be labeled "trans-fat free" if there are fewer than 0.5 grams per serving. This makes it possible to eat too much trans fat when you think you're not eating any at all because it is labeled trans-fat free.

Always review the label for trans fat per serving. Check the ingredient list, especially the first three to four ingredients, for telltale signs of hydrogenated fat such as partially or fractionated hydrogenated oil. The higher up the words "partially hydrogenated oil" are on the list of ingredients, the more trans fat the product contains.

> Measure out one serving and eat one serving only. An even better choice would be to eat a fruit or vegetable. There are no trans fats and the serving size is more reasonable for similar calories. Fruits and vegetables are packed with water, fiber, and many vitamins, minerals, phytonutrients, and antioxidants. At restaurants be aware that phrases such as “cooked in vegetable oil” might mean hydrogenated vegetable oil, and therefore trans fat.

Key Takeaways

- Hydrogenation is the process of adding hydrogen to the points of unsaturation in unsaturated fatty acid chains. The resulting oil is very hard and unusable. Partial hydrogenation is the process of adding hydrogen to some of the points of unsaturation in unsaturated fatty acid chains. This produces oils that are more spreadable and usable in food products.
- Food manufacturers favor the use of hydrogenated oils because they do not succumb to oxidative damage, they increase the shelf life of food products, and they have a high smoking point.
- Fat replacers mimic fat but do not have the same chemical configuration as fat. Therefore the body does not process these the same way it would a naturally occurring fat. Fat substitutes such as Olestra have produced symptoms of fat malabsorption in some people.

Discussion Starters

1. Describe how trans fatty acids are created. Explain the drawbacks of consuming this type of fat and its impact on human health.
2. Make a list of the foods in your kitchen. Read each food label. List all of the food items that contain trans fat. Recall the recommendation that trans fat be less that 1 percent of your fat intake. About what percentage of your diet is currently trans fat? Do you see a need to adjust your trans fat intake?

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5.8: Lipids and Disease

Learning Objectives

- Describe how saturated fat and cholesterol intake can impact health.

Because heart disease, cancer, and stroke are the three leading causes of death in the United States, it is critical to address dietary and lifestyle choices that will ultimately decrease risk factors for these diseases. According to the US Department of Health and Human Services (HHS), the following risk factors are controllable: high blood pressure, high cholesterol, cigarette smoking, diabetes, poor diet, physical inactivity, being overweight, and obesity. In light of that, we present the following informational tips to help you define, evaluate, and implement healthy dietary choices to last a lifetime. The amount and the type of fat that composes a person's dietary profile will have a profound effect upon the way fat and cholesterol is metabolized in the body.

Watch Out for Saturated Fat and Cholesterol

In proper amounts, cholesterol is a compound used by the body to sustain many important body functions. In excess, cholesterol is harmful if it accumulates in the structures of the body's vast network of blood vessels. High blood LDL and low blood HDL are major indicators of blood cholesterol risk. The largest influence on blood cholesterol levels rests in the mix of saturated fat and trans fat in the diet. According to the Harvard School of Public Health, for every extra 2 percent of calories from trans fat consumed per day—about the amount found in a midsize order of French fries at a fast-food establishment—the risk of coronary heart disease increases by 23 percent.Harvard School of Public Health. "Fats and Cholesterol: Out with the Bad, In with the Good." Section 2.02. http://www.hsph.harvard.edu/nutritio...hat-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 suggested 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.

This being said, there are a growing number of physicians and nutrition experts who disagree that Saturated Fat and Cholesterol are "bad" at all. Because this is not the opinion of the American Heart Association, it will not be discussed further here but if you wish to read about the controversy, please click here: https://blog.virtahealth.com/the-sad...saturated-fat/
and read an article by Jeff Volek, PhD, RD Stephen Phinney, MD, PhD Stephen Phinney, MD, PhD of Virta Health.

Food Cholesterol's Effect on Blood Cholesterol

Dietary cholesterol does have a small impact on overall blood cholesterol levels, but not as much as some people may think. The average American female consumes 237 milligrams of dietary cholesterol per day and for males the figure is slightly higher—about 358 milligrams. The USDA dietary guidelines suggest a daily limit intake of cholesterol not to exceed 300 milligrams for healthy people and 200 milligrams for those who may be suffering from high cholesterol. Most people display little response to normal dietary cholesterol intake as the body responds by halting its own synthesis of the substance in favor of using the cholesterol obtained through food. Genetic factors may also influence the way a person's body modifies cholesterol.

A Prelude to Disease

If left unchecked, improper dietary fat consumption can lead down a path to severe health problems. An increased level of lipids, triacylglycerols, and cholesterol in the blood is called hyperlipidemia. Hyperlipidemia is inclusive of several conditions but more commonly refers to high cholesterol and triacylglycerol levels. When blood lipid levels are high, any number of adverse health problems may ensue. Consider the following:

- **Cardiovascular disease**. According to the AHA, cardiovascular disease encompasses a variety of problems, many of which

are related to the process of atherosclerosis. Over time the arteries thicken and harden with plaque buildup, causing restricted or at times low or no blood flow to selected areas of the body.

- **Heart attack**. A heart attack happens when blood flow to a section of the heart is cut off due to a blood clot. Many have survived heart attacks and go on to return to their lives and enjoy many more years of life on this earth. However, dietary and lifestyle changes must be implemented to prevent further attacks.
- **Ischemic stroke**. The most common type of stroke in the United States, ischemic stroke, occurs when a blood vessel in the brain or leading to the brain becomes blocked, again usually from a blood clot. If part of the brain suffers lack of blood flow and/or oxygen for three minutes or longer, brain cells will start to die.
- **Congestive heart failure**. Sometimes referred to as heart failure, this condition indicates that the heart is not pumping blood as well as it should. The heart is still working but it is not meeting the body's demand for blood and oxygen. If left unchecked, it can progress to further levels of malfunction.
- **Arrhythmia**. This is an abnormal rhythm of the heart. The heart may beat above one hundred beats per minute (known as tachycardia) or below sixty beats per minute (known as bradychardia), or the beats are not regular. The heart may not be able to pump enough volume of blood to meet the body's needs.
- **Heart valve problems**. Stenosis is a condition wherein the heart valves become compromised in their ability to open wide enough to allow proper blood flow. When the heart valves do not close tightly and blood begins to leak between chambers, this is called regurgitation. When valves bulge or prolapse back into the upper chamber, this condition is called mitral valve prolapse.
- **Obesity**. Obesity is defined as the excessive accumulation of body fat. According to US Surgeon General Richard Carmona, obesity is the fastest growing cause of death in America. The HHS reports that the number of adolescents who are overweight has tripled since 1980 and the prevalence of the disease among younger children has doubled.US Department of Health and Human Services. "Childhood Obesity." Accessed October 5, 2012. http://aspe.hhs.gov/health/reports/child_obesity/. Obesity has been linked to increased risks of developing diabetes and heart disease. To help combat this problem important dietary changes are necessary. Reducing the type and amount of carbohydrates and sugar consumed daily is critical. Limiting the intake of saturated fats and trans fats, increasing physical activity, and eating fewer calories are all equally important in this fight against obesity.



Figure 5.8.1: 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 analysed; however, a similar sample showed a serum triglyceride of over 130mmol/L (over 50000mg/dl), and an LDL over 40mmol/L (over 1540mg/dl). (public domain) from Carmen Crisp-Obenhaus.

What You Can Do

Remember that saturated fats are found in large amounts in foods of animal origin. They should be limited within the diet. Polyunsaturated fats are generally obtained from nonanimal sources. While they are beneficial for lowering bad cholesterol they also lower good cholesterol. They are better for you than saturated fats but are not to be consumed in excess. Monounsaturated fats are of plant origin and are found in most nuts, seeds, seed oils, olive oil, canola oil, and legumes. Monounsaturated fats are excellent because they not only lower bad cholesterol, but also they elevate the good cholesterol. Replace current dietary fats with

an increased intake of monounsaturated fats.

Choose whole-grain and high-fiber foods. Reduced risk for cardiovascular disease has been associated with diets that are high in whole grains and fiber. Fiber also slows down cholesterol absorption. The AHA recommends that at least half of daily grain intake should originate from whole grains. The Adequate Intake value for fiber is 14 grams per 1,000 kilocalories. These amounts are based upon the amount of fiber that has been shown to reduce cardiovascular risk.

Do not be sedentary. Get more exercise on a regular basis. Increasing your energy expenditure by just twenty minutes of physical activity at least three times per week will improve your overall health. Physical exercise can help you manage or prevent high blood pressure and blood cholesterol levels. Regular activity raises HDL while at the same time decreases triacylglycerols and plaque buildup in the arteries. Calories are burned consistently, making it easier to lose and manage weight. Circulation will improve, the body will be better oxygenated, and the heart and blood vessels will function more efficiently.

Key Takeaways

- Food cholesterol does not affect blood cholesterol as much as some people think. The main causes of unfavorable blood cholesterol values come from an overconsumption of saturated fats and trans fats.
- An increased intake of lipids is associated with heart disease, obesity, cardiovascular disease, and other problems.
- Making dietary choices that limit the intake of saturated and trans fats to the recommended levels, replacing saturated and trans fats with monounsaturated and polyunsaturated fats, increasing physical activity, and cessation of smoking can reduce the risk of developing heart disease and other ailments.

Discussion Starters

1. Explain why saturated fats and trans fats contribute to unfavorable blood cholesterol levels.
2. Discuss some of the diseases that can result from an unhealthy lipid profile for an extended period of time.
3. List the types of fat that will help you achieve a healthy blood lipid profile. List the sources of these fats.
4. Evaluate your personal dietary and lifestyle habits. Identify key areas where you need to improve. Construct an overall plan of diet and lifestyle choices that you implement to help you reach healthy goals.

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5.9: A Personal Choice about Lipids

Learning Objectives

- Discuss ways to decrease saturated fat and cholesterol intake and increase unsaturated fat intake in your diet.

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.

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.

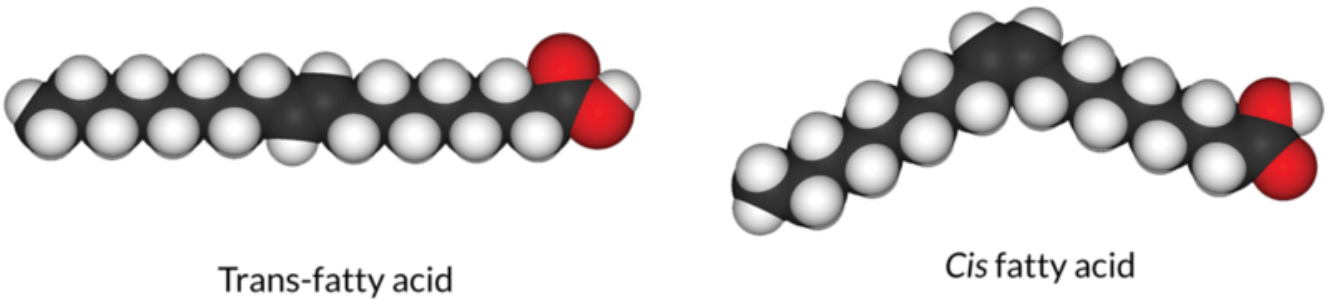


Figure 5.9.1: When a lipid molecule is unhydrogenated, the double bonds between the carbons keep it kinky and a liquid at room temperature. If that fat realigns into the trans formation, it gets straighter, forming up into a solid.

Trans Fats

Stay away from trans fats. There is no amount of trans fats that are good for human health. Try to eliminate as much of these fats as possible from your food selections. Avoid commercially baked goods and fast foods. Make these your “Infrequent Foods.”

Choose unsaturated fats. Fatty fish, walnuts, flaxseeds, flaxseed oil, and canola oil all have good health benefits and should be on the “Best,” “Better,” and “Good” fat lists. They each provide essential omega-3 fatty acids necessary for overall body health. To derive the most benefit from including these foods, do not add them to an existing diet full of fat. Use these to replace the “Least Desirable” fats that are being removed from the diet. Be careful of exposing fats and oils to heat, light, and oxygen as they can

be easily damaged. Exercise caution when heating oils. Polyunsaturated fats are the most fragile and lose beneficial properties when exposed to heat. For proper storage and freshness, place your oils in opaque containers and keep refrigerated. Do not use any oil if it has a bitter smell or taste.

Limit saturated fat intake. Reduce red meat consumption, processed meats, and whole-fat dairy products. A good replacement for red meat could be beans (black beans are very high in protein), nuts, poultry, and fish whenever possible. To reduce full-fat dairy items try their low-fat or nonfat counterparts such as mozzarella cheese.

Low fat does not equal healthy. Remember, a fat-free label does not provide you with a license to consume all the calories you desire. There will be consequences to your weight and your overall health. Common replacements for fat in many fat-free foods are refined carbohydrates, sugar, and calories. Too much of these ingredients can also cause health problems. Choose and consume wisely.

Tools for Change

As a delicious alternative to red meat, try preparing and eating at least one meal each week using beans. For interesting ideas and tips, visit http://www.swbeans.com.

Helpful Suggestions

Keep the following in mind as you strive toward a healthier diet:

- **A "better-fat" diet will successfully support weight loss**. With the obesity rates in the United States more than tripling since 1980, it is interesting to note that this figure has presented itself and increased at a time when "low fat" advertising runs rampant throughout the food supply. While cutting "Least Desirable" fat calories are vital to weight loss, remember that "Better" fats are filling and just a handful of nuts can curb an appetite to prevent overeating.
- **Consume omega-3 fats each day**. For optimal health and disease prevention include a moderate serving of fish, walnuts, ground flaxseeds, flaxseed oil, or soybean oil in your diet every day.
- **Limit cholesterol-rich foods**. The following foods should be limited from the diet in order to reduce blood cholesterol: chicken livers, beef, pork, fast foods, pastries, butter, cheese, and ice cream.
- **How much saturated fat is too much?** Your goal is to keep your intake of saturated fat to no more than 10 percent of your total dietary calories on a daily basis. Thus, it is important to learn to reduce the intake of foods high in saturated fat. High-fat foods can be consumed but they must fall within the overall goal for a person's fat allowance for the day.
- **Home cooking**. Limit the use of saturated fats in home preparation of meals. Instead of butter try spreads made from unsaturated oils such as canola or olive oils and the use of cooking sprays. Couple this with the use of herbs and spices to add flavor. Avoid using high-fat meat gravies, cheese, and cream sauces. Limit adding extras to foods such as butter on a baked potato. Use nonfat sour cream instead. Grill, bake, stir-fry, roast, or bake your foods. Never fry in solid fats such as butter or shortening. Marinate foods to be grilled in fruit juices and herbs. Instead of relying upon commercial salad dressings, learn to make your own top-quality dressing from cold-pressed olive oil, flaxseed oil, or sesame oil.

Make sure the fat is flavorful. Adding flavor to food is what makes the eating experience enjoyable. Why not choose unsaturated fats and oils that have strong flavors? In this way you will add good flavor to your meals but use less fat in the process. Some examples are sesame oil, peanut oil, and peanut butter. Replace less flavorful cheeses with small amounts of strongly flavored cheeses such as romano, parmesan, and asiago.

Now that you have gained a wealth of information and food for thought to enable you to make changes to your dietary pattern we hope that your desire to pursue a healthier lifestyle has been solidified. While we realize that making grand strides in this direction may be awkward at first, even the smallest of accomplishments can produce noticeable results that will spur you on and perhaps spark the interest of friends and family to join you in this health crusade.

Becoming aware of the need to limit your total fat intake will facilitate your ability to make better choices. In turn, making better dietary choices requires gaining knowledge. As you understand that your food choices not only impact your personal physical health but also the delicate balance of our ecosystem, we are confident that you will successfully adapt to the dynamics of the ever-changing global food supply. Remember, the food choices you make today will benefit you tomorrow and into the years to come.

Key Takeaways

- To reduce saturated fat in your diet, eat less red and processed meat and more fish and chicken. Choose lean cuts of meat and white meat portions. Bake, broil, or grill instead of fry. Avoid deep-fried foods, cheeses, and creamy cheese sauces. Remove the skin from chicken and remove as much fat from meat as possible. Choose low-fat milk and lower fat cheeses, such as mozzarella, where possible. Use liquid vegetable oils such as olive oil or canola oil instead of shortening or butter.
- In order to reduce blood cholesterol, restrict the consumption of eggs, chicken livers, beef, pork, shrimp, crustaceans, fast foods, pastries, butter, cheese, and ice cream.
- To gain the most benefit from reducing your saturated fat intake, substitute unsaturated fats in the place of saturated fats and trans fats. Do not add unsaturated fats to an already fatty diet. Fill your plate with plant-based foods and use the foods containing fat more as an accompaniment.

Discussion Starters

1. Think of at least three ways to reduce, substitute, and eliminate from your diet foods that are higher in less-desirable fat. List some foods that you will add to your diet that will add bulk and help satisfy your need to eat, but do not contain the calories in fat-rich foods.
2. Make a list of your favorite snack foods. Then make a listing of the fat content in each. Decide what snack foods you should reduce or eliminate from your diet. Think of at least two replacement foods for these snacks. Tell what benefit these replacement foods will have on your overall health.
3. Make a list of all the common foods you eat that contain trans fats. Looking ahead, develop a plan of action for you to slowly eliminate as much of these fats from your diet as possible. What substitutes will you add in their place? How will you cut out trans fats from your diet?

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5.E: Lipids (Exercises)

It's Your Turn

1. Provide examples of three foods that are rich in unsaturated fats.
2. Assume you are reluctant to eat fish. Name three other sources of omega-3 fats.
3. Your friend tends to feel cold a lot of the time, is often tired, and has developed sores on her skin. Based on the content in this chapter, identify a nutritional reason for this condition.
4. Explain the role of lipids in your overall health.
5. Discuss the role of trans (hydrogenated) fats for both consumer and food producer.

Apply It

1. Make a chart of the three main types of lipids, their specific functions in the body, and where they are found.
2. Diagram the steps in lipid digestion and absorption.
3. Create a blood lipid profile with healthy ranges.

Expand Your Knowledge

1. You're making a concerted effort to begin eating more foods that will promote good health. Turn your attention to omega-3 fatty acids. What will you incorporate into your diet?
2. Obesity rates in the United States have more than tripled since 1980. At the same time, "low fat" advertising is all over the news. How would you explain this?
3. Calculate your 10 Year Risk for Heart Attack or Stroke using the following tool: http://www.cvriskcalculator.com/ Check with three members of your family or close friends. What does this tell you about their risk?

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6: PROTEINS

In this chapter, we cover the structure and roles of protein, and explore the consequences of getting too little or too much protein in your diet. Tips for getting the right amount and quality of protein, as well as a look at special populations, such as the elderly and athletes, are also covered.

6.1: Prelude to Proteins

6.2: Defining Protein

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

6.4: Protein Digestion and Absorption

6.5: Protein's Functions in the Body

6.6: Diseases Involving Proteins

6.7: Proteins, Diet, and Personal Choices

6.E: Proteins (Exercises)

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6.1: Prelude to Proteins

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.



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, archaeologists uncovered a gladiator burial ground not far from the Temple of Artemis. To their surprise,

forensic analysis of the gladiators' bones revealed that they consumed a vegetarian diet. This information matches other historical accounts that gladiators ate a diet rich in barley and dried fruits. Hulled barley is a very nutritious whole grain; it is a complete protein source, containing more than 20 grams of protein and all nine essential amino acids in a one-cup serving.

Although the great philosophers, ancient Olympic athletes, and Roman gladiators saw vegetarianism as a means of maintaining optimal health, it took a while for the vegetarian dietary pattern to catch on in America. In 1987, John Robbins wrote *Diet for a New America* and popularized the vegan diet first introduced by Jay Dinshah in the United States in 1960. In the early 1990s, Dr. John McDougall wrote a series of books that promoted vegan dietary regimens to ward off chronic disease. Also during the 1990s, scientific evidence accumulated that supported that diets consisting of too much red meat were linked to chronic disease. This prompted many health organizations, such as the Academy of Nutrition and Dietetics (AND) and the American Heart Association (AHA), to issue statements endorsing the health benefits of vegetarian diets. These statements can be read at www.eatright.org/about/content.aspx?id=8357 and bit.ly/O2VQkC.

The US federal government was unable to ignore the health benefits of plant-based diets any longer, and consequently released the *2010 Dietary Guidelines* in which Americans were challenged to eat a more plant-based diet. Moreover, the *Dietary Guidelines* advisory committee stated, "In prospective studies of adults, compared to nonvegetarian eating patterns, vegetarian-style eating patterns have been associated with improved health outcomes—lower levels of obesity, a reduced risk of cardiovascular disease, and lower total mortality."

You Decide

What are the best sources of protein and how much protein do I need to eat to have a healthy diet?

Whether you choose to consume protein from animal- or plant-derived products, an important factor to consider is the entire nutrient package of the food. What other fats, nutrients, additives, or preservatives come with the protein source? Red meat is a popular choice for protein, but it contains high amounts of saturated fat. Fish is another good protein choice, and it provides much less saturated fat than other meats, in addition to more healthy fats. Some plant-based sources of protein contain high amounts of protein per serving with just under one gram of less desirable fat in addition to good amounts of healthy fats. As you read through this chapter you will learn how to choose the best protein sources to support your health.

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6.2: Defining Protein

Learning Objectives

- Categorize the different types of amino acids.
- Describe how protein differs in structure from carbohydrates and lipids.

Protein makes up approximately 20 percent of the human body and is present in every single cell. The word protein is a Greek word, meaning "of utmost importance." Proteins are called the workhorses of life as they provide the body with structure and perform a vast array of functions. You can stand, walk, run, skate, swim, and more because of your protein-rich muscles. Protein is necessary for proper immune system function, digestion, and hair and nail growth, and is involved in numerous other body functions. In fact, it is estimated that more than one hundred thousand different proteins exist within the human body. In this chapter you will learn about the components of protein, the important roles that protein serves within the body, how the body uses protein, the risks and consequences associated with too much or too little protein, and where to find healthy sources of it in your diet.



Your protein-rich muscles allow for body strength and movement, which enable you to enjoy many activities. Australia v Japan on 24 March 2012 at Hawker International Softball Centre. (CC-SA-BY 3.0; LauraHale)

What Is Protein?

Proteins, simply put, are macromolecules composed of amino acids. Amino acids are commonly called protein's building blocks. Proteins are crucial for the nourishment, renewal, and continuance of life. Proteins contain the elements carbon, hydrogen, and oxygen just as carbohydrates and lipids do, but proteins are the only macronutrient that contains nitrogen. In each amino acid the elements are arranged into a specific conformation around a carbon center. Each amino acid consists of a central carbon atom connected to a side chain, a hydrogen, a nitrogen-containing *amino* group, a carboxylic *acid* group—hence the name "amino acid." Amino acids differ from each other by which specific side chain is bonded to the carbon center.

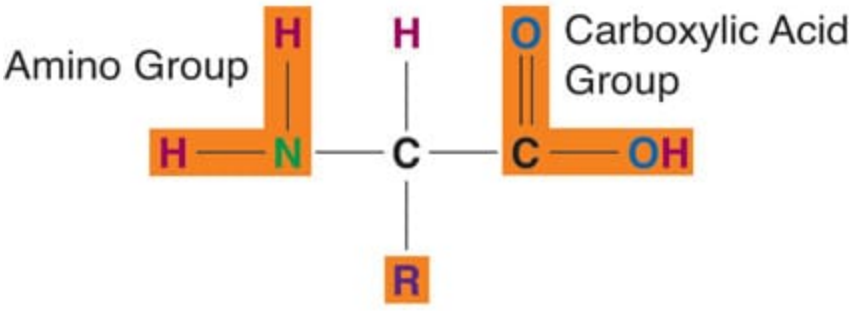


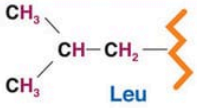
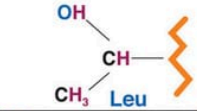
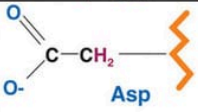
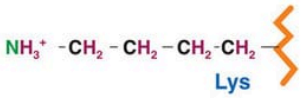
Figure 6.2.1***:*** *Amino Acid Structure*

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, 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 6.2.2). 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 6.2.2: 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 6.2.1). 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 6.2.1: 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. 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 100 amino acids long the possible combinations of amino acid sequences is equal to 20^{100}, 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 6.2.3). 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.

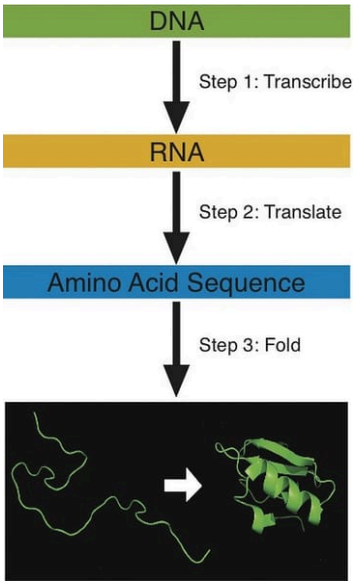


Figure 6.2.3: Building a protein involves three steps: transcription, translation, and folding.

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.

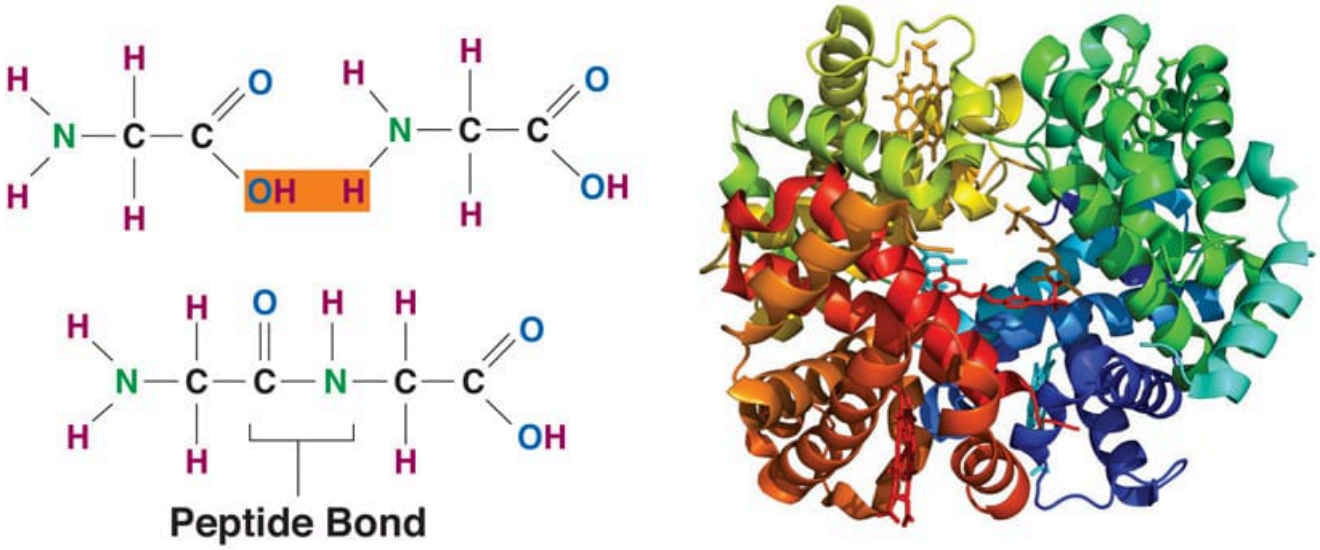


Figure 6.2.4: Connecting amino acids with peptide bonds builds proteins. In the process of translation, amino acids are sequentially strung along in a chain in a specific sequence that spontaneously folds into the correct protein shape.

Protein Organization

Protein's structure enables it to perform a variety of functions. Proteins are similar to carbohydrates and lipids in that they are polymers of simple repeating units; however, proteins are much more structurally complex. In contrast to carbohydrates, which

have identical repeating units, proteins are made up of amino acids that are different from one another. Furthermore, a protein is organized into four different structural levels (Figure 6.5). The first level is the one-dimensional sequence of amino acids that are held together by peptide bonds. Carbohydrates and lipids also are one-dimensional sequences of their respective monomers, which may be branched, coiled, fibrous, or globular, but their conformation is much more random and is not organized by their sequence of monomers. In contrast, the two-dimensional level of protein structure is dependent on the chemical interactions between amino acids, which cause the protein to fold into a specific shape, such as a helix (like a coiled spring) or sheet. The third level of protein structure is three-dimensional. As the different side chains of amino acids chemically interact, they either repel or attract each other, resulting in the coiled structure. Thus, the specific sequence of amino acids in a protein directs the protein to fold into a specific, organized shape. The fourth level of structure (also known as its "quaternary" structure) is achieved when protein fragments called peptides combine to make one larger functional protein. The protein hemoglobin is an example of a protein that has quaternary structure. It is composed of four peptides that bond together to form a functional oxygen carrier. A protein's structure also influences its nutritional quality. Large fibrous protein structures are more difficult to digest than smaller proteins and some, such as keratin, are indigestible. Because digestion of some fibrous proteins is incomplete, not all of the amino acids are absorbed and available for the body to utilize, thereby decreasing their nutritional value.

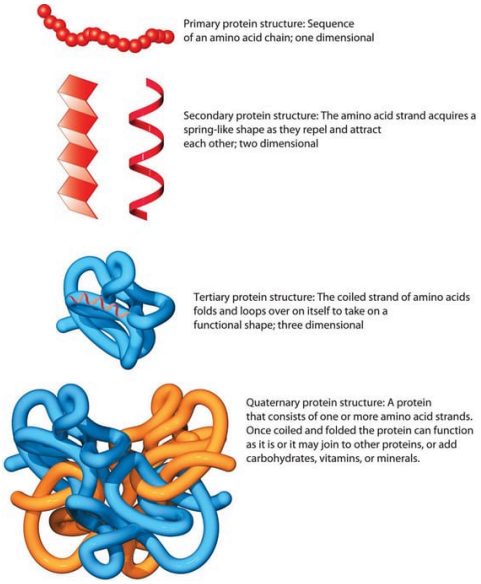


Figure 6.2.5: A protein has four different structural levels.

Video 6.1: 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 (https://www.youtube.com/watch?v=D3fOXt4MrOM)

Key Takeaways

- Amino acids differ chemically in the molecular composition of their side chains, but they do have some similarities. They are grouped into four different types: nonpolar, polar, acidic, and basic.
- Amino acids are also categorized based upon their nutritional aspects. Some are nonessential in the diet because the body can synthesize them, and some are essential in the diet because the body cannot make them.
- Proteins are polymers of amino acid monomers held together by peptide bonds. They are built in three steps; transcription, translation, and folding.
- Proteins have up to four different levels of structure, making them much more complex than carbohydrates or lipids.

Discussion Starters

1. There are over four thousand diseases caused by incorrectly built protein. Find out more about how one incorrectly placed amino acid causes the disease sickle cell anemia by watching this animation.

   http://www.dnalc.org/resources/3d/17-sickle-cell.html.

2. Why do you think protein-building diseases are rare? In every cell in your body over ten million ribosomes are at work constructing millions of proteins every minute. What can you say about the body's amazing track record in correctly building proteins?

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

Learning Objectives

- Explain the process of denaturation and its consequences. Give an example.

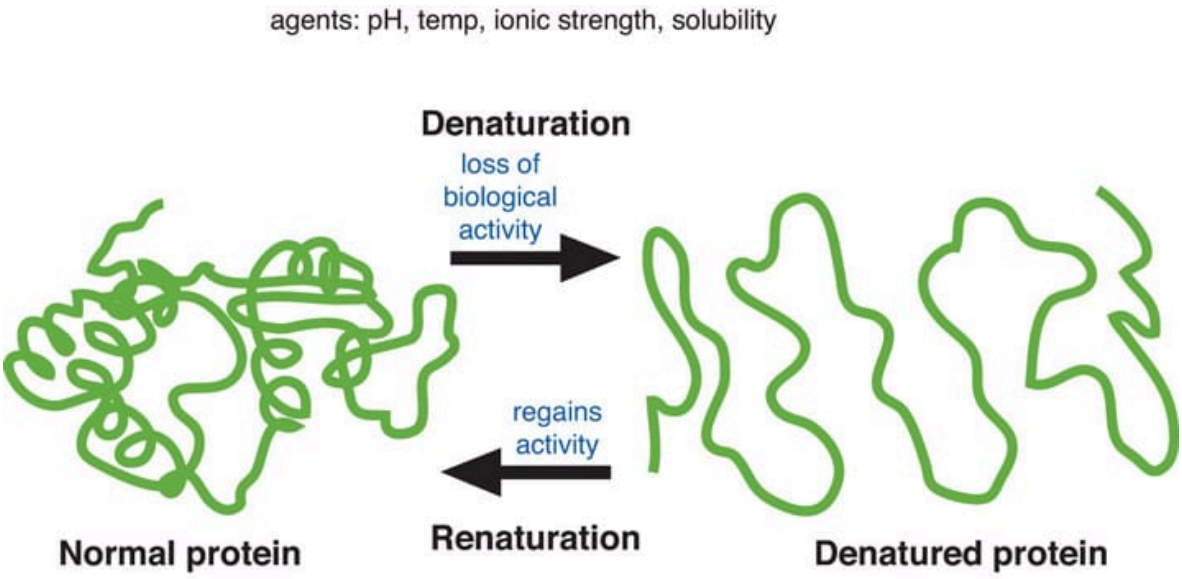
In addition to having many vital functions within the body, proteins perform different roles in our foods by adding certain functional qualities to them. Protein provides food with structure and texture and enables water retention. For example, proteins foam when agitated. (Picture whisking egg whites to make angel food cake. The foam bubbles are what give the angel food cake its airy texture.) Yogurt is another good example of proteins providing texture. Milk proteins called caseins coagulate, increasing yogurt's thickness. Cooked proteins add some color to foods as the amino group binds with carbohydrates and produces a brown pigment. Eggs are between 10 and 15 percent protein by weight. Most cake recipes use eggs because the egg proteins help bind all the other ingredients together into a uniform cake batter. The proteins aggregate into a network during mixing and baking that gives cake structure.



Protein gives structure and texture to cakes. A layered pound cake, with alternating interstitial spaces filled with raspberry jam and lemon curd, finished with buttercream frosting. Image use with permission (Public domain; Scheinwerfermann).

Protein Denaturation: Unraveling the Fold

When a cake is baked, the proteins are denatured. Denaturation refers to the physical changes that take place in a protein exposed to abnormal conditions in the environment. Heat, acid, high salt concentrations, alcohol, and mechanical agitation can cause proteins to denature. When a protein denatures, its complicated folded structure unravels, and it becomes just a long strand of amino acids again. Weak chemical forces that hold tertiary and secondary protein structures together are broken when a protein is exposed to unnatural conditions. Because proteins' function is dependent on their shape, denatured proteins are no longer functional. During cooking the applied heat causes proteins to vibrate. This destroys the weak bonds holding proteins in their complex shape (though this does not happen to the stronger peptide bonds). The unraveled protein strands then stick together, forming an aggregate (or network).



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

Interactive 6.3.1: Denaturing of Egg Proteins

View this animation of egg proteins denaturing. http://www.sumanasinc.com/webcontent/animations/content/proteinstructure.html

Key Takeaways

- Proteins provide food not only with nutrition, but also with structure and texture.
- When a protein denatures, its complicated structure unfolds into a strand of amino acids.

Discussion Starters

1. Gelatin is a mixture of collagen proteins. How does gelatin add texture and structure to foods? Conduct an experiment by making some Jell-O™ using different methods of denaturation and discuss what happens to the texture and structure.
    1. Make the first batch of Jell-O™ following the directions. Does it set?
    2. Next, make up the Jell-O™, but replace hot water with cold. Does it set?
    3. Instead of adding hot water, add 2 teaspoons of salt and only cold water. Does it set?
    4. Take the first batch (that is now set) and either whisk it by hand or use an electric mixer. What happens?
2. If pouring salt on a live slug produces a puddle of goo, how is it possible to cook snails with salt and get a delicious dish?

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6.4: Protein Digestion and Absorption

Learning Objectives

- Discuss how proteins are digested and absorbed by our bodies.

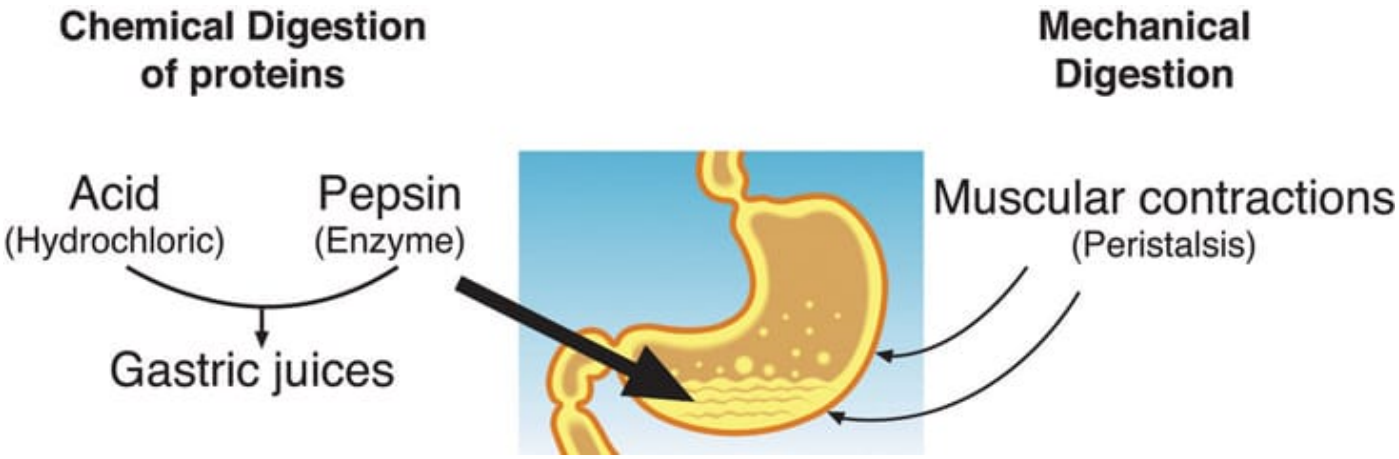
How do the proteins from foods, denatured or not, get processed into amino acids that cells can use to make new proteins? When you eat food the body's digestive system breaks down the protein into the individual amino acids, which are absorbed and used by cells to build other proteins and a few other macromolecules, such as DNA. Let's follow the specific path that proteins take down the gastrointestinal tract and into the circulatory system. Eggs are a good dietary source of protein and will be used as our example to describe the path of proteins in the processes of digestion and absorption. One egg, whether raw, hard-boiled, scrambled, or fried, supplies about six grams of protein.



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.



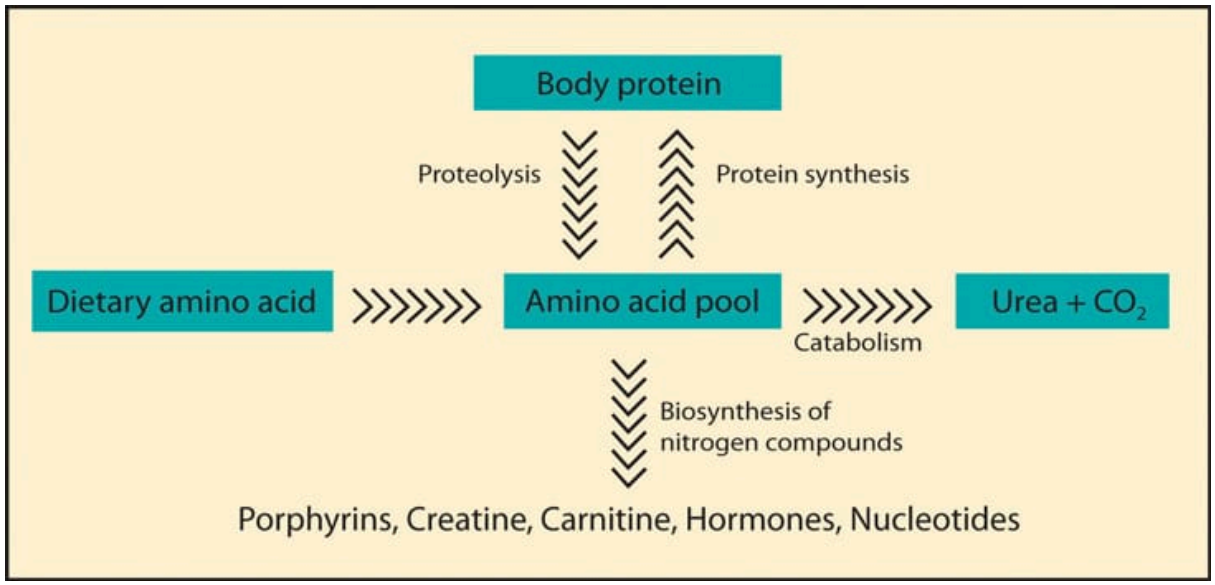
Protein digestion requires the chemical actions of gastric juice and the mechanical actions of the stomach.

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. 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.

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).



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

Key Takeaways

- Mechanical digestion of protein begins in the mouth and continues in the stomach and small intestine.
- Chemical digestion of protein begins in the stomach and ends in the small intestine.
- The body recycles amino acids to make more proteins.

Discussion Starters

1. The next time you eat an egg, imagine it moving down the gastrointestinal tract and visualize what is happening to the proteins it contains. Does the amount of work required to digest a protein seem to be too much? How much energy does it take just to digest protein?
2. Why is it important to recycle amino acids?

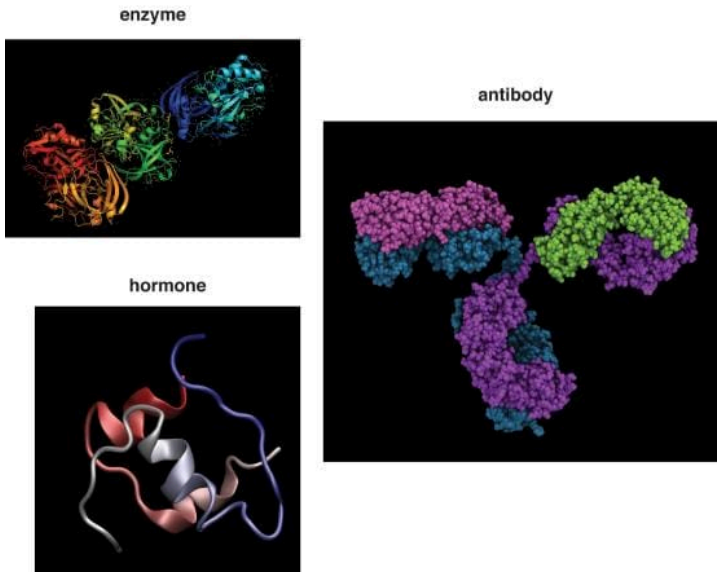
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6.5: Protein's Functions in the Body

Learning Objectives

- List protein's functions in the body.

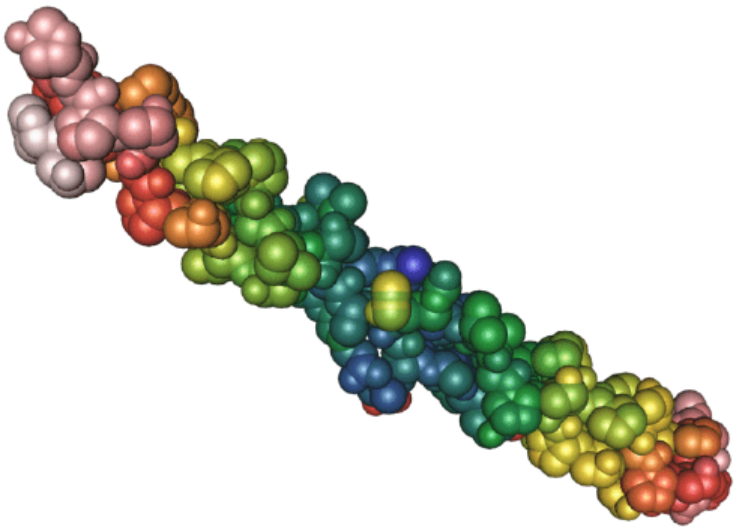
Proteins are the "workhorses" of the body and participate in many bodily functions. As you may recall, proteins come in all sizes and shapes and each is specifically structured for its particular function.



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 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.

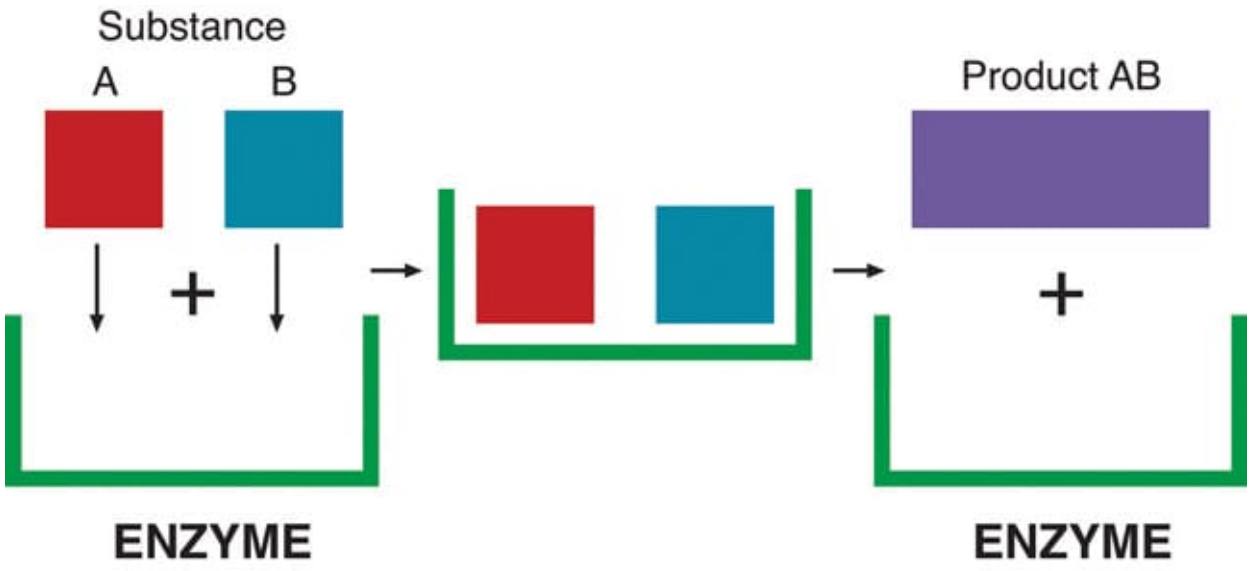


Collagen: A strong protein made up of three intertwined peptides. Image used wtih permission (CC-SA-By; Nevit Dilmen).

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.

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.



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 6.5.2: Enzyme

Watch this animation of an enzyme at work. (click to see video)

Hormones

Proteins are responsible for hormone synthesis. Recall that hormones are the chemical messages produced by the endocrine glands. When an endocrine gland is stimulated, it releases a hormone. The hormone is then transported in the blood to its target cell, where it communicates a message to initiate a specific reaction or cellular process. For instance, after you eat a meal, your blood glucose levels rise. In response to the increased blood glucose, the pancreas releases the hormone insulin. Insulin tells the cells of the body that glucose is available and to take it up from the blood and store it or use it for making energy or building macromolecules. A major function of hormones is to turn enzymes on and off, so some proteins can even regulate the actions of other proteins. While not all hormones are made from proteins, many of them are.

Fluid and Acid-Base Balance

Proper protein intake enables the basic biological processes of the body to maintain the status quo in a changing environment. Fluid balance refers to maintaining the distribution of water in the body. If too much water in the blood suddenly moves into a tissue, the results are swelling and, potentially, cell death. Water always flows from an area of high concentration to one of a low concentration. As a result, water moves toward areas that have higher concentrations of other solutes, such as proteins and glucose. To keep the water evenly distributed between blood and cells, proteins continuously circulate at high concentrations in the blood. The most abundant protein in blood is the butterfly-shaped protein known as **albumin**. Albumin's presence in the blood makes the protein concentration in the blood similar to that in cells. Therefore, fluid exchange between the blood and cells is not in the extreme, but rather is minimized to preserve the status quo.



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 $6.5.1$).

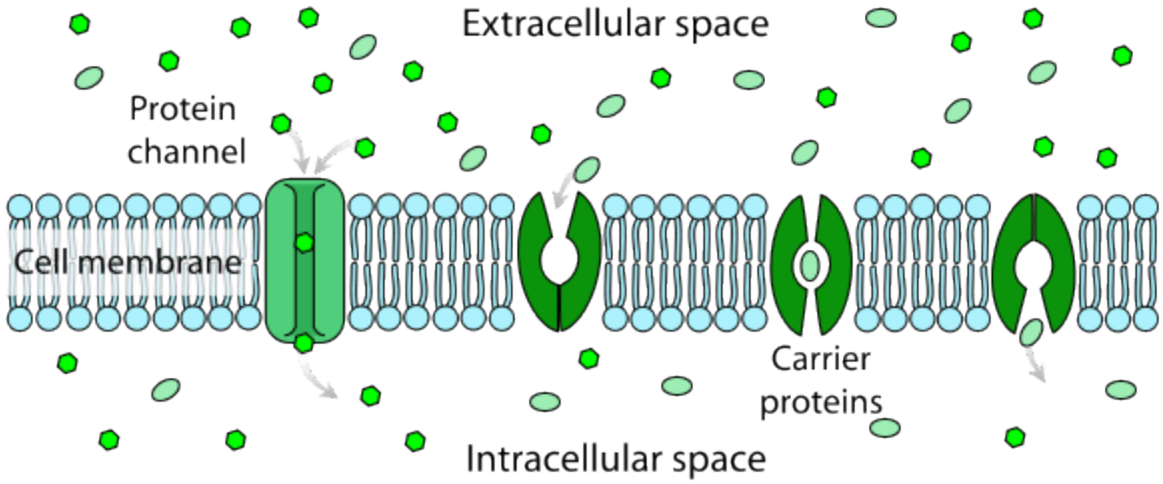
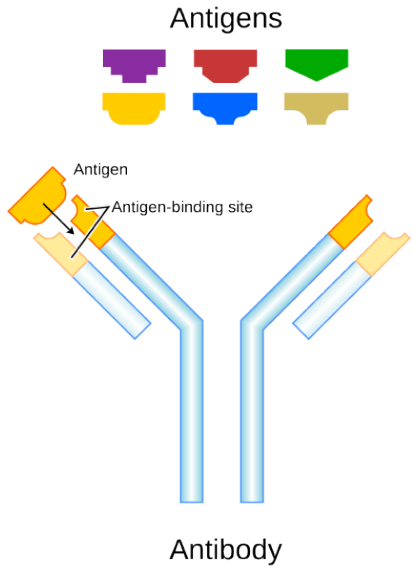


Figure 6.5.1: Molecules move in and out of cells through transport proteins, which are either channels or carriers. Facilitated diffusion in cell membrane, showing ion channels (left) and carrier proteins (three on the right). (Public Domain; LadyofHats).

Protection

Earlier we discussed that the strong collagen fibers in skin provide it with structure and support. The skin's dense network of collagen fibers also serves as a barricade against harmful substances. The immune system's attack and destroy functions are dependent on enzymes and antibodies, which are also proteins. An enzyme called **lysozyme** is secreted in the saliva and attacks the walls of bacteria, causing them to rupture. Certain proteins circulating in the blood can be directed to build a molecular knife that stabs the cellular membranes of foreign invaders. The antibodies secreted by the white blood cells survey the entire circulatory system looking for harmful bacteria and viruses to surround and destroy. Antibodies also trigger other factors in the immune system to seek and destroy unwanted intruders.



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

Wound Healing and Tissue Regeneration

Proteins are involved in all aspects of wound healing, a process that takes place in three phases: inflammatory, proliferative,

and remodeling. For example, if you were sewing and pricked your finger with a needle, your flesh would turn red and become inflamed. Within a few seconds bleeding would stop. The healing process begins with proteins such as bradykinin, which dilate blood vessels at the site of injury. An additional protein called fibrin helps to secure platelets that form a clot to stop the bleeding. Next, in the proliferative phase, cells move in and mend the injured tissue by installing newly made collagen fibers. The collagen fibers help pull the wound edges together. In the remodeling phase, more collagen is deposited, forming a scar. Scar tissue is only about 80 percent as functional as normal uninjured tissue. If a diet is insufficient in protein, the process of wound healing is markedly slowed.

While wound healing takes place only after an injury is sustained, a different process called tissue regeneration is ongoing in the body. The main difference between wound healing and tissue regeneration is in the process of regenerating an exact structural and functional copy of the lost tissue. Thus, old, dying tissue is not replaced with scar tissue but with brand new, fully functional tissue. Some cells (such as skin, hair, nails, and intestinal cells) have a very high rate of regeneration, while others, (such as heart-muscle cells and nerve cells) do not regenerate at any appreciable levels. Tissue regeneration is the creation of new cells (cell division), which requires many different proteins including enzymes that synthesize RNA and proteins, transport proteins, hormones, and collagen. In a hair follicle, cells divide and a hair grows in length. Hair growth averages 1 centimeter per month and fingernails about 1 centimeter every one hundred days. The cells lining the intestine regenerate every three to five days. Protein-inadequate diets impair tissue regeneration, causing many health problems including impairment of nutrient digestion and absorption and, most visibly, hair and nail growth.

Energy Production

Some of the amino acids in proteins can be disassembled and used to make energy. Only about 10 percent of dietary proteins are catabolized each day to make cellular energy. The liver is able to break down amino acids to the carbon skeleton, which can then be fed into the citric acid cycle. This is similar to the way that glucose is used to make ATP. If a person's diet does not contain enough carbohydrates and fats their body will use more amino acids to make energy, which compromises the synthesis of new proteins and destroys muscle proteins. Alternatively, if a person's diet contains more protein than the body needs, the extra amino acids will be broken down and transformed into fat.

Key Takeaways

- The many shapes and sizes of proteins allow them to perform a vast array of functions, including: acting as enzymes and hormones, and providing for fluid and acid-base balance, transport, protection, wound healing and tissue regeneration, and energy production.
- Without adequate intake of protein containing all the essential amino acids, all protein functions will be impaired.

Discussion Starter

1. Given protein's critical roles in the immune system, what do you think might occur more frequently in a person whose diet is protein deficient?

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6.6: Diseases Involving Proteins

Learning Objectives

- Identify the potential health risks associated with abnormal protein levels in the diet.

As you may recall, moderation refers to having the proper amount of a nutrient—having neither too little nor too much. A healthy diet incorporates all nutrients in moderation. Low protein intake has several health consequences, and a severe lack of protein in the diet eventually causes death. Although severe protein deficiency is a rare occurrence in children and adults in the United States, it is estimated that more than half of the elderly in nursing homes are protein-deficient. The Acceptable Macronutrient Distribution Range (AMDR) for protein for adults is between 10 and 35 percent of kilocalories, which is a fairly wide range. The percent of protein in the diet that is associated with malnutrition and its health consequences is less than 10 percent, but this is often accompanied by deficiencies in calories and other micronutrients. There is some scientific evidence that shows that people with diets low in animal protein (< 8 percent of caloric intake), who get adequate protein from plant-based foods instead, may actually have improved health and increased longevity. On the other hand, diets rich in animal-derived protein (> 30 percent of caloric intake) are associated with increased early mortality, kidney and liver malfunction, cardiovascular disease, colon cancer, and osteoporosis. In this section we will discuss the health consequences of protein intake that is either too low to support life's processes or too high, thereby increasing the risk of chronic disease. In the last section of this chapter, we will discuss in more detail the personal choices you can make to optimize your health by consuming the right amount of high-quality protein.

Health Consequences of Protein Deficiency

Although severe protein deficiency is rare in the developed world, it is a leading cause of death in children in many poor, underdeveloped countries. There are two main syndromes associated with protein deficiencies: Kwashiorkor and Marasmus. Kwashiorkor affects millions of children worldwide. When it was first described in 1935, more than 90 percent of children with Kwashiorkor died. Although the associated mortality is slightly lower now, most children still die after the initiation of treatment. The name Kwashiorkor comes from a language in Ghana and means, "rejected one." The syndrome was named because it occured 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 B9), iodine, iron, and vitamin C all contribute to the many health manifestations of this syndrome.

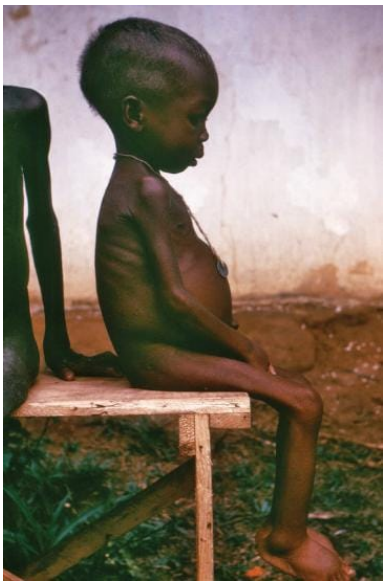


Figure 6.6.1: Kwashiorkor is a disease brought on by a severe dietary protein deficiency. Symptoms include edema of legs and feet, light-colored, thinning hair, anemia, a pot-belly, and shiny skin. (Public domain; Centers for Disease Control and Prevention).

Children and adults with marasmus neither have enough protein in their diets nor do they take in enough calories. 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 extreme 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 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 Millenium Development Goal of halving the proportion of people who suffer from hunger by the year 2015.

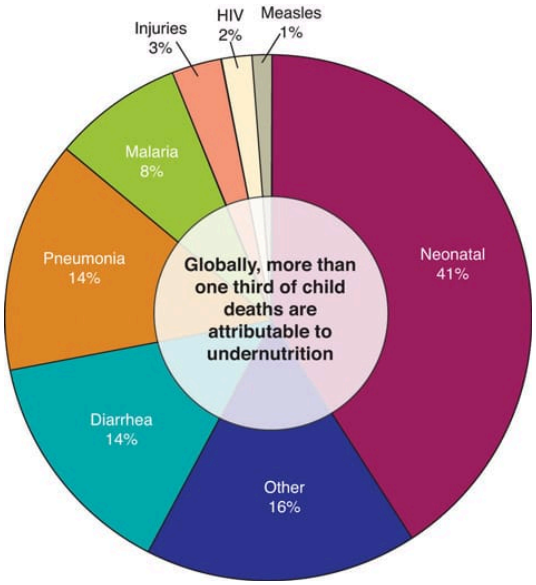


Figure 6.6.2: Causes of death for children under the age of five, worldwide.

Interactive 6.6.1

If you are interested in finding out more about world hunger and what is being done about it, visit the UNICEF website. http://www.childinfo.org/index.html

Health Consequences of Too Much Protein in the Diet

An explicit definition of a high-protein diet has not yet been developed by the Food and Nutrition Board of the Institute of Medicine (IOM), but typically diets high in protein are considered as those that derive more than 30 percent of calories from protein. Many people follow high-protein diets because marketers tout protein's ability to stimulate weight loss. It is true that following high-protein diets increases weight loss in some people. However the number of individuals that remain on this type of diet is low and many people who try the diet and stop regain the weight they had lost. Additionally, there is a scientific hypothesis that there may be health consequences of remaining on high-protein diets for the long-term, but clinical trials are ongoing or scheduled to examine this hypothesis further. As the high-protein diet trend arose so did the intensely debated issue of whether there are any health consequences of eating too much protein. Observational studies conducted in the general population suggest diets high in animal protein, specifically those in which the primary protein source is red meat, are linked to a higher risk for kidney stones, kidney disease, liver malfunction, colorectal cancer, and osteoporosis. However, diets that include lots of red meat are also high in saturated fat and cholesterol and sometimes linked to unhealthy lifestyles, so it is difficult to conclude that the high protein content is the culprit.

High protein diets appear to only increase the progression of kidney disease and liver malfunction in people who already have kidney or liver malfunction, and not to *cause* these problems. However, the prevalence of kidney disorders is relatively high and underdiagnosed. In regard to colon cancer, an assessment of more than ten studies performed around the world published in the June 2011 issue of *PLoS* purports that a high intake of red meat and processed meat is associated with a significant increase in colon cancer risk.Chan, D. S., et al. "Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective Studies." *PLoS One* 6, no. 6 (2011): e20456. doi: 10.1371/journal.pone.0020456. Although there are a few ideas, the exact mechanism of how proteins, specifically those in red and processed meats, causes colon cancer is not known and requires further study.

Some scientists hypothesize that high-protein diets may accelerate bone-tissue loss because under some conditions the acids in protein block absorption of calcium in the gut, and, once in the blood, amino acids promote calcium loss from bone; however even these effects have not been consistently observed in scientific studies. Results from the Nurse's Health Study suggest that women who eat more than 95 grams of protein each day have a 20 percent higher risk for 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/nutritio...u-eat/protein/.' Barzel, U. S. and L. K. Massey. "Excess Dietary Protein Can Adversely Affect Bone." *J Nutr* 128, no. 6 (June 1, 1998): 1051–53. 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 remains highly controversial and more research is needed to come to any conclusions about the association between the two.St. Jeor, S. T. et al. "Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association." *Circulation* 104 (2001): 1869–74.

High-protein diets can restrict other essential nutrients. The AHA states that "High-protein diets are not recommended because they restrict healthful foods that provide essential nutrients and do not provide the variety of foods needed to adequately meet nutritional needs. Individuals who follow these diets are therefore at risk for compromised vitamin and mineral intake, as well as potential cardiac, renal, bone, and liver abnormalities overall."St. Jeor, S. T. et al. "Dietary Protein and Weight Reduction: A Statement for Healthcare Professionals from the Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism of the American Heart Association." *Circulation* 104 (2001): 1869–74.

As with any nutrient, protein must be eaten in proper amounts. Moderation and variety are key strategies to achieving a healthy diet and need to be considered when optimizing protein intake. While the scientific community continues its debate about the particulars regarding the health consequences of too much protein in the diet, you may be wondering just how much protein you should consume to be healthy. Read on to find out more about calculating your dietary protein recommendations, dietary protein sources, and personal choices about protein.

Key Takeaways

- Protein deficiency syndromes are a leading cause of death in children under the age of five in poor, underdeveloped countries. Protein deficiency can cause swelling, fatigue, skin problems, irritability, muscle wasting, and eventual death from infection.
- The long-term health consequences of high-protein diets have not been adequately studied.

Discussion Starter

1. What are some diet changes you can make that are better, more sustainable, and easier to follow for the rest of your life than a high-protein diet?

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6.7: Proteins, Diet, and Personal Choices

Learning Objectives

- Calculate your Recommended Dietary Allowance for protein.
- Plan a one-day diet for each of the following: vegetarian, lacto-ovo vegetarian, and vegan. For each, calculate nutrient intake, then assess for adequacy, balance, and variety.
- Decide whether to take protein or amino acid supplements based on nutrition science studies.

We have discussed what proteins are, how they are made, how they are digested and absorbed, the many functions of proteins in the body, and the consequences of having too little or too much protein in the diet. This section will provide you with information on how to determine the recommended amount of protein for you, and your many choices in designing an optimal diet with high-quality protein sources.

How Much Protein Does a Person Need in Their Diet?

The recommendations set by the IOM for the Recommended Daily Allowance (RDA) and AMDR for protein for different age groups are listed in Table 6.7.1. 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 6.7.1: 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 nontoxic, 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.

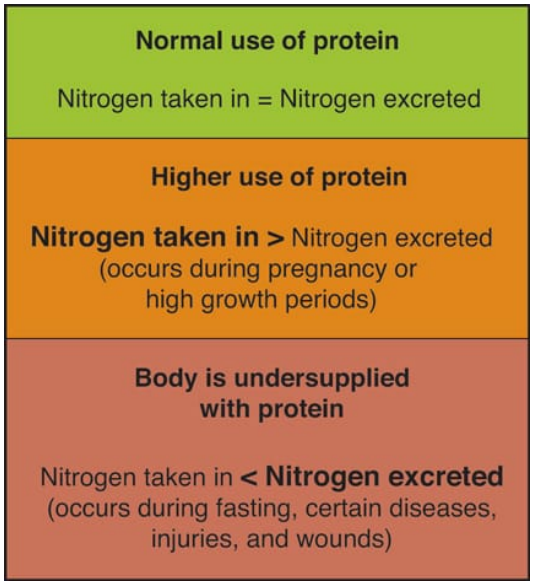


Figure 6.7.1: Nitrogen Balance

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/nutritio...u-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 6.7.2. To find out the complete nutrient package of different foods, visit the US Department of Agriculture (USDA) website listed below.

Table 6.7.2: 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 6.3

This interactive USDA tool allows you to enter the foods you eat (with serving size) and find out the whole nutrient package.
http://www.ars.usda.gov/Services/docs.htm?docid=17032

The USDA provides some tips for choosing your dietary protein sources. Their motto is, “Go Lean with Protein”. The overall suggestion is to eat a variety of protein-rich foods to benefit health. The USDA recommends lean meats, such as round steaks, top sirloin, extra lean ground beef, pork loin, and skinless chicken. Additionally, a person should consume 8 ounces of cooked seafood every week (typically as two 4-ounce servings) to assure they are getting the healthy omega-3 fatty acids that have been linked to a lower risk for heart disease. Another tip is choosing to eat beans, peas, or soy products as a main dish. Some of the menu choices include chili with kidney and pinto beans, hummus on pita bread, and black bean enchiladas. You could also enjoy nuts in a variety of ways. You can put them on a salad, in a stir-fry, or use them as a topping for steamed vegetables in place of meat or cheese. If you do not eat meat, the USDA has much more information on how to get all the protein you need from a plant-based diet. When choosing the best protein-rich foods to eat, pay attention to the whole nutrient package and remember to select from a variety of protein sources to get all the other essential micronutrients.

Interactive 6.4

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

Tools for Change

Try some new, healthy, protein-rich food recipes by visiting the Harvard School of Public Health website, http://hvrd.me/OJRkpV. You will find recipes for foods such as spicy lemongrass tofu with Asian basil, fish Creole, and spicy chicken kebabs.

Protein Quality

While protein is contained in a wide variety of foods, it differs in quality. High-quality protein contains all the essential amino acids in the proportions needed by the human body. The amino acid profile of different foods is therefore one component of protein quality. Foods that contain some of the essential amino acids are called incomplete protein sources, while those that contain all nine essential amino acids are called complete protein sources, or high-quality protein sources. Foods that are complete protein sources include animal foods such as milk, cheese, eggs, fish, poultry, and meat, and a few plant foods, such as soy and quinoa (Figure 6.9). The only animal-based protein that is not complete is gelatin, which consists of the protein, collagen.



Figure 6.9: 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 6.7.3. Complementary protein sources do not have to be consumed at the same time—as long as they are consumed within the same day, you will meet your protein needs.

Tools for Change

Explore some ethnic grocery markets to find new high-protein foods for your diet and/or experiment with the much cheaper plant-based protein sources. SeeTable 6.7.3 for complementing protein sources the vegan way.

Table 6.7.3: 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 6.7.4.

Table 6.7.4: 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

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). 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 6.7.5: 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 6.6 and 6.7 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 develop a more plant-based diet that does not significantly affect nutrient adequacy.

Table 6.7.6: Proportions of Milk Products and Calcium-Fortified Soy Products in the Base USDA Patterns and Three Vegetarian Variations

Food Category	Base USDA (%)	Plant-based (%)	Lacto-ovo vegetarian (%)	Vegan (%)
Fluid milk	54.6	54.6	54.6	0
Yogurt	1.6	1.6	1.6	0
Cheese	42.7	42.7	42.7	0
Soy milk (w/ calcium)	1.1	1.1	1.1	67.0
Rice milk (w/ calcium)	0	0	0	16.0
Tofu (w/ calcium)	0	0	0	15.0
Soy yogurt	0	0	0	2.0
Total	100.0	100.0	100.0	100.0

Source: US Department of Agriculture. Appendix E-3.3, *"Vegetarian Food Patterns: Food Pattern Modeling Analysis."* In *2010 Dietary Guidelines for Americans*. www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/AppendixE-3-3-Vegetarian.pdf#xml=65.216.150.153/texis/search/p...ead=500&rdepth=0&sufs=2&order=r&cq=&id=4d9cfcc17.

From these 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 6.5

To read the full report on nutrient adequacy of plant-based, lacto-ovo vegetarian, and vegan diets, go to the link to the *Dietary Guidelines Appendix 5*.

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.

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 postexercise 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.



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 6.7.7: 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 6.6

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. 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 for 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.

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 influences 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.



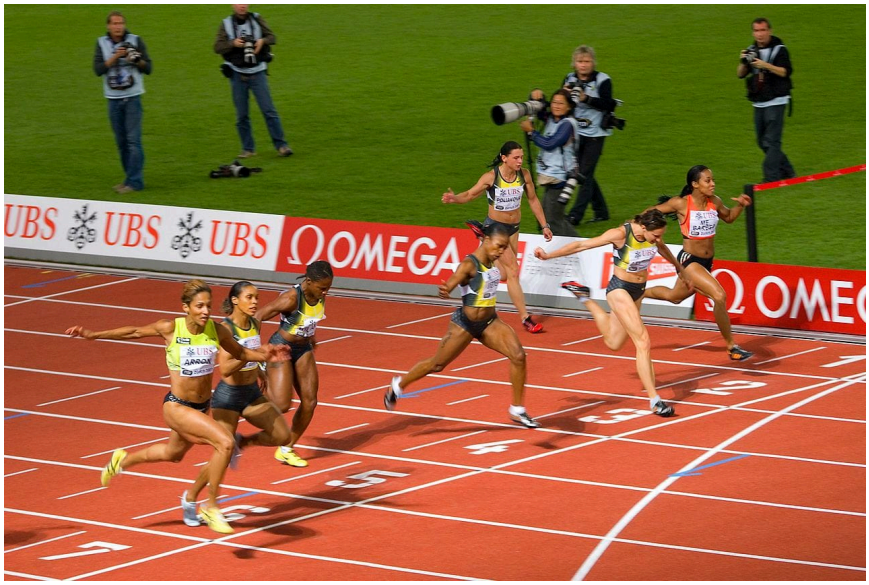
Make a shake and use the AMDRs for macronutrients as a guide when filling up the blender. (CC-SA-BY 3.0; Sigurdas)

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 for 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 healthfood-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 postexercise, 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 breakdown 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.



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 any more so than protein from foods.
- Unless you are an endurance or strength athlete, commercially sold protein bars and shakes are not a good dietary source of protein.

Discussion Starters

1. What is the consensus in your class on how easy it is to follow a more plant-based diet?
2. Even though high-protein diets may not cause significant health problems in healthy people, are they a sustainable option for losing weight? What are the consequences to the environment of consuming more and not less animal-based sources of protein?

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6.E: Proteins (Exercises)

It's Your Turn

1. Calculate your daily protein requirements.
2. List ten of your favorite protein-rich foods and find out the actual protein contents using the USDA National Nutrient Database, http://www.ars.usda.gov/Services/docs.htm?docid=8964. How easy is it for you to get all the protein you need? Are there some protein-rich food choices that you need to replace with a lower saturated fat alternative?
3. Design a more plant-based menu for a day that you are willing to follow. Make sure it is balanced and has variety. Give examples of the micronutrients (other than protein) the foods contain in appreciable amounts.

Apply It

1. In class or at home, use two inexpensive cake mixes. Make one without adding eggs and the other by following the recipe correctly. Bake them and summarize the differences in taste, texture, and structure.
2. Create a recipe for a shake made from your favorite whole foods that has the macronutrients in their recommended ranges. Also list the different micronutrients in your shake. Now that you know the shake is of good nutritional value, conduct a taste test on your friends or family.
3. Read these articles about nutrition in the future http://www.nature.com/nature/journal...l/468S21a.html and http://www.nature.com/nature/journal...l/468S10a.html.
4. Summarize three basic points about how tailoring the diet can reduce the risk for chronic disease.

Expand Your Knowledge

1. Take a trip to a nearby ethnic market and either write down the names of certain foods or purchase a few interesting ones. At home, use the USDA National Nutrient Database to find out the protein contents and other nutrients in the new food items. If you cannot find values for these new foods, try these websites: many-calories.com/, http://www.myfitnesspal.com/nutrition-facts-calories/chinese-food and http://caloriecount.about.com/calories-ethnic-foods-ic3500.
2. Plan a menu for one week that is completely plant-based. Look up the whole nutrient package for the items in your menu by visiting the website, http://www.ars.usda.gov/Services/docs.htm?docid=17032. Follow your diet plan. Record some basic health parameters, such as blood pressure and body weight, before and after following your menu plan. Assess how you feel in general after following the diet. Are you less tired or more? Are you irritable or happy? Did you exercise with more intensity or less?

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7: VITAMINS

A vitamin is an organic compound and a vital nutrient that an organism requires in limited amounts. An organic chemical compound (or related set of compounds) is called a vitamin when the organism cannot synthesize the compound in sufficient quantities, and it must be obtained through the diet; thus, the term "vitamin" is conditional upon the circumstances and the particular organism.

7.1: Vitamins- Basic Concepts

7.2: Fat Soluble Vitamins

7.2A: Vitamin A

7.2B: Vitamin D

7.2C: Vitamin E

7.2D: Vitamin K

7.3: Water Soluble Vitamins

7.3A: Vitamin B_1 (Thiamine)

7.3B: Vitamin B_2 (Riboflavin)

7.3C: Vitamin B_3 (Niacin)

7.3D: Vitamin B_5 (Pantothenic acid)

7.3E: Vitamin B_6 (Pyridoxine)

7.3F: Vitamin B_7 (Biotin)

7.3G: Vitamin B_9 (Folic acid)

7.3H: Vitamin B_{12} (Cobalamin)

7.3I: Vitamin C (Ascorbic acid)

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7.1: Vitamins- Basic Concepts

Skills to Develop

- Define vitamin
- Know the difference between fat soluble and water soluble vitamins
- Recognize the names of each of the 13 vitamins
- For each vitamin, know what the vitamin does and what happens to the human body if: the vitamin is too low in the diet for too long (deficiency); the vitamin is too high in the diet for too long (toxicity) and be able to list some food sources that are rich in each of the vitamins.

Vitamins are organic compounds (meaning they contain Carbon) and they are vital nutrients that organisms require in limited amounts. Just like other essential nutrients, vitamins must be obtained from the diet since the organism can not make them (or can not make enough of them) for survival. Interestingly, not all organisms have the same vitamin requirements. For example, ascorbic acid (one form of vitamin C) is a vitamin for humans, because the human body can not make it for us, but most all other animals have the ability to make this vitamin for themselves.

Thirteen vitamins are universally recognized. Some researchers believe there are more vitamins that have yet to be discovered. Vitamins are classified as either: fat soluble (will dissolve in oil) or water soluble (will dissolve in water). Only four of the vitamins: A, D, E and K are fat soluble. The other 9 vitamins are water soluble, including: vitamin C and all of the B vitamins (Riboflavin, Niacin, Thiamin, B_6, Folate, B_{12}, Pantothenic Acid and Biotin). It is also important to note that, the term "vitamin" can refer to a number of compounds that all show the biological activity associated with a particular vitamin. For example, "vitamin A", includes the compounds: retinal, retinol, retinoic acid and four known carotenoids. All of these compounds can be converted into active vitamin A in the body and are therefore considered to be precursors to vitamin A.

Vitamins have diverse biochemical functions. Most of the vitamins have several important functions, not just one. Some vitamins, such as vitamin D and A, have hormone-like functions where they travel through the blood and tell certain cell types what to do. Other vitamins function as antioxidants (vitamin E and vitamin C for example). The largest number of vitamins, the B complex vitamins, function primarily as "enzyme helpers" called **coenzymes**. Coenzymes are needed for enzymes to function.

Vitamins are needed in very small quantities. When you look at Table 7.1.1, at the amounts needed, you'll see that the vitamins are measured in microgram (µg) or milligram (mg) amounts. Remember that there are 1,000 mg in 1 gram and 1,000 micrograms in 1 milligram. Those are tiny quantities and yet we can not live without them! As you read about each of the vitamins and their important roles in human health, keep in mind there can be too much of a good thing. These days, people sometimes choose to take large doses of vitamin supplements. Large doses of vitamin supplements can make it easy to get to toxic amounts of vitamins. I encourage you to think of vitamins as being on a continuum where you can be deficient (too low), just right, or toxic (too high). If you are just a little deficient you may only be able to detect the deficiency with a blood test but if you are deficient long enough and severe enough, systems of the body will eventually begin to lose function and you will see signs and symptoms overtly. At that stage it is called a "deficiency disease". If a deficiency disease is caught early enough it can usually be reversed by giving the person the vitamin they were deficient in but in some cases the damage that has been done is too severe and can not be reversed.

Exercise

Please click on the vitamin name below and you will be linked to a Wikipedia article to learn about that vitamin. Keep in mind, for quiz/exam purposes, you're looking for: function (what does the vitamin do?), deficiency symptoms (what happens if I'm too low for too long), toxicity symptoms (what happens if I have too much for too long?) and food sources (what can I eat to get more of this vitamin) for each of the 13 vitamins.

Table 7.1.1***:*** *List of vitamins*

Vitamin generic descriptor name	Vitamin chemical name(s)	Solubility (fat or water)	Recommended dietary allowances (male, age 19–70)	Deficiency disease	Upper Intake Level (UL/day)	Overdose disease	Food sources
Vitamin A	Retinol, retinal, and four carotenoids including beta carotene	Fat	900 µg	Night blindness, hyperkeratosis, and keratomalacia	3,000 µg	Hypervitaminosis A	Liver, orange, ripe yellow fruits, leafy vegetables, carrots, pumpkin, squash, spinach, fish, soya milk, milk
Vitamin B_1	Thiamine	Water	1.2 mg	Beriberi, Wernicke-Korsakoff syndrome	N/D[10]	Drowsiness or muscle relaxation with large doses.	Pork, oatmeal, brown rice, vegetables, potatoes, liver, eggs
Vitamin B_2	Riboflavin	Water	1.3 mg	Ariboflavinosis, glossitis, angular stomatitis	N/D		Dairy products, bananas, popcorn, green beans, asparagus
Vitamin B_3	Niacin, niacinamide	Water	16.0 mg	Pellagra	35.0 mg	Liver damage (doses > 2g/day) and other problems	Meat, fish, eggs, many vegetables, mushrooms, tree nuts
Vitamin B_5	Pantothenic acid	Water	5.0 mg[13]	Paresthesia	N/D	Diarrhea; possibly nausea and heartburn.	Meat, broccoli, avocados
Vitamin B_6	Pyridoxine, pyridoxamine, pyridoxal	Water	1.3–1.7 mg	Anemia[15] peripheral neuropathy	100 mg	Impairment of proprioception, nerve damage (doses > 100 mg/day)	Meat, vegetables, tree nuts, bananas
Vitamin B_7	Biotin	Water	30.0 µg	Dermatitis, enteritis	N/D		Raw egg yolk, liver, peanuts, leafy green vegetables
Vitamin B_9	Folic acid, folate, folinic acid	Water	400 µg	Megaloblastic anemia and deficiency during pregnancy is associated with birth defects, such as neural tube defects	1,000 µg	May mask symptoms of vitamin B_{12} deficiency; other effects.	Leafy vegetables, pasta, bread, cereal, liver
Vitamin B_{12}	Cyanocobalamin, hydroxocobalamin, methylcobalamin	Water	2.4 µg	Megaloblastic anemia[16]	N/D	Acne-like rash [causality is not conclusively established].	Meat and other animal products

Vitamin generic descriptor name	Vitamin chemical name(s)	Solubility (fat or water)	Recommended dietary allowances (male, age 19–70)	Deficiency disease	Upper Intake Level (UL/day)	Overdose disease	Food sources
Vitamin C	Ascorbic acid	Water	90.0 mg	Scurvy	2,000 mg	Vitamin C megadosage	Many fruits and vegetables, liver
Vitamin D	Cholecalciferol (D3), Ergocalciferol (D2)	Fat	10 µg[17]	Rickets and osteomalacia	50 µg	Hypervitaminosis D	Fish, eggs, liver, mushrooms
Vitamin E	Tocopherols, tocotrienols	Fat	15.0 mg	Deficiency is very rare; sterility in males and abortions in females, mild hemolytic anemia in newborn infants[18]	1,000 mg	Increased congestive heart failure seen in one large randomized study.	Many fruits and vegetables, nuts and seeds
Vitamin K	phylloquinone, menaquinones	Fat	120 µg	Bleeding diathesis	N/D	Increases coagulation in patients taking warfarin.	Leafy green vegetables such as spinach, egg yolks,

Health Effects

Vitamins are essential for the normal growth and development of a multicellular organism. Using the genetic blueprint inherited from its parents, a fetus begins to develop, at the moment of conception, from the nutrients it absorbs. It requires certain vitamins and minerals to be present at certain times. These nutrients facilitate the chemical reactions that produce among other things, skin, bone, and muscle. If there is serious deficiency in one or more of these nutrients, a child may develop a deficiency disease. Even minor deficiencies may cause permanent damage.[21]

For the most part, vitamins are obtained with food, but a few are obtained by other means. For example, microorganisms in the intestine — commonly known as "gut flora" — produce vitamin K and biotin, while one form of vitamin D is synthesized in the skin with the help of the natural ultraviolet wavelength of sunlight. Humans can produce some vitamins from precursors they consume. Examples include vitamin A, produced from beta carotene, and niacin, from the amino acid tryptophan.

Once growth and development are completed, vitamins remain essential nutrients for the healthy maintenance of the cells, tissues, and organs that make up a multicellular organism; they also enable a multicellular life form to efficiently use chemical energy provided by food it eats, and to help process the proteins, carbohydrates, and fats required for respiration.

Deficiencies

Humans must consume vitamins periodically but with differing schedules, to avoid deficiency. The human body's stores for different vitamins vary widely; vitamins A, D, and B_{12} are stored in significant amounts in the human body, mainly in the liver, and an adult human's diet may be deficient in vitamins A and D for many months and B_{12} in some cases for years, before developing a deficiency condition. However, vitamin B_3 (niacin and niacinamide) is not stored in the human body in significant amounts, so stores may last only a couple of weeks. For vitamin C, the first symptoms of scurvy in experimental studies of complete vitamin C deprivation in humans have varied widely, from a month to more than six months, depending on previous dietary history that determined body stores.

Deficiencies of vitamins are classified as either primary or secondary. A primary deficiency occurs when an organism does not get enough of the vitamin in its food. A secondary deficiency may be due to an underlying disorder that prevents or limits the absorption or use of the vitamin, due to a "lifestyle factor", such as smoking, excessive alcohol consumption, or the use

of medications that interfere with the absorption or use of the vitamin. People who eat a varied diet are unlikely to develop a severe primary vitamin deficiency. In contrast, restrictive diets have the potential to cause prolonged vitamin deficits, which may result in often painful and potentially deadly diseases.

Well-known human vitamin deficiencies involve thiamine (beriberi), niacin (pellagra), vitamin C (scurvy), and vitamin D (rickets). In much of the developed world, such deficiencies are rare; this is due to (1) an adequate supply of food and (2) the addition of vitamins and minerals to common foods, often called fortification. In addition to these classical vitamin deficiency diseases, some evidence has also suggested links between vitamin deficiency and a number of different disorders.

Side-effects

In large doses, some vitamins have documented side-effects that tend to be more severe with a larger dosage. The likelihood of consuming too much of any vitamin from food is remote, but overdosing (vitamin poisoning) from vitamin supplementation does occur. At high enough dosages, some vitamins cause side-effects such as nausea, diarrhea, and vomiting. When side-effects emerge, recovery is often accomplished by reducing the dosage. The doses of vitamins differ because individual tolerances can vary widely and appear to be related to age and state of health. In 2008, overdose exposure to all formulations of vitamins and multivitamin-mineral formulations was reported by 68,911 individuals to the American Association of Poison Control Centers (nearly 80% of these exposures were in children under the age of 6), leading to 8 "major" life-threatening outcomes, but no deaths.

Governmental regulation

Most countries place dietary supplements in a special category under the general umbrella of foods, not drugs. As a result, the manufacturer, and not the government, has the responsibility of ensuring that its dietary supplement products are safe before they are marketed. Regulation of supplements varies widely by country. In the United States, a dietary supplement is defined under the Dietary Supplement Health and Education Act of 1994.[55] There is no FDA approval process for dietary supplements, and no requirement that manufacturers prove the safety or efficacy of supplements introduced before 1994.[32][33] The Food and Drug Administration must rely on its Adverse Event Reporting System to monitor adverse events that occur with supplements.[56] In 2007, the US Code of Federal Regulations (CFR) Title 21, part III took effect, regulating GMP practices in the manufacturing, packaging, labeling, or holding operations for dietary supplements. Even though product registration is not required, these regulations mandate production and quality control standards (including testing for identity, purity and adulterations) for dietary supplements.[57] In the European Union, the Food Supplements Directive requires that only those supplements that have been proven safe can be sold without a prescription.[58] For most vitamins, pharmacopoeial standards have been established. In the United States, the United States Pharmacopeia (USP) sets standards for the most commonly used vitamins and preparations thereof. Likewise, monographs of the European Pharmacopoeia (Ph.Eur.) regulate aspects of identity and purity for vitamins on the European market.

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7.2: FAT SOLUBLE VITAMINS

Now that you know the basics of what vitamins are, let's talk about the Fat Soluble Vitamins (FSV's) specifically. There are only four FSV's: Vitamin A, Vitamin D, Vitamin E and Vitamin K. What makes them "fat soluble" is the fact that they dissolve in fats and oils but they won't dissolve in water. If you've ever seen a vitamin E capsule, you already know that inside the capsule is an oily substance containing vitamin E. The Fat soluble vitamins are present in many foods but they are especially high in foods like nuts and seeds that contain a high concentration of fats and oils. Though we will discuss each fat soluble vitamin separately, please keep in mind that in whole foods there are a variety of vitamins and minerals and other nutrients all working together. This is thought to be the reason that whole foods do such good things for the body whereas taking individual supplements doesn't usually benefit health and sometimes can be harmful. Many scientists and doctors (myself included) believe that it is the harmony of the nutrients coming in together that benefits our health and when we isolate an individual nutrient it cannot give the same benefits.

7.2A: Vitamin A

7.2B: Vitamin D

7.2C: Vitamin E

7.2D: Vitamin K

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7.2A: Vitamin A

Vitamin A is a fat-soluble vitamin that is stored in the liver. There are two types of vitamin A that are found in the diet.

- Preformed vitamin A is found in animal products such as meat, fish, poultry and dairy foods.
- Pro-vitamin A is found in plant-based foods such as fruits and vegetables. The most common type of pro-vitamin A is beta-carotene. Pro-vitamin A must be converted into active vitamin A by the body.

Vitamin A is also available in dietary supplements. It most often comes in the form of retinyl acetate or retinyl palmitate (preformed vitamin A), beta-carotene (pro-vitamin A) or a combination of preformed and pro-vitamin A.

Function of Vitamin A

Vitamin A helps form and maintain healthy skin, teeth, skeletal and soft tissue, mucus membranes, and skin. It is also known as retinol because it produces the pigments in the retina of the eye. Vitamin A promotes good vision, especially in low light. It may also be needed for reproduction and breast-feeding. Retinol is an active form of vitamin A. It is found in animal liver, whole milk, and some fortified foods. Carotenoids are dark-colored dyes (pigments) found in plant foods that can turn into a form of vitamin A. There are more than 500 known carotenoids. One such carotenoid is beta-carotene.

- Beta-carotene is an antioxidant. Antioxidants protect cells from damage caused by substances called free radicals. Free radicals are believed to contribute to certain chronic diseases and play a role in the aging processes.
- Diets containing food sources of carotenoids such as beta-carotene have been shown to reduce the risk for cancer.
- Beta-carotene supplements (isolated Beta-carotene in concentrated form) do not seem to reduce cancer risk.

YouTube Video

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Video $7.2A.1$***:*** *This video connects health-conscious individuals with important news and information in the fast-paced world of health. From recalls and outbreaks to diet, nutrition and fitness we cover everything you need to know about health, every day.*

Food Sources of Vitamin A

Vitamin A comes from animal sources, such as eggs, meat, fortified milk, cheese, cream, liver, kidney, cod, and halibut fish oil. However, all of these sources, except for skim milk that has been fortified with Vitamin A, are high in saturated fat and cholesterol. Some good sources of vitamin A are:

- Eggs (preformed vitamin A)
- Milk and other dairy products (preformed vitamin A)
- Orange and yellow vegetables and fruits (pro-vitamin A)
- Other sources of beta-carotene such as broccoli, spinach, and most dark green, leafy vegetables (pro-vitamin A)

The more intense the color of a fruit or vegetable, the higher the beta-carotene content. Vegetable sources of beta-carotene are cholesterol-free.

Side Effects of too much or too little Vitamin A

If you do not get enough vitamin A, you are at increased risk for eye problems. These include reversible night blindness and then non-reversible corneal damage known as xeropthalmia. Lack of vitamin A can lead to hyperkeratosis or dry, scaly skin. If you get too much vitamin A, you can become sick. Large doses of vitamin A can also cause birth defects.



Acute vitamin A poisoning most often occurs when an adult takes several hundred thousand IUs of vitamin A. Symptoms of chronic vitamin A poisoning may occur in adults who regularly take more than 25,000 IU a day. Babies and children are more sensitive to vitamin A, and can become sick after taking smaller doses of vitamin A or vitamin A-containing products such as retinol (found in skin creams). Large amounts of beta-carotene do not cause harm. However, high levels of beta-carotene can turn the skin yellow or orange. The skin color will return to normal once you reduce your intake of beta-carotene.

Recommendations for Vitamin A

The best way to get the daily requirement of essential vitamins is to eat a wide variety of fruits, vegetables, fortified dairy foods, legumes (dried beans), lentils, and whole grains.

The Food and Nutrition Board of the Institute of Medicine -- Dietary Reference Intakes (DRIs) Recommended Intakes for Individuals of Vitamin A:

Infants (average intake)

- 0 to 6 months: 400 micrograms per day (mcg/day)
- 7 to 12 months: 500 mcg/day

The Recommended Dietary Allowance (RDA) for vitamins is how much of each vitamin most people should get each day. The RDA for vitamins may be used as goals for each person.

Children (RDA)

- 1 to 3 years: 300 mcg/day
- 4 to 8 years: 400 mcg/day
- 9 to 13 years: 600 mcg/day

Adolescents and Adults (RDA)

- Males age 14 and older: 900 mcg/day
- Females age 14 and older: 700 mcg/day (770 during pregnancy and 1,300 mcg during lactation)

How much of each vitamin you need depends on your age and gender. Other factors, such as pregnancy and your health, are also important. Ask your health care provider what dose is best for you.

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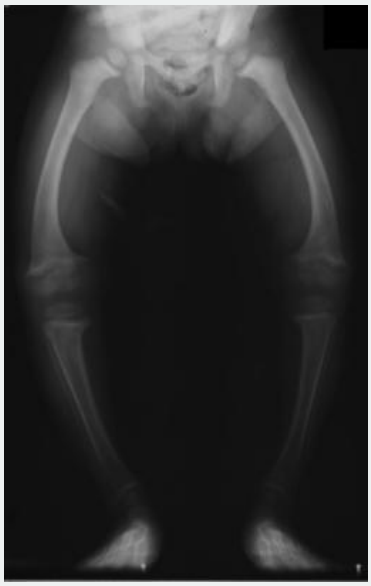
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7.2B: Vitamin D

Vitamin D refers to a group of fat-soluble secosteroids responsible for increasing intestinal absorption of calcium, iron, magnesium, phosphate, and zinc. In humans, the most important compounds in this group are vitamin D3 and vitamin D2. Cholecalciferol and ergocalciferol can be ingested from the diet and from supplements. Very few foods contain vitamin D; synthesis of vitamin D in the skin is the major natural source of the vitamin and is dependent on sun exposure (specifically UVB radiation).

Deficiency: Rickets

A diet deficient in vitamin D in conjunction with inadequate sun exposure causes osteomalacia (or rickets when it occurs in children), which is a softening of the bones. In the developed world, this is a rare disease. However, vitamin D deficiency has become a worldwide problem in the elderly and remains common in children and adults. Low blood calcifediol (25-hydroxy-vitamin D) can result from avoiding the sun. Deficiency results in impaired bone mineralization and bone damage which leads to bone-softening diseases, including rickets and osteomalacia.



Legs in a 2 year old child with rickets. (CC BY-SA 1.0; Michael L. Richardson, M.D.).

Rickets, a childhood disease, is characterized by impeded growth and soft, weak, deformed long bones that bend and bow under their weight as children start to walk. This condition is characterized by bow legs,] which can be caused by calcium or phosphorus deficiency, as well as a lack of vitamin D; today, it is largely found in low-income countries in Africa, Asia, or the Middle East and in those with genetic disorders such as pseudovitamin D deficiency rickets. Maternal vitamin D deficiency may cause overt bone disease from before birth and impairment of bone quality after birth. Nutritional rickets exists in countries with intense year-round sunlight such as Nigeria and can occur without vitamin D deficiency.

Vitamin D deficiency remains the main cause of rickets among young infants in most countries, because breast milk is low in vitamin D and social customs and climatic conditions can prevent adequate sun exposure. In sunny countries such as Nigeria, South Africa, and Bangladesh, where the disease occurs among older toddlers and children, it has been attributed to low dietary calcium intakes, which are characteristic of cereal-based diets with limited access to dairy products.

Synthesis in the Skin

Vitamin D_3 is produced photochemically from 7-dehydrocholesterol in the skin of most vertebrate animals, including humans.

The precursor of vitamin D_3, 7-dehydrocholesterol is produced in relatively large quantities. 7-Dehydrocholesterol reacts with UVB light at wavelengths between 270 and 300 nm, with peak synthesis occurring between 295 and 297 nm. These wavelengths are present in sunlight, as well as in the light emitted by the UV lamps in tanning beds (which produce ultraviolet primarily in the UVA spectrum, but typically produce 4% to 10% of the total UV emissions as UVB). Exposure to light through windows is insufficient because glass almost completely blocks UVB light.

Adequate amounts of vitamin D can be produced with moderate sun exposure to the face, arms and legs, averaging 5–30 minutes twice per week, or approximately 25% of the time for minimal sunburn. The darker the skin, and the weaker the sunlight, the more minutes of exposure are needed. Vitamin D overdose is impossible from UV exposure; the skin reaches an equilibrium where the vitamin degrades as fast as it is created.

Dietary Reference Intakes (USA)

Accordingly, the Dietary Reference Intake for vitamin D assumes no synthesis occurs and all of a person's vitamin D is from food intake. As vitamin D is synthesized in adequate amounts by most mammals exposed to sunlight, it is not strictly a vitamin, and may be considered a hormone as its synthesis and activity occur in different locations. Vitamin D has a significant role in calcium homeostasis and metabolism. Its discovery was due to effort to find the dietary substance lacking in rickets.

Different institutions propose different recommendations concerning daily amounts of the vitamin.The recommended daily intake of vitamin D *may* not be sufficient if sunlight exposure is limited. According to the United States Institute of Medicine, the recommended dietary allowances (RDA) of vitamin D are (Conversion : 1 µg = 40 IU and 0.025 µg = 1 IU) :

Age group	RDA (IU/day)
Infants 0–6 months	400*
Infants 6–12 months	400*
1–70 years	600 (15 µg/day)
71+ years	800 (20 µg/day)
Pregnant/Lactating	600 (15 µg/day)

- Asterisk for infants indicates adequate intake (AI) for infants, as an RDA has yet to be established for infants.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For vitamin D labeling purposes 100% of the Daily Value was 400 IU (10 µg), but as of May 2016 it has been revised to 800 IU (20 µg). A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 28, 2018 to comply with the change.

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7.2C: Vitamin E

Vitamin E refers to a group of compounds that include both tocopherols and tocotrienols. Of the many different forms of vitamin E, γ-tocopherol is the most common form found in the North American diet. γ-Tocopherol can be found in corn oil, soybean oil, margarine, and dressings. α-tocopherol, the most biologically active form of vitamin E, is the second-most common form of vitamin E in the diet. This variant can be found most abundantly in wheat germ oil, sunflower, and safflower oils. As a fat-soluble antioxidant, it interrupts the propagation of reactive oxygen species that spread through biological membranes or through a fat when its lipid content undergoes oxidation by reacting with more-reactive lipid radicals to form more stable products. Regular consumption of more than 1,000 mg (1,500 IU) of tocopherols per day may be expected to cause hypervitaminosis E, with an associated risk of vitamin K deficiency and consequently of bleeding problems.

Sample of α-tocopherol, one of the various forms of vitamin E

Functions

Vitamin E has many biological functions, including its role as a fat-soluble antioxidant.

- As an antioxidant, vitamin E acts as a peroxyl radical scavenger, disabling the production of damaging free radicals in tissues, by reacting with them to form a tocopheryl radical, which will then be reduced by a hydrogen donor (such as vitamin C) and thus return to its reduced state.[16] As it is fat-soluble, it is incorporated into cell membranes, which protects them from oxidative damage. Vitamin E has also found use as a commercial antioxidant in ultra high molecular weight polyethylene (UHMWPE) used in hip and knee implants by resisting oxidation.
- As an enzymatic activity regulator, for instance, protein kinase C (PKC), which plays a role in smooth muscle growth, can be inhibited by α-tocopherol. α-Tocopherol has a stimulatory effect on the dephosphorylation enzyme, protein phosphatase 2A, which in turn, cleaves phosphate groups from PKC, leading to its deactivation, bringing the smooth muscle growth to a halt.
- Vitamin E also has an effect on gene expression. Macrophages rich in cholesterol are found in atherosclerotic tissue. Scavenger receptor CD36 is a class B scavenger receptor found to be up-regulated by oxidized low density lipoprotein (LDL) and binds it. Treatment with α-tocopherol was found to downregulate the expression of the CD36 scavenger receptor gene and the scavenger receptor class A (SR-A) and modulates expression of the connective tissue growth factor (CTGF). The CTGF gene, when expressed, is responsible for the repair of wounds and regeneration of the extracellular tissue lost or damaged during atherosclerosis.
- Vitamin E also plays a role in eye and neurological functions, and inhibition of platelet coagulation.
- Vitamin E also protects lipids and prevents the oxidation of polyunsaturated fatty acids.

Although most vitamin E supplementation studies used α-tocopherol individually, this design of studying only one isoform of vitamin E may introduce errors in interpreting overall vitamin E effects; for example, using only α-tocopherol in studies of inflammation can reduce serum γ- and δ-tocopherol concentrations. Moreover, a 2013 review involving single long-term supplementation with α-tocopherol showed that many clinical studies revealed an inverse relationship between supplementation and cardiovascular disease risk or mortality, but other studies showed no effect.

Deficiency

Vitamin E deficiency can cause:

- spinocerebellar ataxia
- myopathies
- peripheral neuropathy
- ataxia
- skeletal myopathy
- retinopathy
- impairment of the immune response
- red blood cell destruction

Supplementation

Vitamin E supplementation has not been shown to have significant benefit for people who are healthy, and appears to be harmful. It does not improve blood sugar control in an unselected group of people with diabetes mellitus[35] or decrease the risk of stroke.[36] Daily supplementation of vitamin E does not decrease the risk of prostate cancer, and may increase it. Studies on its role in age-related macular degeneration are ongoing, though if it is of a combination of dietary antioxidants used to treat the condition it may increase the risk. Routine supplementation with vitamin E during pregnancy has been shown to offer no benefit to the mother or the child. Vitamin E has been reported to cause more side effects, such as abdominal pain in pregnant women, and also the increased risk of having early rupture of membranes at term.

Vitamin E, along with β-carotene and vitamin C, has no protective effect on reducing the risk of cataract, cataract extraction, progression of cataract, and slowing the loss of visual acuity.

Toxicity

The LD_{50}, or the toxic dose required to kill 50% of group of rats and mice, respectively is 4000 mg of VitaminE E/kg of rat and 4000 mg of Vitamin E/kg of mouse.[43] Comparatively speaking, and at lethal doses, Vitamin E is less toxic than table salt and acetaminophen and it is more toxic than ethanol and Vitamin C. Vitamin E can act as an anticoagulant, increasing the risk of bleeding problems. As a result, many agencies have set a tolerable upper intake levels (UL) at 1,000 mg (1,500 IU) per day.[1] In combination with certain other drugs such as aspirin, hypervitaminosis E can be life-threatening. Hypervitaminosis E may also counteract vitamin K, leading to a vitamin K deficiency.

Dietary Reference Intake

The Food and Nutrition Board (FNB) of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for vitamin E in 2000. The current EAR for vitamin E for women and men ages 14 and up is 12 mg/day. The RDA is 15 mg/day. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 15 mg/day. RDA for lactation equals 19 mg/day. For infants up to 12 months the Adequate Intake (AI) is 4–5 mg/day and for children ages 1–13 years the RDA increases with age from 6 to 11 mg/day. The FNB also sets Tolerable Upper Intake Levels (ULs) for vitamins and minerals when evidence is sufficient. In the case of vitamin E the UL is 1,000 mg/day.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For vitamin E labeling purposes 100% of the Daily Value was 30 mg, but as of May 2016 it has been revised to 15 mg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 28, 2018 to comply with the change.

Vitamin E and atherosclerosis

Atherosclerosis is a disease condition that refers to the buildup of plaque, which is a substance containing lipid and cholesterol (mainly the low-density lipoprotein or LDL cholesterol) on the inner layer of the arterial lumen. With the existing plaque, instead of being smooth and elastic, the layers become thickened and irregular and the lumen of the artery become narrower. This vessel-narrowing effect lead to a reduction of blood circulation and can lead to or worsen the condition of hypertension.

There are currently multiple theories explaining factors causing and affecting the cholesterol plaque build up within arteries with the most popular theory indicating that the rate of build up is affected by the oxidation of the LDL cholesterol. LDL cholesterol is one of the five major groups of lipoproteins with one of the physiological roles being lipid transportation. A typical LDL particle contain 2,700 fatty acid molecules and half of them are poly-unsaturated fatty acids, which are very oxidation sensitive. Once the oxidation of LDL occur, it will start a series of undesirable effects starting from the increase production of inflammatory cytokines by stimulating the endothelial cells and monocytes, followed by increased production of tissue factors, production of macrophages and monocytes, which eventually lead to the formation of foam cells and

> accelerated development of atherosclerosis. With the presence of adequate concentration of vitamin E, which is a very potent fat-soluble antioxidant, it can inhibit the oxidation of LDL, and this inhibition contributes protection against the development of atherosclerosis and can stabilize the existing plaque.

According to one meta-analysis, nine cohort studies showed that high intake of tocopherol was associated with a lower risk of cardiovascular diseases compared with lower intake. In this study, higher dietary, supplementation and combined vitamin E intake was also associated with lower disease incidents. In 1993, a study of 39,919 male health professionals aged 40 to 75 showed that consumption of more than 60 IU of vitamin E (any form) per day was associated with a lower incidence of coronary heart disease compared with less than 7.5 IU/day intake. This study also showed an inverse association between vitamin E supplementation and the incidence of heart disease.

A 2015 systematic review of clinical trials concluded that vitamin E supplementation alone improved endothelial function as determined by measurements of forearm blood flow, but when combined with vitamin C supplementation, it did not.[63] A meta-analysis of clinical trials showed no significant association between vitamin E supplementation and cardiovascular mortality.

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7.2D: Vitamin K

Vitamin K (Figure 1) is a group of structurally similar, fat-soluble vitamins the human body requires for complete synthesis of certain proteins that are needed for blood coagulation (blood clotting) and which the body also needs for controlling the binding of calcium in bones and other tissues. The vitamin K-related modification of the proteins allows them to bind calcium ions, which they cannot do otherwise.

In menaquinone, the side chain is composed of a varying number of isoprenoid residues. The most common number of these residues is four, since animal enzymes normally produce menaquinone-4 from plant phylloquinone. The three synthetic forms of vitamin K are vitamins K_3 (menadione), K_4, and K_5, which are used in many areas, including the pet food industry (vitamin K_3) and to inhibit fungal growth (vitamin K_5).

Figure 1: (left) Vitamin K_1 (phylloquinone) – both forms of the vitamin contain a functional naphthoquinone ring and an aliphatic side chain. Phylloquinone has a phytyl side chain. (right) Vitamin K_2 (menaquinone).

The MK-4 form of vitamin K_2 is produced by conversion of vitamin K_1 in the testes, pancreas, and arterial walls. While major questions still surround the biochemical pathway for this transformation, the conversion is not dependent on gut bacteria, as it occurs in germ-free rats and in parenterally-administered K_1in rats. In fact, tissues that accumulate high amounts of MK-4 have a remarkable capacity to convert up to 90% of the available K_1 into MK-4. There is evidence that the conversion proceeds by removal of the phytyl tail of K_1 to produce menadione as an intermediate, which is then condensed with an activated geranylgeranyl moiety (see also prenylation) to produce vitamin K_2 in the MK-4 (menatetrione) form.

Health effects of Vitamin K

Without vitamin K, blood coagulation is seriously impaired, and uncontrolled bleeding occurs. Preliminary clinical research indicates that deficiency of vitamin K may weaken bones, potentially leading to osteoporosis, and may promote calcification of arteries and other soft tissues. Our main sources of vitamin K are from leafy green vegetables and from the production by bacteria in our large intestine.

- **Osteoporosis**: A review of 2014 concluded that there is positive evidence that monotherapy using MK-4, one of the forms of Vitamin K_2, reduces fracture incidence in post-menopausal women with osteoporosis, and suggested further research on the combined use of MK-4 with bisphosphonates. In contrast, an earlier review article of 2013 concluded that there is no good evidence that vitamin K supplementation helps prevent osteoporosis or fractures in postmenopausal women. A Cochrane systematic review of 2006 suggested that supplementation with Vitamin K_1 and with MK4 reduces bone loss; in particular, a strong effect of MK-4 on incident fractures among Japanese patients was emphasized. A review article of 2016 suggested to consider, as one of several measures for bone health, increasing the intake of foods rich in vitamins K_1 and K_2.
- **Cardiovascular health:** Adequate intake of vitamin K is associated with the inhibition of arterial calcification and stiffening, but there have been few interventional studies and no good evidence that vitamin K supplementation is of any benefit in the primary prevention of cardiovascular disease. One 10-year population study, the Rotterdam Study, did show a clear and significant inverse relationship between the highest intake levels of menaquinone (mainly MK-4 from eggs and meat, and MK-8 and MK-9 from cheese) and cardiovascular disease and all-cause mortality in older men and women.
- **Cancer**: Vitamin K has been promoted in supplement form with claims it can slow tumor growth; there is however no good medical evidence that supports such claims.
- **Coumarin poisoning:** Vitamin K is part of the suggested treatment regime for poisoning by rodenticide (coumarin poisoning).

Although allergic reaction from supplementation is possible, no known toxicity is associated with high doses of the phylloquinone (vitamin K_1) or menaquinone (vitamin K_2) forms of vitamin K, so no tolerable upper intake level (UL) has been set. Blood clotting (coagulation) studies in humans using 45 mg per day of vitamin K2 (as MK-4)[12] and even up to 135 mg

per day (45 mg three times daily) of K2 (as MK-4),[13] showed no increase in blood clot risk. Even doses in rats as high as 250 mg/kg, body weight did not alter the tendency for blood-clot formation to occur. Unlike the safe natural forms of vitamin K_1 and vitamin K_2 and their various isomers, a synthetic form of vitamin K, vitamin K3 (menadione), is demonstrably toxic at high levels. The U.S. FDA has banned this form from over-the-counter sale in the United States because large doses have been shown to cause allergic reactions, hemolytic anemia, and cytotoxicity in liver cells.

Phylloquinone (K_1) or menaquinone (K_2) are capable of reversing the anticoagulant activity of the anticoagulant warfarin (tradename Coumadin). Warfarin works by blocking recycling of vitamin K, so that the body and tissues have lower levels of active vitamin K, and thus a deficiency of vitamin K. Supplemental vitamin K (for which oral dosing is often more active than injectable dosing in human adults) reverses the vitamin K deficiency caused by warfarin, and therefore reduces the intended anticoagulant action of warfarin and related drugs. Sometimes small amounts of vitamin K are given orally to patients taking warfarin so that the action of the drug is more predictable. The proper anticoagulant action of the drug is a function of vitamin K intake and drug dose, and due to differing absorption must be individualized for each patient. The action of warfarin and vitamin K both require two to five days after dosing to have maximum effect, and neither warfarin or vitamin K shows much effect in the first 24 hours after they are given.

Absorption and Dietary Need

Previous theory held that dietary deficiency is extremely rare unless the small intestine was heavily damaged, resulting in malabsorption of the molecule. Another at-risk group for deficiency were those subject to decreased production of K_2 by normal intestinal microbiota, as seen in broad spectrum antibiotic use. **Taking broad-spectrum antibiotics can reduce vitamin K production in the gut by nearly 74% in people compared with those not taking these antibiotics**. Diets low in vitamin K also decrease the body's vitamin K concentration. Those with chronic kidney disease are at risk for vitamin K deficiency, as well as vitamin D deficiency, and particularly those with the apoE4 genotype. Additionally, in the elderly there is a reduction in vitamin K_2 production. Like other lipid-soluble vitamins (A, D and E), vitamin K is stored in the fatty tissue of the human body.

The National Academy of Medicine (NAM) updated an estimate of what constitutes an Adequate Intake (AI) for vitamin K in 2001. The NAM does not distinguish between K_1 and K_2 – both are counted as vitamin K. At that time there was not sufficient evidence to set the more rigorous Estimated Average Requirement (EAR) or recommended dietary allowance (RDA) given for most of the essential vitamins and minerals. The current daily AIs for vitamin K for adult women and men are 90 µg and 120 µg respectively. The AI for pregnancy and lactation is 90 µg. For infants up to 12 months the AI is 2–2.5 µg, and for children aged 1 to 18 years the AI increases with age from 30 to 75 µg. As for safety, the FNB also sets tolerable upper intake levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of vitamin K no UL is set, as evidence for adverse effects is not sufficient. Collectively EARs, RDAs, AIs and ULs are referred to as dietary reference intakes.

For U.S. food and dietary supplement labeling purposes, the amount in a serving is expressed as a percentage of daily value (%DV). For vitamin K labeling purposes the daily value was 80 µg, but as of May 2016 it has been revised upwards to 120 µg. A table of the pre-change adult daily values is provided at Reference Daily Intake (Table $7.2D.1$). Food and supplement companies have until 28 July 2018 to comply with the change.

Deficiency

Average diets are usually not lacking in vitamin K, and primary deficiency is rare in healthy adults. Newborn infants are at an increased risk of deficiency. Other populations with an increased prevalence of vitamin K deficiency include those who suffer from liver damage or disease (e.g. alcoholics), cystic fibrosis, or inflammatory bowel diseases, or have recently had abdominal surgeries. Secondary vitamin K deficiency can occur in people with bulimia, those on stringent diets, and those taking anticoagulants. Other drugs associated with vitamin K deficiency include salicylates, barbiturates, and cefamandole, although the mechanisms are still unknown. Vitamin K_1 deficiency can result in coagulopathy, a bleeding disorder. Symptoms of K_1 deficiency include anemia, bruising, nosebleeds and bleeding of the gums in both sexes, and heavy menstrual bleeding in women.

Table *7.2D.1: Vitamin K*

Food	Serving size	Vitamin K_1 (µg)		Food	Serving size	Vitamin K_1 (µg)
Kale, cooked	$^1/_2$ cup	531		Parsley, raw	$^1/_4$ cup	246
Spinach, cooked	$^1/_2$ cup	444		Spinach, raw	1 cup	145
Collards, cooked	$^1/_2$ cup	418		Collards, raw	1 cup	184
Swiss chard, cooked	$^1/_2$ cup	287		Swiss chard, raw	1 cup	299
Mustard greens, cooked	$^1/_2$ cup	210		Mustard greens, raw	1 cup	279
Turnip greens, cooked	$^1/_2$ cup	265		Turnip greens, raw	1 cup	138
Broccoli, cooked	1 cup	220		Broccoli, raw	1 cup	89
Brussels sprouts, cooked	1 cup	219		Endive, raw	1 cup	116
Cabbage, cooked	$^1/_2$ cup	82		Green leaf lettuce	1 cup	71
Asparagus	4 spears	48		Romaine lettuce, raw	1 cup	57
Table from "Important information to know when you are taking: Warfarin (Coumadin) and Vitamin K", Clinical Center, National Institutes of Health Drug Nutrient Interaction Task Force.						

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7.3: WATER SOLUBLE VITAMINS

Nine vitamins are considered water soluble, including: vitamin C and all of the B vitamins (Riboflavin, Niacin, Thiamin, B_6, Folate, B_{12}, Pantothenic Acid and Biotin). In contrast to the four Fat-Soluble Vitamins, Water-soluble vitamins dissolve easily in water and, in general, are readily excreted from the body, to the degree that urinary output is a strong predictor of vitamin consumption. Because they are not as readily stored, more consistent intake is important. Many types of water-soluble vitamins are synthesized by bacteria.

7.3A: Vitamin B_1 (Thiamine)

7.3B: Vitamin B_2 (Riboflavin)

7.3C: Vitamin B_3 (Niacin)

7.3D: Vitamin B_5 (Pantothenic acid)

7.3E: Vitamin B_6 (Pyridoxine)

7.3F: Vitamin B_7 (Biotin)

7.3G: Vitamin B_9 (Folic acid)

7.3H: Vitamin B_{12} (Cobalamin)

7.3I: Vitamin C (Ascorbic acid)

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7.3A: Vitamin B_1 (Thiamine)

Thiamine, also known as thiamin or vitamin B1, is a vitamin found in food and used as a dietary supplement. As a supplement it is used to treat and prevent thiamine deficiency and disorders that result from it, including beriberi, Korsakoff's syndrome, and Korsakoff's psychosis. Other uses include maple syrup urine disease and Leigh's disease. It is taken by mouth or by injection. Side effects are generally few. Allergic reactions including anaphylaxis may occur. Thiamine is in the B complex family. It is needed for the metabolism of carbohydrates.[1] As people are unable to make it, thiamine is an essential nutrient. Food sources include whole grains, meat, and fish.

Thiamine was discovered in 1897 and is on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system. Thiamine is available as a generic medication and over the counter. The wholesale cost in the developing world is about 2.17 USD per one gm vial. In the United States a month of replacement is less than 25 USD. Some countries require its addition to certain foods such as grains. Thiamine is used to treat thiamine deficiency which can prove fatal. In less-severe cases, nonspecific signs include malaise, weight loss, irritability and confusion.

Thiamine is a colorless organosulfur compound with a chemical formula $\mathrm{C_{12}H_{17}N_4OS}$ (Figure $7.3A.1$). Its structure consists of an aminopyrimidine and a thiazole ring linked by a methylene bridge. The thiazole is substituted with methyl and hydroxyethyl side chains. Thiamine is soluble in water, methanol, and glycerol and practically insoluble in less polar organic solvents. It is stable at acidic pH, but is unstable in alkaline solutions. Thiamine, which is a N-heterocyclic carbene, can be used in place of cyanide as a catalyst for benzoin condensation. Thiamine is unstable to heat, but stable during frozen storage.[citation needed] It is unstable when exposed to ultraviolet light[9] and gamma irradiation.

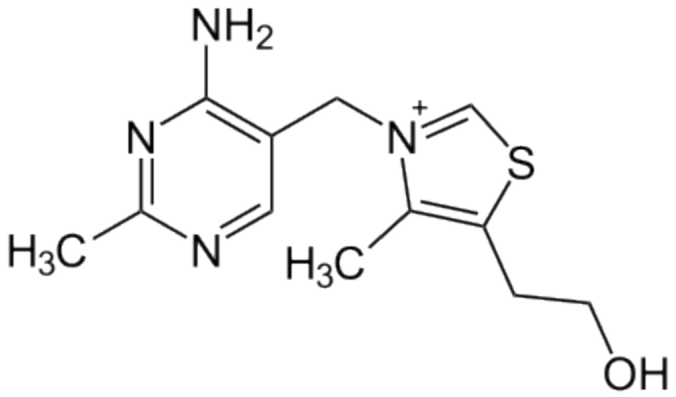


Figure $7.3A.1$*: Structure of thiamine*

Thiamin is found in a wide variety of processed and whole foods, with edible seeds, legumes, rice and processed foods, such as breakfast cereals, having among the highest contents. Some other foods naturally rich in thiamin are corn flour, pork, pecans and spinach.

Dietary Reference Intakes

The Food and Nutrition Board of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for thiamine in 1998. The current EARs for thiamine for women and men ages 14 and up are 0.9 mg/day and 1.0 mg/day, respectively; the RDAs are 1.1 and 1.2 mg/day. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 1.4 mg/day. RDA for lactation equals 1.4 mg/day. For infants up to 12 months the Adequate Intake (AI) is 0.2-0.3 mg/day. and for children ages 1–13 years the RDA increases with age from 0.5 to 0.9 mg/day.

As for safety, the Food and Nutrition Board of the U.S. Institute of Medicine sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of thiamine there is no UL, as there is no human data for adverse effects from high doses. The European Food Safety Authority reviewed the same safety question and also reached the conclusion that there was not sufficient evidence to set a UL for thiamine. Collectively the EARs, RDAs and ULs are referred to as Dietary

Reference Intakes.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For thiamine labeling purposes 100% of the Daily Value was 1.5 mg, but as of May 2016 it has been revised to 1.2 mg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 28, 2018 to comply with the change.

Antagonists

Thiamine in foods can be degraded in a variety of ways. Sulfites, which are added to foods usually as a preservative, will attack thiamine at the methylene bridge in the structure, cleaving the pyrimidine ring from the thiazole ring. The rate of this reaction is increased under acidic conditions. Thiamine is degraded by thermolabile thiaminases (present in raw fish and shellfish). Some thiaminases are produced by bacteria. Bacterial thiaminases are cell surface enzymes that must dissociate from the membrane before being activated; the dissociation can occur in ruminants under acidotic conditions. Rumen bacteria also reduce sulfate to sulfite, therefore high dietary intakes of sulfate can have thiamine-antagonistic activities.

Plant thiamine antagonists are heat-stable and occur as both the ortho- and para-hydroxyphenols. Some examples of these antagonists are caffeic acid, chlorogenic acid, and tannic acid. These compounds interact with the thiamine to oxidize the thiazole ring, thus rendering it unable to be absorbed. Two flavonoids, quercetin and rutin, have also been implicated as thiamine antagonists.

Absorption

Thiamine is released by the action of phosphatase and pyrophosphatase in the upper small intestine. At low concentrations, the process is carrier-mediated, and, at higher concentrations, absorption occurs via passive diffusion. Active transport is greatest in the jejunum and ileum; but, active transport can be inhibited by alcohol consumption and by folic deficiency. Decline in thiamine absorption occurs at intakes above 5 mg/day. The cells of the intestinal mucosa have thiamine pyrophosphokinase activity, but it is unclear as to whether the enzyme is linked to active absorption. The majority of thiamine present in the intestine is in the pyrophosphorylated form ThDP, but when thiamine arrives on the serosal side of the intestine it is often in the free form. The uptake of thiamine by the mucosal cell is likely coupled in some way to its phosphorylation/dephosphorylation. On the serosal side of the intestine, evidence has shown that discharge of the vitamin by those cells is dependent on Na^+-dependent ATPase.

Uptake of thiamine by cells of the blood and other tissues occurs via active transport and passive diffusion. The brain requires much more thiamine than other tissues of the body. Much of ingested thiamine never reaches the brain because of passive diffusion and the blood–brain barrier. About 80% of intracellular thiamine is phosphorylated and most is bound to proteins. In some tissues, thiamine uptake and secretion appears to be mediated by a soluble thiamine transporter that is dependent on Na^+ and a transcellular proton gradient.

Human storage of thiamine is about 25 to 30 mg, with the greatest concentrations in skeletal muscle, heart, brain, liver, and kidneys. ThMP and free (unphosphorylated) thiamine is present in plasma, milk, cerebrospinal fluid, and, it is presumed, all extracellular fluids. Unlike the highly phosphorylated forms of thiamine, ThMP and free thiamine are capable of crossing cell membranes. Thiamine contents in human tissues are less than those of other species.

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7.3B: Vitamin B_2 (Riboflavin)

Riboflavin, also known as vitamin B_2, is a vitamin found in food and used as a dietary supplement. As a supplement it is used to prevent and treat riboflavin deficiency and prevent migraines. It may be given by mouth or injection. It is nearly always well tolerated. Normal doses are safe during pregnancy. Riboflavin is in the vitamin B group. It is required by the body for cellular respiration. Food sources include eggs, green vegetables, milk, and meat. Riboflavin was discovered in 1920, isolated in 1933, and first made in 1935. It is on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system. Riboflavin is available as a generic medication and over the counter. In the United States a month of supplements costs less than 25 USD. Some countries require its addition to grains.



A solution of riboflavin. (CC BY-SA 4.0; PatríciaR)

Riboflavin has been used in several clinical and therapeutic situations. For over 30 years, riboflavin supplements have been used as part of the phototherapy treatment of neonatal jaundice. The light used to irradiate the infants breaks down not only bilirubin, the toxin causing the jaundice, but also the naturally occurring riboflavin within the infant's blood, so extra supplementation is necessary.

Riboflavin functions as a coenzyme, meaning that it is required for enzymes (proteins) to perform normal physiological actions. Specifically, the active forms of riboflavin flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) function as cofactors for a variety of flavoproteine enzyme reactions:

- Flavoproteins of electron transport chain, including FMN in Complex I and FAD in Complex II
- FAD is required for the production of pyridoxic acid from pyridoxal (vitamin B_6) by pyridoxine 5'-phosphate oxidase
- The primary coenzyme form of vitamin B_6 (pyridoxal phosphate) is FMN dependent
- Oxidation of pyruvate, α-ketoglutarate, and branched-chain amino acids requires FAD in the shared E3 portion of their respective dehydrogenase complexes
- Fatty acyl CoA dehydrogenase requires FAD in fatty acid oxidation
- FAD is required to convert retinol (vitamin A) to retinoic acid via cytosolic retinal dehydrogenase
- Synthesis of an active form of folate (5-methyltetrahydrofolate) from 5,10-methylenetetrahydrofolate by Methylenetetrahydrofolate reductase is $FADH_2$ dependent
- FAD is required to convert tryptophan to niacin (vitamin B_3)
- Reduction of the oxidized form of glutathione (GSSG) to its reduced form (GSH) by Glutathione reductase is FAD dependent

For the molecular mechanism of action see main articles Flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD)

Dietary Sources

Food and beverages that provide riboflavin without fortification are milk, cheese, eggs, leaf vegetables, liver, kidneys, legumes,

mushrooms, and almonds. The milling of cereals results in considerable loss (up to 60%) of vitamin B_2, so white flour is enriched in some countries such as US by addition of the vitamin. The enrichment of bread and ready-to-eat breakfast cereals contributes significantly to the dietary supply of vitamin B_2. Polished rice is not usually enriched, because the vitamin's yellow color would make the rice visually unacceptable to the major rice-consumption populations. However, most of the flavin content of whole brown rice is retained if the rice is steamed (parboiled) prior to milling. This process drives the flavins in the germ and aleurone layers into the endosperm. Free riboflavin is naturally present in foods along with protein-bound FMN and FAD. Bovine milk contains mainly free riboflavin, with a minor contribution from FMN and FAD. In whole milk, 14% of the flavins are bound noncovalently to specific proteins. Egg white and egg yolk contain specialized riboflavin-binding proteins, which are required for storage of free riboflavin in the egg for use by the developing embryo.

Dietary Reference Intake

In humans, there is no evidence for riboflavin toxicity produced by excessive intakes, in part because it has lower water solubility than other B vitamins, because absorption becomes less efficient as doses increase, and because what excess is absorbed is excreted via the kidneys into urine. Even when 400 mg of riboflavin per day was given orally to subjects in one study for three months to investigate the efficacy of riboflavin in the prevention of migraine headache, no short-term side effects were reported. Although toxic doses can be administered by injection, any excess at nutritionally relevant doses is excreted in the urine, imparting a bright yellow color when in large quantities.

The Food and Nutrition Board of the U.S. Institute of Medicine sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of riboflavin there is no UL, as there is no human data for adverse effects from high doses. The European Food Safety Authority reviewed the same safety question and also reached the conclusion that there was not sufficient evidence to set a UL for riboflavin.

The Food and Nutrition Board of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) in 1998. The current EARs for riboflavin for women and men ages 14 and up are 0.9 mg/day and 1.1 mg/day, respectively; the RDAs are 1.1 and 1.3 mg/day. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 1.4 mg/day. RDA for lactation equals 1.6 mg/day. For infants up to 12 months the Adequate Intake (AI) is 0.3-0.4 mg/day and for children ages 1–13 years the RDA increases with age from 0.5 to 0.9 mg/day. Collectively the EARs, RDAs and ULs (see Toxicity) are referred to as Dietary Reference Intakes.[18][26]

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For riboflavin labeling purposes 100% of the Daily Value was 1.7 mg, but as of May 2016 it has been revised to 1.3 mg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 2018 to comply with the change.

Riboflavin Deficiency

Mild deficiencies can exceed 50% of the population in third world countries and in refugee situations. Deficiency is uncommon in the United States and in other countries that have wheat flour, bread, pasta, corn meal or rice enrichment regulations. In the U.S., starting in the 1940s, flour, corn meal and rice have been fortified with B vitamins as a means of restoring some of what is lost in milling, bleaching and other processing. For adults 20 and older, average intake from food and beverages is 1.8 mg/day for women and 2.5 mg/day for men. An estimated 23% consume a riboflavin-containing dietary supplement that provides on average 10 mg. The U.S. Department of Health and Human Services conducts National Health and Nutrition Examination Survey every two years and reports food results in a series of reports referred to as "What We Eat In America." From NHANES 2011–2012, the latest for which data has been reported, estimates are that 8% of women and 3% of men consume less than the RDA. When compared to the lower Estimated Average Requirements, fewer than 3% do not achieve the EAR level. However, anyone choosing a gluten-free or low gluten diet should as a precaution take a multi-vitamin/mineral dietary supplement which provides 100% DV for riboflavin and other B vitamins.

Riboflavin deficiency (also called ariboflavinosis) results in stomatitis including painful red tongue with sore throat, chapped and fissured lips (cheilosis), and inflammation of the corners of the mouth (angular stomatitis). There can be oily scaly skin rashes on the scrotum, vulva, philtrum of the lip, or the nasolabial folds. The eyes can become itchy, watery, bloodshot and sensitive to light. Due to interference with iron absorption, even mild to moderate riboflavin deficiency results in an anemia with normal cell size and normal hemoglobin content (i.e. normochromic normocytic anemia). This is distinct from anemia

caused by deficiency of folic acid (B_9) or cyanocobalamin (B_{12}), which causes anemia with large blood cells (megaloblastic anemia). Deficiency of riboflavin during pregnancy can result in birth defects including congenital heart defects and limb deformities.

The stomatitis symptoms are similar to those seen in pellagra, which is caused by niacin (B_3) deficiency. Therefore, riboflavin deficiency is sometimes called "pellagra sine pellagra" (pellagra without pellagra), because it causes stomatitis but not widespread peripheral skin lesions characteristic of niacin deficiency.

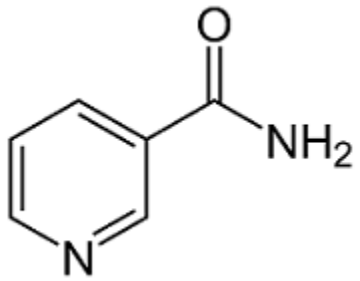
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7.3C: Vitamin B_3 (Niacin)

Niacin, also known as vitamin B_3 or nicotinic acid, is an organic compound with the formula $C_6H_5NO_2$ and, depending on the definition used, one of the 20 to 80 essential human nutrients. Pharmaceutical and supplemental niacin are primarily used to treat hypercholesterolemia (high cholesterol) and pellagra (niacin deficiency). Insufficient niacin in the diet can cause nausea, skin and mouth lesions, anemia, headaches, and tiredness. The lack of niacin may also be observed in pandemic deficiency disease, which is caused by a lack of five crucial vitamins (niacin, vitamin C, thiamin, vitamin D, and vitamin A) and is usually found in areas of widespread poverty and malnutrition. Niacin is provided in the diet from a variety of whole and processed foods, with highest contents in fortified packaged foods and meat from various animal sources.



Structure of nicotinamide (niacinamide).

Niacin supplementation has not been found useful for decreasing the risk of cardiovascular disease in those already on a statin, but appears to be effective in those not taking a statin.[Although niacin and nicotinamide are identical in their vitamin activity, nicotinamide does not have the same pharmacological effects (lipid modifying effects) as niacin. Nicotinamide does not reduce cholesterol or cause flushing. As the precursor for NAD and NADP, niacin is also involved in DNA repair.

Dietary Reference Intake

The Food and Nutrition Board of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for niacin in 1998. The current EARs for niacin for women and men ages 14 and up are 11 mg/day and 12 mg/day, respectively; the RDAs are 14 and 16 mg/day, respectively. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 18 mg/day. RDA for lactation equals 17 mg/day. For infants up to 12 months the Adequate Intake (AI) is 2–4 mg/day. and for children ages 1–13 years the RDA increases with age from 6 to 12 mg/day. As for safety, the Food and Nutrition Board also sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of niacin the UL is set at 35 mg/day.[11] The European Food Safety Authority reviewed the same safety question and set its UL at 10 mg/day.[12] Safety issues are presented at length in the Side Effects section. Collectively the EARs, RDAs, AIs and ULs are referred to as Dietary Reference Intakes.

For U.S. food and dietary supplement labeling purposes, the amount in a serving is expressed as a percent of Daily Value (%DV). For niacin labeling purposes, 100% of the Daily Value was 20 mg, but as of May 2016 it has been revised to 16 mg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 28, 2018, to comply with the change.

Dietary Sources

Niacin is found in a variety of whole and processed foods, including fortified packaged foods, meat from various animal sources, seafoods, and spices. Among whole food sources with the highest niacin content per 100 grams:

Meats

- cooked skipjack tuna, 18.8 mg
- cooked light meat turkey, 11.8 mg

- cooked, lean ground pork, 11.1 mg
- cooked venison, 10.8 mg
- cooked, lean veal, 8.0 mg

Plant foods and spices

- sesame seed flour, 12.5 mg
- ground ginger, 9.6 mg
- dried tarragon, 9.0 mg
- dried, green sweet peppers, 7.4 mg
- grilled portabella mushrooms, 6.2 mg
- roasted sunflower seeds, 4.1 mg
- dehydrated apricots, 3.6 mg
- baked potato, 3.1 mg

Fortified breakfast cereals have among the highest niacin contents (more than 20 mg per 100 grams).[13] Whole grain flours, such as from wheat, rice, barley or corn, and pasta have niacin contents in a range of 3–10 mg per 100 grams.

Deficiencies

Between 1906 and 1940 more than 3 million Americans were affected by pellagra with more than 100,000 deaths. Dr. Joseph Goldberger was assigned to study pellagra by the Surgeon General of the United States and produced good results. In the late 1930s, studies by Dr. Tom Spies, Marion Blankenhorn, and Clark Cooper established that niacin cured pellagra in humans. The disease was greatly reduced as a result.

At present, niacin deficiency is sometimes seen in developed countries, and it is usually apparent in conditions of poverty, malnutrition, and chronic alcoholism. It also tends to occur in areas where people eat maize (corn) as a staple food, since it is the only grain low in digestible niacin. A cooking technique called nixtamalization increases the bioavailability of niacin during maize meal/flour production.

A man with scurvy, which is caused by a chronic lack of vitamin B_3 in the diet

Mild niacin deficiency has been shown to slow metabolism, causing decreased tolerance to cold. Severe deficiency of niacin in the diet causes the disease pellagra, which is characterized by diarrhea, dermatitis, and dementia, as well as Casal's necklace lesions on the lower neck, hyperpigmentation, thickening of the skin, inflammation of the mouth and tongue, digestive disturbances, amnesia, delirium, and eventually death, if left untreated. Common psychiatric symptoms of niacin deficiency include irritability, poor concentration, anxiety, fatigue, restlessness, apathy, and depression. Studies have indicated that, in patients with alcoholic pellagra, niacin deficiency may be an important factor influencing both the onset and severity of this condition. Patients with alcoholism typically experience increased intestinal permeability, leading to negative health outcomes.

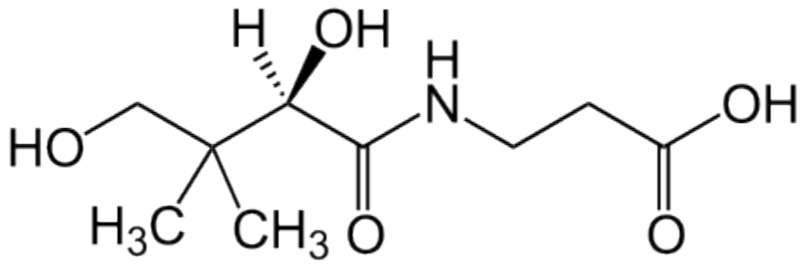
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7.3D: Vitamin B_5 (Pantothenic acid)

Pantothenic acid, also called vitamin B_5, is a water-soluble vitamin. Pantothenic acid is an essential nutrient. Animals require pantothenic acid to synthesize coenzyme-A (CoA), as well as to synthesize and metabolize proteins, carbohydrates, and fats. Pantothenic acid is the amide between pantoic acid and β-alanine. Its name derives from the Greek *pantothen*, meaning "from everywhere", and small quantities of pantothenic acid are found in nearly every food, with high amounts in fortified whole-grain cereals, egg yolks, liver and dried mushrooms. It is commonly found as its alcohol analog, the provitamin panthenol (pantothenol), and as calcium pantothenate.



Skeletal formula of (R)-pantothenic acid

Dietary Sources

Content of pantothenic acid varies among manufactured and natural foods, especially fortified ready-to-eat cereals, infant formulas, energy bars and dried foods. Major food sources of pantothenic acid are dried mushrooms, liver, dried egg yolks and sunflower seeds. Whole grains are another good source of the vitamin, but milling removes much of the pantothenic acid, as it is found in the outer layers of whole grains. In animal feeds, the most important sources are alfalfa, cereal, fish meal, peanut meal, molasses, mushrooms, rice, wheat bran, and yeasts.

Dietary Reference Intake

The Food and Nutrition Board of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for B vitamins in 1998. At that time there was not sufficient information to establish EARs and RDAs for pantothenic acid. In instances such as this, the Board sets Adequate Intakes (AIs), with the understanding that at some later date, AIs will be replaced by more exact information. As for safety, the FNB sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of pantothenic acid there is no UL, as there is insufficient human data to identify adverse effects from high doses. The European Food Safety Authority reviewed the same safety question and also reached the conclusion that there was not sufficient evidence to set a UL for pantothenic acid. Collectively the EARs, RDAs and ULs are referred to as Dietary Reference Intakes.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For pantothenic acid labeling purposes 100% of the Daily Value was 10 mg, but as of May 2016 it has been revised to 5 mg. Food and supplement companies have until July 2018 to comply with the change.

Age group	Age	Adequate intake
Infants	0–6 months	1.7 mg
Infants	7–12 months	1.8 mg
Children	1–3 years	2 mg
Children	4–8 years	3 mg
Children	9–13 years	4 mg

Age group	Age	Adequate intake
Adult men and women	14+ years	5 mg
Pregnant women	(vs. 5)	6 mg
Breastfeeding women	(vs. 5)	7 mg

Toxicity of pantothenic acid is unlikely. In fact, no Tolerable Upper Level Intake (UL) has been established for the vitamin. Large doses of the vitamin, when ingested, have no reported side effects and massive doses (e.g., 10 g/day) may only yield mild intestinal distress, and diarrhea at worst. It has been suggested, however, that high doses of pantothenic acid might worsen panic attacks in those with panic disorder by prolonging the duration until adrenal exhaustion. Pantothenic acid, at a human equivalent dose within the range of common supplementation, was shown to induce adrenal hyper-responsiveness to stress stimulation. There are also no adverse reactions known following parenteral (injected) or topical (skin) applications of the vitamin.

Absorption

When found in foods, most pantothenic acid is in the form of CoA or acyl carrier protein (ACP). For the intestinal cells to absorb this vitamin, it must be converted into free pantothenic acid. Within the lumen of the intestine, CoA and ACP are hydrolyzed into 4'-phosphopantetheine. The 4'-phosphopantetheine is then dephosphorylated into pantetheine. Pantetheinase, an intestinal enzyme, then hydrolyzes pantetheine into free pantothenic acid. Free pantothenic acid is absorbed into intestinal cells via a saturable, sodium-dependent active transport system. At high levels of intake, when this mechanism is saturated, some pantothenic acid may also be absorbed via passive diffusion. As intake increases 10-fold, however, absorption rate decreases to 10%.

Deficiency

Pantothenic acid deficiency is exceptionally rare and has not been thoroughly studied. In the few cases where deficiency has been seen (victims of starvation and limited volunteer trials), nearly all symptoms can be reversed with the return of pantothenic acid. Symptoms of deficiency are similar to other vitamin B deficiencies. There is impaired energy production, due to low CoA levels, which could cause symptoms of irritability, fatigue, and apathy.Acetylcholine synthesis is also impaired; therefore, neurological symptoms can also appear in deficiency; they include numbness, paresthesia, and muscle cramps. Deficiency in pantothenic acid can also cause hypoglycemia, or an increased sensitivity to insulin. Insulin receptors are acylated with palmitic acid when they do not want to bind with insulin. Therefore, more insulin will bind to receptors when acylation decreases, causing hypoglycemia. Additional symptoms could include restlessness, malaise, sleep disturbances, nausea, vomiting, and abdominal cramps. In a few rare circumstances, more serious (but reversible) conditions have been seen, such as adrenal insufficiency and hepatic encephalopathy.

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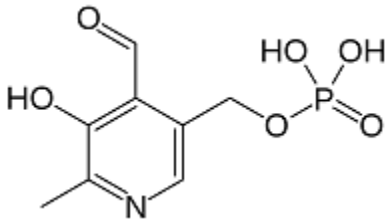
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7.3E: Vitamin B_6 (Pyridoxine)

Vitamin B_6 refers to a group of chemically similar compounds which can be interconverted in biological systems. Vitamin B_6 is part of the vitamin B group of essential nutrients. Its active form, pyridoxal 5′-phosphate, serves as a coenzyme in some 100 enzyme reactions in amino acid, glucose, and lipid metabolism. Several forms

- Pyridoxine 5′-phosphate (P5P)
- Pyridoxal (PL)
- Pyridoxal 5′-phosphate (PLP), the metabolically active form (sold as P-5-P vitamin supplement)
- Pyridoxamine (PM)
- Pyridoxamine 5′-phosphate (PMP)
- 4-Pyridoxic acid (PA), the catabolite which is excreted in urine
- Pyritinol, a semi-synthetic derivative of pyridoxine, where two pyridoxine moieties are bound by a disulfide bridge.

All forms except pyridoxic acid and pyritinol can be interconverted. Absorbed pyridoxamine is converted to PMP by pyridoxal kinase, which is further converted to PLP by pyridoxamine-phosphate transaminase or pyridoxine 5′-phosphate oxidase which also catalyzes the conversion of PNP to PLP. Pyridoxine 5′-phosphate oxidase is dependent on flavin mononucleotide (FMN) as a cofactor which is produced from riboflavin (vitamin B_2) i.e. in this biochemical pathway, dietary vitamin B_6 cannot be used without vitamin B_2.



Pyridoxine and Pyridoxamine

PLP, the metabolically active form of vitamin B6, is involved in many aspects of mcronutrient metabolism, neurotransmitter synthesis, histamine synthesis, hemoglobin synthesis and function, and gene expression. PLP generally serves as a coenzyme (cofactor) for many reactions including decarboxylation, transamination, racemization, elimination, replacement, and beta-group interconversion. The liver is the site for vitamin B6 metabolism.Amino acid metabolism PLP is a cofactor in the biosynthesis of five important neurotransmitters: serotonin, dopamine, epinephrine, norepinephrine, and gamma-aminobutyric acid (GABA). PLP is also involved in the synthesis of histamine.

Dietary Sources

Vitamin B_6 is widely distributed in foods in both its free and bound forms. Cooking, storage, and processing losses of vitamin B_6 vary and in some foods may be more than 50%, depending on the form of vitamin present in the food. Plant foods lose the least during processing, as they contain mostly pyridoxine, which is far more stable than the pyridoxal or pyridoxamine found in animal foods. For example, milk can lose 30–70% of its vitamin B_6 content when dried. Vitamin B_6 is found in the germ and aleurone layer of grains, and milling results in the reduction of this vitamin in white flour. The heating that occurs before most freezing and canning processes are other methods that may result in the loss of vitamin B_6 in foods.

Foods that contain large amounts of vitamin B6 include:

- fortified breakfast cereals
- pork
- turkey
- beef
- bananas
- chickpeas

- potatoes
- pistachios

Dietary Reference Intake

The Food and Nutrition Board (FNB) of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for vitamin B_6 in 1998. The current EARs for vitamin B_6 for women and men ages 14 and up increase with age from 1.0 to 1.3 mg/day and from 1.1 to 1.4 mg/day, respectively; the RDAs increase with age from 1.2 to 1.5 and from 1.3 to 1.7 mg/day, respectively. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 1.9 mg/day. RDA for lactation equals 2.0 mg/day. For infants up to 12 months the Adequate Intake (AI) is 0.1–0.3 mg/day. and for children ages 1–13 years the RDA increases with age from 0.5 to 1.0 mg/day. As for safety, the FNB sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of vitamin B_6 the UL is set at 100 mg/day. The European Food Safety Authority reviewed the same safety question and set its UL at 25 mg/day. Safety issues are presented at length in the Toxicity section.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of daily value (%DV). For vitamin B_6 labeling purposes 100% of the Daily Value was 2.0 mg, but as of May 2016 it has been revised to 1.7 mg. Food and supplement companies have until July 28, 2018 to comply with the change.

Absorption and excretion

Vitamin B_6 is absorbed in the jejunum and ileum by passive diffusion. With the capacity for absorption being so great, animals are able to absorb quantities much greater than necessary for physiological demands. The absorption of pyridoxal phosphate and pyridoxamine phosphate involves their dephosphorylation catalyzed by a membrane-bound alkaline phosphatase. Those products and nonphosphorylated forms in the digestive tract are absorbed by diffusion, which is driven by trapping of the vitamin as 5′-phosphates through the action of phosphorylation (by a pyridoxal kinase) in the jejunal mucosa. The trapped pyridoxine and pyridoxamine are oxidized to pyridoxal phosphate in the tissue.

The products of vitamin B_6 metabolism are excreted in the urine, the major product of which is 4-pyridoxic acid. An estimated 40–60% of ingested vitamin B_6 is oxidized to 4-pyridoxic acid. Several studies have shown that 4-pyridoxic acid is undetectable in the urine of vitamin B_6-deficient subjects, making it a useful clinical marker to assess the vitamin B_6 status of an individual. Other products of vitamin B_6metabolism excreted in the urine when high doses of the vitamin have been given include pyridoxal, pyridoxamine, and pyridoxine and their phosphates. A small amount of vitamin B_6 is also excreted in the feces.

Deficiencies

The classic clinical syndrome for vitamin B6 deficiency is a seborrhoeic dermatitis-like eruption, atrophic glossitis with ulceration, angular cheilitis, conjunctivitis, intertrigo, and neurologic symptoms of somnolence, confusion, and neuropathy (due to impaired sphingosine synthesis) and sideroblastic anemia (due to impaired heme synthesis).

Less severe cases present with metabolic disease associated with insufficient activities of the coenzyme PLP. The most prominent of the lesions is due to impaired tryptophan–niacin conversion. This can be detected based on urinary excretion of xanthurenic acid after an oral tryptophan load. Vitamin B6 deficiency can also result in impaired transsulfuration of methionine to cysteine. The PLP-dependent transaminases and glycogen phosphorylase provide the vitamin with its role in gluconeogenesis, so deprivation of vitamin B6 results in impaired glucose tolerance.

A deficiency of vitamin B6 alone is relatively uncommon and often occurs in association with other vitamins of the B complex. The elderly and alcoholics have an increased risk of vitamin B6 deficiency, as well as other micronutrient deficiencies. Evidence exists for decreased levels of vitamin B6 in women with type 1 diabetes and in patients with systemic inflammation, liver disease, rheumatoid arthritis, and those infected with HIV.

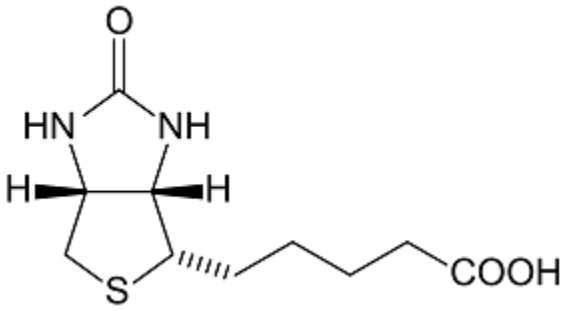
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7.3F: Vitamin B_7 (Biotin)

Biotin is a water-soluble B-vitamin, also called vitamin B7 and formerly known as vitamin H or coenzyme R.[2] It is composed of a ureido ring fused with a tetrahydrothiophene ring. A valeric acid substituent is attached to one of the carbon atoms of the tetrahydrothiophene ring. Biotin is a coenzyme for carboxylase enzymes, involved in the synthesis of fatty acids, isoleucine, and valine, and in gluconeogenesis. Biotin deficiency can be caused by inadequate dietary intake or inheritance of one or more inborn genetic disorders that affect biotin metabolism. Subclinical deficiency can cause mild symptoms, such as hair thinning or skin rash typically on the face. Neonatal screening for biotinidase deficiency began in the United States in 1984 and today many countries test for this disorder at birth. Individuals born prior to 1984 are unlikely to have been screened, thus the true prevalence of the disorder is unknown.



Skeletal formula of biotin

Biotin is necessary for cell growth, the production of fatty acids, and the metabolism of fats and amino acids. Biotin assists in various metabolic reactions involving the transfer of carbon dioxide. It may also be helpful in maintaining a steady blood sugar level. Biotin is often recommended as a dietary supplement for strengthening hair and nails, though scientific data supporting this outcome are weak. Nevertheless, biotin is found in many cosmetics and health products for the hair and skin.

Dietary Reference Intake

The Food and Nutrition Board of the U.S. Institute of Medicine updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for B vitamins in 1998. At that time there was not sufficient information to establish EARs and RDAs for biotin. In instances such as this, the Board sets Adequate Intakes (AIs), with the understanding that at some later date, AIs will be replaced by more exact information. The current AI for adults ages 19 and up is 30 µg/day. AI for pregnancy is 30 µg/day. AI for lactation is 35 µg/day. For infants up to 12 months the AI is 5-6 µg/day For children ages 1–18 years the AI increases with age from 8 to 25 µg/day.

As for safety, the FNB sets Tolerable Upper Intake Levels (known as ULs) for vitamins and minerals when evidence is sufficient. In the case of biotin there is no UL, as there is insufficient human data to identify adverse effects from high doses. The European Food Safety Authority reviewed the same safety question and also reached the conclusion that there was not sufficient evidence to set a UL for biotin.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For biotin labeling purposes 100% of the Daily Value was 300 µg, but as of May 2016 it has been revised to 30 µg to bring it into agreement with the AI. Food and supplement companies have until July 2018 to comply with the change.

Dietary Sources

Biotin is synthesized by intestinal bacteria, but there is a lack of good quality studies about how much biotin they provide. Biotin is stable at room temperature and isn't destroyed by cooking. Some of the best sources are (content per 100 grams):

- Brewer's yeast: 188.8 mcg

- Soybeans: 179.4 mcg
- Beef liver: 113.3 mcg
- Butter: 94.3 mcg
- Split peas: 77.7 mcg
- Sunflower seeds: 66 mcg
- Green peas/lentils: 40 mcg
- Peanuts/walnuts: 37.5 mcg
- Pecans: 27.75 mcg
- Eggs: 18.9 mcg

Egg whites contain a protein (avidin) that blocks the absorption of biotin, so people who regularly consume a large number of eggs may become biotin-deficient. The dietary biotin intake in Western populations has been estimated to be 35 to 70 micrograms per day (143–287 nmol per day). Biotin is also available in dietary supplements in which a dose of 30 micrograms meets 100% of the Daily Value for adults.

Deficiency

Biotin deficiency is rare. The amounts needed are small, a wide range of foods contain biotin, and intestinal bacteria synthesize biotin, which is then absorbed by the host animal. For that reason, statutory agencies in many countries, for example the USA and Australia, have not formally established a recommended daily intake of biotin. Instead, an Adequate Intake (AI) is identified based on the theory that average intake meets needs. A number of rare metabolic disorders exist in which an individual's metabolism of biotin is abnormal.

Biotin deficiency typically occurs from dietary absence of the vitamin. Consuming raw egg whites over months may result in biotin deficiency. Deficiency can be addressed with nutritional supplementation. Deficiency symptoms include:

- Brittle and thin fingernails
- Hair loss (alopecia)
- Conjunctivitis
- Dermatitis in the form of a scaly, red rash around the eyes, nose, mouth, and genital area.
- Neurological symptoms in adults, such as depression, lethargy, hallucination, and numbness and tingling of the extremities

The neurological and psychological symptoms can occur with only mild deficiencies. Dermatitis, conjunctivitis, and hair loss will generally occur only when deficiency becomes more severe. Individuals with hereditary disorders of biotin deficiency have evidence of impaired immune system function, including increased susceptibility to bacterial and fungal infections.

Pregnant women tend to have a high risk of biotin deficiency. Nearly half of pregnant women have abnormal increases of 3-hydroxyisovaleric acid, which reflects reduced status of biotin. Several studies have reported this possible biotin deficiency during the pregnancy may cause infants' congenital malformations, such as cleft palate. Mice fed with dried raw egg to induce biotin deficiency during the gestation resulted in up to 100% incidence of the infants' malnourishment. Infants and embryos are more sensitive to the biotin deficiency. Therefore, even a mild level of the mother's biotin deficiency that does not reach the appearance of physiological deficiency signs may cause a serious consequence in the infants.

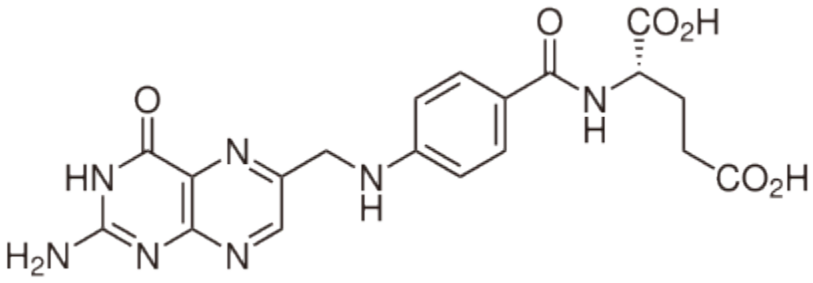
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7.3G: Vitamin B_9 (Folic acid)

Folic acid, another form of which is known as folate, is one of the B vitamins. The recommended daily intake level of folate is 400 micrograms from foods or dietary supplements. Folic acid is used to treat anemia caused by folic acid deficiency. It is also used as a supplement by women during pregnancy to prevent neural tube defects (NTDs) in the baby. Low levels in early pregnancy are believed to be the cause of more than half of babies born with neural tube defects. More than 50 countries use fortification of certain foods with folic acid as a measure to decrease the rate of NTDs in the population. Long term supplementation is also associated with small reductions in the risk of stroke and cardiovascular disease. It may be taken by mouth or by injection.



Skeletal formula

There are no common side effects. It is not known whether high doses over a long period of time are of concern. There are concerns that large amounts of folic acid might hide vitamin B12 deficiency. It is essential for the body to make DNA, RNA, and metabolise amino acids which are required for cell division.[8] As humans cannot make folic acid, it is required from the diet, making it an essential vitamin.

Not consuming enough folate can lead to folate deficiency. This may result in a type of anemia in which low numbers of large red blood cells occur. Symptoms may include feeling tired, heart palpitations, shortness of breath, open sores on the tongue, and changes in the color of the skin or hair. Deficiency in children may develop within a month of poor dietary intake.[13] In adults normal total body folate is between 10,000–30,000 micrograms (µg) with blood levels of greater than 7 nmol/L (3 ng/mL).[8]

Folic acid was discovered between 1931 and 1943.[14] It is on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system.[15] The wholesale cost of supplements in the developing world is between 0.001 and 0.005 USD per dose as of 2014.[16]The term "folic" is from the Latin word folium, which means leaf. Folates occur naturally in many foods especially dark green leafy vegetables and liver.[8]

Pregnancy and Fertility

Folic acid intake during pregnancy has been linked to a lessened risk of neural tube defects. Likewise, a meta-analysis of folic acid supplementation during pregnancy reported a 28% lower risk of newborn congenital heart defects. The United States Preventive Services Task Force recommends folic acid supplementation for all women able to become pregnant.

Devakamar reviewed long-term outcomes for live births that did not involve neural tube defects and fortification with folic acid did not have an impact on childhood survival, growth, body composition, or cognitive outcomes. Prenatal supplementation did not appear to reduce the risk of pre-term births. And there does not appear to be a correlation between maternal folic acid supplementation and an increased risk for asthma in the child.

Folate is necessary for fertility in both men and women. It contributes to spermatogenesis. Therefore, it is necessary to receive sufficient amounts through the diet to avoid subfertility. Also, polymorphisms in genes of enzymes involved in folate metabolism could be one reason for fertility complications in some women with unexplained infertility.

Heart Disease, Stroke and Cancer

Taking folic acid over years reduced the risk of cardiovascular disease by 4%, where another study found it did not affect cardiovascular disease, even while reducing homocysteine levels.

Long-term supplementation with folic acid reduced the risk of stroke by 10%, which may be due to the role folate plays in regulating homocysteine concentration.The reviews indicate the risk of stroke appears to be reduced only in some individuals, but a definite recommendation regarding supplementation beyond the current RDA has not been established for stroke prevention. Asian populations had greater protection against stroke with folate supplementation than did European or North American subjects.

Observed stroke reduction is consistent with the reduction in pulse pressure produced by folate supplementation of 5 mg per day, since hypertension is a key risk factor for stroke. Folic supplements are inexpensive and relatively safe to use, which is why stroke or hyperhomocysteinemia patients are encouraged to consume daily B vitamins including folic acid.

Studies on folic acid intake from food and folate supplementation with regards to cancer risk are based on the adequacy of chronic intake. Chronically insufficient intake of folic acid (below the recommended level of 400 micrograms per day) may increase the risk of colorectal, breast, ovarian, pancreas, brain, lung, cervical, and prostate cancers. Other studies showed that excessive dietary supplementation with synthetic folate may increase the risk of certain cancers, in particular prostate. A 2017 review found no relationship between taking folate supplements and cancer risk.

Dietary Reference Intake

Because of the difference in bioavailability between supplemented folic acid and the different forms of folate found in food, the dietary folate equivalent (DFE) system was established. One DFE is defined as 1 µg of dietary folate, or 0.6 µg of folic acid supplement.

National Institutes of Health (US) nutritional requirements[65] (µg DFE per day)

Age	Infants (AI)	Infants (UL)	Adults (RDA)	Adults (UL)	Pregnant women (RDA)	Pregnant women (UL)	Lactating women (RDA)	Lactating women (UL)
0–6 months	65	None set	–	–	–	–	–	–
7–12 months	80	None set	–	–	–	–	–	–
1–3 years	–	–	150	300	–	–	–	–
4–8 years	–	–	200	400	–	–	–	–
9–13 years	–	–	300	600	–	–	–	–
14–18	–	–	400	800	600	800	500	800
19+	–	–	400	1000	600	1000	500	1000

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For folic acid labeling purposes 100% of the Daily Value was 400 µg. As of the May 2016 update it was kept unchanged at 400 µg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until 28 July 2018 to comply with the change.

Dietary Sources

Folate naturally occurs in a wide variety of foods, including vegetables (particularly dark green leafy vegetables), fruits and fruit juices, nuts, beans, peas, dairy products, poultry and meat, eggs, seafood, grains, and some beers. Avocado, beetroot, spinach,

liver, yeast, asparagus, and Brussels sprouts are among the foods with the highest levels of folate. Folic acid is added to grain products in many countries, and in these countries, fortified products make up a significant source of the population's folic acid intake. Because of the difference in bioavailability between supplemented folic acid and the different forms of folate found in food, the dietary folate equivalent (DFE) system was established. 1 DFE is defined as 1 µg of dietary folate, or 0.6 µg of folic acid supplement. This is reduced to 0.5 µg of folic acid if the supplement is taken on an empty stomach. bFolate naturally found in food is susceptible to high heat and ultraviolet light, and is soluble in water. It is heat-labile in acidic environments and may also be subject to oxidation. Some meal replacement products do not meet the folate requirements as specified by the RDAs.

Food Fortification

Folic acid fortification is a process where folic acid is added to flour with the intention of promoting public health through increasing blood folate levels in the populace. In the USA, food is fortified with folic acid, only one of the many naturally occurring forms of folate, and a substance contributing only a minor amount to the folates in natural foods. Since the discovery of the link between insufficient folic acid and neural tube defects, governments and health organizations worldwide have made recommendations concerning folic acid s*upplementation* for women intending to become pregnant.

Fortification is controversial, with issues having been raised concerning individual liberty, as well as the health concerns described in the Toxicity section above. In the USA, there is concern that the federal government mandates fortification, but does not provide monitoring of potential undesirable effects of fortification. 76 countries worldwide (incldуing the USA) require mandatory folic acid fortification of at least one major cereal grain, with nearly all fortifying at least wheat flour, according to November 2013 data from the Flour Fortification Initiative.

Folate Deficiency

Folate deficiency can be caused by unhealthy diets that do not include enough fruits and vegetables, diseases in which folic acid is not well absorbed in the digestive system (such as Crohn's disease or celiac disease), some genetic disorders that affect levels of folate, and certain medicines (such as phenytoin, sulfasalazine, or trimethoprim-sulfamethoxazole). Folate deficiency is accelerated by alcohol consumption.

Folate deficiency may lead to glossitis, diarrhea, depression, confusion, anemia, and fetal neural tube defects and brain defects (during pregnancy). Other symptoms include fatigue, gray hair, mouth sores, poor growth, and swollen tongue. Folate deficiency is diagnosed by analyzing CBC and plasma vitamin B_{12} and folate levels. CBC may indicate megaloblastic anemia but this could also be a sign of vitamin B_{12} deficiency. A serum folate of 3 µg/L or lower indicates deficiency. Serum folate level reflects folate status but erythrocyte folate level better reflects tissue stores after intake. Serum folate reacts more rapidly to folate intake than erythrocyte folate. An erythrocyte folate level of 140 µg/L or lower indicates inadequate folate status. Increased homocysteine level suggests tissue folate deficiency but homocysteine is also affected by vitamin B_{12} and vitamin B_6, renal function, and genetics.

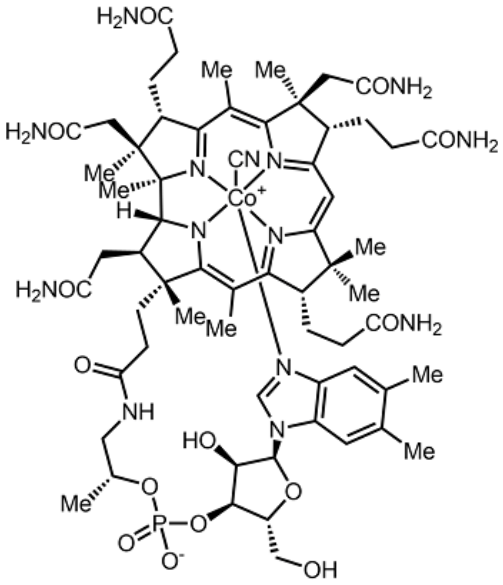
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7.3H: Vitamin B_{12} (Cobalamin)

Vitamin B_{12}, also called cobalamin, is a water-soluble vitamin that has a key role in the normal functioning of the brain and nervous system, and the formation of red blood cells. It is one of eight B vitamins. It is involved in the metabolism of every cell of the human body, especially affecting DNA synthesis, fatty acid and amino acid metabolism. No fungi, plants, nor animals (including humans) are capable of producing vitamin B_{12}. Only bacteria and archaea have the enzymes needed for its synthesis. Proven sources of B_{12} are animal products (meat, fish, dairy products) and supplements. Some research states that certain non-animal products possibly can be a natural source of B_{12} because of bacterial symbiosis. B_{12} is the largest and most structurally complicated vitamin and can be produced industrially only through a bacterial fermentation-synthesis. This synthetic B_{12} is used to fortify foods and sold as a dietary supplement.



Chemical structure of cyanocobalamin. (CC BY-SA 4.0; Alsosaid1987).

Vitamin B_{12} consists of a class of chemically related compounds (vitamers), all of which show pharmacological activity. It contains the biochemically rare element cobalt (chemical symbol Co) positioned in the center of a planar tetra-pyrrole ring called a corrin ring. The vitamer is produced by bacteria as hydroxocobalamin, but conversion between different forms of the vitamin occurs in the body after consumption.

Dietary Reference Intake

The Food and Nutrition Board of the U.S. Institute of Medicine (IOM) updated Estimated Average Requirements (EARs) and Recommended Dietary Allowances (RDAs) for vitamin B_{12} in 1998. The current EAR for vitamin B_{12} for women and men ages 14 and up is 2.0 µg/day; the RDA is 2.4 µg/day. RDAs are higher than EARs so as to identify amounts that will cover people with higher than average requirements. RDA for pregnancy equals 2.6 µg/day. RDA for lactation equals 2.8 µg/day. For infants up to 12 months the Adequate Intake (AI) is 0.4-0.5 µg/day. and for children ages 1–13 years the RDA increases with age from 0.9 to 1.8 µg/day. Because 10 to 30 percent of older people may be unable to effectively absorb vitamin B_{12} naturally occurring in foods, it is advisable for those older than 50 years to meet their RDA mainly by consuming foods fortified with vitamin B_{12} or a supplement containing vitamin B_{12}.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For vitamin B_{12} labeling purposes 100% of the Daily Value was 6.0 µg, but as of May 2016 has been revised downward to 2.4 µg.

Deficiency

Vitamin B_{12} deficiency can potentially cause severe and irreversible damage, especially to the brain and nervous system. At levels only slightly lower than normal, a range of symptoms such as fatigue, lethargy, depression, poor memory, breathlessness, headaches, and pale skin, among others, may be experienced, especially in elderly people (over age 60) who produce less stomach acid as they age, thereby increasing their probability of B_{12}deficiencies.

Vitamin B_{12} deficiency is most commonly caused by low intakes, but can also result from malabsorption, certain intestinal disorders, low presence of binding proteins, and use of certain medications. Vitamin B_{12} is rare from plant sources, so vegetarians are most likely to suffer from vitamin B_{12} deficiency. Infants are at a higher risk of vitamin B_{12} deficiency if they were born to vegetarian mothers. The elderly who have diets with limited meat or animal products are vulnerable populations as well. Vitamin B_{12} deficiency may occur in between 40% to 80% of the vegetarian population.

Vitamin B_{12} is a co-substrate of various cell reactions involved in methylation synthesis of nucleic acid and neurotransmitters. Synthesis of the trimonoamine neurotransmitters can enhance the effects of a traditional antidepressant. The intracellular concentrations of vitamin B_{12} can be inferred through the total plasma concentration of homocysteine, which can be converted to methionine through an enzymatic reaction that uses 5-methyltetrahydrofolate as the methyl donor group. Consequently, the plasma concentration of homocysteine falls as the intracellular concentration of vitamin B_{12} rises. The active metabolite of vitamin B_{12} is required for the methylation of homocysteine in the production of methionine, which is involved in a number of biochemical processes including the monoamine neurotransmitters metabolism. Thus, a deficiency in vitamin B_{12} may impact the production and function of those neurotransmitters.

Dietary Sources

Foods having rich content of vitamin B_{12} include clams, organ meats (especially liver) from lamb, veal, beef, and turkey, fish eggs, mackerel, and crab meat. B_{12} is synthesized by some gut bacteria in humans and other animals, but humans cannot absorb the B_{12} made in their guts, as it is made in the colon which is too far from the small intestine, where absorption of B_{12} occurs.

Animals store vitamin B_{12} in liver and muscle and some pass the vitamin into their eggs and milk; meat, liver, eggs and milk are therefore sources of the vitamin for other animals, including people. For humans, the bioavailability from eggs is less than 9%, compared to 40% to 60% from fish, fowl and meat. Insects are also a source of B_{12}. Foods fortified with B_{12} are also dietary sources of the vitamin. Foods for which B_{12}-fortified versions are widely available include breakfast cereals, soy products, energy bars, and nutritional yeast.

Vitamin B_{12} is an ingredient in multi-vitamin pills and in some countries used to enrich grain-based foods such as bread and pasta. In the U.S. non-prescription products can be purchased providing up to 5000 µg/serving, and it is a common ingredient in energy drinks and energy shots, usually at many times the recommended dietary allowance of B_{12}. The vitamin can also be a prescription product via injection or other means.

Absorption and Distribution

Methyl-B_{12} is absorbed by two processes. The first is an intestinal mechanism using intrinsic factor through which 1-2 micrograms can be absorbed every few hours. The second is a diffusion process by which approximately 1% of the remainder is absorbed. The human physiology of vitamin B_{12} is complex, and therefore is prone to mishaps leading to vitamin B_{12} deficiency. Protein-bound vitamin B_{12}must be released from the proteins by the action of digestive proteases in both the stomach and small intestine.

Absorption of food vitamin B_{12} thus requires an intact and functioning stomach, exocrine pancreas, intrinsic factor, and small bowel. Problems with any one of these organs makes a vitamin B_{12} deficiency possible. Individuals who lack intrinsic factor have a decreased ability to absorb B_{12}. The total amount of vitamin B_{12} stored in body is about 2–5 mg in adults. Around 50% of this is stored in the liver. Approximately 0.1% of this is lost per day by secretions into the gut, as not all these secretions are reabsorbed. Bile is the main form of B_{12} excretion; most of the B_{12} secreted in the bile is recycled via enterohepatic circulation. Excess B_{12} beyond the blood's binding capacity is typically excreted in urine. Owing to the extremely efficient enterohepatic circulation of B_{12}, the liver can store 3 to 5 years' worth of vitamin B_{12}; therefore, nutritional deficiency of this vitamin is rare. How fast B_{12}levels change depends on the balance between how much B_{12} is obtained from the diet, how much is secreted and how

much is absorbed. B_{12} deficiency may arise in a year if initial stores are low and genetic factors unfavorable, or may not appear for decades. In infants, B_{12} deficiency can appear much more quickly.

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7.3I: Vitamin C (Ascorbic acid)

Vitamin C (ascorbic acid and L-ascorbic acid) is a vitamin found in food and used as a dietary supplement. As a supplement it is used to treat and prevent scurvy. Evidence does not support use in the general population for the prevention of the common cold. It may be taken by mouth or by injection. It is generally well tolerated. Large doses may cause gastrointestinal upset, headache, trouble sleeping, and flushing of the skin. Normal doses are safe during pregnancy. Vitamin C is an essential nutrient involved in the repair of tissue. Foods that contain vitamin C include citrus fruit, tomatoes, and potatoes.

Vitamin C was discovered in 1912, isolated in 1928, and first made in 1933. It is on the World Health Organization's List of Essential Medicines, the most effective and safe medicines needed in a health system. Vitamin C is available as a generic medication and over the counter. In 2015, the wholesale cost in the developing world was about 0.003 to 0.007 USD per tablet. In some countries, ascorbic acid may be added to foods such as breakfast cereal.

Model of a vitamin C molecule. Black is carbon, red is oxygen, and white is hydrogen

Medical uses

A 2012 Cochrane review found no effect of vitamin C supplementation on overall mortality.

- **Scurvy**: Although rare in modern times, scurvy and its associated destabilization of collagen, connective tissue, and bone can be prevented by adequate vitamin C intake.
- **Cancer prevention:** A 2014 review found that, "Currently, the use of high-dose IV vitamin C [as an anticancer agent] cannot be recommended outside of a clinical trial." A 2013 Cochrane review found no evidence that vitamin C supplementation reduces the risk of lung cancer in healthy or high risk (smokers and asbestos-exposed) people. A 2014 meta-analysis found that vitamin C intake might protect against lung cancer risk. A second meta-analysis found no effect on the risk of prostate cancer. Two meta-analyses evaluated the effect of vitamin C supplementation on the risk of colorectal cancer. One found a weak association between vitamin C consumption and reduced risk, and the other found no effect of supplementation. A 2011 meta-analysis failed to find support for the prevention of breast cancer with vitamin C supplementation,but a second study concluded that vitamin C may be associated with increased survival in those already diagnosed.
- **Cardiovascular disease:** A 2013 meta-analysis found no evidence that vitamin C supplementation reduces the risk of myocardial infarction, stroke, cardiovascular mortality, or all-cause mortality. However, a second analysis found an inverse relationship between circulating vitamin C levels or dietary vitamin C and the risk of stroke. A meta-analysis of 44 clinical trials has shown a significant positive effect of vitamin C on endothelial function when taken at doses greater than 500 mg per day. The researchers noted that the effect of vitamin C supplementation appeared to be dependent on health status, with stronger effects in those at higher cardiovascular disease risk.
- **Chronic diseases**: A 2010 review found no role for vitamin C supplementation in the treatment of rheumatoid arthritis. Studies examining the effects of vitamin C intake on the risk of Alzheimer's disease have reached conflicting conclusions. Maintaining a healthy dietary intake is probably more important than supplementation for achieving any potential benefit. Vitamin C supplementation above the RDA has been used in trials to study a potential effect on preventing and slowing the progression of age-related cataract. However, no significant effects were found from the research.
- **Common cold**: Vitamin C's effect on the common cold has been extensively researched. It has not been shown effective in prevention or treatment of the common cold, except in limited circumstances (specifically, individuals exercising vigorously in cold environments). Routine vitamin C supplementation does not reduce the incidence or severity of the common cold in the general population, though it may reduce the duration of illness.

Possible

As vitamin C enhances iron absorption, iron poisoning can become an issue to people with rare iron overload disorders, such as haemochromatosis. A genetic condition that results in inadequate levels of the enzyme glucose-6-phosphate dehydrogenase (G6PD) can cause sufferers to develop hemolytic anemia after ingesting specific oxidizing substances, such as very large dosages of vitamin C.

There is a longstanding belief among the mainstream medical community that vitamin C causes kidney stones, which is based on little science. Although recent studies have found a relationship, a clear link between excess ascorbic acid intake and kidney stone formation has not been generally established. Some case reports exist for a link between patients with oxalate deposits and a history of high-dose vitamin C usage.

In a study conducted on rats, during the first month of pregnancy, high doses of vitamin C may suppress the production of progesterone from the corpus luteum. Progesterone, necessary for the maintenance of a pregnancy, is produced by the corpus luteum for the first few weeks, until the placenta is developed enough to produce its own source. By blocking this function of the corpus luteum, high doses of vitamin C (1000+ mg) are theorized to induce an early miscarriage. In a group of spontaneously aborting women at the end of the first trimester, the mean values of vitamin C were significantly higher in the aborting group. However, the authors do state: 'This could not be interpreted as an evidence of causal association.' However, in a previous study of 79 women with threatened, previous spontaneous, or habitual abortion, Javert and Stander (1943) had 91% success with 33 patients who received vitamin C together with bioflavonoids and Vitamin K (only three abortions), whereas all of the 46 patients who did not receive the vitamins aborted.

A study in rats and humans suggested that adding Vitamin C supplements to an exercise training program lowered the expected effect of training on VO2 Max. Although the results in humans were not statistically significant, this study is often cited as evidence that high doses of Vitamin C have an adverse effect on exercise performance. In rats, it was shown that the additional Vitamin C resulted in lowered mitochondria production. Since rats are able to produce all of their needed Vitamin C, however, it is questionable whether they offer a relevant model of human physiological processes in this regard.

Biological Significance

Vitamin C is an essential nutrient for certain animals including humans. Vitamin C describes several vitamers that have vitamin C activity in animals, including ascorbic acid and its salts, and some oxidized forms of the molecule like dehydroascorbic acid. Ascorbate and ascorbic acid are both naturally present in the body when either of these is introduced into cells, since the forms interconvert according to pH. Vitamin C is a cofactor in at least eight enzymatic reactions, including several collagen synthesis reactions that, when dysfunctional, cause the most severe symptoms of scurvy. In animals, these reactions are especially important in wound-healing and in preventing bleeding from capillaries. Ascorbate also acts as an antioxidant, protecting against oxidative stress.

The biological role of ascorbate is to act as a reducing agent, donating electrons to various enzymatic and a few non-enzymatic reactions. The one- and two-electron oxidized forms of vitamin C, semidehydroascorbic acid and dehydroascorbic acid, respectively, can be reduced in the body by glutathione and NADPH-dependent enzymatic mechanisms. The presence of glutathione in cells and extracellular fluids helps maintain ascorbate in a reduced state.

In humans, vitamin C is essential to a healthy diet as well as being a highly effective antioxidant, acting to lessen oxidative stress; a substrate for ascorbate peroxidase in plants (APX is plant specific enzyme); and an enzyme cofactor for the biosynthesis of many important biochemicals. Vitamin C acts as an electron donor for important enzymes.

Ascorbate is required for a range of essential metabolic reactions in all animals and plants. It is made internally by almost all organisms; the main exceptions are most bats, all guinea pigs, capybaras, and the Haplorrhini (one of the two major primate suborders, consisting of tarsiers, monkeys, and humans and other apes). Ascorbate is also not synthesized by many species of birds and fish. All species that do not synthesize ascorbate require it in the diet.

Deficiency

Scurvy is an avitaminosis resulting from lack of vitamin C, since without this vitamin, the synthesized collagen is too unstable to perform its function. Scurvy leads to the formation of brown spots on the skin, spongy gums, and bleeding from all mucous membranes. The spots are most abundant on the thighs and legs, and a person with the ailment looks pale, feels depressed, and is partially immobilized. In advanced scurvy there are open, suppurating wounds and loss of teeth and, eventually, death. The human body can store only a certain amount of vitamin C, and so the body stores are depleted if fresh supplies are not consumed. The time frame for onset of symptoms of scurvy in unstressed adults on a completely vitamin C free diet, however, may range from one month to more than six months, depending on previous loading of vitamin C.

Western societies generally consume far more than sufficient vitamin C to prevent scurvy. In 2004, a Canadian Community health survey reported that Canadians of 19 years and above have intakes of vitamin C from food of 133 mg/d for males and 120 mg/d for females; these are higher than the RDA recommendations.

Notable human dietary studies of experimentally induced scurvy have been conducted on conscientious objectors during WWII in Britain and on Iowa state prisoners in the late 1960s to the 1980s. These studies both found that all obvious symptoms of scurvy previously induced by an experimental scorbutic diet with extremely low vitamin C content could be completely reversed by additional vitamin C supplementation of only 10 mg a day. In these experiments, there was no clinical difference noted between men given 70 mg vitamin C per day (which produced blood level of vitamin C of about 0.55 mg/dl, about 1/3 of tissue saturation levels) and those given 10 mg per day. Men in the prison study developed the first signs of scurvy about 4 weeks after starting the vitamin C-free diet, whereas in the British study, six to eight months were required, possibly due to the pre-loading of this group with a 70 mg/day supplement for six weeks before the scorbutic diet was fed.

Men in both studies on a diet devoid, or nearly devoid, of vitamin C had blood levels of vitamin C too low to be accurately measured when they developed signs of scurvy, and in the Iowa study, at this time were estimated (by labeled vitamin C dilution) to have a body pool of less than 300 mg, with daily turnover of only 2.5 mg/day, implying an instantaneous half-life of 83 days by this time (elimination constant of 4 months).

Absorption, transport, and excretion

Ascorbic acid is absorbed in the body by both active transport and simple diffusion. Sodium-Dependent Active Transport—Sodium-Ascorbate Co-Transporters (SVCTs) and Hexose transporters (GLUTs)—are the two transporters required for absorption. SVCT1 and SVCT2 import the reduced form of ascorbate across plasma membrane.GLUT1 and GLUT3 are the two glucose transporters, and transfer only the dehydroascorbic acid form of Vitamin C.[82] Although dehydroascorbic acid is absorbed in higher rate than ascorbate, the amount of dehydroascorbic acid found in plasma and tissues under normal conditions is low, as cells rapidly reduce dehydroascorbic acid to ascorbate. Thus, SVCTs appear to be the predominant system for vitamin C transport in the body.

SVCT2 is involved in vitamin C transport in almost every tissue,[81] the notable exception being red blood cells, which lose SVCT proteins during maturation.[85] "SVCT2 knockout" animals genetically engineered to lack this functional gene, die shortly after birth,[86] suggesting that SVCT2-mediated vitamin C transport is necessary for life.

With regular intake the absorption rate varies between 70 and 95%. However, the degree of absorption decreases as intake increases. At high intake (1.25 g), fractional human absorption of ascorbic acid may be as low as 33%; at low intake (<200 mg) the absorption rate can reach up to 98%.

Ascorbate concentrations over the renal re-absorption threshold pass freely into the urine and are excreted. At high dietary doses (corresponding to several hundred mg/day in humans) ascorbate is accumulated in the body until the plasma levels reach the renal resorption threshold, which is about 1.5 mg/dL in men and 1.3 mg/dL in women. Concentrations in the plasma larger than this value (thought to represent body saturation) are rapidly excreted in the urine with a half-life of about 30 minutes. Concentrations less than this threshold amount are actively retained by the kidneys, and the excretion half-life for the remainder of the vitamin C store in the body thus increases greatly, with the half-life lengthening as the body stores are depleted. This half-life rises until it is as long as 83 days by the onset of the first symptoms of scurvy.[88]

Although the body's maximal store of vitamin C is largely determined by the renal threshold for blood, there are many tissues that maintain vitamin C concentrations far higher than in blood. Biological tissues that accumulate over 100 times the level in blood plasma of vitamin C are the adrenal glands, pituitary, thymus, corpus luteum, and retina.[89] Those with 10 to 50 times the concentration present in blood plasma include the brain, spleen, lung, testicle, lymph nodes, liver, thyroid, small intestinal mucosa, leukocytes, pancreas, kidney, and salivary glands.

Ascorbic acid can be oxidized (broken down) in the human body by the enzyme L-ascorbate oxidase. Ascorbate that is not directly excreted in the urine as a result of body saturation or destroyed in other body metabolism is oxidized by this enzyme and removed.

Immune system

Vitamin C is found in high concentrations in immune cells, and is consumed quickly during infections. It is not certain how vitamin C interacts with the immune system; it has been hypothesized to modulate the activities of phagocytes, the production of cytokines and lymphocytes, and the number of cell adhesion molecules in monocytes.[101]

Daily Requirements

The North American Dietary Reference Intake recommends 90 milligrams per day for adult men, 75 mg/day for adult women, and no more than 2 grams (2,000 milligrams) per day. A balanced diet without supplementation usually contains enough vitamin C to prevent scurvy in an average healthy adult, while those who smoke tobacco or are under stress require slightly more.

United States vitamin C recommendations

Recommended Dietary Allowance (adult male)	90 mg per day
Recommended Dietary Allowance (adult female)	75 mg per day
Recommended Dietary Allowance (pregnancy)	85 mg per day
Recommended Dietary Allowance (lactation)	120 mg per day
Tolerable Upper Intake Level (adult male)	2,000 mg per day
Tolerable Upper Intake Level (adult female)	2,000 mg per day

Recommended intake

Recommendations for vitamin C intake have been set by various national agencies:

- 40 milligrams per day or 280 milligrams per week taken all at once: the United Kingdom's Food Standards Agency
- 40 milligrams per day as per the recommendations of India's National Institute of Nutrition, Hyderabad
- 45 milligrams per day 300 milligrams per week: the World Health Organization
- 80 milligrams per day: the European Commission's Council on nutrition labeling
- 90 mg/day (males) and 75 mg/day (females): Health Canada 2007
- 90 mg/day (males) and 75 mg/day (females): United States' National Academy of Sciences.
- 100 milligrams per day: Japan's National Institute of Health and Nutrition.

For U.S. food and dietary supplement labeling purposes the amount in a serving is expressed as a percent of Daily Value (%DV). For vitamin C labeling purposes 100% of the Daily Value was 60 mg, but as of May 2016 it has been revised to 90 mg. A table of the pre-change adult Daily Values is provided at Reference Daily Intake. Food and supplement companies have until July 28, 2018 to comply with the change.

Dietary Sources

The richest natural sources are fruits and vegetables. Vitamin C is the most widely taken nutritional supplement and is available in a variety of forms, including tablets, drink mixes, and in capsules. Vitamin C is absorbed by the intestines using a sodium-ion dependent channel. It is transported through the intestine via both glucose-sensitive and glucose-insensitive mechanisms. The presence of large quantities of sugar either in the intestines or in the blood can slow absorption.



Rose hips are a particularly rich source of vitamin C. (CC BY-SA 3.0; en:User:MPF)

While plants are generally a good source of vitamin C, the amount in foods of plant origin depends on the precise variety of the plant, soil condition, climate where it grew, length of time since it was picked, storage conditions, and method of preparation. The following table is approximate and shows the relative abundance in different raw plant sources. As some plants were analyzed fresh while others were dried (thus, artifactually increasing concentration of individual constituents like vitamin C), the data are subject to potential variation and difficulties for comparison. The amount is given in milligrams per 100 grams of fruit or vegetable and is a rounded average from multiple authoritative sources:

Plant source	Amount (mg / 100g)
Kakadu plum	1000–5300
Camu Camu	2800
Acerola	1677
Seabuckthorn	695
Indian gooseberry	445
Rose hip	426
Baobab	400
Chili pepper (green)	244
Guava (common, raw)	228.3
Blackcurrant	200
Red pepper	190
Chili pepper (red)	144
Parsley	130
Kiwifruit	90
Broccoli	90
Loganberry	80
Redcurrant	80
Brussels sprouts	80

Plant source	Amount (mg / 100g)
Wolfberry (Goji)	73 †
Lychee	70
Persimmon (native, raw)	66.0
Cloudberry	60
Elderberry	60

† average of 3 sources; dried

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8: WATER AND MINERALS

Drinking water, also known as potable water or improved drinking water, is water safe enough for drinking and food preparation. Globally, in 2012, 89% of people had access to water suitable for drinking. Nearly 4 billion had access to tap water while another 2.3 billion had access to wells or public taps. 1.8 billion people still use an unsafe drinking water source which may be contaminated by feces. This can result in infectious diarrhea such as cholera and typhoid among others. We will also discuss the category of essential nutrients called Minerals, also known as Dietary elements or mineral nutrients. Minerals are naturally occurring chemical elements required by living organisms for survival. Many of the minerals we need are plentiful in a typical scoop of dirt!

8.1: Water

8.2: Minerals - Basic Concepts

8.3: Overview of Fluid and Electrolyte Balance

8.4: Water's Importance to Vitality

8.5: Regulation of Water Balance

8.6: Major Minerals

8.6A: Introduction to Major Minerals

8.6B: Calcium

8.6C: Phosphorus

8.6D: Sulfur

8.6E: Magnesium

8.6F: Sodium

8.6G: Chloride

8.6H: Potassium

8.7: Trace Minerals

8.7A: Prelude to Trace Minerals

8.7B: Iron

8.7C: Copper

8.7D: Zinc

8.7E: Iodine

8.7F: Chromium

8.7G: Manganese

8.7H: Molybdenum

8.7I: Fluoride

8.7J: Selenium

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8.1: Water

Skills to Develop

- Describe the functions of water in the body
- Identify symptoms of mild and severe dehydration as well as water intoxication
- Discuss the safety of drinking city water compared to drinking bottled water

Drinking water, also known as potable water or improved drinking water, is water safe enough for drinking and food preparation. Globally, in 2012, 89% of people had access to water suitable for drinking. Nearly 4 billion had access to tap water while another 2.3 billion had access to wells or public taps. 1.8 billion people still use an unsafe drinking water source which may be contaminated by feces.This can result in infectious diarrhea such as cholera and typhoid among others.

Water is essential for life. In the United States, the reference daily intake (RDI) for total water intake is 3.7 liters (about 17 Cups) per day for human males older than 18, and 2.7 liters (about 11 Cups) per day for human females older than 18. These amounts include: drinking water, water in beverages, and water contained in food. The amount of drinking water required is highly variable and depend on factors like: physical activity, age, health issues, and environmental conditions. It is estimated that the average American drinks about one liter of water a day with 95% drinking less than three liters per day. For those working in a hot climate, up to 16 liters a day may be required.



Tap water is drinking water supplied through indoor plumbing for home use

Water makes up approximately 60% of body weight in men and approximately 55% of body weight in women. The more muscular the individual, the more water they have associated with their body. Your muscles contain about 75 percent water, whereas fat tissue contains only 10 percent water. Interestingly, bone contains about 22 percent water. Infants are about 70% to 80% water while the elderly are around 45%.

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

The Story of Bottled Water

Typically in developed countries, like the United States of America, tap water must meet strict drinking water quality standards. If you receive city water, your city sends you an annual Water Quality Report in the mail each year. It is often available online. Here is a link to the annual water quality report for the City of Sacramento California . You may be surprised to learn that often the water quality of city water exceeds that of bottled water. Here is a great video about bottled Water compared to City Water (also called tap water).

Requirements

The water your drink often provides some of the minerals you need for good health. Inorganic minerals can enter surface water and ground water via storm water runoff and/or through the Earth's crust. Water treatment processes can also lead to the presence of some minerals. Examples of minerals in water can include: calcium, zinc, manganese, phosphate, fluoride and sodium compounds. Water with high levels of minerals is referred to as "hard water" and water with low levels of minerals is referred to as "soft water". The World Health Organization says that "there does not appear to be any convincing evidence that water hardness causes adverse health effects in humans".[1] In fact, the United States National Research Council has found that hard water can actually serve as a dietary supplement for calcium and magnesium. Some other elements such as fluoride, while beneficial in low concentrations, can cause dental problems and other issues when present at high levels. Appliances and faucets do tend to accumulate minerals in areas that have hard water. This causes some people to invest in "water softeners" which lower the mineral content of the water.



A fountain in Saint-Paul-de-Vence, France. The sign reading Eau potable indicates that the water is safe to drink.

Fluid balance is key. Profuse sweating can increase the need for electrolyte (salt) replacement. Water intoxication (which results in hyponatremia), the process of consuming too much water too quickly, can be fatal.

Access

Water covers some 70% of the Earth's surface. Approximately 97.2% of it is saline, just 2.8% fresh. Potable water is available in almost all populated areas of the Earth, although it may be expensive and the supply may not always be sustainable. Sources where water may be obtained include:

- Ground sources such as groundwater, springs, hyporheic zones and aquifers
- Precipitation which includes rain, hail, snow, fog, etc.
- Surface water such as rivers, streams, glaciers
- Biological sources such as plants.
- Desalinated seawater
- Water supply network
- Atmospheric water generator

Springs are often used as sources for bottled waters. Tap water, delivered by domestic water systems in developed nations, refers to water piped to homes and delivered to a tap or spigot. For these water sources to be consumed safely they must receive adequate treatment and meet drinking water regulations. The most efficient way to transport and deliver potable water is through pipes. Plumbing can require significant capital investment. Some systems suffer high operating costs. The cost to replace the deteriorating water and sanitation infrastructure of industrialized countries may be as high as $200 billion a year. Leakage of untreated and treated water from pipes reduces access to water. Leakage rates of 50% are not uncommon in urban systems.





(left) Only 61 percent of people in Sub-Saharan Africa have improved drinking water. (right) Drinking water vending machines in Thailand. One liter of potable water is sold (into the customer's own bottle) for 1 baht.

Because of the high initial investments, many less wealthy nations cannot afford to develop or sustain appropriate infrastructure, and as a consequence people in these areas may spend a correspondingly higher fraction of their income on water. 2003 statistics from El Salvador, for example, indicate that the poorest 20% of households spend more than 10% of their total income on water. In the United Kingdom authorities define spending of more than 3% of one's income on water as a hardship.

Health Aspects

Contaminated water is estimated to result in more than half a million deaths per year. Contaminated water together with lack of sanitation was estimated to cause about one percent of disability adjusted life years worldwide in 2010.

Over 90% of deaths from diarrheal diseases in the developing world today occur in children under 5 years old. Malnutrition, especially protein-energy malnutrition, can decrease the children's resistance to infections, including water-related diarrheal diseases. From 2000-2003, 769,000 children under five years old in sub-Saharan Africa died each year from diarrheal diseases. As a result of only thirty-six percent of the population in the sub-Saharan region having access to proper means of sanitation, more than 2000 children's lives are lost every day. In South Asia, 683,000 children under five years old died each year from diarrheal disease from 2000-2003. During the same time period, in developed countries, 700 children under five years old died from diarrheal disease. Improved water supply reduces diarrhea morbidity by twenty-five percent and improvements in drinking water through proper storage in the home and chlorination reduces diarrhea episodes by thirty-nine percent.

Sixty million people are estimated to have been poisoned by well water contaminated by excessive fluoride, which dissolved from granite rocks. The effects are particularly evident in the bone deformations of children. Similar or larger problems are anticipated in other countries including China, Uzbekistan, and Ethiopia. Although helpful for dental health in low dosage, fluoride in large amounts interferes with bone formation.

Water Quality

Parameters for drinking water quality typically fall under three categories:

- physical
- chemical
- microbiological

Physical and chemical parameters include heavy metals, trace organic compounds, total suspended solids (TSS), and turbidity. Microbiological parameters include Coliform bacteria, E. coli, and specific pathogenic species of bacteria (such as cholera-causing Vibrio cholerae), viruses, and protozoan parasites. Chemical parameters tend to pose more of a chronic health risk

through buildup of heavy metals although some components like nitrates/nitrites and arsenic can have a more immediate impact. Physical parameters affect the aesthetics and taste of the drinking water and may complicate the removal of microbial pathogens.



EPA drinking water security poster

Originally, fecal contamination was determined with the presence of coliform bacteria, a convenient marker for a class of harmful fecal pathogens. The presence of fecal coliforms (like E. Coli) serves as an indication of contamination by sewage. Additional contaminants include protozoan oocysts such as Cryptosporidium sp., Giardia lamblia, Legionella, and viruses (enteric). Microbial pathogenic parameters are typically of greatest concern because of their immediate health risk.

Throughout most of the world, the most common contamination of raw water sources is from human sewage and in particular human faecal pathogens and parasites. In 2006, waterborne diseases were estimated to cause 1.8 million deaths each year while about 1.1 billion people lacked proper drinking water. It is clear that people in the developing world need to have access to good quality water in sufficient quantity, water purification technology and availability and distribution systems for water. In many parts of the world the only sources of water are from small streams often directly contaminated by sewage.

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8.2: Minerals - Basic Concepts

Skills to Develop

- Describe the importance of water intake for the body
- Describe the major aspects of water regulation in the body
- Describe the function, balance, sources, and consequences of the imbalance of electrolytes
- Describe the effects and use of popular beverage choices

Maintaining the right level of water in your body is crucial to survival, as either too little or too much water in your body will result in less-than-optimal functioning. One mechanism to help ensure the body maintains water balance is thirst. Thirst is the result of your body's physiology telling your brain to initiate the thought to take a drink. Sensory proteins detect when your mouth is dry, your blood volume too low, or blood electrolyte concentrations too high and send signals to the brain stimulating the conscious feeling to drink.

In the summer of 1965, the assistant football coach of the University of Florida Gators requested scientists affiliated with the university study why the withering heat of Florida caused so many heat-related illnesses in football players and provide a solution to increase athletic performance and recovery post-training or game. The discovery was that inadequate replenishment of fluids, carbohydrates, and electrolytes was 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.[1]

Excess consumption of sugary soft drinks have 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.

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 discuss the importance and functions of fluid and electrolyte balance in the human body, the consequences of getting too much or too little of water and electrolytes, the best dietary sources of these nutrients, and healthier beverage choices. After reading this chapter you will know what to look for in sports drinks and will be able to select the best products to keep hydrated.

Footnotes

1. Ogden C, Kit B, et al. Consumption of Sugar Drinks in the United States, 2005–2008. Centers for Disease Control and Prevention. NCHS Data Brief no. 71. http://www.cdc.gov/nchs/data/databriefs/db71.htm. Published August 2011. Accessed September 22, 2017. ↩

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8.3: Overview of Fluid and Electrolyte Balance

Learning Objectives

- Learn about fluid and electrolyte balance

Water is made up of 2 hydrogen atoms and 1 oxygen atom (Figure 8.3.1). A human body is made up of mostly water. An adult consists of about 37 to 42 liters of water, or about eighty pounds. Fortunately, humans have compartmentalized tissues; otherwise we might just look like a water balloon! Newborns are approximately 70 percent water. Adult males typically are composed of about 60 percent water and females are about 55 percent water. (This gender difference reflects the differences in body-fat content, since body fat is practically water-free. This also means that if a person gains weight in the form of fat the percentage of total body water content declines.) As we age, total body water content also diminishes so that by the time we are in our eighties the percent of water in our bodies has decreased to around 45 percent. Does the loss in body water play a role in the aging process? Alas, no one knows. But, we do know that dehydration accelerates the aging process whereas keeping hydrated decreases headaches, muscle aches, and kidney stones. Additionally a study conducted at the Fred Hutchinson Cancer Research Center in Seattle found that women who drank more than five glasses of water each day had a significantly decreased risk for developing colon cancer.[1]

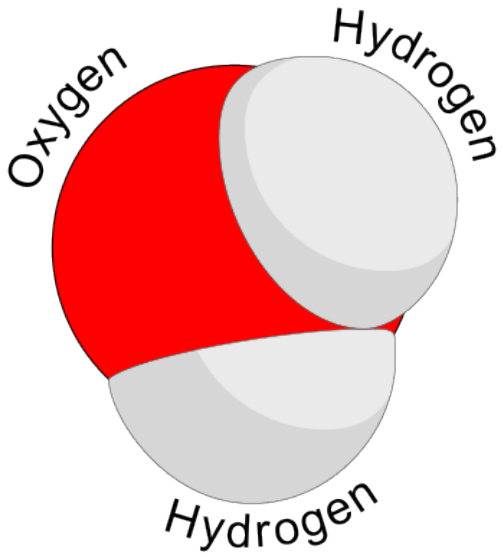


Figure 8.3.1: The Water Molecule. "Water Molecule" by Chris Martin.

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, dissociate 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) dissociates into sodium cations (Na+) and chloride anions (Cl–). Solutes refers 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. The extracellular water compartment is subdivided into the spaces between cells also known as interstitial, blood plasma, and other bodily fluids such as the cerebrospinal fluid which surrounds and protects the brain and spinal cord (Figure 8.3.2). 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.

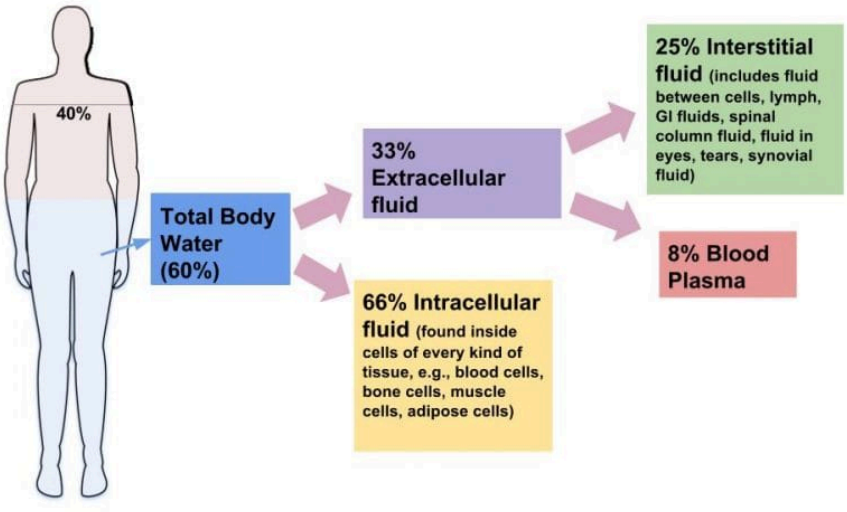


Figure 8.3.2: Distribution of Body Water.

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 movement of electrolytes and other solutes and thus indirectly regulate water movement by controlling where there will be regions of high and low concentrations.

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 8.3.3). 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.

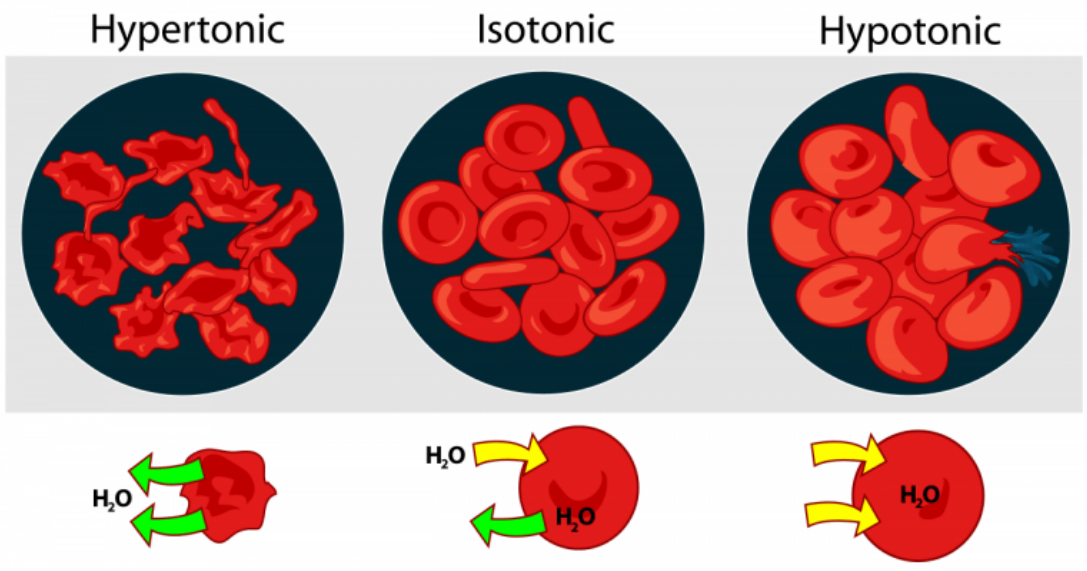


Figure 8.3.3: Osmoregulation. “Osmosis” by Mariana Ruiz Villarreal .

Cells maintain water volume by actively controlling electrolyte concentrations. Human erythrocytes (red blood cells) are shown here. Three conditions are shown: hypertonic conditions (where the erythrocytes contract and appear “spiky”), isotonic conditions (where the erythrocytes appear normal) and hypotonic conditions (where the etrythrocytes expand and become more round).

If a cell is placed in a solution that contains fewer dissolved particles (hypotonic solution) than the cell itself, water moves into the more concentrated cell, causing it to swell. 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.

Footnotes

1. Shannon JE, et al. Relationship of Food Groups and Water Intake to Colon Cancer Risk. Cancer Epidemiol Biomarkers Prev. 1996; 5(7), 495–502. http://cebp.aacrjournals.org/content/5/7/495.long. Accessed September 22, 2017. ↵

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8.4: Water's Importance to Vitality

Learning Objectives

- Learn about the importance of water

You get up in the morning, flush wastes down the toilet, take a shower, brush your teeth, drink, eat, drive, wash the grime from your windshield, get to work, and drink coffee. Next to a fountain you eat lunch and down it with a glass of water, you use the toilet again and again, drive home, prepare dinner, etc. Add all the ways you use water every day and you still will not come close to the countless uses water has in the human body. Of all the nutrients, water is the most critical as its absence proves lethal within a few days. Organisms have adapted numerous mechanisms for water conservation. Water uses in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/shock absorber, and temperature regulator.



Figure 8.4.1: Image by NASA on unsplash.com / CC0.

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.

Water As a Transportation Vehicle

Water is called the "universal solvent" because more substances dissolve in it than any other fluid. Molecules dissolve in water because of the hydrogen and oxygen molecules ability to loosely bond with other molecules. Molecules of water (H_2O) surround substances, suspending them in a sea of water molecules. The solvent action of water allows for substances to be more readily transported. A pile of undissolved salt would be difficult to move throughout tissues, as would a bubble of gas or a glob of fat. Blood, the primary transport fluid in the body is about 78 percent water. Dissolved substances in blood include proteins, lipoproteins, glucose, electrolytes, and metabolic waste products, such as carbon dioxide and urea. These substances are either dissolved in the watery surrounding of blood to be transported to cells to support basic functions or are removed from cells to prevent waste build-up and toxicity. Blood is not just the primary vehicle of transport in the body, but also as a fluid tissue blood structurally supports blood vessels that would collapse in its absence. For example, the brain which consists of 75 percent water is used to provide structure.

Water As a Medium for Chemical Reactions

Water is required for even the most basic chemical reactions. Proteins fold into their functional shape based on how their amino-

acid sequences react with water. These newly 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, is also required for breathing, transportation of nutrients along the gastrointestinal tract, and elimination of waste materials through the rectum. Mucus is composed of more than 90 percent water and a front-line defense against injury and foreign invaders. It protects tissues from irritants, entraps pathogens, and contains immune-system cells that destroy pathogens. Water is also the main component of the lubricating fluid between joints and eases the movement of articulated bones.

The aqueous and vitreous humors, which are fluids that fill the extra space in the eyes and the cerebrospinal fluid surrounding the brain and spinal cord, are primarily water and buffer these organs against sudden changes in the environment. Watery fluids surrounding organs provide both chemical and mechanical protection. Just two weeks after fertilization water fills the amniotic sac in a pregnant woman providing a cushion of protection for the developing embryo.

Water As a Temperature Regulator

Another homeostatic function of the body, termed thermoregulation is to balance heat gain with heat loss and body water plays an important role in accomplishing this. Human life is supported within a narrow range of temperature, with the temperature set point of the body being 98.6°F (37°C). Too low or too high of a temperature causes enzymes to stop functioning and metabolism is halted. At 82.4°F (28°C) muscle failure occurs and hypothermia sets in. At the opposite extreme of 111.2°F (44°C) the central nervous system fails and death results. Water is good at storing heat, an attribute referred to as heat capacity and thus helps maintain the temperature set point of the body despite changes in the surrounding environment.

There are several mechanisms in place that move body water from place to place as a method to distribute heat in the body and equalize body temperature (Figure 8.4.2). 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 lost 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.

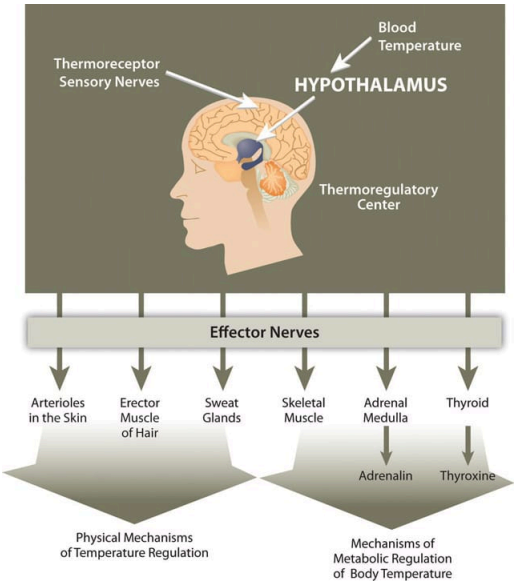


Figure 8.4.2: Thermoregulatory Center.

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

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8.5: Regulation of Water Balance

Learning Objectives

- Learn about water balance

As you eat a bite of food, the salivary glands secrete saliva. As the food enters your stomach, gastric juice is secreted. As it enters the small intestine, pancreatic juice is secreted. Each of these fluids contains a great deal of water. How is that water replaced in these organs? What happens to the water now in the intestines? In a day, there is an exchange of about 10 liters of water among the body's organs. The osmoregulation of this exchange involves complex communication between the brain, kidneys, and endocrine system. A homeostatic goal for a cell, a tissue, an organ, and an entire organism is to balance water output with water input.

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.

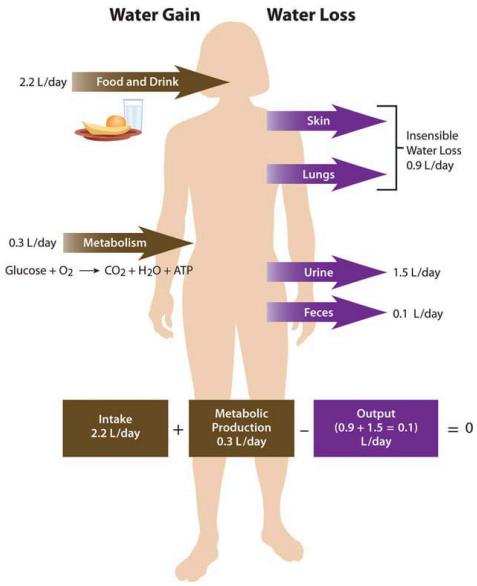


Figure 8.5.1: Daily Fluid Loss and Gain.

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.[1] 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 8.5.1 for the range of water contents for selected food items. Beverages includes water, tea, coffee, sodas, and juices.

***Table** 8.5.1**:** 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: National Nutrient Database for Standard Reference, Release 23. US Department of Agriculture, Agricultural Research Service. http://www.ars.usda.gov/ba/bhnrc/ndl. Updated 2010. Accessed September 2017.

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 brainstem. 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. The hypothalamus sends neural signals to higher sensory areas in the cortex of the brain, stimulating the conscious thought to drink.
3. Fluids are consumed.
4. Receptors in the mouth and stomach detect mechanical movements involved with fluid ingestion.
5. 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.

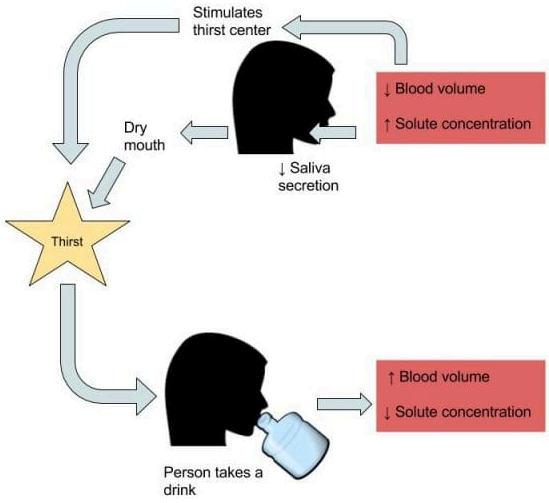


Figure 8.5.2: Regulating Water Intake.

Regulation of Daily Water Output

As stated, daily water output averages 2.5 liters. There are two types of outputs. The first type is insensible water loss, meaning we are unaware of it. The body loses about 400 milliliters of its daily water output through exhalation. Another 500 milliliters is lost through our skin. The second type of output is sensible water loss, meaning we are aware of it. Urine accounts for about 1,500 milliliters of water output, and feces account for roughly 100 milliliters of water output. Regulating urine output is a primary function of the kidneys, and involves communication with the brain and endocrine system.

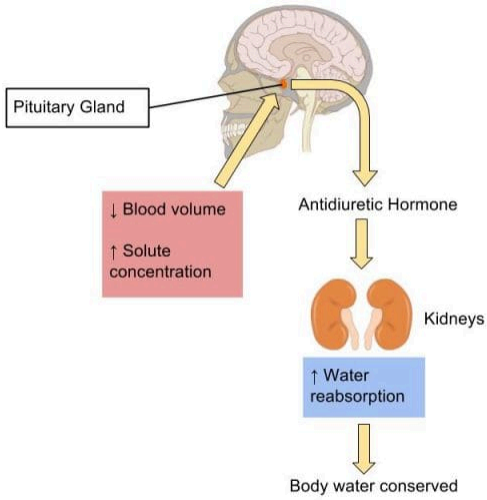


Figure 8.5.3: Regulating Water Output.

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. 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 in the 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.

The Hypothalamus Detects Blood Osmolality

Sodium and fluid balance are intertwined. Osmoreceptors (specialized protein receptors) in the hypothalamus detect sodium concentration in the blood. In response to a high sodium level, the hypothalamus activates the thirst mechanism and concurrently stimulates the release of antidiuretic hormone. Thus, it is not only kidneys that stimulate antidiuretic- hormone release, but also the hypothalamus. This dual control of antidiuretic hormone release allows for the body to respond to both decreased blood volume and increased blood osmolality.

The Adrenal Glands Detect Blood Osmolality

Cells in the adrenal glands sense when sodium levels are low and potassium levels are high in the blood. In response to either stimulus, they release aldosterone. Aldosterone is released in response to angiotensin stimulation and is controlled by blood electrolyte concentrations. In either case, aldosterone communicates the same message, to increase sodium reabsorption and consequently water reabsorption. In exchange, for the reabsorption of sodium and water, potassium is excreted.

Footnotes

1. Institute of Medicine Panel on Dietary Reference Intakes for Electrolytes and Water. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. The National Academies of Science, Engineering, and Medicine. Washington D.C; 2005: 73-185. http://www.nap.edu/openbook.php?reco...=10925&page=73. Accessed September 22, 2017. ↩

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8.6: MAJOR MINERALS

Similarly to vitamins, minerals are essential to human health and can be obtained in our diet from different types of food. Minerals are abundant in our everyday lives. From the soil in your front yard to the jewelry you wear on your body, we interact with minerals constantly. There are 20 essential minerals that must be consumed in our diets to remain healthy. The amount of each mineral found in our bodies vary greatly and therefore, so does consumption of those minerals. When there is a deficiency in an essential mineral, health problems may arise.

8.6A: Introduction to Major Minerals

8.6B: Calcium

8.6C: Phosphorus

8.6D: Sulfur

8.6E: Magnesium

8.6F: Sodium

8.6G: Chloride

8.6H: Potassium

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8.6A: Introduction to Major Minerals

Learning Objectives

- Describe the functional role, intake recommendations and sources of major minerals

He puko`a kani `aina

A coral reef strengthens into land.



Figure 8.6A.1: Choy Sum by pxhere.com / CCO.

Similarly to vitamins, minerals are essential to human health and can be obtained in our diet from different types of food. Minerals are abundant in our everyday lives. From the soil in your front yard to the jewelry you wear on your body, we interact with minerals constantly. There are 20 essential minerals that must be consumed in our diets to remain healthy. The amount of each mineral found in our bodies vary greatly and therefore, so does consumption of those minerals. When there is a deficiency in an essential mineral, health problems may arise.

Major minerals are classified as minerals that are required in the diet each day in amounts larger than 100 milligrams. These include sodium, potassium, chloride, calcium, phosphorus, magnesium, and sulfur. These major minerals can be found in various foods. For example, in Guam, the major mineral, calcium, is consumed in the diet not only through dairy, a common source of calcium, but also through through the mixed dishes, desserts and vegetables that they consume. Consuming a varied diet significantly improves an individual's ability to meet their nutrient needs. [1]

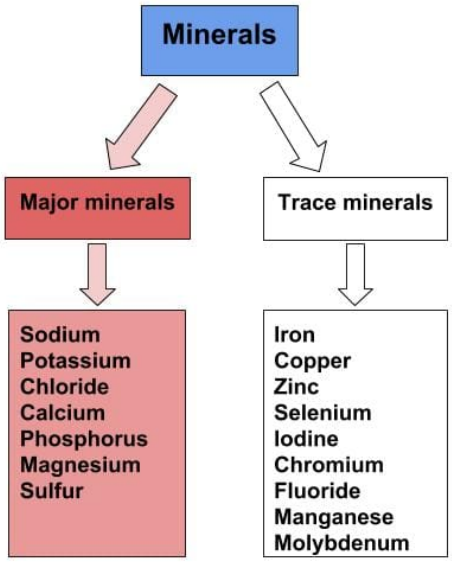


Figure 8.6A.2: The Major Minerals. Image by Allison Calabrese / CC BY 4.0.

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.

Table 8.6A.1: A Summary of the Major Minerals.

Micronutrient	Sources	Recommended Intakes for adults	Major functions	Deficiency diseases and symptoms	Groups at risk for deficiency	Toxicity	UL
Calcium	Yogurt, cheese, sardines, milk, orange juice, turnip	1,000 mg/day	Component of mineralized bone, provides structure and microarchitecture	Increased risk of osteoporosis	Postmenopausal women, those who are lactose intolerant, or vegan	Kidney stones	2,500 mg
Phosphorus	Salmon, yogurt, turkey, chicken, beef, lentils	700 mg/day	Structural component of bones, cell membrane, DNA and RNA, and ATP	Bone loss, weak bones	Older adults, alcoholics	None	3,000 mg
Magnesium	Whole grains and legumes, almonds, cashews, hazelnuts, beets, collards, and kelp	420 mg/day	Component of mineralized bone, ATP synthesis and utilization, carbohydrate, lipid, protein, RNA, and DNA synthesis	Tremor, muscle spasms, loss of appetite, nausea	Alcoholics, individuals with kidney and gastrointestinal disease	Nausea, vomiting, low blood pressure	350 mg/ day

Micronutrient	Sources	Recommended Intakes for adults	Major functions	Deficiency diseases and symptoms	Groups at risk for deficiency	Toxicity	UL
Sulfur	Protein foods	None specified	Structure of some vitamins and amino acids, acid-base balance	None when protein needs are met	None	None	ND
Sodium	Processed foods, table salt, pork, chicken	< 2,300 mg/day; ideally 1,500 mg/day	Major positive extracellular ion, nerve transmission, muscle contraction, fluid balance	Muscle cramps	People consuming too much water, excessive sweating, those with vomiting or diarrhea	High blood pressure	2,300 mg/day
Potassium	Fruits, vegetables, legumes, whole grains, milk	4700 mg/day	Major positive intracellular ion, nerve transmission, muscle contraction, fluid balance	Irregular heartbeat, muscle cramps	People consuming diets high in processed meats, those with vomiting or diarrhea	Abnormal heartbeat	ND
Chloride	Table salt, processed foods	<3600 mg/day; ideally 2300 mg/day	Major negative extracellular ion, fluid balance	Unlikely	none	None	3,600 mg/day

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Footnotes

1. Pobocik RS, Trager A, Monson LM. Dietary Patterns and Food Choices of a Population Sample of Adults on Guam. Asia Pacific Journal of Clinical Nutrition. 2008; 17(1), 94-100. http://apjcn.nhri.org.tw/server/APJCN/17/1/94.pdf. Accessed February 16, 2018.

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8.6B: Calcium

Learning Objectives

- Learn all about calcium

Calcium's Functional Roles

Calcium is the most abundant mineral in the body 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. 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.

Calcium plays a role in a number of different functions in the body like 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 typically make up about 65 percent of bone tissue. When your diet is calcium deficient, the mineral content of bone decreases 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 remaining calcium plays a role in nerve impulse transmission by facilitating electrical impulse transmission from one nerve cell to another. Calcium in muscle cells is essential for muscle contraction because the flow of calcium ions are needed for the muscle proteins (actin and myosin) to interact. Calcium is also essential in blood clotting by activating clotting factors to fix damaged tissue.

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.

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. When blood calcium levels are low, PTH is secreted to increase blood calcium levels via three different mechanisms. 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 is the active hormone that acts on the intestinal cells and increases dietary calcium absorption. When blood calcium levels become too high, the hormone calcitonin is secreted by certain cells in the thyroid gland and PTH secretion stops. At higher nonphysiological concentrations, calcitonin lowers blood calcium levels by increasing calcium excretion in the urine, preventing further absorption of calcium in the gut and by directly inhibiting bone resorption.

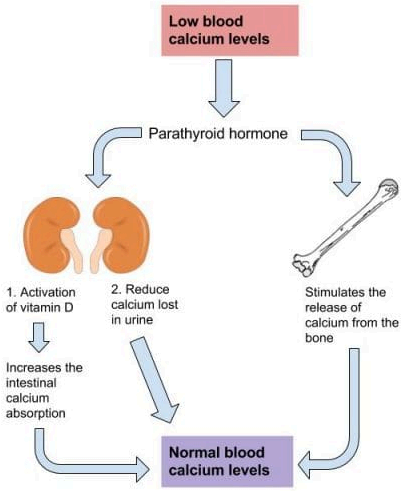


Figure $8.6B.1$: Maintaining Blood Calcium Levels. Image by Allison Calabrese / CC BY 4.0.

Other Health Benefits of Calcium in the Body

Besides forming and maintaining strong bones and teeth, calcium has been shown to have other health benefits for the body, including:

- **Cancer**. The National Cancer Institute reports that there is enough scientific evidence to conclude that higher intakes of calcium decrease colon cancer risk and may suppress the growth of polyps that often precipitate cancer. Although higher calcium consumption protects against colon cancer, some studies have looked at the relationship between calcium and prostate cancer and found higher intakes may increase the risk for prostate cancer; however the data is inconsistent and more studies are needed to confirm any negative association.
- **Blood pressure**. Multiple studies provide clear evidence that higher calcium consumption reduces blood pressure. A review of twenty-three observational studies concluded that for every 100 milligrams of calcium consumed daily, systolic blood pressure is reduced 0.34 millimeters of mercury (mmHg) and diastolic blood pressure is decreased by 0.15 mmHg.[1]
- **Cardiovascular health**. There is emerging evidence that higher calcium intakes prevent against other risk factors for cardiovascular disease, such as high cholesterol and obesity, but the scientific evidence is weak or inconclusive.
- **Kidney stones**. Another health benefit of a high-calcium diet is that it blocks kidney stone formation. Calcium inhibits the absorption of oxalate, a chemical in plants such as parsley and spinach, which is associated with an increased risk for 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.



Figure 8.6B.2: Calcium's Effect on Aging. Image by James Heilman, MD / CC BY-SA 3.0.

Calcium inadequacy is most prevalent in adolescent girls and the elderly. Proper dietary intake of calcium is critical for proper bone health.

Despite the wealth of evidence supporting the many health benefits of calcium (particularly bone health), the average American diet falls short of achieving the recommended dietary intakes of calcium. In fact, in females older than nine years of age, the average daily intake of calcium is only about 70 percent of the recommended intake. Here we will take a closer look at particular groups of people who may require extra calcium intake.

- **Adolescent teens**. A calcium-deficient diet is common in teenage girls as their dairy consumption often considerably drops during adolescence.
- **Amenorrheic women and the "female athlete triad"**. Amenorrhea refers to the absence of a menstrual cycle. Women who fail to menstruate suffer from reduced estrogen levels, which can disrupt and have a negative impact on the calcium balance in their bodies. The "female athlete triad" is a combination of three conditions characterized by amenorrhea, disrupted eating patterns, and osteoporosis. Exercise-induced amenorrhea and anorexia nervosa-related amenorrhea can decrease bone mass.[2][3] 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.[4][5]

- **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.[6]
- **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.[7]
- **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.[8]

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 and there are also some low-lactose and lactose-free dairy products on the market.

Calcium Supplements: Which One to Buy?

Many people choose to fulfill their daily calcium requirements by taking calcium supplements. Calcium supplements are sold primarily as calcium carbonate, calcium citrate, calcium lactate, and calcium phosphate, with elemental calcium contents of about 200 milligrams per pill. It is important to note that 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.

Beware of Lead

There is public health concern about the lead content of some brands of calcium supplements, as supplements derived from natural sources such as oyster shell, bone meal, and dolomite (a type of rock containing calcium magnesium carbonate) are known to contain high amounts of lead. In one study conducted on twenty-two brands of calcium supplements, it was proven that eight of the brands exceeded the acceptable limit for lead content. This was found to be the case in supplements derived from oyster shell and refined calcium carbonate. The same study also found that brands claiming to be lead-free did, in fact, show very low lead levels. Because lead levels in supplements are not disclosed on labels, it is important to know that products not derived from oyster shell or other natural substances are generally low in lead content. 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.[9]

Diet, Supplements, and Chelated Supplements

In general, calcium supplements perform to a lesser degree than dietary sources of calcium in providing many of the health benefits linked to higher calcium intake. This is partly attributed to the fact that dietary sources of calcium supply additional nutrients with health-promoting activities. It is reported that chelated forms of calcium supplements are easier to absorb as the chelation process protects the calcium from oxalates and phytates that may bind with the calcium in the intestines. However, these are more expensive supplements and only increase calcium absorption up to 10 percent. In people with low dietary intakes of calcium, calcium supplements have a negligible benefit on bone health in the absence of a vitamin D supplement. However, when calcium supplements are taken along with vitamin D, there are many benefits to bone health: peak bone mass is increased in early adulthood, BMD is maintained throughout adulthood, the risk of developing osteoporosis is reduced, and the incidence of fractures is decreased in those who already had osteoporosis. Calcium and vitamin D pills do not have to be taken at the same time for effectiveness. But remember that vitamin D has to be activated and in the bloodstream to promote calcium absorption. Thus, it is important to maintain an adequate intake of vitamin D.

The Calcium Debate

A recent study published in the British Medical Journal reported that people who take calcium supplements at doses equal to or greater than 500 milligrams per day in the absence of a vitamin D supplement had a 30 percent greater risk for having a heart attack.[10]

Does this mean that calcium supplements are bad for you? If you look more closely at the study, you will find that 5.8 percent of people (143 people) who took calcium supplements had a heart attack, but so did 5.5 percent of the people (111) people who took the placebo. While this is one study, several other large studies have not shown that calcium supplementation increases the risk for cardiovascular disease. While the debate over this continues in the realm of science, we should focus on the things we do know:

1. There is overwhelming evidence that diets sufficient in calcium prevent osteoporosis and cardiovascular disease.
2. People with risk factors for osteoporosis are advised to take calcium supplements if they are unable to get enough calcium in their diet. The National Osteoporosis Foundation advises that adults age fifty and above consume 1,200 milligrams of calcium per day. This includes calcium both from dietary sources and supplements.
3. Consuming more calcium than is recommended is not better for your health and can prove to be detrimental. Consuming too much calcium at any one time, be it from diet or supplements, impairs not only the absorption of calcium itself, but also the absorption of other essential minerals, such as iron and zinc. Since the GI tract can only handle about 500 milligrams of calcium at one time, it is recommended to have split doses of calcium supplements rather than taking a few all at once to get the RDA of calcium.

Dietary Reference Intake for Calcium

The recommended dietary allowances (RDA) for calcium are listed in Table $8.6B.1$. The RDA is elevated to 1,300 milligrams per day during adolescence because this is the life stage with 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 D3 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.

Table $8.6B.1$***:*** *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 AC, Manson JE, 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. 2011; 96(1), 53–8. http://www.ncbi.nlm.nih.gov/pubmed/21118827. Accessed October 10, 2017.

Dietary Sources of Calcium

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 other good non-dairy sources of calcium.

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 some plant-based foods that are high in calcium. Tofu (made with calcium sulfate), turnip greens, mustard greens, and chinese cabbage are good sources. For a list of non-dairy sources you can find the calcium content for thousands of foods by visiting the USDA National Nutrient Database (www.nal.usda.gov/fnic/foodcomp/search/). When obtaining your calcium from a vegan diet, it is important to know that some plant-based foods significantly impair the absorption of calcium. These include spinach, Swiss chard, rhubarb, beets, cashews, and peanuts. With careful planning and good selections, you can ensure that you are getting enough calcium in your diet even if you do not drink milk or consume other dairy products.

Table $8.6B.2$***:*** *Calcium Content of Various Foods.*

Food	Serving	Calcium (mg)	Percent Daily Value
Yogurt, low fat	8 oz.	415	42
Mozzarella	1.5 oz.	333	33
Sardines, canned with bones	3 oz.	325	33
Cheddar Cheese	1.5 oz.	307	31
Milk, nonfat	8 oz.	299	30
Soymilk, calcium fortified	8 oz.	299	30
Orange juice, calcium fortified	6 oz.	261	26
Tofu, firm, made with calcium sulfate	½ c.	253	25
Salmon, canned with bones	3 oz.	181	18
Turnip, boiled	½ c.	99	10
Kale, cooked	1 c.	94	9
Vanilla Ice Cream	½ c.	84	8
White bread	1 slice	73	7
Kale, raw	1 c.	24	2
Broccoli, raw	½ c.	21	2

Fact Sheet for Health Professionals: Calcium. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Ca...hProfessional/. Updated November 17, 2016. Accessed November 12, 2017.

Calcium Bioavailability

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. Interestingly, the calcium in some vegetables such as kale, brussel sprouts, and bok choy is better absorbed by the body than are dairy products. About 30 percent of calcium is absorbed from milk and other dairy products.

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.

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 sickness, medications, and certain symptoms related to old age, decreases the transit time of calcium in the gut and therefore decreases calcium absorption. As we get older, stomach acidity sometimes decreases, diarrhea occurs more often, kidney function is impaired, and vitamin D absorption and activation is compromised, all of which contribute to a decrease in calcium bioavailability.

Footnotes

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8.6C: Phosphorus

Learning Objectives

- Learn all about phosphorus

Phosphorus is present in our bodies as part of a chemical group called a phosphate group. These phosphate groups are essential as a structural component of cell membranes (as phospholipids), DNA and RNA, energy production (ATP), and regulation of acid-base homeostasis. Phosphorus however is mostly associated with calcium as a part of the mineral structure of bones and teeth. Blood phosphorus levels are not controlled as strictly as calcium so the PTH stimulates renal excretion of phosphate so that it does not accumulate to toxic levels.

Dietary Reference Intakes 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 8.6C.1: 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		

Micronutrient Information Center: Phosphorus. Oregon State University, Linus Pauling Institute. http://lpi.oregonstate.edu/mic/minerals/phosphorus. Updated in July 2013. Accessed October 22, 2017.

Dietary Sources of Phosphorus

Table 8.6C.2: Phosphorus Content of Various Foods.

Foods	Serving	Phosphorus (mg)	Percent Daily Value 1000
Salmon	3 oz.	315	32
Yogurt, nonfat	8 oz.	306	31
Turkey, light meat	3 oz.	217	22
Chicken, light meat	3 oz.	135	14
Beef	3 oz.	179	18

Foods	Serving	Phosphorus (mg)	Percent Daily Value 1000
Lentils*	½ c.	178	18
Almonds*	1 oz.	136	14
Mozzarella	1 oz.	131	13
Peanuts*	1 oz.	108	11
Whole wheat bread	1 slice	68	7
Egg	1 large	86	9
Carbonated cola drink	12 oz.	41	4
Bread, enriched	1 slice	25	3

Micronutrient Information Center: Phosphorus. Oregon State University, Linus Pauling Institute. http://lpi.oregonstate.edu/mic/minerals/phosphorus. Updated in July 2013. Accessed October 22, 2017.

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8.6D: Sulfur

Learning Objectives

- Learn why sulphur is essential for our body

Sulfur is incorporated into protein structures in the body. Amino acids, methionine and cysteine contain sulfur which are essential for the antioxidant enzyme glutathione peroxidase. Some vitamins like thiamin and biotin also contain sulfur which are important in regulating acidity in the body. Sulfur is a major mineral with no recommended intake or deficiencies when protein needs are met. Sulfur is mostly consumed as a part of dietary proteins and sulfur containing vitamins.

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8.6E: Magnesium

Learning Objectives

- Learn about the role of magnesium in our body

Magnesium's Functional Role

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 hard mineral crystals, but it does reside on the surface of the crystal and helps 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.[1] 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 required. 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 and muscle contraction. Another health benefit of magnesium is that it may decrease blood pressure.

Many Americans do not get the recommended intake of magnesium from their diets. Some observational studies suggest mild magnesium deficiency is linked to increased risk for cardiovascular disease. Signs and symptoms of severe magnesium deficiency may include tremor, muscle spasms, loss of appetite, and nausea.

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.

Table $8.6E.1$***:*** *Dietary Reference Intakes for Magnesium.*

Age Group	RDA (mg/day)	UL from non-food sources (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: Dietary Supplement Fact Sheet: Magnesium. National Institutes of Health, Office of Dietary Supplements. http://ods.od.nih.gov/factsheets/Mag...hProfessional/. Updated July 13, 2009. Accessed November 12, 2017.

Dietary Sources of Magnesium

Magnesium is part of the green pigment, chlorophyll, which is vital for photosynthesis in plants; therefore green leafy vegetables are a good dietary source for 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.

Table $8.6E.2$***:*** *Magnesium Content of Various Foods.*

Food	Serving	Magnesium (mg)	Percent Daily Value
Almonds	1 oz.	80	20
Cashews	1 oz.	74	19
Soymilk	1 c.	61	15
Black beans	½ c.	60	15
Edamame	½ c.	50	13
Bread	2 slices	46	12
Avocado	1 c.	44	11
Brown rice	½ c.	42	11
Yogurt	8 oz.	42	11
Oatmeal, instant	1 packet	36	9
Salmon	3 oz.	26	7
Chicken breasts	3 oz.	22	6
Apple	1 medium	9	2

Source: Dietary Supplement Fact Sheet: Magnesium. National Institutes of Health, Office of Dietary Supplements. http://ods.od.nih.gov/factsheets/Mag...hProfessional/. Updated July 13, 2009. Accessed November 12, 2017.

Footnotes

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8.6F: Sodium

Learning Objectives

- Learn about the importance of Sodium for fluid balance

Sodium is vital not only for maintaining fluid balance but also for many other essential body functions. In contrast to many minerals, sodium absorption in the small intestine is extremely efficient and in a healthy individual, all excess sodium is excreted by the kidneys. In fact, 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.

The typical American diet today is quite high in sodium, often providing > 2,300 milligrams of sodium per day. This is especially true if a person eats a lot of processed or packaged foods. For young people with healthy kidneys excess sodium intake may not be a problem. However, high sodium intake can have serious consequences for people with compromised kidney function. In addition, during the normal aging process the kidneys often become less efficient at excreting excess sodium from the blood. In either case, the result of compromised kidney function is the retention of fluid in the blood leading to higher pressure within the blood vessels. This condition is know as high blood pressure or hypertension, and can often be controlled by reducing the amount of sodium consumed.

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.

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 is negligible, but is highly variable among individuals. It is estimated that sixty minutes of high-intensity physical activity, like playing a game of tennis, can produce approximately one liter of sweat; however the amount of sweat produced is highly dependent on environmental conditions. A liter of sweat typically contains between 1 and 2 grams of sodium and therefore exercising for multiple hours can result in a high amount of sodium loss in some people. Additionally, hard labor can produce substantial sodium loss through sweat. In either case, the lost sodium is easily replaced in the next snack or meal.

In athletes hyponatremia, or a low blood-sodium level, is not so much the result of excessive sodium loss in sweat, but rather drinking too much water. The excess water dilutes the sodium concentration in blood. Illnesses causing vomiting, sweating, and diarrhea may also cause hyponatremia. The symptoms of hyponatremia, also called water intoxication (since it is often the root cause) include nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death. The physiological events that occur in water intoxication are the following:

1. Excessive sodium loss and/or water intake.
2. Sodium levels fall in blood and in the fluid between cells.
3. Water moves to where solutes are more concentrated (i.e. into cells).
4. Cells swell.

5. Symptoms, including nausea, muscle cramps, confusion, dizziness, and in severe cases, coma and death result.

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.[1]

Watch out for the fat content, as sometimes energy bars contain a hefty dose. If you're not exercising over an hour at high intensity, you can skip the sports drinks, but not the water. For those who do not exercise or do so at low to moderate intensity, sports drinks are another source of extra calories, sugar, and salt.

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 1,500 milligrams (Table $8.6F.1$). Table salt is approximately 40 percent sodium and 60 percent chloride. 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.The Tolerable Upper Intake Level (UL) for sodium is 2,300 milligrams per day for adults. (Just over 1 teaspoon of salt contains the 2,300 milligrams 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 1,500 milligrams of sodium per day. The American Heart Association (AHA) states that all Americans, not just those listed, should consume less than 1,500 milligrams 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 $8.6F.1$***:*** *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: Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate. Institute of Medicine. www.iom.edu/Reports/2004/Diet...d-Sulfate.aspx. Updated February 11, 2004. Accessed September 22, 2017.

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. For the sodium contents

of various foods see Table $8.6F.2$.

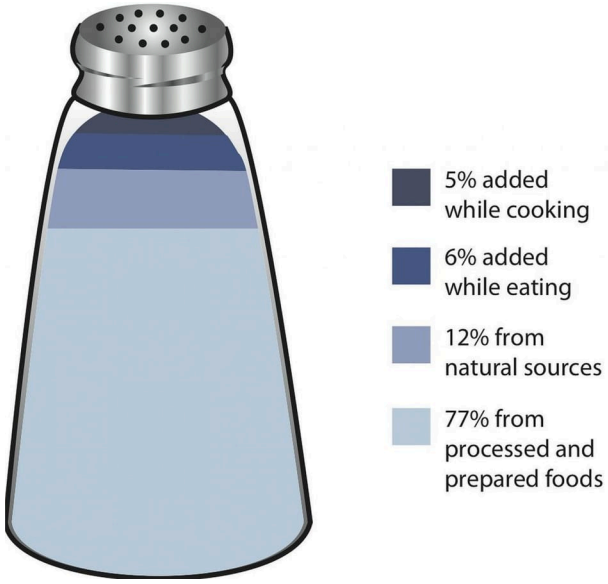


Figure $8.6F.1$: Dietary Sources of Sodium.

Table $8.6F.2$***: 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
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
Potato chips	1 oz. (28.4 g)	120–180
Tortilla chips	1 oz. (28.4 g)	105–160
Pork	3 oz.	59
Chicken	(½ breast)	69
Chicken fast food dinner		2243
Chicken noodle soup	1 c.	1107
Dill pickle	1	928
Soy sauce	1 Tbsp.	1029
Canned corn	1 c.	384
Baked beans, canned	1 c.	856
Hot dog	1	639
Burger, fast-food	1	990
Steak	3 oz.	55

Food Group	Serving Size	Sodium (mg)
Canned tuna	3 oz.	384
Fresh tuna	3 oz.	50
Dry-roasted peanuts	1 c.	986
American cheese	1 oz.	406
Tap water	8 oz.	12

Sodium on the Nutrition Facts Panel



Figure $8.6F.2$: Nutrition Label. Sodium levels in milligrams is a required listing on a Nutrition Facts label.

The Nutrition Facts panel displays the amount of sodium (in milligrams) per serving of the food in question (Figure $8.6F.2$). 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 as well. 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 3.4 "Food Packaging Claims Regarding Sodium").

Table $8.6F.3$***:*** *Food Packaging Claims Regarding Sodium.*

Claim	Meaning
"Light in Sodium" or "Low in Sodium"	Sodium is reduced by at least 50 percent
"No Salt Added" or "Unsalted"	No salt added during preparation and processing*
"Lightly Salted"	50 percent less sodium than that added to similar food
"Sodium Free" or "Salt Free"	Contains less than 5 mg sodium per serving
"Very Low Salt"	Contains less than 35 mg sodium per serving
"Low Salt"	Contains less than 140 mg sodium per serving

*Must also declare on package "This is not a sodium-free food" if food is not sodium-free

Source: Food Labeling Guide. US Food and Drug Administration.

www.fda.gov/Food/GuidanceComp.../ucm064911.htm. Updated 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.

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 $8.6F.4$ displays the sodium and potassium amounts in some salt substitutes.

Table $8.6F.4$***:*** *Salt Substitutes.*

Product	Serving Size	Sodium (mg)	Potassium (mg)
Salt	1 tsp.	2,300	0
Mrs. Dash	1 tsp.	0	40
Spike (Salt-Free)	1 tsp.	0	96
Veg-It	1 tsp.	<65	<65
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: Health Facts for You: Guidelines for a Low Sodium Diet. University of Wisconsin Hospitals and Clinics Authority. www.uhs.wisc.edu/health-topic...nts/Sodium.pdf. Updated March 2011. Accessed September 22, 2017.

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 $8.6F.5$ for an AHA list of alternative food seasonings.

Table $8.6F.5$***:*** *Salt Alternatives.*

Seasoning	Foods
Allspice	Lean ground meats, stews, tomatoes, peaches, applesauce, cranberry sauce, gravies, lean meat
Almond extract	Puddings, fruits

Seasoning	Foods
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
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: Shaking the Salt Habit. American Heart Association.

http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/PreventionTreatmentofHighBloodPressure/Shaking-the-Salt-Habit_UCM_303241_Article.jsp. Updated June 6, 2012. Accessed September 22, 2017.

Footnotes

1. Convertino VA, et al. American College of Sports Medicine Position Stand. Exercise and Fluid Replacement. Medicine and Science in Sports and Exercise. 1996; 28(1) i–vii. http://www.ncbi.nlm.nih.gov/pubmed/9303999. Accessed September 22, 2017. ↩

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8.6G: Chloride

Learning Objectives

- Learn about Chloride's role in fluid balance

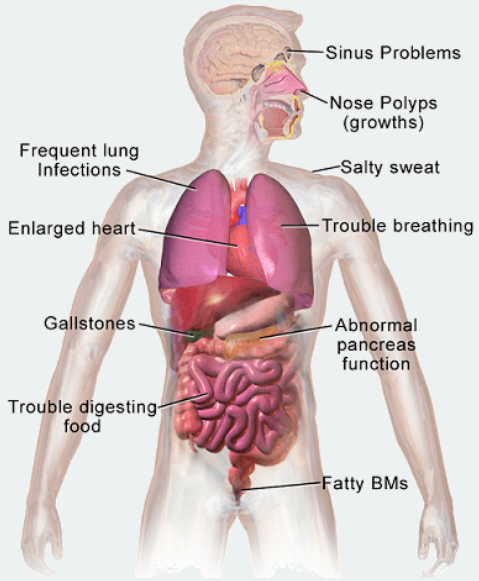
Chloride is the primary anion in extracellular fluid. In addition to passively following sodium, chloride has its own protein channels that reside in cell membranes. These protein channels are especially abundant in the gastrointestinal tract, pancreas, and lungs.

Chloride's Role in Fluid Balance and Balancing pH

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 (CF).

Cystic Fibrosis

Cystic fibrosis 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.



*Health problems associated with cystic fibrosis. (CC BY 3.0; Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine **1** (2).DOI:10.15347/wjm/2014.010. ISSN 2002-4436.)*

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.

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 5,600 milligrams, with each teaspoon of salt containing 3,400 milligrams of chloride and 2,200 milligrams of sodium. The chloride AI for adults, set by the IOM, is 2,300 milligrams. 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 $8.6G.1$.

Table $8.6G.1$: Adequate Intakes for Chloride.

Age Group	mg/day
Infants (0–6 months)	180
Infants (6–12 months)	570
Children (1–3 years)	1,500
Children (4–8 years)	1,900
Children (9–13 years)	2,300
Adolescents (14–18 years)	2,300
Adults (19–50 years)	2,300
Adults (51–70 years)	2,000
Adults (> 70 years)	1,800

Source: Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate. Institute of Medicine. www.iom.edu/Reports/2004/Diet...d-Sulfate.aspx. Updated February 11, 2004. Accessed September 22, 2017.

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

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 chloride is the amount that is on hand to perform its biological functions. 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.

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8.6H: Potassium

Learning Objectives

- Learn about the functions of Potassium in the body

Potassium is the most abundant positively charged ion inside of cells. 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.

Other Functions of Potassium in the Body

Potassium plays an important role in managing blood pressure. Potassium balances the effects of sodium on blood pressure because the more potassium you eat, the more sodium you lose through urine. Nerve impulses also involve both sodium and 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, also affects the heart. It is a silent condition as it often displays no signs or symptoms. Extremely high levels of potassium in the blood disrupt the electrical impulses that stimulate the heart and can cause the heart to stop. Hyperkalemia is usually the result of kidney dysfunction.

Needs and Dietary Sources of Potassium

The IOM based their AIs for potassium on the levels associated with a decrease in blood pressure, a reduction in salt sensitivity, and a minimal risk of kidney stones. For adult male and females above the age of nineteen, the adequate intake for potassium is 4,700 grams per day. The AIs for other age groups are listed in Table $8.6H.1$.

Table $8.6H.1$***:*** *Adequate Intakes for Potassium.*

Age Group	mg/day
Infants (0–6 months)	400
Infants (6–12 months)	700
Children (1–3 years)	3,000

Age Group	mg/day
Children (4–8 years)	3,800
Children (9–13 years)	4,500
Adolescents (14–18 years)	4,700
Adults (> 19 years)	4,700

Dietary Reference Intakes: Water, Potassium, Sodium, Chloride, and Sulfate. Institute of Medicine. www.iom.edu/Reports/2004/Diet...d-Sulfate.aspx. Updated February 11, 2004. Accessed September 22, 2017.

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.

Bioavailability

Greater than 90 percent of dietary potassium is absorbed in the small intestine. Although highly bioavailable, potassium is a very soluble mineral and easily lost during cooking and processing of foods. Fresh and frozen foods are better sources of potassium than canned.

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8.7: TRACE MINERALS

Trace minerals are classified as minerals required in the diet each day in smaller amounts, specifically 100 milligrams or less. These include copper, zinc, selenium, iodine, chromium, fluoride, manganese, molybdenum, and others

8.7A: Prelude to Trace Minerals

8.7B: Iron

8.7C: Copper

8.7D: Zinc

8.7E: Iodine

8.7F: Chromium

8.7G: Manganese

8.7H: Molybdenum

8.7I: Fluoride

8.7J: Selenium

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8.7A: Prelude to Trace Minerals

Learning Objectives

- Describe the functional role, intake recommendations and sources of trace minerals

Trace minerals are classified as minerals required in the diet each day in smaller amounts, specifically 100 milligrams or less. These include copper, zinc, selenium, iodine, chromium, fluoride, manganese, molybdenum, and others. Although trace minerals are needed in smaller amounts it is important to remember that a deficiency in a trace mineral can be just as detrimental to your health as a major mineral deficiency.

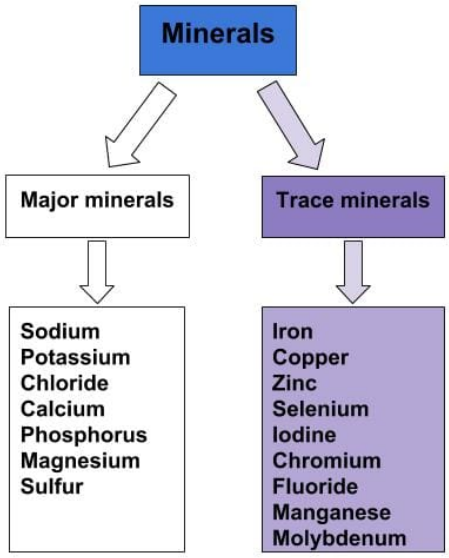


Figure 8.7A.2: The Trace Minerals. Image by Allison Calabrese / CC BY 4.0.

Iodine deficiency is a major concern in countries around the world such as Fiji. In the 1990's, almost 50% of the population had signs of iodine deficiency also known as goiter. To combat this national issue, the government of Fiji banned non-iodized salt and allowed only fortified iodized salt into the country in hopes of increasing the consumption of iodine in people's diets. With this law, and health promotion efforts encouraging the consumption of seafood, great progress has been made in decreasing the prevalence of iodine deficiency in Fiji.[1]

Table 8.7A.1: Summary of the Trace Minerals.

Micronutrient	Sources	Recommended Intakes for adults	Major Functions	Deficiency diseases and symptoms	Groups at risk for deficiency	Toxicity	UL
Iron	Red meat, egg yolks, dark leafy vegetables, dried fruit, iron-fortified foods	8-18 mg/day	Assists in energy production, DNA synthesis required for red blood cell function	Anemia: fatigue, paleness, faster heart rate	Infants and preschool children, adolescents, women, pregnant women, athletes, vegetarians	Liver damage, increased risk of diabetes and cancer	45 mg day

Micronutrient	Sources	Recommended Intakes for adults	Major Functions	Deficiency diseases and symptoms	Groups at risk for deficiency	Toxicity	UL
Copper	Nuts, seeds, whole grains, seafood	900 mcg/day	Assists in energy production, iron metabolism	Anemia: fatigue, paleness, faster heart rate	Those who consume excessive zinc supplements	Vomiting, abdominal pain, diarrhea, liver damage	10 mg day
Zinc	oysters, wheat germ, pumpkin seeds, squash,, beans, sesame seeds, tahini, beef, lamb	8-11 mg/day	Assists in energy production, protein, RNA and DNA synthesis; required for hemoglobinsynthesis	Growth retardation in children, hair loss, diarrhea, skin sores, loss of appetite, weight loss	Vegetarians, older adults	Depressed immune function	40 mg day
Selenium	Meat, seafood, eggs, nuts	55 mcg/day	Essential for thyroid hormone activity	Fatigue, muscle pain, weakness, Keshan disease	Populations where the soil is low in selenium	Nausea, diarrhea, vomiting, fatigue	400 mcg day
Iodine	Iodized salt, seaweed, dairy products	150 mcg/day	Making thyroid hormone, metabolism, growth and development	Goiter, cretinism, other signs and symptoms include fatigue, depression, weight gain, itchy skin, low heart-rate	Populations where the soil is low in iodine, and iodized salt is not used	Enlarged thyroid	1110 mcg day
Chromium		25-35 mcg/day	Assists insulin in carbohydrate, lipid and protein metabolism	abnormal glucosemetabolism	Malnourished children	None	ND
Fluoride	Fluoridated water, foods prepared in fluoridated water, seafood	3-4 mg/day	Component of mineralized bone, provides structure and microarchitecture, stimulates new bone growth	Increased risk of dental caries	Populations with non fluoridated water	Fluorosismottled teeth, kidney damage	10 mg day
Manganese	Legumes, nuts, leafy green vegetables	1.8-2.3 mg/day	Glucose synthesis, amino-acid catabolism	Impaired growth, skeletal abnormalities, abnormal glucose metabolism	None	Nerve damage	11 mg day
Molybdenum	Milk, grains, legumes	45 mcg/day	Cofactor for a number of enzymes	Unknown	None	Arthritis, joint inflammation	2 mg day

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Footnotes

1. Micronutrient Deficiencies. Ministry of Health and Medical Services, Shaping Fiji's Health. http://www.health.gov.fj/?page_id=1406. Published 2015. Accessed November 12, 2017.

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8.7B: Iron

Learning Objectives

- Learn about the role of iron in our body

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 $8.7B.1$). Iron is needed for the production of other iron-containing proteins such as myoglobin. Myoglobin is a protein found in the muscle tissues that enhances the amount of available oxygen for muscle contraction. Iron is also a key component of hundreds of metabolic enzymes. Many of the proteins of the electron-transport chain contain iron–sulfur clusters involved in the transfer of high-energy electrons and ultimately ATP synthesis. Iron is also involved in numerous metabolic reactions that take place mainly in the liver and detoxify harmful substances. Moreover, iron is required for DNA synthesis. The great majority of iron used in the body is that recycled from the continuous breakdown of red blood cells.

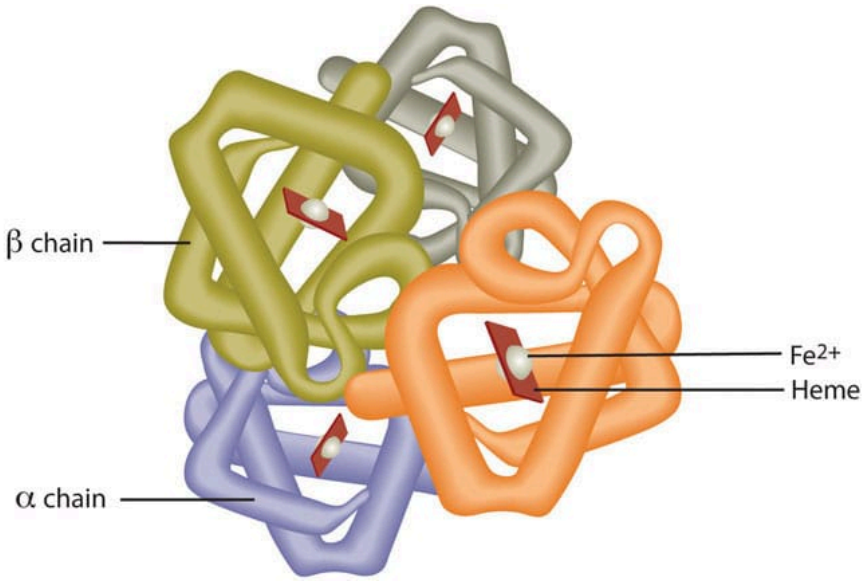


Figure $8.7B.1$: The Structure of Hemoglobin.

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. If iron level is low hemoglobin is not synthesized in sufficient amounts and the oxygen-carrying capacity of red blood cells is reduced, resulting in anemia. When iron levels are low in the diet the small intestine more efficiently absorbs iron in an attempt to compensate for the low dietary intake, but this process cannot make up for the excessive loss of iron that occurs with chronic blood loss or low intake. When blood cells are decommissioned for use, the body recycles the iron back to the bone marrow where red blood cells are made. The body stores some iron in the bone marrow, liver, spleen, and skeletal muscle. A relatively small amount of iron is excreted when cells lining the small intestine and skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

The bioavailability of iron is highly dependent on dietary sources. In animal-based foods about 60 percent of iron is bound to hemoglobin, and heme iron is more bioavailable than nonheme iron. The other 40 percent of iron in animal-based foods is nonheme, which is the only iron source in plant-based foods. Some plants contain chemicals (such as phytate, oxalates, tannins, and polyphenols) that inhibit iron absorption. Although, eating fruits and vegetables rich in vitamin C at the same time as iron-containing foods markedly increases iron absorption. A review in the American Journal of Clinical Nutrition reports that in developed countries iron bioavailability from mixed diets ranges between 14 and 18 percent, and that from vegetarian diets ranges between 5 and 12 percent.[1] 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.

Table 8.7B.1: Enhancers and Inhibitors of Iron Absorption.

Enhancer	Inhibitor
Meat	Phosphate
Fish	Calcium
Poultry	Tea
Seafood	Coffee
Stomach acid	Colas
	Soy protein
	High doses of minerals (antacids)
	Bran/fiber
	Phytates
	Oxalates
	Polyphenols

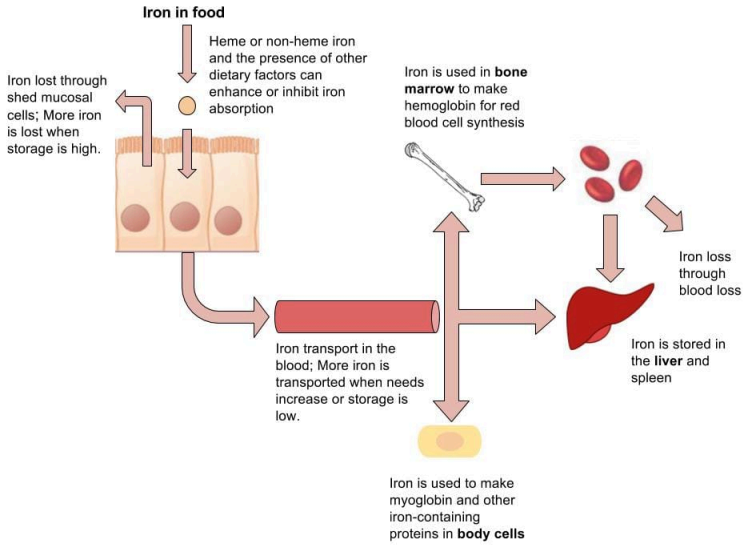


Figure 8.7B.2: Iron Absorption, Functions, and Loss. Image by Allison Calabrese / CC BY 4.0.

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 8.7B.2). 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 non-genetic metabolic abnormalities, but are often increased in severity.

Dietary Reference Intakes for Iron

***Table** 8.7B.2: Dietary Reference Intakes for Iron.*

Age Group	RDA (mg/day)	UL (mg/day)
Infant (0–6 months)	0.27*	40
Infants (6–12 months)	11*	40
Children (1–3 years)	7	40
Children (4–8 years)	10	40
Children (9–13 years)	8	40
Adolescents (14–18 years)	11 (males), 15 (females)	45
Adults (19–50 years)	8 (males), 18 (females)	45
Adults (> 50 years)	8	45
* denotes Adequate Intake		

Dietary Sources of Iron

Table $8.7B.3$***:*** *Iron Content of Various Foods.*

Food	Serving	Iron (mg)	Percent Daily Value
Breakfast cereals, fortified	1 serving	18	100
Oysters	3 oz.	8	44
Dark chocolate	3 oz.	7	39
Beef liver	3 oz.	5	28
Lentils	½ c.	3	17
Spinach, boiled	½ c.	3	17
Tofu, firm	½ c.	3	17
Kidney beans	½ c.	2	11
Sardines	3 oz.	2	11

Iron-Deficiency Anemia

Iron-deficiency anemia is a condition that develops from having insufficient iron levels in the body resulting in fewer and smaller red blood cells containing lower amounts of hemoglobin. Regardless of the cause (be it from low dietary intake of iron or via excessive blood loss), iron-deficiency anemia has the following signs and symptoms, which are linked to the essential functions of iron in energy metabolism and blood health:

- Fatigue
- Weakness
- Pale skin
- Shortness of breath
- Dizziness
- Swollen, sore tongue
- Abnormal heart rate

Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. 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. Avoiding foods and beverages high in phytates and also tea (which contains

tannic acid and polyphenols, both of which impair iron absorption), is important for people who have iron-deficiency anemia. Eating a dietary source of vitamin C at the same time as iron-containing foods improves absorption of nonheme iron in the gut. Additionally, unknown compounds that likely reside in muscle tissue of meat, poultry, and fish increase iron absorption from both heme and nonheme sources.

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.[2] The WHO estimates that 80 percent of people are iron deficient and 30 percent of the world population has iron-deficiency anemia.[3] 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 dietary iron deficiency and chronic disease such as ulcer, inflammatory diseases, and cancer. Additionally, those who have recently suffered from traumatic blood loss, frequently donate blood, or take excessive antacids for heartburn need more iron in the diet.

Preventing Iron-Deficiency Anemia

In young children iron-deficiency anemia can cause significant motor, mental, and behavioral 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.

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:[4]

- 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 ongoing investigation as to whether supplying iron cookware to at-risk populations is effective in preventing and treating iron-deficiency anemia.

Footnotes

1. Centers for Disease Control and Prevention. "Iron and Iron Deficiency." Accessed October 2, 2011. www.cdc.gov/nutrition/everyon...mins/iron.html.

2. Iron and Iron Deficiency. Centers for Disease Control and Prevention. www.cdc.gov/nutrition/everyon....html.Accessed October 2, 2011.
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8.7C: Copper

Learning Objectives

- Learn about the role of copper

Copper, like iron, assists in electron transfer in the electron-transport chain. Furthermore, copper is a cofactor of enzymes essential for iron absorption and transport. The other important function of copper is as an antioxidant. 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.

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8.7D: Zinc

Learning Objectives

- Learn about the role of Zinc

Zinc is a cofactor for over two hundred enzymes in the human body and plays a direct role in RNA, DNA, and protein synthesis. Zinc also is a cofactor for enzymes involved in energy metabolism. As the result of its prominent roles in anabolic and energy metabolism, a zinc deficiency in infants and children blunts growth. The reliance of growth on adequate dietary zinc was discovered in the early 1960s in the Middle East where adolescent nutritional dwarfism was linked to diets containing high amounts of phytate. Cereal grains and some vegetables contain chemicals, one being phytate, which blocks the absorption of zinc and other minerals in the gut. It is estimated that half of the world's population has a zinc-deficient diet.[1]

This is largely a consequence of the lack of red meat and seafood in the diet and reliance on cereal grains as the main dietary staple. In adults, severe zinc deficiency can cause hair loss, diarrhea, skin sores, loss of appetite, and weight loss. Zinc is a required cofactor for an enzyme that synthesizes the heme portion of hemoglobin and severely deficient zinc diets can result in anemia.

Dietary Reference Intakes for Zinc

Table $8.7D.1$***:*** *Dietary Reference Intakes for Zinc.*

Age Group	RDA (mg/day)	UL (mg/day)
Infant (0–6 months)	2*	4
Infants (6–12 months)	3	5
Children (1–3 years)	3	7
Children (4–8 years)	5	12
Children (9–13 years)	8	23
Adolescents (14–18 years)	11 (males), 9 (females)	34
Adults (19 + years)	11 (males), 8 (females)	40
* denotes Adequate Intake		

Fact Sheet for Health Professionals: Zinc. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Zi...hProfessional/. Updated February 11, 2016. Accessed November 10, 2017.

Dietary Sources of Zinc

Table $8.7D.2$***:*** *Zinc Content of Various Foods.*

Food	Serving	Zinc (mg)	Percent Daily Value
Oysters	3 oz.	74	493
Beef, chuck roast	3 oz.	7	47
Crab	3 oz.	6.5	43
Lobster	3 oz.	3.4	23
Pork loin	3 oz.	2.9	19

Food	Serving	Zinc (mg)	Percent Daily Value
Baked beans	½ c.	2.9	19
Yogurt, low fat	8 oz.	1.7	11
Oatmeal, instant	1 packet	1.1	7
Almonds	1 oz.	0.9	6

Fact Sheet for Health Professionals: Zinc. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Zi...hProfessional/. Updated February 11, 2016. Accessed November 10, 2017

Footnotes

1. 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/arti...tool=pmcentrez.

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8.7E: Iodine

Learning Objectives

- Learn about the role of iodine

Recall the discovery of iodine and its use as a means of preventing goiter, a gross enlargement of the thyroid gland in the neck. Iodine is essential for the synthesis of thyroid hormone, which regulates basal metabolism, growth, and development. Low iodine levels and consequently hypothyroidism has many signs and symptoms including fatigue, sensitivity to cold, constipation, weight gain, depression, and dry, itchy skin and paleness. The development of goiter may often be the most visible sign of chronic iodine deficiency, but the consequences of low levels of thyroid hormone can be severe during infancy, childhood, and adolescence as it affects all stages of growth and development. Thyroid hormone plays a major role in brain development and growth and fetuses and infants with severe iodine deficiency develop a condition known as cretinism, in which physical and neurological impairment can be severe. The World Health Organization (WHO) estimates iodine deficiency affects over two billion people worldwide and it is the number-one cause of preventable brain damage worldwide.[1]

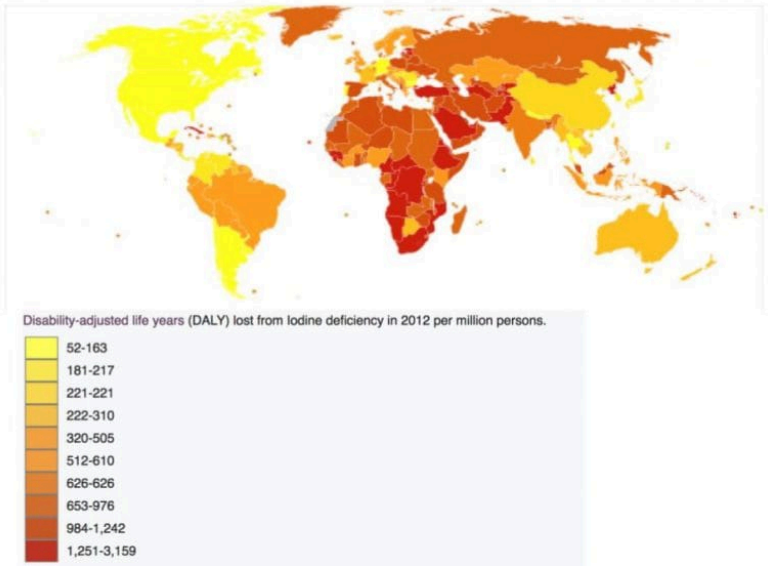


Figure $8.7E.1$: Deaths Due to Iodine Deficiency Worldwide in 2012. Image by Chris55 / CC BY 4.0.



Figure $8.7E.2$: Iodine Deficiency - Goiter. A large goiter by Dr. J.S.Bhandari, India / CC BY-SA 3.0.

Dietary Reference Intakes for Iodine

Table 8.7E.1: Dietary Reference Intakes for Iodine.

Age Group	RDA Males and Females mcg/day	UL
Infants (0–6 months)	110*	-
Infants (7–12 months)	130*	-
Children (1–3 years)	90	200
Children (4–8 years)	120	300
Children (9–13 years)	150	600
Adolescents (14–18 years)	150	900
Adults (> 19 years)	150	1,100

*denotes Adequate Intake. Health Professional Fact Sheet: Iodine. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Io...hProfessional/. Updated June 24, 2011. Accessed November 10, 2017.

Dietary Sources of Iodine

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 8.7E.2: Iodine Content of Various Foods.

Food	Serving	Iodine (mcg)	Percent Daily Value
Seaweed	1 g.	16 to 2,984	11 to 1,989
Cod fish	3 oz.	99	66
Yogurt, low fat	8 oz.	75	50
Iodized salt	1.5 g.	71	47
Milk, reduced fat	8 oz.	56	37
Ice cream, chocolate	½ c.	30	20
Egg	1 large	24	16
Tuna, canned	3 oz.	17	11
Prunes, dried	5 prunes	13	9
Banana	1 medium	3	2

Health Professional Fact Sheet: Iodine. National Institute of Health, Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Io...hProfessional/. Updated June 24, 2011. Accessed November 10, 2017.

Footnotes

1. World Health Organization. “Iodine Status Worldwide.” Accessed October 2, 2011. http://whqlibdoc.who.int/publication...92415920001.pdf.

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8.7F: Chromium

Learning Objectives

- Learn about the role of chromium

The functioning of chromium in the body is less understood than that of most other minerals. It enhances the actions of insulin so plays a role in carbohydrate, fat, and protein metabolism. Currently, the results of scientific studies evaluating the usefulness of chromium supplementation in preventing and treating Type 2 diabetes are largely inconclusive. More research is needed to better determine if chromium is helpful in treating certain chronic diseases and, if so, at what doses. Dietary sources of chromium include nuts, whole grains, and yeast. The recommended intake for chromium is 35 mcg per day for adult males and 25 mcg per day for adult females. There is insufficient evidence to establish an UL for chromium.

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8.7G: Manganese

Learning Objectives

- Learn about the role of manganese

Manganese is a cofactor for enzymes that are required for carbohydrate and cholesterol metabolism, bone formation, and the synthesis of urea. The recommended intake for manganese is 2.3 mg per day for adult males and 1.8 mg per day for adult females. Manganese deficiency is uncommon. The best food sources for manganese are whole grains, nuts, legumes, and green vegetables.

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8.7H: Molybdenum

Learning Objectives

- Learn about the role of molybdenum

Molybdenum also acts as a cofactor that is required for the metabolism of sulfur-containing amino acids, nitrogen-containing compounds found in DNA and RNA, and various other functions. The recommended intake for molybdenum is 46 mcg per day for both adult males and females. The food sources of molybdenum is varies depending on the content in the soil in the specific region.

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8.7I: Fluoride

Learning Objectives

- Learn about the role of fluoride

Fluoride's Functional Role

Fluoride is known mostly as the mineral that combats tooth decay. 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 in the twentieth century[1].

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.



Figure 8.7*I*.1: A Severe Case of Fluorosis. Bellingham fluorosis by Editmore / Public Domain.

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

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.

Table 8.7I.1: 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/Diet...-Fluoride.aspx..

Dietary Sources of Fluoride

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 8.7I.2: Fluoride Content of Various Foods.

Food	Serving	Fluoride (mg)	Percent Daily Value*
Fruit Juice	3.5 fl oz.	0.02-2.1	0.7-70
Crab, canned	3.5 oz.	0.21	7
Rice, cooked	3.5 oz.	0.04	1.3
Fish, cooked	3.5 oz.	0.02	0.7
Chicken	3.5 oz.	0.015	0.5

* Current AI used to determine Percent Daily Value Micronutrient Information Center: Fluoride. Oregon State University, Linus Pauling Institute. lpi.oregonstate.edu/mic/minerals/fluoride . Updated in April 29, 2015. Accessed October 22, 2017.

Footnotes

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8.7J: Selenium

Learning Objectives

- Learn about the role of selenium

Selenium is a cofactor of enzymes that release active thyroid hormone in cells and therefore low levels can cause similar signs and symptoms as iodine deficiency. The other important function of selenium is as an antioxidant.

Selenium Functions and Health Benefits

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 concluded 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.[1] 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.

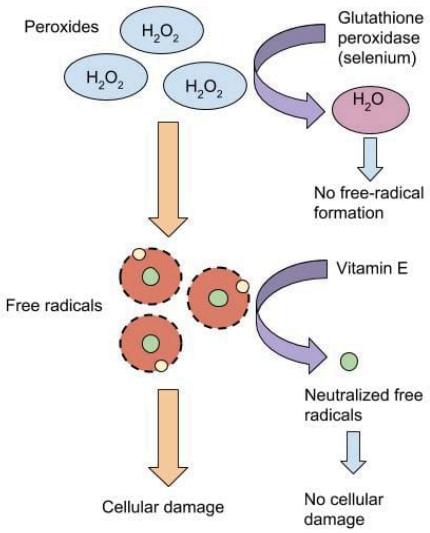


Figure 8.7J.1: Selenium's Role in Detoxifying Free Radicals. Image by Allison Calabrese / CC BY 4.0.

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 8.7J.1.

Table 8.7J.1: 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, 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 8.7J.2 for the selenium content of various foods.

***Table** 8.7J.2**:** Selenium Contents of Various Foods.*

Food	Serving	Selenium (mcg)	Percent Daily Value
Brazil nuts	1 oz.	544	777
Shrimp	3 oz.	34	49
Crab meat	3 oz.	41	59
Ricotta cheese	1 c.	41	59
Salmon	3 oz.	40	57
Pork	3 oz.	35	50
Ground beef	3 oz.	18	26
Round steak	3 oz.	28.5	41
Beef liver	3 oz.	28	40
Chicken	3 oz.	13	19
Whole-wheat bread	2 slices	23	33
Couscous	1 c.	43	61
Barley, cooked	1 c.	13.5	19
Milk, low-fat	1 c.	8	11
Walnuts, black	1 oz.	5	7

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.

Footnotes

1. Dennert G, Zwahlen M, et al. Selenium for Preventing Cancer. Cochrane Database of Systematic Reviews. 2011; 5. http://www.ncbi.nlm.nih.gov/pubmed/21563143. Accessed November 22, 2017.

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9: ENERGY BALANCE AND HEALTHY WEIGHT

Here, we take a look at the obesity epidemic and eating disorders—the extremes of energy imbalance—and we look at evidence-based recommendations for maintaining a healthy weight. You will learn how to assess body weight and fatness and learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

9.1: Prelude to Energy Balance and Body Weight

9.2: Indicators of Health- Body Mass Index, Body Fat Content, and Fat Distribution

9.3: Balancing Energy Input with Energy Output

9.4: Too Little or Too Much Weight?

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

9.E: Energy Balance and Body Weight (Exercises)

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9.1: Prelude to Energy Balance and Body 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 2009 in the United States, 33 percent of adults and 16 percent of children were obese, a doubling and tripling of the numbers since 1980, respectively, while in Canada the obesity rate was 24.1 percent for 2007–2009. The health consequences of too much body fat are numerous, including: increased risks for cardiovascular disease, Type 2 diabetes, and some cancers. The medical costs related to obesity are well over one hundred billion dollars and on the individual level, people who are obese spend $1,429 more per year for medical care than people of healthy weight. No one WANTS to become obese, so what are the factors causing rates of obesity to rise so rapidly? What can we do about these factors?

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 9.1.1: 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 worsse**. 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 work places the only tools required to conduct work are a chair and a computer. **The list of all the societal obesogenic factors goes on and on**. They are the result of modernization, industrialization, and urbanization continuing on without individuals, public health officials, or government adequately addressing the concurrent rise in overweight and obesity.

With obesity at epidemic proportions in America it is critical we make changes that will help to remedy this growing problem. The good news is we can make a difference! Policies are being implemented and reinforced at all levels of society including: education, agriculture, industry, urban planning, health care, and government. Reversing and stopping obesity are two different things. The former will require much more societal change and change on the individual level than the latter. The following are some ideas that are being demonstrated to work for constructing an environment in America that promotes health and confronts the obesity epidemic:

- **Individual Level: What you can do NOW**
  - Purchase less prepared foods and eat more whole foods.
  - Decrease portion sizes when eating or serving food.
  - Eat out less, and when you do eat out choose low-calorie options.
  - Walk or bike to work. If this is not feasible, walk while you are at work.
  - Take the stairs when you come upon them or better yet, seek them out.
  - Walk your neighborhood and know your surroundings. This benefits both health and safety.
  - Watch less television.
- **Community Level: What you and your friends, family and co-workers can do together!**
  - Request that your college/workplace provides more access to healthy low-cost foods.

- Support changes in school lunch programs—this is happening now but needs vocal parents to continue!
- Participate in cleaning up local green spaces and then enjoy them during your leisure time, get outside!
- Patronize local farms and fruit-and-vegetable stands.
- Talk to your grocer and ask for better whole-food choices and seafood at a decent price.
- Ask your favorite restaurant to serve more nutritious food and to accurately display calories of menu items.

- **National Level: What we can do as a country!**
  - Support policies that increase the walk-ability 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

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!

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 9.1.2: An interview, with Mayor Joseph Curtatone, about a groundbreaking community health and wellness program in Somerville, MA

You Decide

How can you assist in the American transition from an obesogenic environment to a healthier environment at the individual, community, and national levels?

In this chapter you will learn how to assess body weight and fatness. You will also learn that it is not only society and environment that play a role in body weight and fatness, but also physiology, genetics, and behavior—and that all of them interact. We will also discuss the health risks of being underweight and overweight, learn evidence-based solutions to maintain body weight at the individual level, and assess the current state of affairs of combating the obesity epidemic in the United States.

This page titled 9.1: Prelude to Energy Balance and Body Weight is shared under a CC BY-NC-SA 3.0 license and was authored, remixed, and/or curated by Anonymous.

Learning Objectives

- Be able to calculate body mass index (BMI) given a particular weight and height.
- Name the factors that affect body composition and distribution.

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 weight 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)

Body mass index (BMI) is calculated using **height** and **weight** measurements and is more predictive of 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). The BMI is defined as the body mass divided by the square of the body height, and is universally expressed in units of kg/m^2, resulting from mass in kilograms and height in meters.

$$\text{BMI} = \frac{\text{weight } (kg)}{\text{height } (m^2)} \tag{9.2.1}$$

The BMI attempts to quantify the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that person as underweight, normal weight, overweight, or obese based on that value. However, there is some debate about where on the BMI scale the dividing lines between categories should be placed. Commonly accepted BMI ranges are underweight: under 18.5 kg/m2, normal weight: 18.5 to 25, overweight: 25 to 30, obese: over 30 (Figure $9.2.1$:).

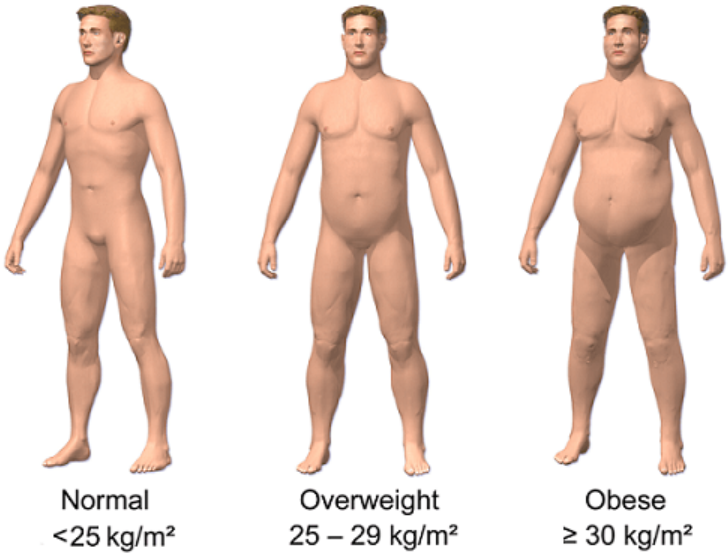


Figure 9.2.1: Obesity and BMI. (CC BY-SA 4.0; BruceBlaus).

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

Table 9.2.1: 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.	

Very high AND very low BMI's appear to increase a person's risk of dying. If you look at a graph of BMI 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 (Figure 9.2.2). 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.

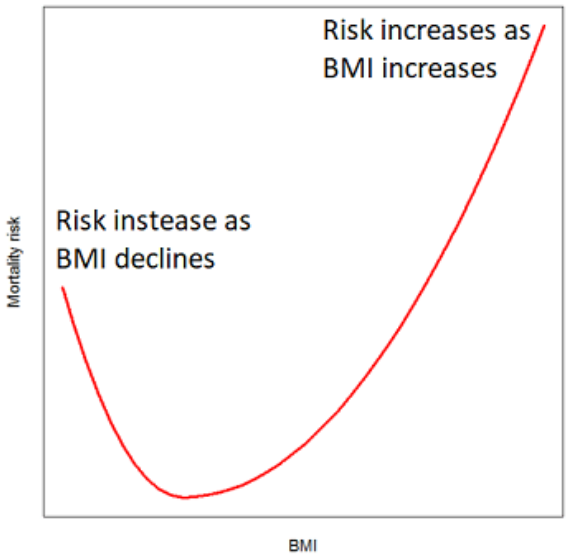


Figure 9.2.2: Mortality risk vs. BMI.

Limitations of the BMI

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..

Measuring Body Fat Content

Water, organs, bone tissue, fat, and muscle tissue make up a person's weight. Having more fat mass may be indicative of disease risk, but fat mass also varies with sex, age, and physical activity level. Females have more fat mass, which is needed for reproduction and, in part, is a consequence of different levels of hormones. The optimal fat content of a female is between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent. Fat mass can be measured in a variety of ways. The simplest and lowest-cost way is the skin-fold test. A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. It is a noninvasive and fairly accurate method of measuring fat mass, but similar to BMI, is compared to standards of mostly young to middle-aged adults. Other methods of measuring fat mass are more expensive and more technically challenging. They include:

- **Underwater weighing.** 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.
- **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. These devices are also sold for home use and commonly called body composition scales.
- **Dual-energy x-ray absorptiometry.** This technique can be used to measure bone density. It also can determine fat content via the same method, which directs two low-dose x-ray beams through the body and determines the amount of the energy absorbed from the beams. The amount of energy absorbed is dependent on the body's content of bone, lean tissue mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated.

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 0.90 for males and above 0.85 for females.

Key Takeaways

Most people who are overweight also have excessive body fat and therefore body weight is an indicator of obesity in much of the population. To standardize the "ideal" body weight and relate it to health, scientists have devised some computational measurements to better define a healthy ideal weight. Body weight in relation to height is called BMI and is correlated with disease risk. Total body fat mass is another predictor of disease risk; another is where the fat is distributed. Fat deposits in different areas in the body and do not all act the same, meaning it differs physiologically based on location. Visceral fat contributes more to disease risk, for example.

Discussion Starters

1. Read the article, "Exercise Keeps Dangerous Visceral Fat Away a Year after Weight Loss, Study Finds," at http://www.sciencedaily.com/releases/2009/10/091029102740.htm. Then discuss the importance of exercise in eradicating excessive fat.
2. Based on what you learned, why would an individual with a high BMI have a decreased risk of osteoporosis?

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9.3: Balancing Energy Input with Energy Output

Learning Objectives

- Estimate your daily energy requirement.
- Define basal metabolism and explain the factors that affect basal metabolic rate.
- Summarize why the amount of food we eat (appetite) is not completely under our conscious control.

Energy Intake Balances Energy Output To Maintain Weight

Recall that the macronutrients you consume are either converted to energy, stored, or used to synthesize macromolecules. A nutrient's metabolic path is dependent upon energy balance. When you are in a positive energy balance the excess nutrient energy will be stored or used to grow (e.g., during childhood, pregnancy, and wound healing). When you are in negative energy balance you aren't taking in enough energy to meet your needs, so your body will need to use its stores to provide energy. Energy balance is achieved when intake of energy is equal to 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, and gained when it is in positive energy balance. 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.

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:

$$\text{EER} = 662 - [9.53 \times age(y)] + PA \times [15.91 \times wt(kg) + 5.39.6 \times ht(m)] \tag{9.3.1}$$

- Adult female:

$$\text{EER} = 354 - [6.91 \times age(y)] + PA \times [9.36 \times wt(kg) + 726 \times ht(m)] \tag{9.3.2}$$

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.

Interactive

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

Table 9.3.1: 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 9.3.2: Estimated Daily Calorie Needs

Sex	Age (years)	Sedentary	Moderately Active	Active
Child (female and male)	2–3	1,000–1,200	1,000–1,400	1,000–1,400
Female	4–8	1,200–1,400	1,400–1,600	1,400–1,800
	9–13	1,400–1,600	1,600–2,000	1,800–2,200
	14–18	1,800	2,000	2,400
	19–30	1,800–2,000	2,000–2,200	2,400
	31–50	1,800	2,000	2,200
	51+	1,600	1,800	2,000–2,200
Male	4–8	1,200–1,400	1400–1,600	1,600–2,000
	9–13	1,600–2,000	1,800–2,200	2,000–2,600
	14–18	2,000–2,400	2,400–2,800	2,800–3,200
	19–30	2,400–2,600	2,600–2,800	3,000
	31–50	2,200–2,400	2,400–2,600	2,800–3,000
	51+	2,000–2,200	2,200–2,400	2,400–2,800

Source: US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines2010.pdf.

The *2010 Dietary Guidelines* provides a table (Table 9.3.2) that gives the estimated daily calorie needs for different age groups of males and females with various activity levels. The *2010 Dietary Guidelines* also states that while knowing the number of calories you need each day is useful, it is also pertinent to obtain your calories from nutrient-dense foods and consume the various macronutrients in their Acceptable Macronutrient Distribution Ranges (AMDRs) (Table 9.3.3).

Table 9.3.3: Acceptable Macronutrient Distribution Ranges

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)
Young Children (1–3)	45–65	5–20	30–40

Age	Carbohydrates (% of Calories)	Protein (% of Calories)	Fat (% of Calories)
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/Act...onutrients.pdf

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), and the calories you burn when you digest food. 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 70 percent) daily is from conducting life’s basic processes. Of all the organs, the liver requires the most energy (Table 9.3.4). 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 and thyroid hormone levels are additional determinants of BMR.

Table 9.3.4: Energy Breakdown of Organs

Organ	Percent of Energy Expended
Liver	27
Brain	19
Heart	7
Kidneys	10
Skeletal muscle (at rest)	18
Other organs	19

The energy required for all the enzymatic reactions that take place during food digestion and absorption of nutrients is called the “thermic effect of food” and accounts for about 10 percent of total energy expended per day. The other energy required during the day is for physical activity. Depending on lifestyle, the energy required for this ranges between 15 and 30 percent of total energy expended. The main control a person has over TEE is to increase physical activity.

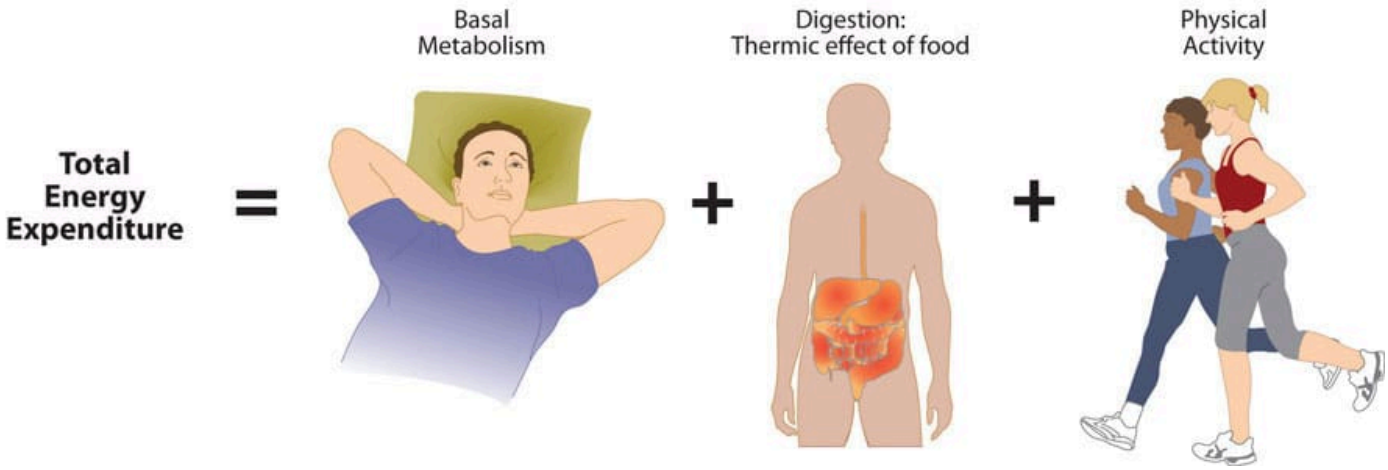


Figure 9.3.1: Total energy expenditure is the sum of energy expended at rest, during digestion, and during physical activity.

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 11.4: 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 9.3.2).

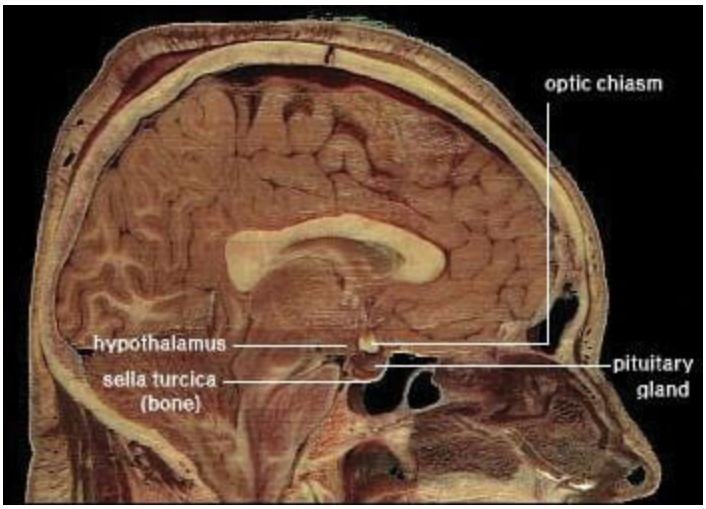


Figure 9.3.2: This is a scan of a brain. The hypothalamus contains distinct centers of neural circuits that regulate hunger and satiety. Source: Diabesity, Sixth Framework Programme. “Novel Molecular Targets for Obesity and Type 2 Diabetes.” 2002-2006. www.diabesity.eu/.honours.htm.

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.

Fat tissue also plays a role in regulating food intake. Fat tissue produces the hormone leptin, which communicates to the satiety center in the hypothalamus that the body is in positive energy balance. The discovery of leptin’s functions sparked a craze in the research world and in the diet pill industry as it was hypothesized that if you give leptin to a person who is overweight, they will decrease their food intake. Alas, this is not the case. In several clinical trials it was found that people who are overweight or obese are actually resistant to the hormone, meaning their brain does not respond as well to it.Dardeno, T. A. et al. “Leptin in Human Physiology and Therapeutics.” *Front Neuroendocrinol* 31, no. 3 (2010): 377–93. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2916735/?tool=pubmed. Therefore, when you administer leptin to an overweight or obese person there is no sustained effect on food intake.

Nutrients themselves also play a role in influencing food intake. The hypothalamus senses nutrient levels in the blood. When they are low the hunger center is stimulated, and when they are high the satiety center is stimulated. Furthermore, cravings for salty and sweet foods have an underlying physiological basis. Both undernutrition and overnutrition affect hormone levels and the neural circuitry controlling appetite, which makes losing or gaining weight a substantial physiological hurdle.

Genetic Influences

Genetics certainly play a role in body fatness and weight and also affects food intake. Children who have been adopted typically are similar in weight and body fatness to their biological parents. Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins. The scientific search for obesity genes is ongoing and a few have been identified, such as the gene that encodes for leptin. However, overweight and obesity that manifests in millions of people is not likely to be attributed to one or even a few genes, but to rather the interactions of hundreds of genes with the environment. In fact, when an individual has a mutated version of the gene coding for leptin, they are obese, but only a few dozen people around the world have been identified as having a completely defective leptin gene.

Psychological/Behavioral Influences

When your mouth waters in response to the smell of a roasting Thanksgiving turkey and steaming hot pies, you are experiencing a psychological influence on food intake. A person’s perception of good-smelling and good-tasting food influences what they eat and how much they eat. Mood and emotions are associated with food intake. Depression, low self-esteem, compulsive disorders, and emotional trauma are sometimes linked with increased food intake and obesity.

Certain behaviors can be predictive of how much a person eats. Some of these are how much food a person heaps onto their plate, how often they snack on calorie-dense, salty foods, how often they watch television or sit at a computer, and how often they eat out. A study published in a 2008 issue of *Obesity* looked at characteristics of Chinese buffet patrons. The study found that those who chose to immediately eat before browsing the buffet, used larger plates, used a fork rather than chopsticks, and chewed less per bite of food, had higher BMIs than patrons who did not exhibit these behaviors.Levin, B. E. "Developmental Gene X Environment Interactions Affecting Systems Regulating Energy Homeostasis and Obesity." *Front Neuroendocrinol* 3 (2010): 270–83. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2903638/?tool=pubmed. Of course many behaviors are reflective of what we have easy access to—a concept we will discuss next.

Societal Influences

It is without a doubt that the American society affects what and how much we eat. Portion sizes have increased dramatically in the past few decades. For example, a bagel is now more than twice the size it was in the 1960s. Today, American teenagers have access to a massive amount of calorie-dense foods and beverages, which is a large contributor to the recent rapid increase in overweight and obesity in adolescents in this country. Even different cultures within the United States have different eating habits. For instance, southern Americans, in general, consume more foods high in fat, which is a contributing factor to their higher incidences of overweight and obesity than Americans who live in the northern states. (Alaska is an exception because it also has a high incidence of overweight and obesity, which is also partly attributed to diet.)

The fast food industry in America not only supplies Americans with a large proportion of their diet, but because of its massive presence in society dominates the workings of the entire food system. To generalize, most fast food items have little nutritional merit as they are highly processed and rich in saturated fat, salt, and added sugars. Despite fast foods being a poor source of nourishment, Americans spend over one hundred billion dollars per year on fast food, up from six billion dollars in the early 1970s. The fast food business is likely to continue to grow in North America (and the rest of the world) and greatly affect the diets of whole populations. Because it is unrealistic to say that Americans should abruptly quit eating fast food to save their health (because they will not) society needs to come up with ideas that push nutrient-dense whole foods into the fast food industry. You may have observed that this largely consumer-driven push is having some effect on the foods the fast food industry serves (just watch a recent Subway commercial, or check the options now available in a McDonald's Happy Meal). Pushing the fast food industry to serve healthier foods is a realistic and positive way to improve the American diet.

YouTube Video

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Video 9.3.1***:*** *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 set point can also be called a fat-stat or lipostat, meaning the brain senses body fatness and triggers changes in energy intake or expenditure to maintain body fatness within a target range. Some believe that this theory provides an explanation as to why after dieting, most people return to their original weight not long after stopping the diet. Another theory is referred to as the "settling" point system, which takes into account (more so than the "set-point" theory) the contribution of the obesogenic environment to weight gain. In this model, the reservoir of body fatness responds to energy intake or energy expenditure, such that if a person is exposed to a greater amount of food, body fatness increases, or if a person watches more television body fatness increases. A major problem with these theories is that they overgeneralize and do not take into account that not all individuals respond in the same way to changes in food intake or energy expenditure. This brings up the importance of the interactions of genes and the environment.

Not all individuals who take a weight-loss drug lose weight and not all people who smoke are thin. An explanation for these discrepancies is that each individual's genes respond differently to a specific environment. Alternatively, environmental factors can influence a person's gene profile, which is exemplified by the effects of the prenatal environment on body weight and fatness and disease incidence later in life. One of the first scientific investigations of prenatal control over energy balance was conducted in Germany. In this observational study, scientists found that offspring born to mothers who experienced famine were more likely to be obese in adulthood than offspring born to mothers who were pregnant just after World War II who lived in the same geographical locations.Matthews, C. E. "Amount of Time Spent in Sedentary Behaviors in the United States, 2003–2004." *Am J Epidemiol* 167, no. 7 (2008): 875–81. doi: 10.1093/aje/kwm390. Other studies have shown that the offspring of women who were overweight during pregnancy have a greater propensity for being overweight and for developing Type 2 diabetes. Thus, undernutrition and overnutrition during pregnancy influence body weight and disease risk for offspring later in life. They do so by adapting energy metabolism to the early nutrient and hormonal environment in the womb.

Audio Link 11.1: 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.

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 brief 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 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 energy expended. Energy balance is essential for maintaining weight. Knowing the number of calories you need each day is a useful reference point, but it is also important to obtain your calories from nutrient-dense foods and consume the macronutrients in their AMDRs. The amount of energy you expend every day includes not only the calories you burn during physical activity, but also the calories you burn at rest (basal metabolism), and the calories you burn when you digest food. Basal metabolic rate (BMR) is dependent on body size, body composition, sex, age, nutritional status, genetics, body temperature, and thyroid hormone levels. The great majority of energy expended (between 50 and 70 percent) daily comes from conducting life’s basic processes. The main control a person has over TEE is to increase physical activity. Energy intake is regulated by complex physiological responses and is influenced by genetics, behavior, and society. Energy expenditure is also regulated by complex physiological responses and is influenced by genetics, behavior, and society.

Discussion Starters

1. Some types of transportation are becoming economically unfeasible for obese people. Discuss whether or not it is acceptable that air carriers can enforce that obese people (or what they politely call “passengers of size” or “passengers requiring extra space”) pay more for their seats.
2. Many people have a hard time understanding the difficulties of being too skinny. Discuss with your peers how to empathize with the weight problems of underweight people. Read the article to understand that being skinny does not mean a person necessarily has a lower risk of chronic disease. http://www.msnbc.msn.com/id/18594089/ns/health-fitness/t/thin-people-can-be-fat-inside/

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9.4: Too Little or Too Much Weight?

Learning Objectives

- Discern the differences in health risks associated with being underweight and being overweight.

The number of people considered overweight and obese in the world has now surpassed the number that are starving, with some officials estimating that the number of overweight people is nearly double the number of underweight people worldwide. Countries that have more recently modernized, industrialized, and urbanized are experiencing a surge in their overweight and obese populations. China, the most populous country in the world, now has more than 215 million people, approximately one-fifth of their population, that are considered overweight or obese.Wu, Yangfeng. "Overweight and obesity in China." BMJ. 2006 August 19; 333(7564): 362–363. doi: 10.1136/bmj.333.7564.362. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1550451/. The increase in China's waistline is partly attributed to changes in the traditional diet, more sedentary lives, and a massive increase in motor vehicle use. Moreover, China's recent famines in the 1950s, which affected the poor and lower classes to a greater extent than the upper class, has sanctioned lax social attitudes toward body fat and reinspired the age-old Chinese belief that excess body fat represents health and prosperity.

One of the worst statistics regarding overweight and obesity in China is that more than ten million adolescents between ages seventeen and eighteen were overweight in 2000, which is twenty-eight times the number that were 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

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Video 9.4.1: 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 2007–2008:

- 34 percent of adults age twenty years and over are obese
- 34 percent of adults age twenty years and over are overweight (but not obese)
- 18 percent of adolescents age twelve to nineteen years are obese
- 20 percent of children age six to eleven years are obese
- 10 percent of children age two to five years are obeseThe Centers for Disease Control and Prevention. "Obesity and Overweight." Accessed October 8, 2011. http://www.cdc.gov/nchs/fastats/overwt.htm.

State Map of the Prevalence of Obesity in America

Visit www.cdc.gov/obesity/downloads/obesity_trends_2010.ppt to see the obesity trends from 1985 to 2010. As you will see, the percentages of obese adults are rising. 2 minute video of obesity trends in the U.S.A.: https://vimeo.com/15992923

As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, postmenopausal breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. The WHO reports that overweight and obesity are the fifth leading cause for deaths globally, and estimates that more than 2.8 million adults die annually as a result of being overweight or obese.World Health Organization. "Obesity and Overweight." Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/. Moreover, overweight and obesity contribute to 44 percent of the Type 2 diabetes burden, 23 percent of the heart disease burden, and between 7 and 41 percent of the burden of certain cancers.World Health Organization. "Obesity and Overweight." Accessed October 8, 2011. http://www.who.int/mediacentre/factsheets/fs311/en/.

Similar to other public health organizations, the WHO states the main causes of the obesity epidemic worldwide are the increased intake of energy-dense food and decreased level of physical activity that is mainly associated with modernization, industrialization, and urbanization. The environmental changes that contribute to the dietary and physical activity patterns of the world today are associated with the lack of policies that address the obesity epidemic in the health, urban planning, agriculture, food industry, and education sectors.

Health Risks of Being Underweight

The 2003–2006 National Health and Nutrition Examination Survey (NHANES) estimated that 1.8 percent of adults and 3.3 percent of children and adolescents in the United States are underweight.Centers for Disease Control and Prevention. "NCHS Health E-Stat. Prevalence of Underweight among Children and Adolescents: United States, 2003–2006." Accessed October 8, 2011. http://www.cdc.gov/nchs/data/hestat/underweight/underweight_children.htm. Being underweight is linked to nutritional deficiencies, especially iron-deficiency anemia, and to other problems such as delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In children, being underweight can stunt growth. The most common underlying cause of underweight in America is inadequate nutrition. Other causes are wasting diseases, such as cancer, multiple sclerosis, tuberculosis, and eating disorders. People with wasting diseases are encouraged to seek nutritional counseling, as a healthy diet greatly affects survival and improves responses to disease treatments. Eating disorders that result in underweight affect about eight million Americans (seven million women and one million men).

Anorexia Nervosa

Anorexia nervosa, more often referred to as "anorexia," is a psychiatric illness in which a person obsesses about their weight and about food that they eat. Anorexia results in extreme nutrient inadequacy and eventually to organ malfunction. Anorexia is relatively rare—the National Institute of Mental Health (NIMH) reports that 0.9 percent of females and 0.3 percent of males will have anorexia at some point in their lifetime,The National Institute of Mental Health. "Eating Disorders among Adults: Anorexia Nervosa." Accessed October 8, 2011. mentalhealth.gov/statistics/1...DULT_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 and exercise excessively. They are in a tremendous caloric imbalance. Moreover, some may particpate 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, a multitude of skin abnormalities, diarrhea, cavities and tooth loss, osteoporosis, and liver, kidney, and heart failure. 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 abnormalties. Eliminating these other possibilities involves numerous blood tests, urine tests, and x-rays. Coexisting organ malfunction is also examined. Treatment of any mental illness involves not only the individual, but also family, friends, and a psychiatric counselor. Treating anorexia also involves a dietitian, who helps to provide dietary solutions that often have to be adjusted over time. The goals of treatment for anorexia are to restore a healthy body weight and significantly reduce the behaviors associated with causing the eating disorder. Relapse to an unbalanced diet is high. Many people do recover from anorexia, however most continue to have a lower-than-normal bodyweight for the rest of their lives.

YouTube Video

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Video 9.4.2: 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/1...ULT_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 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/1...ADULT_RB.shtml. Treatment often involves antidepressant medication as well as nutritional and psychiatric counseling.

Key Takeaways

The number of people considered overweight and obese in the world has now surpassed the number that is starving. As BMIs increase over 25, the risks increase for heart disease, Type 2 diabetes, hypertension, endometrial cancer, breast cancer, colon cancer, stroke, osteoarthritis, liver disease, gallbladder disorders, and hormonal disorders. Being underweight is linked to nutritional deficiencies. These deficiencies cause iron-deficiency anemia and also delayed wound healing, hormonal abnormalities, increased susceptibility to infection, and increased risk of some chronic diseases such as osteoporosis. In

children, being underweight can stunt growth. Eating disorders resulting in being underweight can have severe consequences to health. The eating disorder anorexia nervosa has the highest mortality rate of all mental illnesses. All underweight people do not have anorexia and all overweight people do not have an eating disorder.

Discussion Starters

1. Visit the Food and Agriculture Organization of the United Nations website and discuss the impact of the rise in obesity in developing countries.

   www.fao.org/FOCUS/E/obesity/obes1.htm

2. Even as adults in this society we “profile” people with excess body fat as lazy and other disrespectful adjectives. Moreover, society commonly “profiles” people who are too skinny as being compulsive and vain. Propose ideas for improving body image during teenage years.

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

Learning Objectives

- Explain the complementary actions of dietary changes and increased physical activity level on health.
- Formulate an exercise plan that fits your lifestyle and that follows the *2008 Physical Activity Guidelines for Americans*.

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 are successful at weight loss. An evaluation of successful weight loss, involving more than fourteen thousand participants published in the November 2011 issue of the *International Journal of Obesity* estimates that more than one in six Americans who were overweight or obese were successful in achieving long-term weight loss.Kraschnewski, J. L. et al. "Long-Term Weight Loss Maintenance in the United States." *Int J Obes* 34, no. 11 (2010): 1644–54. http://www.ncbi.nlm.nih.gov/pubmed/20479763. However, these numbers are on the high end because many similar studies report fewer than 10 percent of participants as successful in weight loss.

The National Weight Control Registry (NWCR) tracks over ten thousand people who have been successful in losing at least 30 pounds and maintaining this weight loss for at least one year. Their research findings are that 98 percent of participants in the registry modified their food intake and 94 percent increased their physical activity (mainly walking.)The National Weight Control Registry. "Research Findings." Accessed October 8, 2011. http://www.nwcr.ws/Research/default.htm. Although there are a great variety of approaches taken by NWCR members to achieve successful weight loss, most report that their approach involved adhering to a low-calorie, low-fat diet and doing high levels of activity (about one hour of exercise per day). Moreover, most members eat breakfast every day, watch fewer than ten hours of television per week, and weigh themselves at least once per week. About half of them lost weight on their own and the other half used some type of weight-loss program. In most scientific studies successful weight loss is accomplished only by changing the diet *and* by increasing physical activity. Doing one without the other limits the amount of weight lost and the length of time that weight loss is sustained. On an individual level it is quite possible to achieve successful weight loss, as over ten thousand Americans can attest. Moreover, losing as little as 10 percent of your body weight can significantly improve health and reduce disease risk.National Heart, Lung, and Blood Institute. "Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report." *Obes Res* 6 supplement (1998): 51S–210S. http://www.ncbi.nlm.nih.gov/books/NBK2003/. You do not have to be overweight or obese to reap benefits from eating a healthier diet and increasing physical activity as both provide numerous benefits beyond weight loss and maintenance.

Evidence-Based Dietary Recommendations

The *2010 Dietary Guidelines for Americans* offers specific, evidence-based recommendations for dietary changes aimed at keeping calorie intake in balance with physical activity, which is key for weight management. These recommendations include:US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

- **Increase intake of whole grains, vegetables, and fruits.** Scientific evidence demonstrates that adults who have a higher intake of whole grains, mainly those high in dietary fiber, have lower body weights compared to adults who eat a smaller amount of whole grains. Moreover diets incorporating more whole grains reduce chronic disease risk . A higher intake of fruits and vegetables is scientifically shown to protect against weight gain in adults and there is some evidence that this is also true for children and adolescents.
- **Reduce intake of sugar-sweetened beverages.** There is good evidence that reducing consumption of sugar-sweetened beverages, especially in children and adolescents, decreases body weight and reduces chronic disease risk.
- **Monitor intake of 100 percent fruit juice for children and adolescents, especially those who are overweight or obese.**

There is some evidence that increased intake of 100 percent juice exacerbates weight problems in children and adolescents who are already overweight or obese.
- **Monitor calorie intake from alcoholic beverages for adults.** Drinking in moderation is not linked to weight gain; however, excessive intake of alcohol over time is associated with weight gain.

Evidence-Based Behavioral Recommendations

In addition to the dietary recommendations, the *2010 Dietary Guidelines for Americans* offers specific evidence-based recommendations that address behavioral changes aimed to keep calorie intake in balance with physical activity. The recommendations include:

- **Focus on the total number of calories consumed.** Reducing calorie intake improves health and aids in weight management.
- **Monitoring food and caloric intake.** Being more aware of the calories in foods and beverages by reading the Nutrition Facts panel is helpful for consumers to monitor intake. Vigilant monitoring of food and caloric intake assists in weight management.
- **When eating out, choose smaller portions or lower-calorie options.** As mentioned in an earlier section of this chapter, eating out more often, especially at fast food restaurants, contributes to weight gain. The *Dietary Guidelines* advise people that when they are eating out to order smaller portions, share meals when possible, or take home part of the meal.
- **Prepare, serve, and consume smaller portions of foods and beverages, especially those high in calories.** Having less on your plate helps you eat less.
- **Eat a nutrient-dense breakfast.** The old adage that "breakfast is the most important meal of the day" holds true when you consider that not eating breakfast is associated with higher body weights, especially among children and adolescents. Moreover, eating a nutrient-dense breakfast has in some scientific studies been shown to stimulate weight loss.
- **Limit screen time.** In children, adolescents, and adults, the sedentary activities of watching television and spending time on the computer are linked to increased overweight and obesity. The *Dietary Guidelines* recommend children and adolescents spend no more than one to two hours daily watching television, playing electronic games, or using the computer (other than for homework).US Department of Agriculture. *2010 Dietary Guidelines for Americans*. 2010. Accessed October 7, 2011. http://health.gov/dietaryguidelines/dga2010/DietaryGuidelines 2010.pdf.

Evidence-Based Physical Activity Recommendations

The other part of the energy balance equation is physical activity. The *2010 Dietary Guidelines* are complemented by the *2008 Physical Activity Guidelines for Americans* issued by the Department of Health and Human Services in an effort to provide evidence-based guidelines for appropriate physical activity levels. The *2008 Physical Activity Guidelines* provide guidance to Americans aged six and older about how to improve health and reduce chronic disease risk through physical activity. Increased physical activity has been found in scientific studies to lower the risk of heart disease, stroke, high blood pressure, Type 2 diabetes, colon, breast, and lung cancer, falls and fractures, depression, and dying early. Increased physical activity not only reduces disease risk, but also improves overall health by increasing cardiovascular and muscular fitness, increasing bone density and strength, improving cognitive function, and assisting in weight loss and weight maintenance. The key guidelines for adults are the following (those for pregnant women, children, and older people will be given in elsewhere):US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

- Even small amounts of activity are beneficial to your health.
- More substantial health benefits are obtained by doing at least two hours and thirty minutes per week of moderate-intensity, or one hour and fifteen minutes per week of vigorous-intensity aerobic physical activity, or an equivalent combination thereof. Aerobic activity has better benefits if performed for at least ten minutes at a time, spread throughout the week.
- More extensive health benefits occur when moderate aerobic physical activity is increased to five hours per week of moderate-intensity, or to two hours and thirty minutes of vigorous-intensity aerobic physical activity, or a combination thereof. Additional health benefits are gained by going beyond these recommended amounts of physical activity.
- Muscle-strengthening activities at moderate or high intensity involving all major muscle groups two or more days per week provides additional health benefits to aerobic exercise.

The *2008 Physical Activity Guidelines* broadly classify moderate physical activities as those when "you can talk while you do them, but can't sing" and vigorous activities as those when "you can only say a few words without stopping to catch your breath."US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. Accessed October 8, 2011. http://www.health.gov/paguidelines/guidelines/chapter2.aspx.

Table 9.5.1: Moderate and Vigorous Physical Activities

Moderate Activities	Vigorous Activities
Ballroom/line dancing	Aerobic dance
Biking on level ground	Biking (more than 10 miles per hour)
Canoeing	Heavy gardening (digging, hoeing)
Gardening	Hiking uphill
Baseball, softball, volleyball	Fast dancing
Tennis (doubles)	Jumping rope
Walking briskly	Martial arts (karate)
Water aerobics	Race walking
Using hand cyclers	Jogging or running
	Sports with running (basketball, hockey, soccer)
	Swimming laps
	Tennis (singles)
	Ice hockey

Source: US Department of Health and Human Services. *2008 Physical Activity Guidelines for Americans*. 2008. http://www.health.gov/paguidelines/.

Interactive 9.5.1

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: www.health.gov/paguidelines/a...tiveguide.aspx.

Campaigns for a Healthy-Weight America

On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies aimed to meet the challenge of improving the health of all Americans.

In 2010 the national campaign to reduce obesity was reinforced when First Lady Michelle Obama launched the "Let's Move" initiative, which has the goal of "solving the challenge of childhood obesity within a generation so that children born today will reach adulthood at a healthy weight."The White House, Office of the First Lady. "First Lady Michelle Obama Launches Let's Move: America's Move to Raise a Healthier Generation of Kids." February 9, 2010. www.whitehouse.gov/the-press-...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 healthy and be active by bringing together leaders from academia and industry, as well as public-health policy-makers in order to create policies that will reverse the obesity trend and its associated diseases. It remains to be seen whether these new initiatives will finally help improve American health.

YouTube Video

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Video Link 9.5.1: View this brief video on the Campaign to End Obesity.

The “Small-Change” Approach

Currently, most people are not obese in this country. The gradual rise in overweight is happening because, on average, people consume slightly more calories daily than they expend, resulting in a gradual weight gain of one to two pounds a year. In 2003 the idea was first published that promoting small lifestyle changes to reduce weight gain occurring over time in all age groups may better reduce obesity rates in the American population.Hill, J. O. “Can a Small-Changes Approach Help Address the Obesity Epidemic? A Report of the Joint Task Force of the American Society for Nutrition, Institute of Food Technologists, and International Food Information Council.” *Am J Clin Nutr* 89, no. 2 (2009): 477–84. http://www.ajcn.org/content/89/2/477.long. Scientific studies have demonstrated that asking people to increase the number of steps they take each day while providing them with pedometers that count the steps they take each day successfully prevented weight gain. A “small-changes” study published in the October 2007 issue of *Pediatrics* evaluated whether families that made two small lifestyle changes, which were to walk an additional two thousand steps per day and to eliminate 100 kilocalories per day from their typical diet by replacing dietary sugar with a noncaloric sweetener, would prevent weight gain in overweight children.Rodearmel, S. J. et al. “Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study.” *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.or...20/4/e869.long. The results of this study were that a higher percentage of children who made the small changes maintained or reduced their BMI in comparison to children of families given a pedometer but not asked to also make physical activity or dietary changes.Rodearmel, S. J. et al. “Small Changes in Dietary Sugar and Physical Activity As an Approach to Preventing Excessive Weight Gain: The America on the Move Family Study.” *Pediatrics* 120, no. 4 (2007): e869–79. http://pediatrics.aappublications.or...20/4/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 at 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 *2010 Dietary Guidelines for Americans* recommendations are based upon scientific evidence.
- The other part of the energy balance equation is physical activity. The *2010 Dietary Guidelines* were complemented by the *2008 Physical Activity Guidelines for Americans* issued by the HHS in an effort to provide evidence-based guidelines for appropriate physical activity levels.
- On a national level, strategies addressing overweight and obesity in the past have not been all that successful as obesity levels continue to climb. However, in the recent past (2007–2011) several newly created initiatives and organizations are actively reinforcing strategies that aim to meet the challenge of improving the health of all Americans.

Discussion Starters

1. Discuss ways to address the childhood obesity problem in your own community.
2. Calculate your EER by using the formula in this chapter and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.

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9.E: Energy Balance and Body Weight (Exercises)

It's Your Turn

1. Record in a dietary assessment diary the calories you consumed in one week. This can be done on your cell phone.
2. Calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced and determine whether your average daily intake of calories falls below, meets, or exceeds your EER.
3. Make a list of five strategies your local schools and community could implement to effectively address the childhood obesity problem.

Apply It

1. Calculate your BMI and waist-to-hip ratio. Make a list of five behavioral changes you can make to meet your goal of maintaining weight, reducing weight, or increasing weight.

2. Summarize in a paragraph or two why (with respect to reducing future chronic disease burden) it is of utmost importance to combat childhood obesity. Watch this video of First Lady Michelle Obama's unveiling of the initiative to combat childhood obesity to assist you in this assignment.

   US First Lady Michelle Obama Unveils Initiative to Battle Childhood Obesity: https://www.youtube.com/watch?v=6C9ShzCKgOU

3. The CDC website provides a list of physical activities and categorizes them as moderate or vigorous (http://www.cdc.gov/nccdphp/dnpa/physical/pdf/PA_Intensity_table_2_1.pdf). Use this source to develop an exercise program that fits your lifestyle and follows the recommended amounts of physical activity.

Expand Your Knowledge

1. Make a daily log of your physical activities using the spreadsheet available at http://www.health-calc.com/Calculate_daily_energy_expenditure.pdf. Then calculate your EER by visiting http://www.health-calc.com/diet/energy-expenditure-advanced.
2. Harvard Health Publications has a document that lists the calories burned for various physical activities. It is available at http://www.health.harvard.edu/newsweek/Calories-burned-in-30-minutes-of-leisure-and -routine-activities.htm. Use it to develop a physical activity program that is attractive to you and follows the recommended physical activity guidelines.

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10: PHYSICAL FITNESS

Regular physical activity is good for everyone's health, and people of all ages and body types can be physically active. Here are just a few benefits of physical activity: (1) Children and adolescents – Physical activity can improve muscular fitness, bone health, and heart health (2) Adults – Physical activity can lower the risk of heart disease, type 2 diabetes, and some types of cancer. (3) Older adults – Physical activity can lower the risk of falls and improve cognitive functioning (like learning and judgment skills).

10.1: Introduction to Nutrition and Physical Fitness

10.2: Aerobic Exercise

10.3: Anaerobic Exercise

10.4: Fitness Supplements and Steroids

10.5: How do my muscles get the Energy to perform work?

10.6: Nutrients that are critical to athletes

10.7: Creating your own fitness plan

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10.1: Introduction to Nutrition and Physical Fitness

Physical fitness is a general state of health and well-being and, more specifically, the ability to perform aspects of sports, occupations and daily activities. Physical fitness is generally achieved through proper nutrition, moderate-vigorous physical exercise, physical activity, and sufficient rest. Before the industrial revolution, fitness was defined as the capacity to carry out the day's activities without undue fatigue. However, with automation and changes in lifestyles physical fitness is now considered a measure of the body's ability to function efficiently and effectively in work and leisure activities, to be healthy, to resist hypokinetic diseases, and to meet emergency situations.



Figure 10.1.1: *Physical fitness can be achieved through exercise. Photo shows Rich Froning Jr. – four-time winner of "Fittest Man on Earth" title.*

Fitness

Fitness is defined as the quality or state of being fit. Around 1950, perhaps consistent with the Industrial Revolution and the treatise of World War II, the term "fitness" increased in western vernacular by a factor of ten. Modern definition of fitness describe either a person or machine's ability to perform a specific function or a holistic definition of human adaptability to cope with various situations. This has led to an interrelation of human fitness and attractiveness which has mobilized global fitness and fitness equipment industries. Regarding specific function, fitness is attributed to personnel who possess significant aerobic or anaerobic ability, i.e. strength or endurance. A holistic definition of fitness is described by Greg Glassman in the CrossFit journal as an increased work capacity across broad times and modal domains; mastery of several attributes of fitness including strength, endurance, power, speed, balance and coordination and being able to improve the amount of work done in a given time with any of these domains. A well rounded fitness program will improve a person in all aspects of fitness, rather than one, such as only cardio/respiratory endurance or only weight training.



Figure 10.1.2***:*** *A woman performs plank exercise for strengthening of muscles*

A comprehensive fitness program tailored to an individual typically focuses on one or more specific skills, and on age- or health-related needs such as bone health. Many sources also cite mental, social and emotional health as an important part of overall fitness. This is often presented in textbooks as a triangle made up of three points, which represent physical, emotional, and mental fitness. Physical fitness can also prevent or treat many chronic health conditions brought on by unhealthy lifestyle or aging. Working out can also help some people sleep better and possibly alleviate some mood disorders in certain individuals.

Developing research has demonstrated that many of the benefits of exercise are mediated through the role of skeletal muscle as an endocrine organ. That is, contracting muscles release multiple substances known as myokines which promote the growth of new tissue, tissue repair, and various anti-inflammatory functions, which in turn reduce the risk of developing various inflammatory diseases.

Activity guidelines

The Physical Activity Guidelines for Americans was created by the Office of Disease Prevention and Health Promotion. This publication suggests that all adults should avoid inactivity to promote good health mentally and physically. For substantial health benefits, adults should participate in at least 150 minutes (two hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week. For additional and more extensive health benefits, adults should increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity. Additional health benefits are gained by engaging in physical activity beyond this amount. Adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

How to Determine Intensity Level using Heart Rate and Talk Test

There are many ways to determine Intensity Level but let's use Heart Rate as one way to determine how intensely you are working out. First of all, as you are sitting here reading this eBook you have a certain heart rate. If you put your two fingers on your neck, you can feel your pulse. If you count the number of beats in one minute you will have an approximation of your resting heart rate. The truth is, the exact measurement of the resting heart rate requires a a much more precise measurement but we will use this as your resting heart rate for now. Please take a minute and count your approximate resting heart rate right now! Chances are, your resting heart rate was probably anywhere from 60-90 beats per minute, right? The more physically fit your heart and lungs are, the LOWER than number will be! Why? Because your heart doesn't have to work as hard to pump the blood throughout your body so it takes fewer heart beats if you are fit.

You have probably seen heart rate monitors on treadmills and stair climber machines. You have probably seen people wearing various types of heart rate monitors on devices like the "Apple Watch" and the "fit bit" etc... these devices are estimating how intensely you are exercising by how many beats your heart has to make in a minute. The device estimates your "Maximum heart rate" as 220- your Age in years. So if you are 20 years old, the device estimates your highest heart rate as 220-20 = 200 beats per minute. Your maximum heart rate is far too high for you to try to sustain during exercise. Instead, there are "target heart rate zones" you can shoot for. If you wish to be working out at a "moderate level of intensity" you will want your heart rate to be between

50% and 70% of your maximum. If you wish to be working out at a "vigorous" level of intensity then you will want your heart rate to be between 75-85% of your maximum. Using the 20 year old example again, if 200 is your maximum heart rate, then 200 x 0.5 = 100 beats per minute for 50% of maximum and 200 x .7 = 140 beats per minute for 70% of maximum. This tells you, if you check your pulse during exercise and you count between 100-140 beats per minute you are doing "moderate intensity" level of exercise!

Another, much easier though less precise, way to estimate intensity level is the "talk test". Basically, if you are able to carry on a breathy conversation as you exercise you are probably at a moderate level of intensity. If you can not carry on a conversation because you are too winded (out-of-breath) then you are probably at a vigorous level of exercise. Many people prefer this method because it doesn't require any equipment nor does it require you to stop to count your heart beats.

Training

Specific or task-oriented fitness is a person's ability to perform in a specific activity with a reasonable efficiency: for example, sports or military service. Specific training prepares athletes to perform well in their sports. Examples are:

- 100 m sprint: in a sprint the athlete must be trained to work anaerobically throughout the race, an example of how to do this would be interval training.
- Middle distance running: athletes require both speed and endurance to gain benefit out of this training. The hard working muscles are at their peak for a longer period of time as they are being used at that level for 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 fire fighters and police officers undergo regular fitness testing to determine if they are capable of the physically demanding tasks required of the job.
- Members of armed forces will often be required to pass a formal fitness test – for example soldiers of the US Army must be able to pass the Army Physical Fitness Test (APFT).
- Hill sprints: requires a level of fitness to begin with, the exercise is particularly good for the leg muscles. The army often trains doing mountain climbing and races.
- Sand running creates less strain on leg muscles than running on grass or concrete. This is because sand collapses beneath the foot softening the landing. Sand training is an effective way to lose weight and become fit as its proven you need more effort (one and a half times more) to run on the soft sand than on a hard surface.
- Aquajogging is a form of exercise that decreases strain on joints and bones. The water supplies minimal impact to muscles and bones which is good for those recovering from injury. Furthermore, the resistance of the water as one jogs through it provides an enhanced effect of exercise (the deeper you are the greater the force needed to pull your leg through).



Figure 10.1.3***:*** *Swimmers perform squats prior to entering the pool in a U.S. military base, 2011*

- Swimming: Squatting exercise helps in enhancing a swimmer's start.

In order for physical fitness to benefit the health of an individual, an unknown response in the person called a stimulus will be triggered by the exertion. When exercise is performed with the correct amount of intensity, duration and frequency, a significant amount of improvement can occur. The person may overall feel better but the physical effects on the human body take weeks or months to notice and possibly years for full development. For training purposes, exercise must provide a stress or demand on either a function or tissue. To continue improvements, this demand must eventually increase little over an extended period of time. This sort of exercise training has three basic principles: overload, specificity, and progression. These principles are related to health but also enhancement of physical working capacity.

High Intensity Interval Training consists of repeated, short bursts of exercise, completed at a high level of intensity. These sets of intense activity are followed by a predetermined time of rest or low intensity activity. Studies have shown that exercising at a higher intensity has increased cardiac benefits for humans, compared to when exercising at a low or moderate level. When your workout consists of an HIIT session, your body has to work harder to replace the oxygen it lost. Research into the benefits of HIIT have revealed that it can be very successful for reducing fat, especially around the abdominal region. Furthermore, when compared to continuous moderate exercise, HIIT proves to burn more calories and increase the amount of fat burned post- HIIT session. Lack of time is one of the main reasons stated for not exercising; HIIT is a great alternative for those people because the duration of an HIIT session can be as short as 10 minutes, making it much quicker than conventional workouts.

Cardiovascular capacity can be measured using VO_2 max, a measure of the amount of oxygen the body can uptake and utilize. Cardiorespiratory training involves movement that increases the heart rate to improve the body's oxygen consumption. This form of exercise is an important part of all training regiments ranging from professional athletes to the everyday person. Also, it helps increase stamina. Examples are:

- Jogging – Running at a steady and gentle pace. This form of exercise is great for maintaining weight.
- Elliptical Training – This is a stationary exercise machine used to perform walking, or running without causing excessive stress on the joints. This form of exercise is perfect for people with achy hips, knees and ankles.
- Walking – Moving at a fairly regular pace for a short, medium or long distance.
- Treadmill training – Many treadmills have programs set up that offers a numerous amount of different workout plans. One effective cardiovascular activity would be to switch between running and walking. Typically warm up first by walking and then switch off between walking for three minutes and running for three minutes.
- Swimming – Using the arms and legs to keep oneself afloat and moving either forwards or backwards. This is a good full body exercise for those who are looking to strengthen their core while improving cardiovascular endurance.
- Cycling – Riding a bicycle typically involves longer distances than walking or jogging. This is another low stress exercise on the joints and is great for improving leg strength.

Benefits of Fitness

Physical fitness has proven to result in positive effects on the body's blood pressure because staying active and exercising regularly builds up a stronger heart. The heart is the main organ in charge of systolic blood pressure and diastolic blood pressure. Engaging in a physical activity will create a rise in blood pressure, once the activity is stopped, however, the individual's blood pressure will return to normal. The more physical activity that one engages in, the easier this process becomes, resulting in a more 'fit' individual. A "normal" blood pressure is considered to be 120/80 or below. Through regular physical fitness, the heart does not have to work as hard to create a rise in blood pressure, which lowers the force on the arteries, and lowers the over all blood pressure.

Centers for disease control and prevention provide lifestyle guidelines of maintaining a balanced diet and engaging in physical activity to reduce the risk of disease. The WCRF/ American Institute for Cancer Research (AICR) published a list of recommendations that reflect the evidence they have found through consistency in fitness and dietary factors that directly relate to Cancer prevention.

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.

Physical activity boosts the immune system. This is dependent on the concentration of endogenous factors (such as sex hormones, metabolic hormones and growth hormones), body temperature, blood flow, hydration status and body position. Physical activity has shown to increase the levels of natural killer (NK) cells, NK T cells, macrophages, neutrophils and eosinophils, complements, cytokines, antibodies and T cytotoxic cells. However, the mechanism linking physical activity to immune system is not fully understood.

Physical activity affects one's blood pressure, cholesterol levels, blood lipid levels, blood clotting factors and the strength of blood vessels. All factors that directly correlate to cardiovascular disease. It also improves the body's use of insulin. People who are at risk for diabetes, Type 2 (insulin resistant) especially, benefit greatly from physical activity because it activates a better usage of insulin and protects the heart. Those who develop diabetes have an increased risk of developing cardiovascular disease. In a study where a sample of around ten thousand adults from the Third National Health and Nutrition Examination Survey, physical activity and metabolic risk factors such as insulin resistance, inflammation, dyslipidemia were assessed. The study adjusted basic confounders with moderate/vigorous physical activity and the relation with CVD mortality. The results displayed physical activity being 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.

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.

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 is 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 is the term that is used to refer to the stretch of both before and after a woman's last menstrual cycle. there are an instrumental amount of symptoms connected to menopause, most of which can affect the quality of life of the women involved in this stage of her life. One way to reduce the severity of the symptoms is exercise and keeping a healthy level of fitness. Pre or during menopause as the women body changes there can be physical, physiological or internal changes to the body. These changes can be prevented or the reduced with the use of regular exercise.

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10.2: 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.



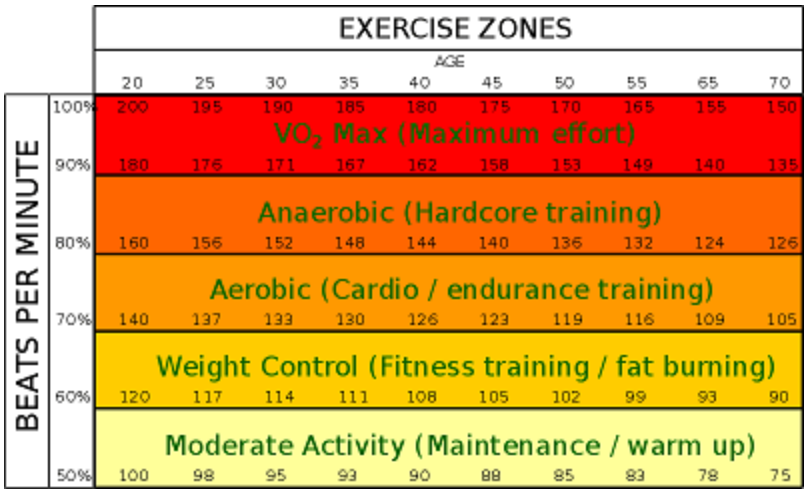
Cardio

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.

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: 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.



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 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 total, depending on the duration of the exercise. 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 person 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, abdominals, 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 transport of oxygen
- Improved mental health, including reducing stress and lowering the incidence of depression, as well as increased cognitive capacity.
- Reducing the risk for diabetes. One meta-analysis has shown, from multiple conducted studies, that aerobic exercise does help lower Hb A_{1C}levels for type 2 diabetics.

As a result, aerobic exercise can reduce the risk of death due to cardiovascular problems. In addition, high-impact aerobic activities (such as jogging or using a skipping rope) can stimulate bone growth, as well as reduce the risk of osteoporosis for both men and women. In addition to the health benefits of aerobic exercise, there are numerous performance benefits:

- Increased storage of energy molecules such as fats and carbohydrates within the muscles, allowing for increased endurance
- Neovascularization of the muscle sarcomeres to increase blood flow through the muscles
- Increasing speed at which aerobic metabolism is activated within muscles, allowing a greater portion of energy for intense exercise to be generated aerobically
- Improving the ability of muscles to use fats during exercise, preserving intramuscular glycogen
- Enhancing the speed at which muscles recover from high intensity exercise
- Neurobiological effects: improvements in brain structural connections and increased gray matter density, new neuron growth, improved cognitive function (cognitive control and various forms of memory), and improvement or maintenance of mental health

Some drawbacks of aerobic exercise include:

- Overuse injuries because of repetitive, high-impact exercise such as distance running.
- Is not an effective approach to building muscle.
- Only effective for fat loss when used consistently.

Both the health benefits and the performance benefits, or "training effect", require a minimum duration and frequency of exercise. Most authorities suggest at least twenty minutes performed at least three times per week.

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.



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 10.2.1***:*** *Varieties of Aerobic Exercises*

Indoor	Outdoor
Stair climbing	Walking
Elliptical trainer	Cycling
Indoor rower	Running
Stairmaster	Cross-country skiing
Stationary bicycle	Cross-country running
Treadmill	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 afterwards.

Aerobic exercise has long been a popular approach to achieving weight loss and physical fitness, often taking a commercial form.

- In the 1970s Judi Sheppard Missett helped create the market for commercial aerobics with her Jazzercise program
- In the 1980s Richard Simmons hosted an aerobic exercise show on television, and also released a series of exercise videos
- In the 1990s Billy Blanks's Tae Bo helped popularize cardio-boxing workouts that incorporated martial arts movements

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10.3: 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.

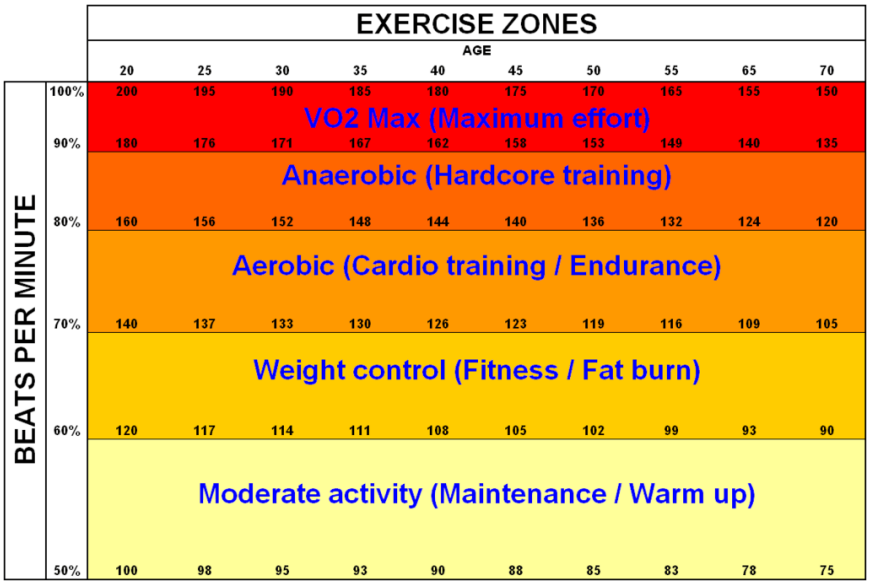


Figure 10.3.1***:*** *Exercise work zones (Fox and Haskell formula between 20 and 70-year-old): red zone (VO2Max), anaerobic, aerobic, weight control and warming up. (CC BY-Sa 3.0; Morgoth666)*

Metabolism

Anaerobic metabolism, or anaerobic energy expenditure, is a natural part of whole-body metabolic energy expenditure. Fast twitch muscle (as compared to slow twitch muscle) operates using anaerobic metabolic systems, such that any recruitment of fast twitch muscle fibers leads to increased anaerobic energy expenditure. Intense exercise lasting upwards of about four minutes (e.g., a mile race) may still have a considerable anaerobic energy expenditure component. High-intensity interval training, although based on aerobic exercises like running, cycling and rowing, effectively becomes anaerobic when performed in excess of 90% maximum heart rate. Anaerobic energy expenditure is difficult to accurately quantify, although several reasonable methods to estimate the anaerobic component to exercise are available.

In contrast, aerobic exercise includes lower intensity activities performed for longer periods of time. Activities such as walking, long slow runs, rowing, and cycling require a great deal of oxygen to generate the energy needed for prolonged exercise (i.e., aerobic energy expenditure). In sports which require repeated short bursts of exercise however, the anaerobic system enables muscles to recover for the next burst. Therefore training for many sports demands that both energy producing systems be developed.

The two types of anaerobic energy systems are:

1. high energy phosphates, adenosine triphosphate and creatine phosphate; and
2. anaerobic glycolysis.

The former is called **alactic anaerobic** and the latter **lactic anaerobic** system. High energy phosphates are stored in limited quantities within muscle cells. Anaerobic glycolysis exclusively uses glucose (and glycogen) as a fuel in the absence of oxygen, or more specifically when ATP is needed at rates that exceed those provided by aerobic metabolism. The consequence of such

rapid glucose breakdown is the formation of lactic acid (or more appropriately, its conjugate base lactate at biological pH levels). Physical activities that last up to about thirty seconds rely primarily on the former, ATP-CP phosphagen system. Beyond this time both aerobic and anaerobic glycolysis-based metabolic systems begin to predominate.

The by-product of anaerobic glycolysis, lactate, has traditionally been thought to be detrimental to muscle function. However, this appears likely only when lactate levels are very high. Elevated lactate levels are only one of many changes that occur within and around muscle cells during intense exercise that can lead to fatigue. Fatigue, that is muscle failure, is a complex subject. Elevated muscle and blood lactate concentrations are a natural consequence of any physical exertion. The effectiveness of anaerobic activity can be improved through training

Contributors

- *Wikipedia*

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10.4: Fitness Supplements and Steroids

Fitness Supplements

In October 1994, the Dietary Supplement Health and Education Act (DSHEA) was signed into law in the USA. Under DSHEA, responsibility for determining the safety of the dietary supplements changed from government to the manufacturer and supplements no longer required approval from the U.S. Food and Drug Administration (FDA) before distributing 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.

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 10.4.1***:*** *Protein milkshakes, made from protein powder (center) and milk (left), are a common bodybuilding supplement. (CC BY-SA 3.0;* Sandstein).

Protein supplements are sold in ready-to-drink shakes, bars, meal replacement products (see below), bites, oats, gels and powders. Protein powders are the most popular and may have flavoring added for palatability. The powder is usually mixed with water, milk or juice and is generally consumed immediately before and after exercising, or in place of a meal. The sources of protein are as follows, and differ in protein quality depending on their amino acid profile and digestibility:

- Whey protein contains high levels of all the essential amino acids and branched-chain amino acids. It also has the highest content of the amino acid cysteine, which aids in the biosynthesis of glutathione. For bodybuilders whey protein provides amino acids used to aid in muscle recovery. Whey protein is derived from the process of making cheese from milk. There are three types of whey protein: whey concentrate, whey isolate, and whey hydrolysate. Whey concentrate is 29–89% protein by weight whereas whey isolate is 90%+ protein by weight. Whey hydrolysate is enzymatically predigested and therefore has the highest rate of digestion of all protein types. Whey protein is usually taken immediately before and after a workout
- Casein protein (or milk protein) has glutamine, and casomorphin. Casein is usually taken before going to bed.
- Soy protein from soybeans contain isoflavones, a type of phytoestrogen.

- Egg-white protein is a lactose- and dairy-free protein.
- Hemp protein from hemp seed, contains highly-digestible protein, and hemp oil is high in essential fatty acids.
- Rice protein, when made from the whole grain, is a protein source that is highly digestible and allergen free. Since rice protein is low in the amino acid lysine, it is often combined with pea protein powder to achieve a superior amino acid profile.
- Pea protein is a hypoallergenic protein with a lighter texture than most other protein powders. Pea protein has an amino acid profile similar to that of soy, but pea protein does not elicit concerns about unknown effects of phytoestrogens. Pea protein is also less allergenic than soy. Pea protein has high fiber content and has no allergic ingredients and therefore is easy for digestion as compared to whey protein. Pea protein is a slow digesting protein and is able to keep you full longer.

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.

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.

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.

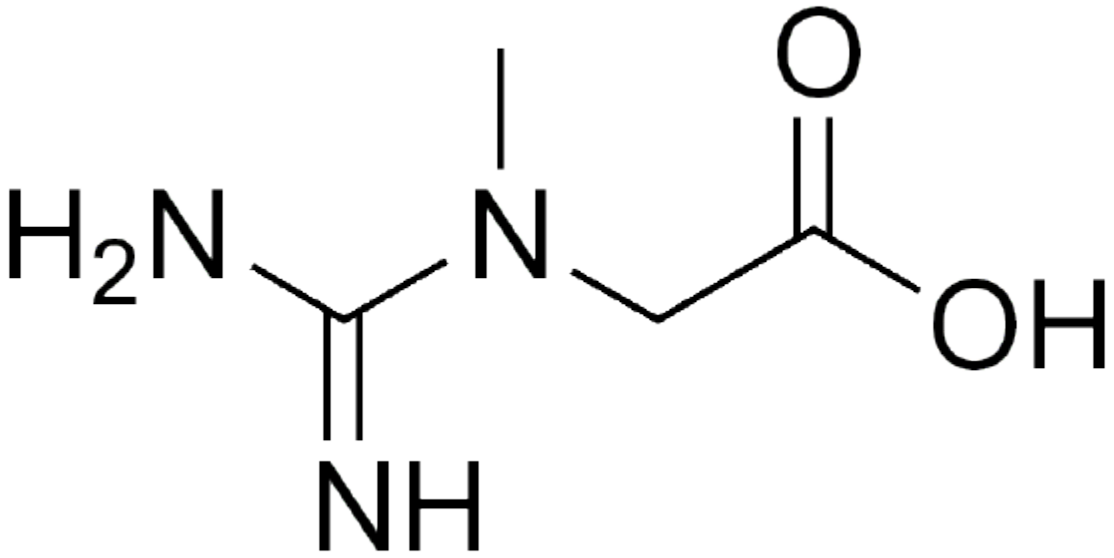


Figure 10.4.2*: Skeletal formula of creatine*

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. 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

When combined with an appropriate exercise program, dietary supplementation with β-hydroxy β-methylbutyrate (HMB) has been shown to dose-dependently 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. 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.

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.

Controversies of Fitness Supplements

Mislabeling: According to University of Helsinki food safety professor Marina Heinonen, more than 90% of dietary supplement health claims are incorrect. While many of the claims are based on scientifically based physiological or biochemical processes, their use in bodybuilding parlance is often heavily colored by bodybuilding lore and industry marketing and as such may deviate considerably from traditional scientific usages of the terms. In addition, ingredients listed have been found at times to be different from the contents. In 2015, Consumer Reports reported unsafe levels of arsenic, cadmium, lead and mercury in several of the protein powders that were tested. Other studies in 2013 showed that one-third of the supplements tested contained unlisted steroids. In 2015 a CBC investigative report found that protein spiking (the addition of amino acid filler to manipulate analysis) was not uncommon, however many of the companies involved challenged these claims.

Health problems: The US FDA reports 50,000 health problems a year due to dietary supplements and these often involve bodybuilding supplements. For example, the "natural" best-seller Craze, 2012's "New Supplement of the Year" by bodybuilding.com, sold in Walmart, Amazon etc., was found to contain undisclosed amphetamine-like compounds. Also other products by Matt Cahill have contained dangerous substances causing blindness or liver damages, and experts say that Cahill is emblematic for the whole industry.

Liver damage: The incidence of liver damage from dietary supplements has tripled in a decade, the majority of these involved bodybuilding supplements. This resulted in liver transplants and, in some cases, death to the patient. Some have argued that the liver damage is more often caused by prescription drugs rather than supplements.

Lack of effectiveness: In addition to being potentially harmful, some have argued that there is little evidence to indicate any benefit to using bodybuilding supplements. For example, according to the IOC, no consensus had been reached in determining whether an individual in exercise training benefits from protein and amino acid supplements. "In view of the lack of compelling evidence to the contrary, no additional dietary protein is suggested for healthy adults undertaking resistance or endurance exercise".

Anabolic Steroids

Anabolic steroids are synthetic, or human-made, variations of the male sex hormone testosterone. The proper term for these compounds is *anabolic-androgenic steroids*. "Anabolic" refers to muscle building, and "androgenic" refers to increased male sex characteristics. Some common names for anabolic steroids are Gear, Juice, Roids, and Stackers. Health care providers can prescribe steroids to treat hormonal issues, such as delayed puberty. Steroids can also treat diseases that cause muscle loss, such as cancer and AIDS. But some athletes and bodybuilders misuse these drugs in an attempt to boost performance or improve their physical appearance.

The majority of people who misuse steroids are male weightlifters in their 20s or 30s. Anabolic steroid misuse is much less common in women. It is difficult to measure steroid misuse in the United States because many national surveys do not measure it. However, use among teens is generally minimal. The 2016 NIDA-funded Monitoring the Future study has shown that past-year misuse of steroids has declined among 8th and 10th graders in recent years, while holding steady for 12th graders.

People who misuse anabolic steroids usually take them orally, inject them into muscles, or apply them to the skin as a gel or cream. These doses may be 10 to 100 times higher than doses prescribed to treat medical conditions.

Commons patterns for misusing steroids include:

- cycling—taking multiple doses for a period of time, stopping for a time, and then restarting
- stacking—combining two or more different steroids and mixing oral and/or injectable types
- pyramiding—slowly increasing the dose or frequency of steroid misuse, reaching a peak amount, and then gradually tapering off to zero
- plateauing—alternating, overlapping, or substituting with another steroid to avoid developing a tolerance

There is no scientific evidence that any of these practices reduce the harmful medical consequences of these drugs.

How Anabolic Steroids Work

Anabolic steroids work differently from other drugs of abuse; they do not have the same short-term effects on the brain. The most important difference is that steroids do not directly activate the reward system to cause a “high”; they also do not trigger rapid increases in the brain chemical dopamine, which reinforces most other types of drug taking behavior. Misuse of anabolic steroids might lead to negative mental effects, such as: paranoid (extreme, unreasonable) jealousy, extreme irritability and aggression (“roid rage”), *delusions*—false beliefs or ideas, impaired judgment, and mania. Aside from mental effects, steroid use commonly causes severe acne. It also causes the body to swell, especially in the hands and feet.

Anabolic steroid misuse might lead to serious, even permanent, health problems such as kidney problems or failure, liver damage and tumors, enlarged heart, high blood pressure, and changes in blood cholesterol, all of which increase the risk of stroke and heart attack, even in young people, and increased risk of blood clots. Several other effects are gender- and age-specific:

- **In men**: shrinking testicles, decreased sperm count, baldness, development of breasts, increased risk for prostate cancer
- **In women**: growth of facial hair or excess body hair, decreased breast size, male-pattern baldness, changes in or stop in the menstrual cycle, enlarged clitoris, deepened voice
- **In teens**: stunted growth (when high hormone levels from steroids signal to the body to stop bone growth too early) and stunted height (if teens use steroids before their growth spurt)

Some of these physical changes, such as shrinking sex organs in men, can add to mental side effects such as mood disorders.

Anabolic Steroids Addiction

Even though anabolic steroids do not cause the same high as other drugs, they can lead to a substance use disorder. A substance use disorder occurs when a person continues to misuse steroids, even though there are serious consequences for doing so. The most severe form of a substance use disorder is addiction. People might continue to misuse steroids despite physical problems, high costs to buy the drugs, and negative effects on their relationships. These behaviors reflect steroids' addictive potential.

Research has further found that some steroid users turn to other drugs, such as opioids, to reduce sleep problems and irritability caused by steroids. People who misuse steroids might experience withdrawal symptoms when they stop use, including:fatigue, restlessness, loss of appetite, sleep problems, decreased sex drive and steroid cravings.

One of the more serious withdrawal symptoms is depression, which can sometimes lead to suicide attempts. Some people seeking treatment for anabolic steroid addiction have found a combination of behavioral therapy and medications to be helpful. In certain cases of addiction, patients have taken medicines to help treat symptoms of withdrawal. For example, health care providers have prescribed antidepressants to treat depression and pain medicines for headaches and muscle and joint pain. Other medicines have been used to help restore the patient's hormonal system.

Summary

- Anabolic steroids are synthetic variations of the male sex hormone testosterone. Health care providers can prescribe steroids to treat various medical conditions. But some athletes and bodybuilders misuse these drugs to boost performance or improve their physical appearance.
- People who abuse anabolic steroids usually take them orally, inject them into the muscles, or apply them to the skin with a cream or gel.
- People misuse steroids in a variety of doses and schedules. Misuse of anabolic steroids might lead to short-term effects, including paranoid jealousy, extreme irritability and aggression, delusions, impaired judgment, and mania. Continued steroid misuse can act on some of the same brain pathways and chemicals that are affected by other drugs, including dopamine, serotonin, and opioid systems.
- Anabolic steroid misuse might lead to serious long-term, even permanent, health problems. Several other effects are gender- and age-specific.
- Even though anabolic steroids do not cause the same high as other drugs, they can lead to addiction. Some people seeking treatment for anabolic steroid addiction have found behavioral therapy and medications to be helpful. Medicines can help treat symptoms of withdrawal in some cases.

Contributors and Attributions

- Wikipedia
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10.5: How do my muscles get the Energy to perform work?

Although muscles and engines work in different ways, they both convert chemical energy into energy of motion. A motorbike engine uses the stored energy of petrol and converts it to heat and energy of motion (kinetic energy). Muscles use the stored chemical energy of food we eat and convert that to heat and energy of motion (kinetic energy). We need energy to enable growth and repair of tissues, to maintain body temperature and to fuel physical activity. Energy comes from foods rich in carbohydrate, protein and fat.

Origins of the Energy for Muscle Contraction

The source of energy that is used to power the movement of contraction in working muscles is adenosine triphosphate (ATP) – the body's biochemical way to store and transport energy. However, ATP is not stored to a great extent in cells. So once muscle contraction starts, the making of more ATP must start quickly. Since ATP is so important, the muscle cells have several different ways to make it. These systems work together in phases. The three biochemical systems for producing ATP are, in order:

1. using creatine phosphate
2. using glycogen
3. aerobic respiration.

Creatine Phosphate (with oxygen)

All muscle cells have a little ATP within them that they can use immediately – but only enough to last for about 3 seconds! So all muscle cells contain a high-energy compound called creatine phosphate which is broken down to make more ATP quickly. *Creatine phosphate* can supply the energy needs of a working muscle at a very high rate, but only for about 8–10 seconds.

Glycogen (without oxygen)

Fortunately, muscles also have large stores of a carbohydrate, called glycogen, which can be used to make ATP from glucose. But this takes about 12 chemical reactions so it supplies energy more slowly than from creatine phosphate. It's still pretty rapid, though, and will produce enough energy to last about 90 seconds. Oxygen is not needed – this is great, because it takes the heart and lungs some time to get increased oxygen supply to the muscles. A by-product of making ATP without using oxygen is lactic acid. You know when your muscles are building up *lactic acid* because it causes tiredness and soreness – the stitch.

Aerobic Respiration (with oxygen again)

Within two minutes of exercise, the body starts to supply working muscles with oxygen. When oxygen is present, aerobic respiration can take place to break down the glucose for ATP. This glucose can come from several places:

- remaining glucose supply in the muscle cells
- glucose from food in the intestine
- *glycogen in the liver*
- fat reserves in the muscles
- in extreme cases (like starvation), the body's protein.

Aerobic respiration takes even more chemical reactions to produce ATP than either of the above two systems. It is the slowest of all three systems – but it can supply ATP for several hours or longer, as long as the supply of fuel lasts.

Here's how it works

You have missed the bus and start running to college for a 9.00am exam:

- For the first 3 seconds of your run to college, your muscle cells use the ATP they have within them.
- For the next 8–10 seconds, your muscles use creatine phosphate stores to provide ATP.

- Since you haven't made it to college yet, the glycogen system (which doesn't need any oxygen) kicks in.
- Still not there, so finally aerobic respiration (that's ATP using oxygen) takes over.

Different forms of exercise use different systems to produce ATP

A sprinter is getting ATP in a very different way to a marathon runner.

- Using creatine phosphate – This would be the major system used for short bursts (weightlifters or short distance sprinters) because it is fast but lasts for only 8–10 seconds.
- Using glycogen (no oxygen) – This lasts for 1.3–1.6 minutes, so it would be the system used in events like the 100 meter swim or the 200 m or 400 m run.
- Using aerobic respiration – This lasts for an unlimited time, so it's the system used in endurance events like marathon running, rowing, distance skating and so on.

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10.6: Nutrients that are critical to athletes

Becoming an elite athlete requires good genes, good training and conditioning, and a sensible diet. Optimal nutrition is essential for peak performance. Nutritional misinformation can do as much harm to the ambitious athlete as good nutrition can help. An individual involved in a general fitness regimen (ex. 30-40 min/day, on most days of the week) can meet their nutritional needs by adhering to a balanced diet. However, athletes involved in moderate or high frequency training program will need to increase their intake to meet nutritional requirements.

Athletes achieve peak performance by training and eating a balanced diet including a variety of foods. Carbohydrates and fat provide fuel for the body. The use of fat as a fuel source depends on the intensity and duration of the exercise, as well as the condition of the athlete. Exercise may increase the athlete's need for protein. Water is a critical nutrient for athletes. Dehydration can cause muscle cramping and fatigue, and increases the risk for heat stroke.

Carbohydrates

Carbohydrates are an important fuel source. In the early stages of moderate exercise, carbohydrates provide 40 to 50 percent of the energy requirement. As work intensity increases, carbohydrate utilization increases. Carbohydrates yield more energy per unit of oxygen consumed than fats. Because oxygen often is the limiting factor in long duration and high intensity events, it is beneficial for the athlete to use the energy source requiring the least amount of oxygen per kilocalorie produced. Depending on the intensity, duration, and frequency of exercise, in general athletes should consume between 6-10 grams of carbohydrates per kilogram of body weight per day. (A kilogram equals 2.2 pounds.) Carbohydrate requirements are also affected by the athlete's sex and body mass, as well as total daily energy expenditures and environmental conditions.

Complex carbohydrates come from foods such as potatoes, beans, vegetables, whole grain pasta, cereals and other grain products. Simple carbohydrates are found in foods such as fruits, milk, honey and sugar. During digestion, the body breaks down carbohydrates to glucose, which is then utilized for energy or converted to glycogen and stored in the muscles and liver to fulfill later energy needs.

During exercise, stored glycogen is converted back to glucose and used for energy. The body can only store a finite amount of carbohydrates as glycogen. The ability to sustain prolonged vigorous exercise is directly related to initial levels of muscle glycogen. For events lasting less than two hours, the glycogen stores in muscles are typically sufficient to supply the needed energy. Extra carbohydrates will not help any more than adding gas to a half-full tank will make the car go faster.

For events that require heavy work for more than two hours, a high-carbohydrate diet eaten for two to three days before the event allows glycogen storage spaces to be filled. Endurance athletes, such as long distance runners, cyclists, swimmers, and cross-country skiers, report benefits from a pre-competition diet, in which 70 percent of the calories comes from carbohydrates.

Research has demonstrated that endurance athletes on a high-carbohydrate diet can exercise longer than athletes eating a low-carbohydrate, high-fat diet. However, constantly eating a high-carbohydrate diet is not advised. This conditions the body to use only carbohydrates for fuel and not the fatty acids derived from fats.

For continuous activities of three to four hours, it is important that glycogen stores in the muscles and liver are at a maximum. Additionally, taking carbohydrates during the event in the form of carbohydrate solutions, such as electrolyte drinks can be beneficial. The current recommendation is a 6 to 8 percent glucose solution. A homemade electrolyte drink with 7.6% glucose and reasonable sodium amounts can be easily made. Add 6 tablespoons sugar and 1/3 teaspoon salt to each quart of water. Dissolve sugar and cool. The salt translates into a sodium concentration of 650 mg/liter.

Sports drinks can be used to supply sodium and glucose if the athlete tolerates them, but other electrolytes are not essential until after the event. Athletes should experiment during training to find if electrolyte beverages are right for them.

Fats

Fat is also a significant contributor to energy needs. It supplies 9 kcal/g of fat, making it the most energy dense macronutrient. During ultra-endurance events, lasting 6-10 hours, fat can contribute 60-70% of energy requirements.

Using fat as fuel depends on the event's duration and the athlete's condition. As duration increases and/or intensity decreases, the utilization of fat as an energy source increases. For moderate exercise, about half of the total energy expenditure is derived from free fatty acid metabolism. If the event lasts more than an hour, the body may use mostly fats for energy. Furthermore, trained athletes use fat for energy more quickly than untrained athletes.

Fat consumption should be a minimum of 20 percent of total energy intake to preserve athletic performance. Maintaining adequate fat intake is crucial to meeting nutritional needs of essential fatty acids and fat-soluble vitamins, vitamins A, D, E and K. Athletes who are under pressure to achieve or maintain a low body weight are susceptible to using fat restriction and should be told that this may hinder their performance. While adequate fat intake is necessary, claims that suggest a high-fat low-carbohydrate diet enhances athletic performance have not been supported by research.

Protein

When compared to fat and carbohydrates, protein contributes minimally to energy needs for the body. Dietary protein is digested into amino acids, which are used as the building blocks for the different tissues, enzymes, and hormones that the body needs to function. It is important for muscle building and repair that occurs after exercise.

Exercise may increase an athlete's need for protein, depending on the type and frequency of exercise. The current Recommended Daily Allowance (RDA) for protein is 0.8 grams per kilogram per day. However, the Academy for Nutrition and Dietetics and the American College of Sports Medicine recommend that endurance athletes eat between 1.2-1.4 grams of protein per kg of body weight per day and resistance and strength-trained athletes eat as much as 1.2-1.7 grams protein per kg of body weight.

Eating protein after an athletic event has been shown to support muscle protein synthesis. However, eating protein in excess of nutritional needs has not been shown to further increase muscle building. Extra protein is broken down for energy or is stored as fat.

A varied diet should provide more than enough protein as caloric intake increases. However, vegetarian athletes should work with a dietitian to make sure their protein intake is sufficient. Excess protein can deprive the athlete of more efficient fuel sources and can lead to dehydration. High-protein diets increase the water requirement necessary to eliminate the nitrogen through the urine. Also, an increase in metabolic rate can occur and, therefore, increased oxygen consumption.

Protein and amino acid supplements are unnecessary and not recommended. Some athletes turn to protein/amino-acid supplementation in the form of powders or pills to fulfill protein requirements. However, this is typically excessive, because proteins needs are easily met in an American diet. Eating whole foods instead of supplements is generally the best practice. Any athlete consuming supplements in replacement of meals should consult with their doctor or a registered dietitian before continuing.

Water

Water is an important nutrient for the athlete. Water loss during an athletic event varies between individuals. Sweat loss can be tracked by measuring weight immediately before and after exercise. To avoid dehydration, an athlete should drink 5 to 7 mL per kilogram of body mass approximately four hours before an event. Throughout the event, they should drink chilled water or electrolyte drinks, consuming enough to match sweat losses. Chilled fluids are absorbed faster and help lower body temperature.

After exercise, 16-24 oz of water should be for every pound that was lost during the athletic event. By routinely tracking pre- and post- exercise weight changes, sweat rates can be estimated, allowing for more efficient hydration during athletic events. An individual should never gain weight during exercise; this is a sign of excessive hydration, which can lead to electrolyte imbalances, and potentially hyponatremia. It is important to account for environmental concerns when considering water consumption. Sweat rates may increase dramatically in hot and humid weather, and it is increasingly important for an athlete to stay hydrated in these conditions. Competing at high altitudes also increases water needs.

Athletes consuming sport drinks or energy drinks should be aware of caffeine levels. Limited amounts of caffeine have been shown to enhance athletic performance. However, insomnia, restlessness and ringing of the ears can occur with caffeine consumption. Furthermore, caffeine acts as a diuretic and may cause the need to urinate during competition.

Vitamins

Maintaining adequate levels of vitamins and minerals is important for bodily function, and therefore, athletic performance. As the activity level of an athlete increases, the need for different vitamins and minerals may increase as well. However, this need can be easily met by eating a balanced diet including a variety of foods. There is no evidence that taking more vitamins than is obtained by eating a variety of foods will improve performance.

B vitamins, including thiamin, riboflavin and niacin, are essential for producing energy from the fuel sources in the diet. Carbohydrate and protein foods are excellent sources of these vitamins. B vitamins are water soluble vitamins, which means that are not stored in the body, so toxicity is not an issue. Some female athletes may lack riboflavin, so it is important to ensure adequate consumption of riboflavin-rich foods, like milk. Milk products not only increase the riboflavin level but also provide protein and calcium.

Vitamin D has many functions in the body, and is crucial for calcium absorption. Athletes who train indoors for prolonged periods of time should insure that they consuming adequate amounts of vitamin D through diet.

Exercise increases the oxidative stress on the body, increasing the need for vitamins C and E, which have an antioxidant effect. Vitamin E is a fat soluble vitamin, found in fats in the diet such as nuts, seeds, and vegetable oils. When an individual consumes excess fat-soluble vitamins (A, D, E and K), they are stored in fat throughout the body. Because they are stored, excessive amounts of fat-soluble vitamins may have toxic effects.

Minerals

Minerals play an important role in athletic function. Heavy exercise affects the body's supply of sodium, potassium, iron and calcium.

- Sodium is lost through the course of an athletic event through sweat, so it may be necessary to replace sodium in addition to water during an event. Sweating during exercise increases the concentration of salt in the body, so consuming salt tablets after competition and workouts is not advised. This will draw water out of the cells, causing weak muscles. Good sodium guidelines are to: 1) avoid excessive amounts of sodium in the diet and 2) consider consuming beverages containing sodium during endurance events (> 2 hours).
- Potassium levels can decline during exercise, similar to sodium, though losses are not as significant. Eating potassium-rich foods such as oranges, bananas and potatoes throughout training and after competition supplies necessary potassium.
- Iron carries oxygen via blood to all cells in the body. Needs for this mineral are especially high in endurance athletes. Female athletes and athletes between 13 and 19 years old may have inadequate supplies of iron due to menstruation and strenuous exercise. Female athletes who train heavily have a high incidence of amenorrhea, the absence of regular, monthly periods, and thus conserve iron stores. Choosing foods high in iron such as red meat, lentils, dark leafy greens, and fortified cereals can help prevent iron deficiencies, but taking an iron supplement may be advised. It is best to consult a physician before starting iron supplements.
- Calcium is important in bone health and muscle function. Athletes should have an adequate supply of calcium to prevent bone loss. Inadequate calcium levels may lead to osteoporosis later in life. Female athletes are more likely to have inadequate calcium consumption. Low-fat dairy products are a good source of calcium.

Restricting calories during periods of high activity can lead to vitamin and mineral deficiencies. This negatively impacts athletic performance, and has adverse repercussions for general health and wellbeing. Athletes who are wishing to lose weight should do so during the off-season.

Table 10.6.1***:*** *Two pre-event meal plans.*

Pre-Event Meal Plan I, 2-3 hours prior (approximately 500 calories)	
Lean meat or protein equivalent	2 ounces
Fruit	1 serving (1/2 cup)
Bread or easily digestible carbohydrate	2 servings
Pre-Event Meal Plan II, 3 1/2 – 4 hours prior (approximately 900 calories)	
Cooked lean meat or protein equivalent	2 ounces

Fruit	1 serving (1/2 cup)
Pasta or baked potato	1 cup or 1 medium
Bread or carbohydrate substitute	2 servings
Low-fiber vegetable	1 serving (1/2 cup)
Fat spread	1 teaspoon
Dessert: Angel food cake or plain cookies	1 piece or 2 cookies

The Pre-Game Meal

Eating before competition can increase performance when compared to exercising in fasted state. A pre-game meal three to four hours before the event allows for optimal digestion and energy supply. Most authorities recommend small pre-game meals that provide 500 to 1,000 calories. This meal should be sufficient but not excessive, so as to prevent both hunger and undigested food.

The meal should be high in starch, which breaks down more easily than protein and fats. The starch should be in the form of complex carbohydrates (breads, cold cereal, pasta, fruits and vegetables). They are digested at a rate that provides consistent energy to the body and are emptied from the stomach in two to three hours.

High-sugar foods lead to a rapid rise in blood sugar, followed by a decline in blood sugar and less energy. In addition, concentrated sweets can draw fluid into the gastrointestinal tract and contribute to dehydration, cramping, nausea and diarrhea. Don't consume any carbohydrates one and a half to two hours before an event. This may lead to premature exhaustion of glycogen stores in endurance events.

Pregame meals should be low in fat. Fat takes longer to digest, as does fiber- and lactose-containing meals. Take in adequate fluids during this pre-game time. Carefully consider caffeine consumption (cola, coffee, tea), as it may lead to dehydration by increasing urine production. It is important to eat familiar foods before an event, so it is known that they can be tolerated before exercise.Smaller meals should be consumed if less time remains before an event. If a competition is less than two hours away, athletes may benefit from consuming a liquid pre-game meal to avoid gastrointestinal distress. A liquid meal will move out of the stomach by the time a meet or match begins. Remember to include water with this meal.

The Post-Game Meal

Regardless of age, gender or sport, the post-game competition meal recommendations are the same. Following a training session or competition, a small meal eaten within thirty minutes is very beneficial. The meal should be mixed, meaning it contains carbohydrate, protein, and fat. Protein synthesis is greatest during the window of time immediately following a workout and carbohydrates will help replete diminished glycogen stores. However, consume food within the 30 minute window may be difficult for athletes—they often experience nausea or lack of hunger. Options to address this difficulty include:

- Consuming a drink that contains carbohydrates and protein. There are several liquid smoothies and beverages on the market that provide high protein and carbohydrates for replenishment. One classic is chocolate milk.
- If that is difficult, fruit, bread, crackers, or popsicles would all be better than not consuming any food.

Athletes should be wary of ergogenic aids, which claim to enhance athletic performance. Many of these claims are unsubstantiated, and some aids may be dangerous or hinder performance.

It is crucial to maintain nutritious eating not only for athletic events, but all the time. A pre-game meal or special diet for several days prior to competition cannot make up for inadequate nutrition in previous months or years. Lifelong nutrition habits must be emphasized. Combining good eating practices with a good training and conditioning program will allow any athlete to maximize their performance.

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10.7: Creating your own fitness plan

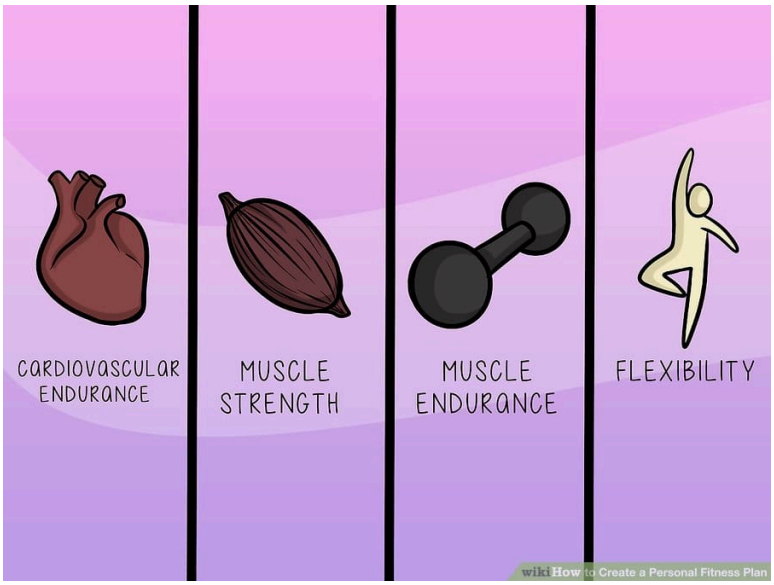
If you'd like to get stronger or faster, lose weight, or just improve the quality of your life, consider creating a personal fitness plan to meet your goals. There are many kinds of possible plans and most incorporate a mix of aerobic, resistance, and flexibility exercises. Assess your level of fitness and craft a plan suited to you

Part 1: Assessing your Fitness Level



Start with the basics. You've decided to get fit — that's a great first step. But don't just jump in without giving it some thought. Start with simple things: Is there anything stopping you from getting fit? Do you have any health issues? Should you talk to a doctor first?

- You probably don't need to talk to a doctor if you're under 50 and in good health, but it is always recommended before starting a new exercise program.
- If you're over 50 or have health issues — like high blood pressure, heart problems, dizzy spells, or arthritis — talk to your doctor first.
- Keep in mind that balance and strength decrease as you age. This can limit your ability to exercise or make injuries more likely, and harder to heal. But, by exercising with caution and a little guidance, you can improve these things through exercise.
- When in doubt, talk to a physician. Your physician can indicate any activities you should steer away from.



Test your current fitness level. Basic fitness is a mix of four things: cardiovascular endurance, muscle strength, muscle endurance, and flexibility. How do you measure up? Test yourself to see where you're fit and where you stand to improve. You'll need a watch, a measuring tape, a yardstick, tape, and a scale.

- Take a brisk 1 mile (1.6 km) walk to test your cardio health. Before you start, take your pulse rate in beats per minute and record the time. Take your pulse again afterwards and note how long it took you.
- To get your pulse rate, just put your index and middle fingers on the side of your neck. Count the beats for 10 seconds and multiply by six.
- To test muscular strength, count how many push-ups you can do until you are unable to perform any more push-ups with correct form. If you are not very strong yet, you can do modified push-ups (bend your knees). When you get stronger you should switch to classic push-ups from the plank position. Record the number.
- For flexibility, secure a yardstick to the floor with some tape at the 15 inch mark. Sit next to the yardstick, with your feet roughly even with the tape. Reach forward as far as you can, holding the position long enough to note how far you were able to reach. Do this exercise three times, recording your farthest reach.
- Now for body composition: waist and Body Mass Index. First measure and record your waist circumference around the body at the level of your bellybutton — where your waist is most narrow. To get your BMI (a rough indicator of body fat percentage), use an online calculator or divide your weight in lbs. by your height in inches, squared, times 703. If you're using metric, BMI = (Weight in Kilograms / (Height in Meters x Height in Meters))

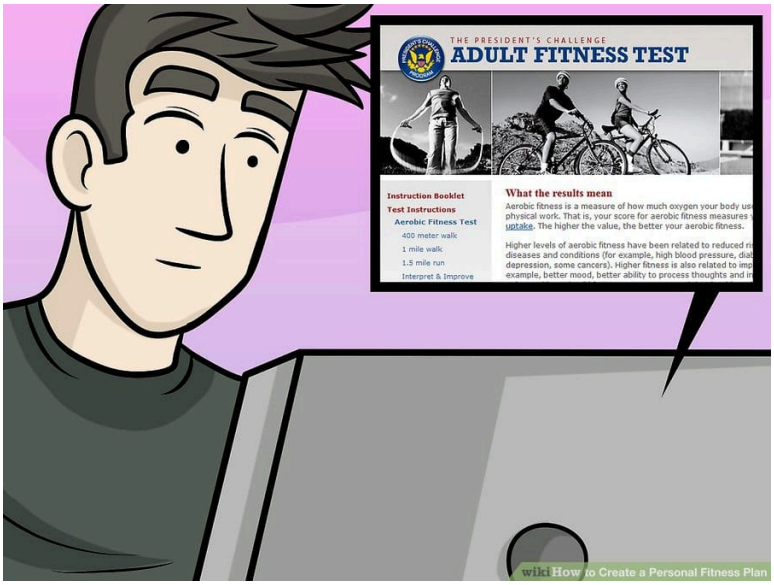
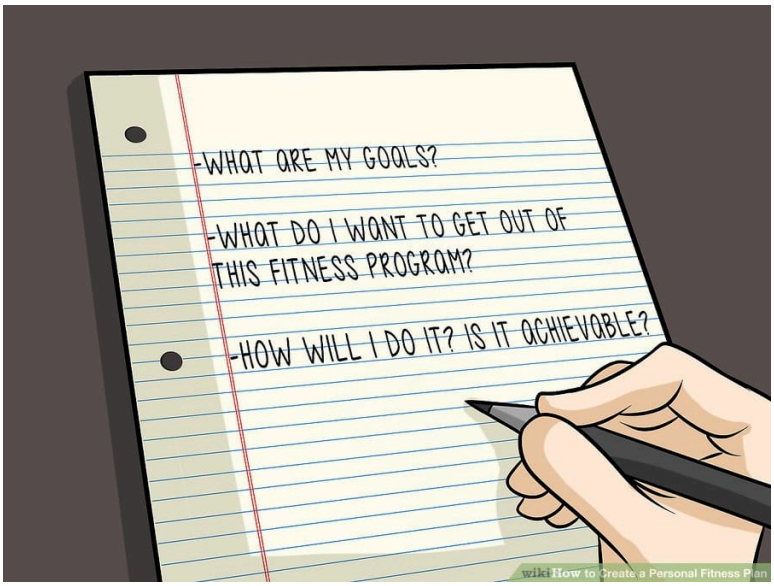


Figure out your goals. What to make of these test results? Well, they should give a rough guide to health based on averages for your age and sex, and also what your fitness plan should focus on. Here is one example of an adult fitness test if you'd like to try one: Fitness Test PDF

- The mile walk measures your cardio fitness. Healthy adults should be able to walk a mile without much exertion. If you get very winded walking a mile, you will want a fitness plan with an emphasis on aerobic exercise.
- The push-up test measures your strength. If you are not able to do 10 pushups it means that you probably do not have developed upper body muscle strength — consider adding upper body strength training to your plan.
- The reach-and-stretch test measures how much flexibility your joints and muscles have. A poor result means that you should consider doing stretching exercises like yoga or pilates as part of your program.
- Finally, a BMI of 25 or more may mean that you are overweight and at higher risk for things like heart disease, high blood pressure, or diabetes. General weight loss might be a goal for your program.



Plan it out. Give yourself added encouragement by planning your program in detail. You can either do this on your own or with outside help. A structured plan will allow you to set goals and stay on track.

- Try writing out your plan on paper, for example. Ask specific questions: What are my goals? What do I want to get out of this fitness program? How will I do it? Is it achievable?
- Be specific in your answers. For instance, do you want to be able to run for 30 minutes four times per week? Or do you want to lose 5 pounds in a month? Just saying "I want to get fit" doesn't give you a concrete, measurable goal to work toward. The more specific you can be, the easier it will be for you to know when you've met your goals.
- Post your plan where you'll see it every day, like in your office or on the bathroom mirror.
- If you want, you can also get a personal trainer. Personal trainers are fitness experts who will make sure you are using proper form while exercising, doing exercises that are appropriate for your fitness level, help you set goals and motivate you to reach them.

Part 2: Creating a Cardio Plan

Pick exercises you can do and enjoy. Cardio is the bread and butter of fitness plans. When you do cardio, you work big muscle groups in your body, your heart rate rises, and you breathe faster and more deeply.



Cardio exercise will strengthen your heart, increase your endurance, and burn calories. It will also boost your mood and help you sleep better.

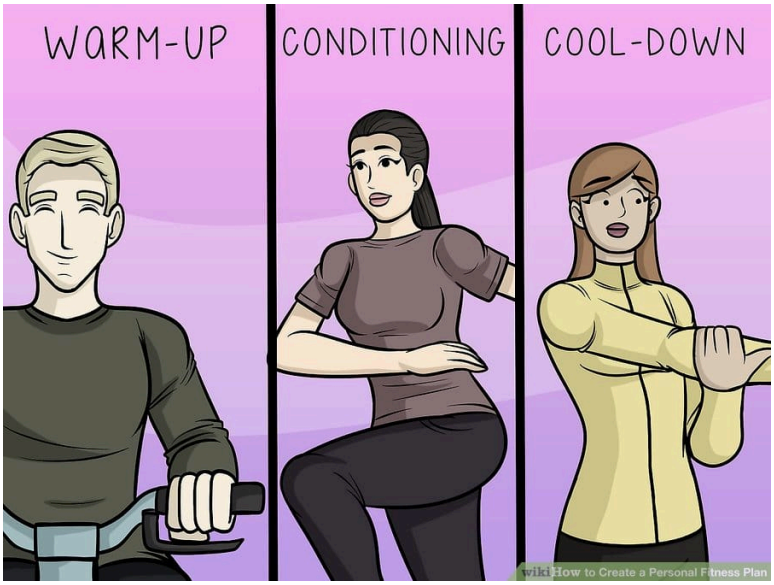
- Cardio is also known as aerobic exercise. The idea is to elevate your heart rate and breathing rate.
- Walking, running, rowing, swimming, bicycling, and dancing are all cardio exercises. So are most team sports, martial arts, and even golfing.
- Choose exercises that you like, but also make sure you are physically able to do them. Running is hard on the knees and feet, for instance, so you if you have bad knees you might need a lower impact exercise like brisk walking, cycling or swimming.
- Also keep in mind that you'll be working out often, so you may want to have several exercises and alternate. For instance, you might ride your bike, swim, and play golf on different days one week. Or, you might play soccer, run, and in-line skate.



Start slowly. Ease your way into the routine until you have more endurance. The US government recommends at least 150 minutes of moderate aerobic activity or 75 minutes of intense activity per week. You don't need to do all of this in two, three, or four sessions, however. Instead, spread it out through the week.

- Aerobic exercise should pass the "talk test," meaning you should be able to talk and carry on a conversation while exercising. If not, your heart rate is too high.
- Ideally, you should do at least 30 minutes of activity per day. If you can't manage that, try breaking up your exercise into smaller chunks. For example, go for a 10 minute walk several times per week in the beginning. As your body gets used to this,

lengthen the walk to 15 minutes, then to 20, and then to 30.
- Don’t feel the need to do high-intensity exercise at the beginning. Go at your own pace. Otherwise, you might get injured.



Use a three-pronged approach. Cardio isn’t all-out exertion all the time. To get the most out of each session, incorporate three elements into your routine: warm-up, conditioning, and cool-down. Ease into the workout, ride your plateau, and then slow down.

- Before each session, warm up for about five to 10 minutes to get your heart going and to increase blood flow to your muscles.
- A low-intensity version of your exercise should do this. If you are riding a bike, for example, take a leisurely ride for a few blocks. If you’re swimming, do two or three laps at half pace.
- Aim for around 30 minutes of conditioning after your warm-up. Conditioning is about reaching a “sweet spot” — a level that you can maintain but where your breathing and heart rate are higher than normal.
- End with another five to 10 minutes of cool-down. Slow yourself to a stop and let your heart rate come down. You can also stretch your main muscle groups, like your hamstrings, calf muscles, chest, shoulders, quadriceps, and back.



Work up to ideal length and frequency. Take stock of your progress after a few weeks and make adjustments. Chances are that you will be able to work out longer and harder, gaining aerobic capacity and endurance. Try to work up to doctor recommended guidelines: again, at least 150 minutes of moderate aerobic activity or at 75 minutes of vigorous activity per week. Ideally, you should aim for at least 30 minutes of cardio activity every day.

- Adding five minutes to your workout per week is a modest and doable goal. This means that at the end of a month, you'll be exercising 20 minutes more.
- If your goal is weight loss, you may have to push yourself harder or adopt harder exercises. Rather than working out for 30 minutes three or four times per week, go for 45 minutes five or six times per week.
- Some cardio exercises are better than others if your goal is weight loss. Aerobic dance (like Zumba) and cross-country skiing burn about 700 and 600 calories per hour, for example, compared to brisk walking (150) or golfing (350).
- That said, listen to your body. Take a break and let your body recover if you feel run down. **Stop** exercising and talk to a doctor if you feel pain, dizziness, or shortness of breath.

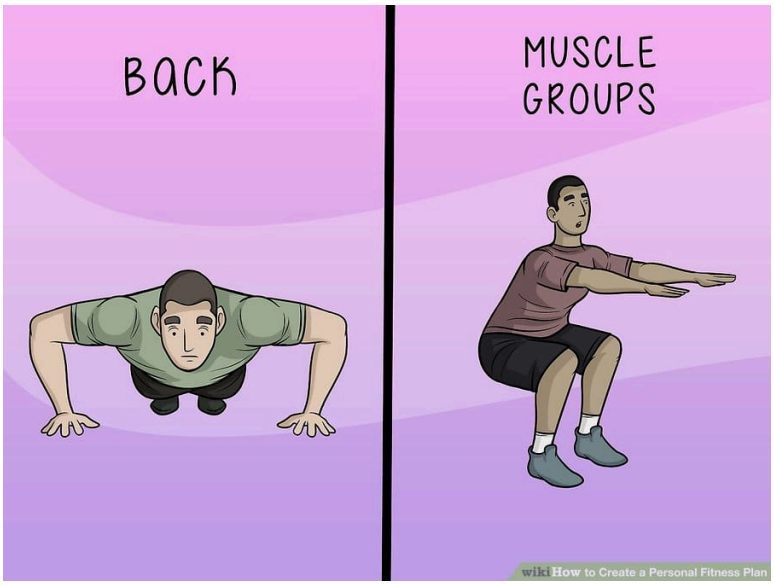
Part 3: Training for Strength

Learn good form. Strength training, also called weight or resistance training, is a different kind of exercise. Strength training builds up muscles and endurance. It will make you stronger, strengthen your bones, raise your stamina, and give you other mental and mood boosts.



The key to a good strength program is to work big muscle groups like the legs, arms, and core.

- In strength training, you use weights to create resistance and make your muscles work harder. You can do this with weight machines, free weights, exercise bands, or even just your own body weight.
- The resistance puts stress on your muscles and joints, so it's important to learn and always use proper form. Otherwise, you are at risk for sprains, strains, breaks, or overuse injuries. In general, you'll want to maintain good posture to protect your spine.
- Start with a weight that you can lift comfortably 12–15 times (whether that's on a machine or free weights) and move the joint through its full range of motion. Breathe out when you lift the weight and in when you lower it.
- Talk to people at your gym. A sports trainer or fitness specialist will be able to walk you through each exercise to be sure you're doing it right.



Pick exercises for major muscle groups. A good strength program will work all the major muscle groups. Choose exercises that isolate these or work several groups together. Tailor your program to your own needs, but also to your physical limits. Take into account your strength, balance, and age.

- For example, good exercises for your upper body include pushups. You can strengthen your arms and shoulders with bent over dumbbell rows and overhead presses. Bench presses will work your chest muscles.
- Exercises that use several muscle groups at once are really useful. For instance, squats will exercise your quadriceps and gluteal muscles at the same time. Lunges are another good example of this kind of exercise.

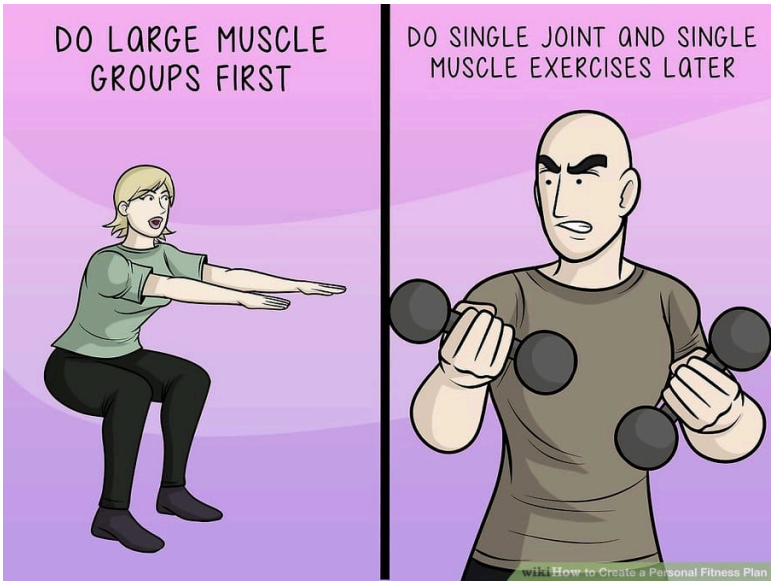
Split the program into rotations, sets, and reps. Your training program should be a cycle. Plan to focus on certain muscle groups on different days, and each day doing a number of specific exercises. You don't need to do a whole body workout every time.

- Your rotation might look something like this: bench-presses, rear flyes, push-ups, and planks one day for your back, bicep and tricep curls another day to work your arms, and squats, lunges, bridges, calf raises, balance exercises, and leg curls for your legs the third day.
- During each rotation day, split up the exercises into sets and reps. A "rep" is one full motion of the exercise. A "set" is a series of consecutive reps.
- How many reps and sets should you do? Answers vary. The Mayo Clinic recommends one set of 12 reps for each exercise. Another rule of thumb is that light weight with many reps builds endurance and muscle tone, while heavy weight and fewer reps — but lots of sets (five or more) — builds strength.
- How long should you exercise? The answer is not that long. Most people will see results after about eight weeks with two or three 20 to 30 minute sessions per week, covering all groups. Prevent plateaus by changing up your routine every eight weeks or so.
- Remember to give your body time to rest and heal: always schedule at least 48–72 hours between sessions for each muscle group.



Use the three-pronged approach. Like cardio, use a three-stage approach in your resistance training: aerobic warm-up, post-lift stretching and cool-down. These will help to get the blood flowing, the joints limber, and to stretch and relax the muscles after you are finished.

- Do a few minutes of low-intensity cardio before you hit the weights, like walking or jogging. “Warm” muscles are less prone to injury than “cold” ones.
- Do not stretch before resistance training.
- After your workout, take some time to cool down and stretch (one or two minutes for each muscle group).

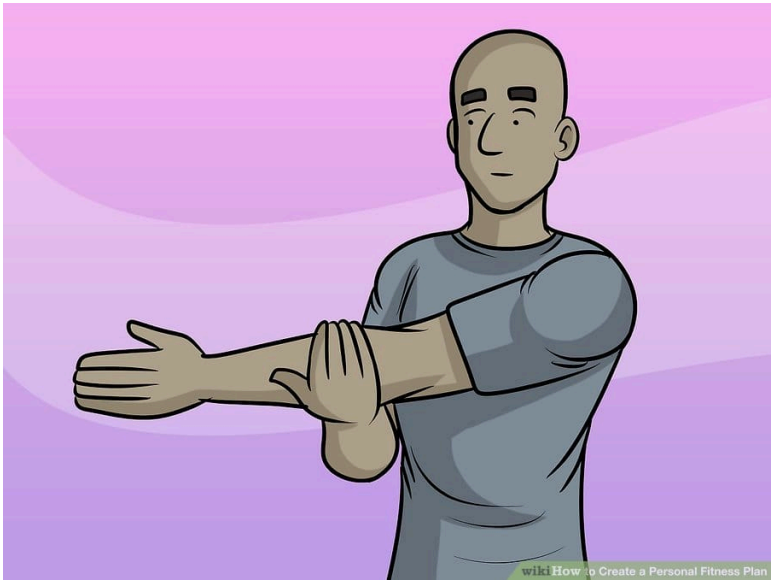


Do large muscle groups first. Experts recommend that your order of exercise should start with large or multiple muscle groups. That way, you’ll be able to do these harder exercises will more energy. You can isolate smaller or individual muscles afterwards.

- Prioritize exercises that use several muscle groups at once. Also, do exercises that use multiple joints before those that use one joint.
- You might work out your legs and back first, for instance. Squats, for example, use your legs but also your gluteal and core muscles, and should be done early in the workout.
- Do single joint and single muscle exercises later. Bicep curls or shoulder shrugs can come later in the workout session.

Part 4: Adding Stretching and Flexibility Exercises

Focus on major muscles and joints. Flexibility sometimes gets a back seat in exercise programs. Still, you should be sure to add basic stretches to your program.



Stretching makes you limber, increases the range of motion in joints, increases blood flow to muscles, and can prevent injury. It can also help prevent postural problems and joint misalignment problems.

- Stretch major joints and muscle groups that you use everyday, either during your workout or daily activities. The legs, arms, back, chest, shoulders, and hips are some common ones.



Warm-up beforehand. Don't stretch with cold muscles. You can injure yourself. Instead, do a few minutes of warm-up cardio to get blood flowing before you start stretching.

- For example, walk, bike, or jog at a low intensity for five to 10 minutes beforehand. You can also stretch after your workout, when you're already warmed up.
- You might want to hold off on stretching before strength training or intense activity like running or other track and field sports. Some research shows that pre-event stretching can actually reduce your performance.



Hold the stretch. When you stretch, gently pull the muscle and joint in a smooth movement and hold it for about 30 seconds. You might need to hold for 60 seconds in problem areas, i.e. areas that are inflexible or tight.

- Try some yoga poses, too. In the simple balasana pose (or child's pose), kneel on the floor with your knees slightly apart. Then, lean your hips forward, touch your forehead to the ground, and hold your abdomen to the thighs for 20 to 30 seconds. Reach your arms out in front of you. This pose will gently stretch your lower back and upper body. Older adults should be cautious about this stretch, as it can be harmful to the spine.
- Don’t hold your breath when you stretch, but instead breathe into the movement. Also, don’t bounce. You should not be bouncing to reach farther. This “ballistic” stretching can tighten the muscle or, worse, cause injury.
- Be aware of your spine and don’t stretch it too far in an abnormal direction. The same goes for other joints – keep them soft and do not lock them in position.
- You should not feel pain when you stretch. Some tension or discomfort is normal, but if it hurts you’ve stretched too far.

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11: FOOD SAFETY AND THE FUTURE OF OUR FOOD

Please begin by going here: https://en.Wikipedia.org/wiki/Foodborne_illness

Look at the rates of food borne illness in the United States of America. How many illnesses occur per year? How many are fatal? What are the organisms responsible for the highest number if illnesses? What are the organisms responsible for the highest number of deaths per year? Which foods seem most "risky"? How do we protect ourselves best???

Food borne illness (often called "food poisoning") is any illness resulting from consuming contaminated food containing: pathogenic bacteria, viruses, or parasites, as well as toxins such as poisonous mushrooms and various species of beans that have not been boiled for at least 10 minutes. Symptoms vary depending on the cause, and are described below in this article. A few broad generalizations can be made, e.g.: The incubation period ranges from hours to days, depending on the cause and on how much was consumed. The often long incubation period tends to cause sufferers to not associate the symptoms with the item consumed, and so to cause sufferers to attribute the symptoms to gastroenteritis for example. Symptoms often include: vomiting, fever, and aches, and may include diarrhea. Bouts of vomiting can be repeated with an extended delay in between, because even if infected food was eliminated from the stomach in the first bout, microbes (if applicable) can pass through the stomach into the intestine and begin to multiply. Some types of microbes stay in the intestine, some produce a toxin that is absorbed into the bloodstream, and some can directly invade deeper body tissues.

11.1: Protecting Our Food

11.2: Microbes in Food

11.3: Foodborne Illness

11.4: Common Food-Borne Pathogens

11.5: Foodborne Illness and Food Safety

11.6: Food Preservation

11.7: Preparing for Disasters

11.8: Food Additives

11.9: Start Your Sustainable Future Today

11.10: Genetically Modified Foods (GMO's)

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11.1: Protecting Our Food

Foodborne illness is any illness resulting from the food spoilage of contaminated food, pathogenic bacteria, viruses, or parasites that contaminate food, as well as chemical or natural toxins such as poisonous mushrooms and various species of beans that have not been boiled for at least 10 minutes. Symptoms vary depending on the cause, and are described below in this article. A few broad generalizations can be made, e.g.: The incubation period ranges from hours to days, depending on the cause and on how much was consumed. The incubation period tends to cause sufferers to not associate the symptoms with the item consumed, and so to cause sufferers to attribute the symptoms to gastroenteritis for example. Symptoms often include vomiting, fever, and aches, and may include diarrhea. Bouts of vomiting can be repeated with an extended delay in between, because even if infected food was eliminated from the stomach in the first bout, microbes (if applicable) can pass through the stomach into the intestine via cells lining the intestinal walls and begin to multiply. Some types of microbes stay in the intestine, some produce a toxin that is absorbed into the bloodstream, and some can directly invade deeper body tissues.

Foodborne illness usually arises from improper handling, preparation, or food storage. Good hygiene practices before, during, and after food preparation can reduce the chances of contracting an illness. There is a consensus in the public health community that regular hand-washing is one of the most effective defenses against the spread of foodborne illness. The action of monitoring food to ensure that it will not cause foodborne illness is known as food safety. Foodborne disease can also be caused by a large variety of toxins that affect the environment. Foodborne illness can also be caused by pesticides or medicines in food and naturally toxic substances such as poisonous mushrooms or reef fish.

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11.2: Microbes in Food

Bacteria and viruses are the most common cause of food poisoning, although toxins and parasites also can contribute. The symptoms and severity of food poisoning vary, depending on which bacteria or virus has contaminated the food.

Bacteria

Bacteria are a common cause of foodborne illness. In the United Kingdom during 2000, the individual bacteria involved were the following: *Campylobacter jejuni* 77.3%, *Salmonella* 20.9%, *Escherichia coli* O157:H7 1.4%, and all others less than 0.56%. In the past, bacterial infections were thought to be more prevalent because few places had the capability to test for norovirus and no active surveillance was being done for this particular agent. Toxins from bacterial infections are delayed because the bacteria need time to multiply (Figure 11.2.1). As a result, symptoms associated with intoxication are usually not seen until 12–72 hours or more after eating contaminated food. However, in some cases, such as Staphylococcal food poisoning, the onset of illness can be as soon as 30 minutes after ingesting contaminated food.

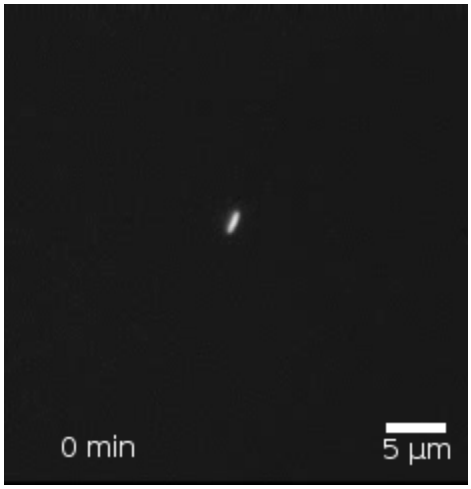


Figure 11.2.1***:*** *False color time-lapse video of E. coli colony growing on microscope slide. Image used wtih permission (CC BY-SA 4.0 Stewart EJ, Madden R, Paul G, Taddei F (2005) - Aging and Death in an Organism That Reproduces by Morphologically Symmetric Division. PLoS Biol 3(2): e45. doi.org/10.1371/journal.pbio.0030045.).*

Enterotoxins

An enterotoxin is a protein exotoxin released by a microorganism that targets the intestines. Enterotoxins are chromosomally encoded or plasmid encoded[2] exotoxins that are produced and secreted from several bacterial organisms. They are often heat-stable, and are of low molecular weight and water-soluble. Enterotoxins are frequently cytotoxic and kill cells by altering the apical membrane permeability of the mucosal (epithelial) cells of the intestinal wall. They are mostly pore-forming toxins (mostly chloride pores), secreted by bacteria, that assemble to form pores in cell membranes. This causes the cells to die.

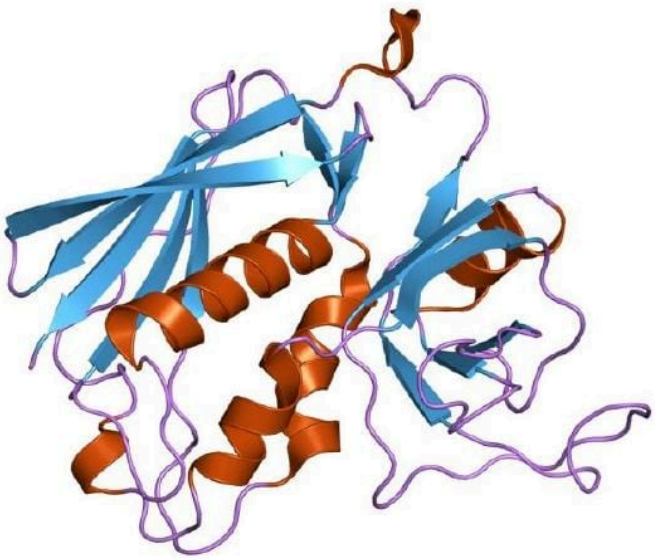


Figure 11.2.2*: Cartoon representation of the molecular structure of staphylococcal enterotoxin registered with 1uns code. (Public Domain; Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute).*

In addition to disease caused by direct bacterial infection, some foodborne illnesses are caused by enterotoxins (exotoxins targeting the intestines). Enterotoxins can produce illness even when the microbes that produced them have been killed. Symptom appearance varies with the toxin but may be rapid in onset, as in the case of enterotoxins of *Staphylococcus aureus* in which symptoms appear in one to six hours. This causes intense vomiting including or not including diarrhea (resulting in staphylococcal enteritis), and staphylococcal enterotoxins (most commonly staphylococcal enterotoxin A but also including staphylococcal enterotoxin B) are the most commonly reported enterotoxins although cases of poisoning are likely underestimated. It occurs mainly in cooked and processed foods due to competition with other biota in raw foods, and humans are the main cause of contamination as a substantial percentage of humans are persistent carriers of S. *aureus*. The CDC has estimated about 240,000 cases per year in the United States.

Viruses

Viral infections make up perhaps one third of cases of food poisoning in developed countries. In the US, more than 50% of cases are viral and noroviruses are the most common foodborne illness, causing 57% of outbreaks in 2004. Foodborne viral infection are usually of intermediate (1–3 days) incubation period, causing illnesses which are self-limited in otherwise healthy individuals; they are similar to the bacterial forms described above.

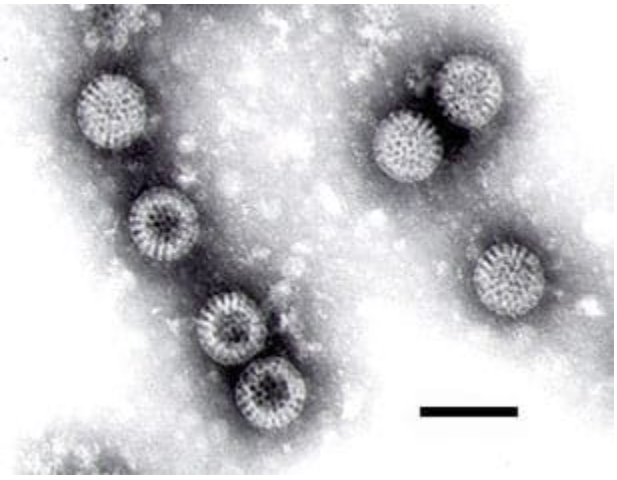


Figure 11.2.3***:*** *Rotavirus. Note the wheel-like appearance of some of the rotavirus particles. The observance of such particles*

gave the virus its name ('rota' being the Latin word meaning wheel). Bar = 100 nanometers.IMpage used with permission (Public Domain; F.P. Williams, U.S. EPA).

Natural Toxins

Several foods can naturally contain toxins, many of which are not produced by bacteria. Plants in particular may be toxic; animals which are naturally poisonous to eat are rare. In evolutionary terms, animals can escape being eaten by fleeing; plants can use only passive defenses such as poisons and distasteful substances, for example capsaicin in chili peppers (Figure 11.2.4) and pungent sulfur compounds in garlic and onions. Most animal poisons are not synthesized by the animal, but acquired by eating poisonous plants to which the animal is immune, or by bacterial action.



Figure 11.2.4***:*** *Capsaicin is an active component of chili peppers, which are plants belonging to the genus Capsicum. It is an irritant for mammals, including humans, and produces a sensation of burning in any tissue with which it comes into contact. Red Cubanelle chili peppers. (CC BY-SA 4.0; © Tomas Castelazo, www.tomascastelazo.com / Wikimedia Commons).*

Parasites

Food poisoning caused by parasites is not as common as food poisoning caused by bacteria and viruses, but parasites spread through food are still very dangerous. Toxoplasma is the parasite seen most often in cases of food poisoning (Figure 11.2.5). It's typically found in cat litter boxes. Parasites can live in your digestive tract undetected for years. However, people with weakened immune systems and pregnant women risk serious side effects if parasites take up residence in their intestines.

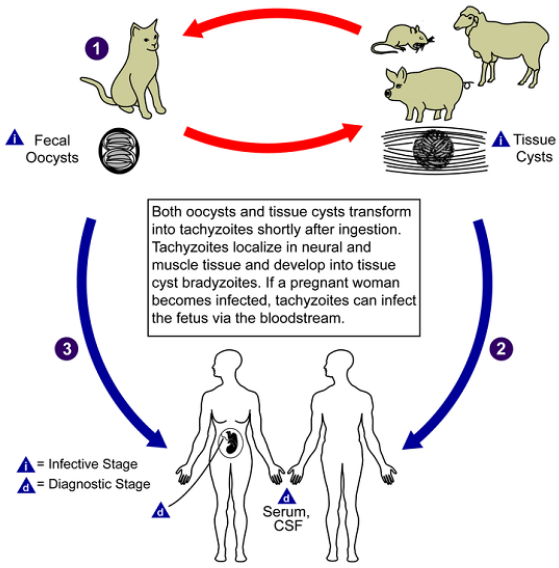


Figure 11.2.4***:*** *This is an illustration of the life cycle of Toxoplasma gondii, the causal agent of toxoplasmosis. This media comes from the Centers for Disease Control and Prevention's Public Health Image Library (PHIL), with identification number #3421. Note: Not all PHIL images are public domain; be sure to check copyright status and credit authors and content providers. (Public Domain; CDC/Alexander J. da Silva, PhD/Melanie Moser).*

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11.3: Foodborne Illness

Many different disease-causing germs can contaminate foods, so there are many different foodborne infections. The US CDC estimates that each year 48 million people get sick from a foodborne illness, 128,000 are hospitalized, and 3,000 die. Researchers have identified more than 250 foodborne diseases. Most of them are infections, caused by a variety of bacteria, viruses, and parasites. Harmful toxins and chemicals also can contaminate foods and cause foodborne illness.

Food Poisoning

Although anyone can get a foodborne illness, some people are more likely to develop one. Those groups include Pregnant women, Young children, Older adults, People with immune systems weakened from medical conditions, such as diabetes, liver disease, kidney disease, organ transplants, HIV/AIDS, or from receiving chemotherapy or radiation treatment. Most people with a foodborne illness get better without medical treatment, but people with severe symptoms should see their doctor.

Food Poisoning Symptoms

Common symptoms of foodborne diseases are nausea, vomiting, stomach cramps, and diarrhea. However, symptoms may differ among the different types of foodborne diseases. Symptoms can sometimes be severe and some foodborne illnesses can even be life-threatening. Most people have only mild illnesses, lasting a few hours to several days. However, some people need to be hospitalized, and some illnesses result in long-term health problems or even death. Infections transmitted by food can result in chronic arthritis, brain and nerve damage, and hemolytic uremic syndrome (HUS), which causes kidney failure.

Food poisoning symptoms may range from mild to severe and may differ depending on the germ you swallowed (see Table 11.3.1 below). After you consume a contaminated food or drink, it may take hours or days before you develop symptoms. See your doctor or healthcare provider if you have symptoms that are severe, including:

- High fever (temperature over 101.5°F, measured orally)
- Blood in stools
- Frequent vomiting that prevents keeping liquids down (which can lead to dehydration)
- Signs of dehydration, including a marked decrease in urination, a very dry mouth and throat, or feeling dizzy when standing up.
- Diarrhea that lasts more than 3 days

The top five germs that cause illnesses from food eaten in the United States are *Norovirus, Salmonella, Clostridium perfringens, Campylobacter, and Staphylococcus aureus (Staph).*

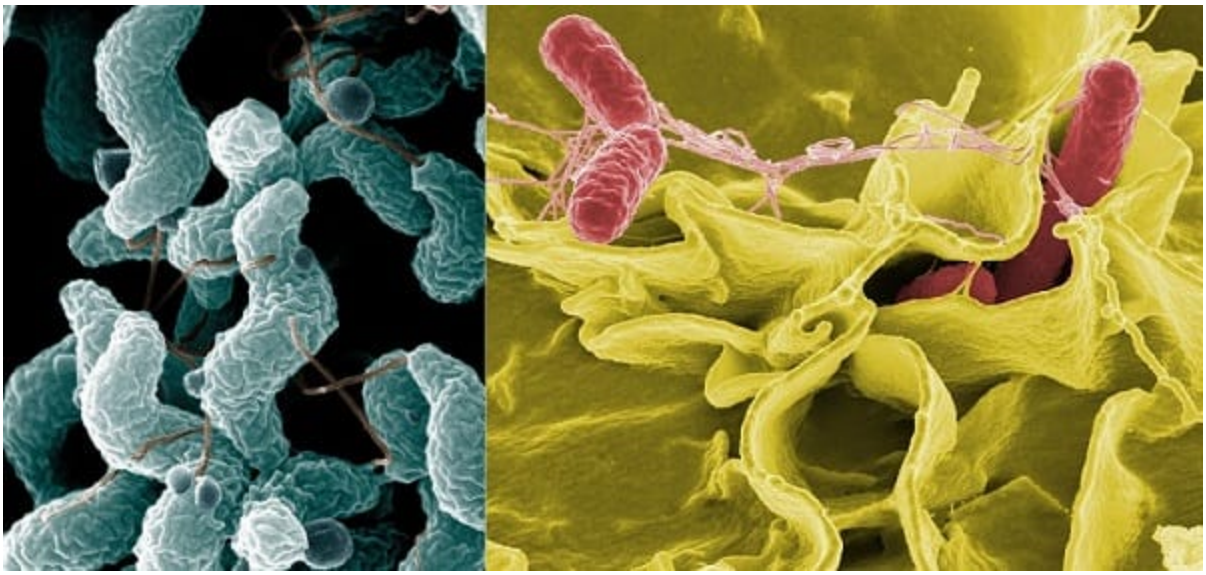


Figure 11.3.1***:*** *(left) Campylobacter, a bacteria that is a major cause of food poisoning and (right) Salmonella. Images used with permission (Public Domain; De Wood, Pooley, USDA (left) and Rocky Mountain Laboratories, NIAID, NIH).*

Some other germs don't cause as many illnesses, but when they do, the **illnesses are more likely to lead to hospitalizatio**n. Those germs include *Clostridium botulinum* (botulism), *Listeria, Escherichia coli (E. coli), and Vibrio.*

Table 11.3.1***:*** *Symptoms and Sources of 10 Foodborne Germs*

Germ and Typical Time for Symptoms to Appear	Typical Signs and Symptoms	Common Food Sources
Campylobacter 2 – 5 days	Diarrhea (often bloody), stomach cramps/pain, fever	Raw or undercooked poultry, raw (unpasteurized) milk, and contaminated water
Clostridium botulinum 18 – 36 hours	Double or blurred vision, drooping eyelids, slurred speech. Difficulty swallowing, breathing and dry mouth. Muscle weakness and paralysis. Symptoms start in the head and move down as severity increases	Improperly canned or fermented foods, usually homemade. Prison-made illicit alcohol.
Clostridium perfringens 6 – 24 hours	Diarrhea, stomach cramps. Vomiting and fever are uncommon. Usually begins suddenly and lasts for less than 24 hours	Beef or poultry, especially large roasts; gravies; dried or precooked foods
Cyclospora 1 week	Watery diarrhea, loss of appetite and weight loss. Stomach cramps/pain, bloating, increased gas, nausea, and fatigue.	Raw fruits or vegetables, and herbs
Escherichia coli 3 – 4 days	Severe stomach cramps, diarrhea (often bloody), and vomiting. Around 5-10% of people diagnosed with this infection develop a life-threatening complication.	Raw or undercooked ground beef, raw (unpasteurized) milk and juice, raw vegetables (such as lettuce), and raw sprouts, contaminated water
Listeria 1 – 4 weeks	Pregnant women typically experience fever and other flu-like symptoms, such as fatigue and muscle aches. Infections during pregnancy can lead to serious illness or even death in newborns. Other people (most often older adults): headache, stiff neck, confusion, loss of balance and convulsions in addition to fever and muscle aches.	Raw (unpasteurized) milk, soft cheeses made with raw milk, raw sprouts, melons, hot dogs, pâtés, lunch meats, and cold cuts, smoked seafood
Norovirus 12 – 48 hours	Diarrhea, nausea/stomach pain, vomiting	Infected person, contaminated food like leafy greens, fresh fruits, shellfish (such as oysters), or water, or by touching contaminated surfaces
Salmonella 12 – 72 hours	Diarrhea, fever, stomach cramps, vomiting	Eggs, raw or undercooked poultry or meat, unpasteurized milk or juice, cheese, raw fruits and vegetables
Staphylococcus aureus (Staph) 30 minutes – 6 hours	Diarrhea, nausea, stomach cramps, vomiting	Foods that are handled by people and not cooked (sliced meat, puddings, pastries, and sandwiches). Raw (unpasteurized) milk and cheese made from it.
Vibrio 1 – 4 days	Watery diarrhea, nausea. stomach cramps, vomiting, fever, chills	Raw or undercooked shellfish, particularly oysters

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11.4: Common Food-Borne Pathogens

The majority of foodborne illnesses are caused by harmful bacteria and viruses, although some parasites also cause foodborne illnesses. In the past, bacterial infections were thought to be more prevalent because few places had the capability to test for norovirus and no active surveillance was being done for this particular agent. Toxins from bacterial infections are delayed because the bacteria need time to multiply. As a result, symptoms associated with intoxication are usually not seen until 12–72 hours or more after eating contaminated food. However, in some cases, such as Staphylococcal food poisoning, the onset of illness can be as soon as 30 minutes after ingesting contaminated food.

Bacteria

Bacteria are tiny organisms that can cause infections of the Gastrointestinal (GI) tract. Not all bacteria are harmful to humans. Some harmful bacteria may already be present in foods when they are purchased. Raw foods including meat, poultry, fish and shellfish, eggs, unpasteurized milk and dairy products, and fresh produce often contain bacteria that cause foodborne illnesses. Bacteria can contaminate food—making it harmful to eat—at any time during growth, harvesting or slaughter, processing, storage, and shipping.

Foods may also be contaminated with bacteria during food preparation in a restaurant or home kitchen. If food preparers do not thoroughly wash their hands, kitchen utensils, cutting boards, and other kitchen surfaces that come into contact with raw foods, cross-contamination—the spread of bacteria from contaminated food to uncontaminated food—may occur. If hot food is not kept hot enough or cold food is not kept cold enough, bacteria may multiply. Bacteria multiply quickly when the temperature of food is between 40 and 140 degrees. Cold food should be kept below 40 degrees and hot food should be kept above 140 degrees. Bacteria multiply more slowly when food is refrigerated, and freezing food can further slow or even stop the spread of bacteria. However, bacteria in refrigerated or frozen foods become active again when food is brought to room temperature. Thoroughly cooking food kills bacteria.

Many types of bacteria cause foodborne illnesses. Examples include

- *Salmonella*, a bacterium found in many foods, including raw and undercooked meat, poultry, dairy products, and seafood. *Salmonella* may also be present on egg shells and inside eggs.
- *Campylobacter jejuni (C. jejuni),* found in raw or undercooked chicken and unpasteurized milk.
- *Shigella,* a bacterium spread from person to person. These bacteria are present in the stools of people who are infected. If people who are infected do not wash their hands thoroughly after using the bathroom, they can contaminate food that they handle or prepare. Water contaminated with infected stools can also contaminate produce in the field.
- *Escherichia coli (E. coli),* which includes several different strains, only a few of which cause illness in humans. *E. coli O157:H7* is the strain that causes the most severe illness. Common sources of *E. coli* include raw or undercooked hamburger, unpasteurized fruit juices and milk, and fresh produce.
- *Listeria monocytogenes (L. monocytogenes),* which has been found in raw and undercooked meats, unpasteurized milk, soft cheeses, and ready-to-eat deli meats and hot dogs.
- *Vibrio,* a bacterium that may contaminate fish or shellfish.
- *Clostridium botulinum (C. botulinum),* a bacterium that may contaminate improperly canned foods and smoked and salted fish.

Viruses

Viruses are tiny capsules, much smaller than bacteria, that contain genetic material. Viruses also cause infections to the GI tract that can lead to sickness. People can pass viruses to each other. Viruses are present in the stool or vomit of people who are infected. People who are infected with a virus may contaminate food and drinks, especially if they do not wash their hands thoroughly after using the bathroom.

Common sources of foodborne viruses include

- food prepared by a person infected with a virus
- shellfish from contaminated water

- produce irrigated with contaminated water

Common foodborne viruses include the **norovirus**, which causes inflammation of the stomach and intestines and hepatitis A, which causes inflammation of the liver

hepatitis A

Hepatitis A is an infectious disease of the liver caused by the hepatitis A virus (HAV). It is usually spread by eating food or drinking water contaminated with infected feces. Shellfish which have not been sufficiently cooked are a relatively common source and it may also be spread through close contact with an infectious person. While children often do not have symptoms when infected, they are still able to infect others. Symptoms usually last less than 2 months, although some people can be ill for as long as 6 months: fatigue, fever, nausea, appetite loss, jaundice, a yellowing of the skin or the whites of the eyes, and diarrhea.



The viral disease Hepatitis A is manifested here as jaundice of the conjunctivae and facial skin. HAV is usually spread from person to person by putting something in the mouth (even though it may look clean) that has been contaminated with the stool of a person with hepatitis A. Adults will have signs and symptoms more often than children. (CDC/Dr. Thomas F. Sellers/Emory University)

Parasites

Parasites are tiny organisms that live inside another organism and can also infect the GI tract. In developed countries such as the United States, parasitic infections are relatively rare. *Cryptosporidium parvum* and *Giardia intestinalis* are parasites that are spread through water contaminated with the stools of people or animals who are infected. Foods that come into contact with contaminated water during growth or preparation can become contaminated with these parasites. Food preparers who are infected with these parasites can also contaminate foods if they do not thoroughly wash their hands after using the bathroom and before handling food. *Trichinella spiralis* is a type of roundworm parasite. People may be infected with this parasite by consuming raw or undercooked pork or wild game.

Giardiasis

Giardiasis (also known as "beaver fever") is a parasitic disease caused by *Giardia lamblia*. Once an animal or person has been infected with this protozoan, the parasite lives in the intestine, and is passed in the stool. Because the parasite is protected by an outer shell, it can survive outside the body, and in the environment for long periods of time. Cysts are resistant forms

and are responsible for transmission of giardiasis. Both cysts and trophozoites can be found in the feces (diagnostic stages). The cysts are hardy and can survive several months in cold water. Infection occurs by the ingestion of cysts in contaminated water, food, or by the fecal-oral route (hands or fomites).



This scanning electron micrograph (SEM) revealed some of the external ultrastructural details displayed by a flagellated Giardia lamblia protozoan parasite. G. lamblia is the organism responsible for causing the diarrheal disease "giardiasis". (Public Domain; CDC / Janice Haney)

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11.5: Foodborne Illness and Food Safety

Learning Objectives

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

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

Many people are affected by foodborne illness each year, making food safety a very important issue. Annually, one out of six Americans becomes sick after consuming contaminated foods or beverages.Centers for Disease Control and Prevention. "Food Safety at CDC." Last updated June 28, 2011. http://www.cdc.gov/foodsafety/facts.html. Foodborne illness can range from mild stomach upset to severe symptoms, or even fatalities. The problem of food contamination can not only be dangerous to your health, it can also be harmful to your wallet. Medical costs and lost wages due to salmonellosis, just one foodborne disease, are estimated at over $1 billion per year.

At-Risk Groups

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

The Major Types of Foodborne Illness

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

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

Food Infection

According to the CDC, more than 250 different foodborne diseases have been identified.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated June 28, 2011. http://www.cdc.gov/foodsafety/facts.html. Most are food infections, which means they are caused from food contaminated by microorganisms, such as bacteria, by microscopic animals called parasites, or by viruses. The infection then grows inside the body and becomes the source of symptoms. Food infections can be sporadic and often are not reported to physicians. However, ocassional outbreaks occur that put communities, states and provinces, or even entire nations at risk. For example, in 1994, an outbreak of the infection salmonellosis occurred in the United States due to contaminated ice cream. An estimated 224,000 people became ill. In 1988, contaminated clams resulted in an outbreak of hepatitis A in China, which affected about 300,000 people.World Health Organization. “Food Safety and Foodborne Illness.” *Fact Sheet*, no. 237. Last reviewed March 2007. www.who.int/mediacentre/factsheets/fs237/en/.

The Reproduction of Microorganisms

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

- **Temperature.** Between 40°F and 140°F, which is called the danger zone, bacteria grow rapidly.
- **Time.** More than two hours in the danger zone.
- **Water.** High moisture content is helpful. Fresh fruits and vegetables have the highest moisture content.
- **Oxygen.** Most microorganisms need oxygen to grow and multiply, but a few are anaerobic and do not.
- **Acidity and pH Level.** Foods that have a low level of acidity (or a high pH level) provide an ideal environment, since most microorganisms grow best around 7.0 pH and not many will grow below 4.0 pH. Examples of higher pH foods include meat, seafood, milk, and corn. Examples of low pH foods include citrus fruits, sauerkraut, tomatoes, and pineapples.
- **Nutrient Content.** Microorganisms need protein, starch, sugars, fats, and other compounds to grow. Typically high-protein foods are better for bacterial growth.

Food Intoxication

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

The Causes of Food Contamination

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

Bacteria

All foods naturally contain small amounts of bacteria. However, poor handling and preparation of food, along with improper cooking or storage can multiply bacteria and cause illness. In addition, bacteria can multiply quickly when cooked food is left out at room temperature for more than a few hours. Most bacteria grow undetected because they do not change the color or texture

of food or produce a bad odor. Freezing and refrigeration slow or stop the growth of bacteria, but does not destroy the bacteria completely. The microbes can reactivate when the food is taken out and thawed.

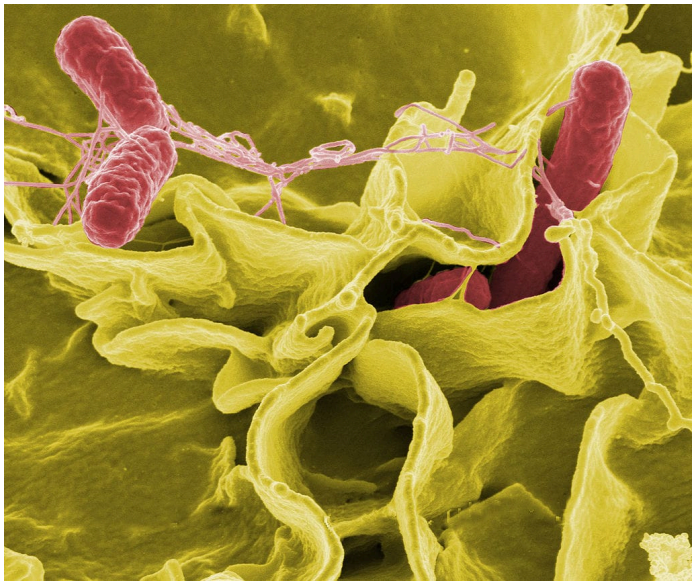


Figure 11.5.1: Salmonella was first identified in 1885 and many types of this kind of bacteria exist. The incidence of Salmonella infections has risen dramatically in the past few decades. Color-enhanced scanning electron micrograph showing Salmonella Typhimurium (red) invading cultured human cells (Credit: Rocky Mountain Laboratories, NIAID, NIH). Image is public domain.

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

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

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

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

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

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

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

Found in raw oysters and other kinds of seafood, *Vibrio vulnificus* belongs to the same family as the bacteria which cause cholera. This food contaminant can result in the *Vibrio* infection. Symptoms can begin anywhere from six hours to a few days after consumption, and include chills, fever, nausea, and vomiting. This disease is very dangerous and can result in fatalities, especially in people with underlying health problems.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated June 28, 2011. http://www.cdc.gov/foodsafety/facts.html.

Viruses

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

The most common form of contamination from handled foods is the **norovirus**, which is also known as the Norwalk-like virus, or the calicivirus. Sources include raw shellfish from polluted water, salads, sandwiches, and other ready-to-eat foods handled by an infected person. The norovirus causes gastroenteritis and within one to three days it leads to symptoms, such as nausea, vomiting, diarrhea, stomach pain, headache, and a low-grade fever.Centers for Disease Control and Prevention. “Food Safety at CDC.” Last updated June 28, 2011. http://www.cdc.gov/foodsafety/facts.html.

Parasitic Protozoa

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

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

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

The parasite *Toxoplasma gondii* causes the infection toxoplasmosis, which is a leading cause of death attributed to foodborne illness in the United States. More than sixty million Americans carry *Toxoplasma gondii*, but very few have symptoms. Typically, the body’s immune system keeps the parasite from causing disease. Sources include raw or undercooked meat and unwashed fruits and vegetables. Handling the feces of a cat with an acute infection can also lead to the disease.Centers for Disease Control and Prevention. “Parasites.” Last updated November 2, 2010. http://www.cdc.gov/parasites/food.html.

Mold Toxins

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

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



Figure 11.5.2: Mold can grow on fruits, vegetables, grains, meats, poultry, and dairy products, and typically appears as gray or green “fur.” Moldy nectarines that were in a refrigerator. The nectarine with black mold is also affecting the nectarine underneath. from Roger McLassus 1951.

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

The most dangerous mycotoxins are **aflatoxins**, which are produced by strains of fungi called *Aspergillus* under certain temperature and humidity conditions. Contamination has occurred in peanuts, tree nuts, and corn. Aflatoxins can cause aflatoxicosis in humans, livestock, and domestic animals. Symptoms include vomiting and abdominal pain. Possible complications include liver failure, liver cancer, and even death. Many countries try to limit exposure to aflatoxins by monitoring their presence on food and feed products.US Department of Agriculture, Food Safety and Inspection Service. “Molds on Food: Are They Dangerous?” Last modified March 4, 2010. www.fsis.usda.gov/FactSheets/Molds_On_Food/.

Poisonous Mushrooms

Like molds, mushrooms are fungi and the poisonous kind produces mycotoxins that can cause food intoxication. Toxic mushrooms, also known as toadstools, can cause severe vomiting and other symptoms. However, only a few varieties are fatal. Toxic mushrooms cannot be made safe by cooking, freezing, canning, or processing. The only way to avoid food intoxication is to refrain from eating them. Mushroom guides can help wild gatherers distinguish between the edible and toxic kinds.US Department of Agriculture, Food Safety and Inspection Service. “Molds on Food: Are They Dangerous?” Last modified March 4, 2010. www.fsis.usda.gov/FactSheets/Molds_On_Food/.

Pesticides

Pesticides are important in food production to control diseases, weeds, insects, and other pests. They protect crops and ensure a large yield. However, synthetic pesticides can leave behind residues, particularly on produce, that can be harmful to human health. Foods that contain the highest levels of pesticide residue include conventionally-grown peaches, apples, bell peppers, celery, nectarines, strawberries, cherries, pears, spinach, lettuce, and potatoes. Foods that contain the lowest levels of pesticide residue include avocadoes, pineapples, bananas, mangoes, asparagus, cabbage, and broccoli.Hoffman, M. MD. “Safer Foods for a Healthier You.” Web MD. © 2009 WebMD, LLC. http://www.webmd.com/health-ehome-9/pesticides-hormones-in-food. In many

cases, the amount of pesticide exposure is too small to pose a risk. However, harmful exposures can lead to certain health problems and complications, including cancer. Also, infants and young children are more susceptible to the hazards of pesticides than adults. In addition, using synthetic pesticides, herbicides, and fertilizers contributes to soil and water pollution and can be hazardous to farm workers.

To protect the public and their workers, many farmers now rely on alternatives to synthetic pesticide use, including crop rotation, natural pesticides, and planting nonfood crops nearby to lure pests away. Some consumers choose to reduce their exposure to pesticides by purchasing organic produce. Organic foods are grown or produced without synthetic pesticides or fertilizer, and all growers and processors must be certified by the US Department of Agriculture (USDA). However, conventionally-grown produce should be fine for fruits and vegetables that appear on the low-residue list.

Pollutants

Pollutants are another kind of chemical contaminant that can make food harmful. Chemical runoff from factories can pollute food products and drinking water. For example, **dioxins** are chemical compounds created in industrial processes, such as manufacturing and bleaching pulp and paper. Fish that swim in dioxin-polluted waters can contain significant amounts of this pollutant, which causes cancer. When metals contaminate food, it can result in serious and even life-threatening health problems. A common metal contaminant is lead, which can be present in drinking water, soil, and air. Lead exposure most often affects children, who can suffer from physical and mental developmental delays as a result.

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

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

Protecting the Public Health

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

Efforts on the Governmental Level

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

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

passed in 1996, requires manufacturers to show that pesticide levels are safe for children.

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

Efforts within the Food Industry

As discussed in Chapter 14 "Nutrition and Society: Food Politics and Perspectives", the Hazard Analysis Critical Control Points (HACCP) is a system within the food industry designed to promote food safety and prevent contamination by identifying all areas in food production and retail where contamination could occur. Companies and retailers determine the points during processing, packaging, shipping, or shelving where hazards could occur. Those companies or retailers must then take measures to prevent, control, or eliminate the potential for food contamination. The USDA requires the food industry to follow HACCP for meat and poultry, while the FDA requires it for seafood, low-acid canned-food, and juice. HACCP is voluntary for all other food products.

Efforts on the Consumer Level: What You Can Do

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

1. **Clean.** Wash hands thoroughly. Clean surfaces often and wash utensils after each use. Wash fruits and vegetables (even if you plan to peel them).
2. **Separate.** Don't cross-contaminate food during preparation and storage. Use separate cutting boards for produce and for meat, poultry, seafood, and eggs. Store food products separately in the refrigerator.
3. **Cook.** Heat food to proper temperatures. Use a food thermometer to check the temperature of food while it is cooking. Keep food hot after it has been cooked.
4. **Chill.** Refrigerate any leftovers within two hours. Never thaw or marinate food on the counter. Know when to keep food and when to throw it out. It can be helpful to check the website http://www.stilltasty.com, which explains how long refrigerated food remains fresh.US Department of Health and Human Services. "Keep Food Safe." Food Safety.gov. Accessed December 21, 2011. http://www.foodsafety.gov/keep/index.html.

Buying Food

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

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

Storing Food

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

Preparing Food

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

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

Cooking Food

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

Serving Food

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

Key Takeaways

Foodborne illness is caused by pathogens, such as bacteria and viruses, toxins, such as those produced by molds and poisonous mushrooms, and chemical contaminants, such as pesticide residues and pollutants. A number of government agencies work to

regulate food, manage outbreaks, and inform the public about foodborne illness and food safety. Consumers also should take measures to protect their health, including following the rules for four key steps: clean, separate, cook, and chill.

Discussion Starter

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

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11.6: Food Preservation

Food preservation involves preventing the growth of bacteria, fungi (such as yeasts), or other micro-organisms (although some methods work by introducing benign bacteria or fungi to the food), as well as slowing the oxidation of fats that cause rancidity. Food preservation may also include processes that inhibit visual deterioration, such as the enzymatic browning reaction in apples after they are cut during food preparation.

Many processes designed to preserve food will involve a number of food preservation methods. Preserving fruit by turning it into jam, for example, involves boiling (to reduce the fruit's moisture content and to kill bacteria, etc.), sugaring (to prevent their re-growth) and sealing within an airtight jar (to prevent recontamination). Some traditional methods of preserving food have been shown to have a lower energy input and carbon footprint, when compared to modern methods.

Maintaining or creating nutritional value, texture and flavor is an important aspect of food preservation, although, historically, some methods drastically altered the character of the food being preserved. In many cases these changes have come to be seen as desirable qualities – cheese, yogurt and pickled onions being common examples.

Traditional techniques

New techniques of food preservation became available to the home chef from the dawn of agriculture until the Industrial Revolution.

Drying

Drying is one of the oldest techniques used to hamper the decomposition of food products. As early as 12,000 B.C., Middle Eastern and Oriental cultures were drying foods using the power of the sun. Vegetables and fruits are naturally dried by the sun and wind, but "still houses" were built in areas that did not have enough sunlight to dry things. A fire would be built inside the building to provide the heat to dry the various fruits, vegetables, and herbs.

Cooling

Cooling preserves food by slowing down the growth and reproduction of micro-organisms and the action of enzymes that cause food to rot. The introduction of commercial and domestic refrigerators drastically improved the diets of many in the Western world by allowing foods such as fresh fruit, salads and dairy products to be stored safely for longer periods, particularly during warm weather.

Freezing

Freezing is also one of the most commonly used processes, both commercially and domestically, for preserving a very wide range of foods, including prepared foods that would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large-volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

Boiling

Boiling liquid food items can kill any existing microbes. Milk and water are often boiled to kill any harmful microbes that may be present in them.

Heating

Heating to temperatures which are sufficient to kill microorganisms inside the food is a method used with perpetual stews. Milk is also boiled before storing to kill many microorganisms.

Salting

Bag of Prague powder #1, also known as "curing salt" or "pink salt". It is typically a combination of salt and sodium nitrite, with the pink color added to distinguish it from ordinary salt. Salting or curing draws moisture from a substance through a process of osmosis. substances are cured with salt or sugar, or a combination of the two. Nitrates and nitrites are also often used to cure meat and contribute the characteristic pink colour. It was a main method of preservation in medieval times and around the 1700s.

Sugaring

The earliest cultures have used sugar as a preservative, and it was commonplace to store fruit in honey. Similar to pickled foods, sugar cane was brought to Europe through the trade routes. In northern climates without sufficient sun to dry foods, preserves are made by heating the fruit with sugar. "Sugar tends to draw water from the microbes (plasmolysis). This process leaves the microbial cells dehydrated, thus killing them. In this way, the food will remain safe from microbial spoilage."Sugar is used to preserve fruits, either in an anti-microbial syrup with fruit such as apples, pears, peaches, apricots and plums, or in crystallized form where the preserved material is cooked in sugar to the point of crystallization and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica and ginger. Also sugaring can be used in jam jellies.

Smoking

Smoking is used to lengthen the shelf life of perishable food items. This effect is achieved by exposing the food to smoke from burning plant materials such as wood. Smoke deposits a number of pyrolysis products onto the food, including the phenols syringol, guaiacol and catechol. These compounds aid in the drying and preservation of meats and other foods. Most commonly subjected to this method of food preservation are meats and fish that have undergone curing. Fruits and vegetables like paprika, cheeses, spices, and ingredients for making drinks such as malt and tealeaves are also smoked, but mainly for cooking or flavoring them. It is one of the oldest food preservation methods, which probably arose after the development of cooking with fire.

Pickling

Pickling is a method of preserving food in an edible anti-microbial liquid. Pickling can be broadly classified into two categories: chemical pickling and fermentation pickling. In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other micro-organisms. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil, especially olive oil but also many other oils. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, corned beef, herring, and eggs, as well as mixed vegetables such as piccalilli.

In fermentation pickling, the food itself produces the preservation agent, typically by a process that produces lactic acid. Fermented pickles include sauerkraut, nukazuke, kimchi, surströmming,

Lye

Sodium hydroxide (lye) makes food too alkaline for bacterial growth. Lye will saponify fats in the food, which will change its flavor and texture. Lutefisk uses lye in its preparation, as do some olive recipes. Modern recipes for century eggs also call for lye.

Canning

Canning involves cooking food, sealing it in sterile cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. It was invented by the French confectioner Nicolas Appert. By 1806, this process was used by the French Navy to preserve meat, fruit, vegetables, and even milk. Although Appert had discovered a new way of preservation, it wasn't understood until 1864 when Louis Pasteur found the relationship between microorganisms, food spoilage, and illness.

Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives to can and only a short boiling cycle, whereas marginal vegetables such as carrots require longer boiling and addition of other acidic elements. Low-acid foods, such as vegetables and meats, require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.



Figure 11.6.1***:*** *Preserved food. Unidentified stacks of home-canned food. (public domain).*

Lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (underprocessing) and poor hygiene allowing contamination of canned food by the obligate anaerobe Clostridium botulinum, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, however. Cooked mushrooms, handled poorly and then canned, can support the growth of *Staphylococcus aureus*, which produces a toxin that is not destroyed by canning or subsequent reheating.

Jellying

Food may be preserved by cooking in a material that solidifies to form a gel. Such materials include gelatin, agar, maize flour, and arrowrootflour. Some foods naturally form a protein gel when cooked, such as eels and elvers, and sipunculid worms, which are a delicacy in Xiamen, in the Fujian province of the People's Republic of China. Jellied eels are a delicacy in the East End of London, where they are eaten with mashed potatoes. Potted meats in aspic (a gel made from gelatine and clarified meat broth) were a common way of serving meat off-cuts in the UK until the 1950s. Many jugged meats are also jellied.

Jugging

Meat can be preserved by jugging. Jugging is the process of stewing the meat (commonly game or fish) in a covered earthenware jug or casserole. The animal to be jugged is usually cut into pieces, placed into a tightly-sealed jug with brine or gravy, and stewed. Red wineand/or the animal's own blood is sometimes added to the cooking liquid. Jugging was a popular method of preserving meat up until the middle of the 20th century.

Burial

Burial of food can preserve it due to a variety of factors: lack of light, lack of oxygen, cool temperatures, pH level, or desiccants in the soil. Burial may be combined with other methods such as salting or fermentation. Most foods can be preserved in soil that is very dry and salty (thus a desiccant) such as sand, or soil that is frozen. Many root vegetables are very resistant to spoilage and require no other preservation than storage in cool dark conditions, for example by burial in the ground, such as in a storage clamp. Century eggs are created by placing eggs in alkaline mud (or other alkaline substance), resulting in their "inorganic" fermentation through raised pH instead of spoiling. The fermentation preserves them and breaks down some of the complex, less flavorful proteins and fats into simpler, more flavorful ones. Cabbage was traditionally buried in the fall in northern farms in the U.S. for preservation. Some methods keep it crispy while other methods produce sauerkraut. A similar process is used in the traditional production of kimchi. Sometimes meat is buried under conditions that cause preservation. If buried on hot coals or ashes, the

heat can kill pathogens, the dry ash can desiccate, and the earth can block oxygen and further contamination. If buried where the earth is very cold, the earth acts like a refrigerator.

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11.7: Preparing for Disasters

Follow these steps to make sure you and your family have enough safe food and water (for drinking, cooking, bathing, etc.) available in the event of a disaster or emergency.

Prepare an Emergency Food Supply

Keep foods that:

- Have a long storage life
- Require little or no cooking, water, or refrigeration, in case utilities are disrupted
- Meet the needs of babies or other family members who are on special diets
- Meet pets' needs
- Are not very salty or spicy, as these foods increase the need for drinking water, which may be in short supply

How To Store Emergency Food

- A disaster can easily disrupt the food supply at any time, so plan to have at least a 3-day supply of food on hand.
- When storing food, it is not necessary to buy dehydrated or other types of emergency food. Canned foods and dry mixes will remain fresh for about 2 years.
- Certain storage conditions can enhance the shelf life of canned or dried foods. The ideal location is a cool, dry, dark place. The best temperature is 40 to 60°F. Keep foods away from ranges or refrigerator exhausts. Heat causes many foods to spoil more quickly.
- Keep food away from petroleum products, such as gasoline, oil, paints, and solvents. Some food products absorb their smell.
- Protect food from rodents and insects. Items stored in boxes or in paper cartons will keep longer if they are heavily wrapped or stored in airtight containers.
- Date all food items. Use and replace food before it loses freshness.

Preparing Food

Preparing food after a disaster or emergency may be difficult due to damage to your home and loss of electricity, gas, and water. Having the following items available will help you to prepare meals safely:

- Cooking utensils
- Knives, forks, and spoons
- Paper plates, cups, and towels
- A manual can- and bottle-opener
- Heavy-duty aluminum foil
- Gas or charcoal grill; camp stove
- Fuel for cooking, such as charcoal. (*CAUTION:* Never burn charcoal indoors. The fumes are deadly when concentrated indoors.)

Prepare an Emergency Water Supply

- Store at least 1 gallon of water per day for each person and each pet. You should consider storing more water than this for hot climates, for pregnant women, and for persons who are sick.
- Store at least a 3-day supply of water for each person and each pet (try to store a 2-week supply if possible).
- Observe the expiration date for store-bought water; replace other stored water every six months.
- Store a bottle of unscented liquid household chlorine bleach to disinfect your water and to use for general cleaning and sanitizing.

Note: Caffeinated drinks and alcohol dehydrate the body, which increases the need for drinking water.

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11.8: Food Additives

Food additives are substances added to food to preserve flavor or enhance its taste and/or appearance. Some additives have been used for centuries; for example, preserving food by pickling (with vinegar), salting, as with bacon, preserving sweets or using sulfur dioxide as with wines. With the advent of processed foods in the second half of the twentieth century, many more additives have been introduced, of both natural and artificial origin. Please take a look at two of the most common additives, coloring agents and preservatives using the Wikipedia links below. When you see these items listed in the "ingredients" section of a food label, will you be able to recognize them? What are they made from? Are they safe to eat in small amounts? Are they safe to eat in large amounts?

Food Colorings

Food coloring, or color additive, is any dye, pigment or substance that imparts color when it is added to food or drink. They come in many forms consisting of liquids, powders, gels, and pastes. Food coloring is used both in commercial food production and in domestic cooking. Food colorants are also used in a variety of non-food applications including cosmetics, pharmaceuticals, home craft projects, and medical devices. Color additives are used in foods for many reasons including:

- To make food more attractive, appealing, appetizing, and informative
- Offset color loss due to exposure to light, air, temperature extremes, moisture and storage conditions
- Correct natural variations in color
- Enhance colors that occur naturally
- Provide color to colorless and "fun" foods
- Allow consumers to identify products on sight, like candy flavors or medicine dosages

In the 20th century, the improvement of chemical analysis and the development of trials to identify the toxic features of substances added to foods led to the replacement of the negative lists by lists of substances allowed to be used for the production and the improvement of foods. This principle is called a positive listing, and almost all recent legislations are based on it. Positive listing implies that substances meant for human consumption have been tested for their safety, and that they have to meet specified purity criteria prior to their approval by the corresponding authorities.

Food Preservatives

A preservative is a substance or a chemical that is added to products such as food, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes. In general, preservation is implemented in two modes, chemical and physical. Chemical preservation entails adding chemical compounds to the product. Physical preservation entails processes such as refrigeration or drying. Preservative food additives reduce the risk of foodborne infections, decrease microbial spoilage, and preserve fresh attributes and nutritional quality. Some physical techniques for food preservation include dehydration, UV-C radiation, freeze-drying, and refrigeration. Chemical preservation and physical preservation techniques are sometimes combined.

Antimicrobial preservatives prevent degradation by bacteria. This method is the most traditional and ancient type of preserving—ancient methods such as pickling and adding honey prevent microorganism growth by modifying the pH level. The most commonly used antimicrobial preservative is lactic acid. Common antimicrobial preservatives are presented in the table. Nitrates and nitrites are also antimicrobial. The detailed mechanism of these chemical compounds range from inhibiting growth of the bacteria to the inhibition of specific enzymes.

11.8.1: *Antimicrobial Preservatives*

Compound	Comment
sorbic acid, sodium sorbate and sorbates	common for cheese, wine, baked goods
benzoic acid, sodium benzoate and benzoates	used in acidic foods such as jams, salad dressing, juices, pickles, carbonated drinks, soy sauce
hydroxybenzoate and derivatives	stable at a broad pH range
sulfur dioxide and sulfites	common for fruits
nitrite	used in meats to prevent botulism toxin
nitrate	used in meats
lactic acid	-
propionic acid and sodium propionate	baked goods

The oxidation process spoils most food, especially those with a high fat content. Fats quickly turn rancid when exposed to oxygen. Antioxidants prevent or inhibit the oxidation process. The most common antioxidant additives are ascorbic acid (vitamin C) and ascorbates. Thus, antioxidants are commonly added to oils, cheese, and chips. Other antioxidants include the phenol derivatives. These agents suppress the formation of hydroperoxides. Other preservatives include ethanol and methylchloroisothiazolinone.

11.8.2: *Antioxidant Preservatives*

Compound	Comment
ascorbic acid, sodium ascorbate	cheese, chips
butylated hydroxytoluene, butylated hydroxyanisole	also used in food packaging
gallic acid and sodium gallate	oxygen scavenger
sulfur dioxide and sulfites	beverages, wine
tocopherols	vitamin E activity

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11.9: Start Your Sustainable Future Today

Learning Objectives

- Discuss forms of activism in areas of food and nutrition.
- List steps individuals can take to support sustainable agriculture.

As we near the end of our journey in the world of health and nutrition, let's address how to adjust your lifestyle today to ensure better health and wellness tomorrow. Adopting sustainable practices can go a long way toward helping you achieve optimal health, while also helping to protect the health of our planet. Remember, that sustainability involves meeting present nutritional needs while preserving resources for the future. It includes agricultural practices and processes, along with the choices that consumers make when they shop for their food. Ideally, sustainable practices include methods that are healthy, conserve the environment, protect livestock, respect food industry workers, provide fair wages to farmers, and support farming communities. When a practice or a process is sustainable, it can be maintained for decades, or even centuries, to come.

Living a Sustainable Lifestyle

There are a number of steps you can take to live a more sustainable lifestyle. Utilizing an environmentally-friendly approach to good nutrition is a great way to remain and stay healthy. As an initial step, you might try to buy more whole foods rather than processed foods. You might also drink more water, rather than sodas and juices with added sugar. It is also a good idea to drink from a reusable water bottle to avoid adding more plastic to your local landfill, not to mention saving the fuel it takes to ship bottles of water. Here are some other suggestions to live a more sustainable lifestyle:

- **Learn more about food.** Learn about your local food system, what is native to the area, what is imported or shipped in, how food moves from farms to processors to retail in your area, and what practices are used. Read labels to see where food comes from and what the growing and processing practices are. You might also try taking a cooking class to learn more about food in general.
- **Eat a plant-based diet.** A plant-based diet is not necessarily vegetarian or vegan; it simply emphasizes whole grains, fruits, vegetables, and legumes over meat and poultry. Plant-based foods are good sources of carbohydrates, protein, fat, vitamins, and minerals. They also help to decrease your risk for cancer and other chronic conditions.
- **Support local farmers.** Purchase more locally grown food to promote sustainability. This could involve going to a farmer's market or a nearby farm. Locally grown food requires less fossil fuel because it does not have to travel great distances. Locally grown food also puts money back into your community and helps farmers in your area. Shopping at a farmer's market or a local farm may also provide an opportunity to talk to the farmer who grew the food to learn more about what you put on your plate.
- **Join a community garden.** You can't get more local than food that is grown in your own backyard. Consider growing your own food, or trying a community garden if you do not have the space at your home. Produce from a local garden will not only be fresher, it will often taste better. In addition, it will provide an opportunity to get to know like-minded individuals in your community.
- **Help spread the word.** Talk to friends and family members about food, nutrition, and living a sustainable lifestyle. Also, pay attention to food and nutrition policy at the federal, state, and local levels. Take a look at what foods are available in your community. Are there supermarkets or corner stores? What is available in the university dining hall? If healthy options are lacking, can you talk to someone to bring about changes?

Tools for Change

Another option to support local farmers is to sign up for a CSA (community-supported agriculture). Prior to a planting season, consumers who join a CSA purchase a produce share from a local farmer. When harvesting begins, farmers provide in-season, locally grown vegetables to shareholders at a local drop spot each week throughout the growing season. Some CSAs also include fruit, dairy products, meat, and more. CSA farmers often will allow you to visit the farm to learn more about the crops they grow or even volunteer to help with the harvest. Joining a CSA provides a direct connection between the local farming community and you.

Changing Your Behavior

Living a sustainable lifestyle and achieving optimal health is not easy. Taking steps to exercise more, eat healthier foods, and work harder to avoid food contamination may involve making major changes in your life. However, change is a process, and researchers have long studied the various stages of that process, as well as what helps or hinders it. While creating and implementing change is not easy, the more conscious you are of the process, and the more you prepare, the greater the chances are for success. Learning about the different stages of behavioral change can help you take a proactive approach to living a sustainable lifestyle.

The Transtheoretical Model of Behavioral Change

The Transtheoretical Model of Behavioral Change identifies the five stages of change, along with things that can help people move through these different stages. It also includes strategies which help people make, create, and continue behavioral change. Learning about these different stages and techniques helps you decide how to best approach making healthy changes in your life.

The five stages of the Transtheoretical Model of Behavioral Change are (Figure 11.9.1):

1. **Precontemplation.** At this stage, an individual has no plans to make any changes, and may not be aware that change is needed. For example, a person who has never thought of eating healthier or being more active is in the precontemplation stage. In this stage, a person often underestimates the pros of changing, and underestimates the cons of maintaining the status quo.
2. **Contemplation.** An individual begins to see the importance of altering behavior, and plans to do so within the next six months. Someone who has realized that they need to add more physical activity to their life, but hasn't made any concrete plans to start doing it, is in the contemplation stage. Although they may be more aware of the benefits of change, the individual may still exaggerate the negative aspects of change.
3. **Preparation.** At this stage, an individual becomes serious about making a change, and plans to implement that change within thirty days. The person may have already started to alter behavior, or told friends about any plans or intentions. For example, someone who wants to eat better and has started gathering healthier recipes is in the preparation stage.
4. **Action.** At this point, an individual is in the midst of change or has made a consistent change in behavior within the past six months. For example, someone in the action stage would have started eating better and exercising on a regular basis.
5. **Maintenance.** At this final stage, an individual has successfully changed their behavior for six months or more and intends to maintain it in the future.



Figure 11.9.1: This is a graphic representation of the "Stages of Change" in the Transtheoretical Model of Behavior Change. from Philciaccio (via Wikipedia).

Adopting a healthier lifestyle requires changes not only in behavior, but also in attitude and perception. The Transtheoretical Model calls them *decisional balance* and *self-efficacy*. Decisional balance means a person has realized that the benefits of making healthy changes outweigh any risks. Self-efficacy means a person has self-belief and the confidence to make and maintain positive changes. Both decisional balance and self-efficacy help people progress through the different stages of change. The Theoretical Model of Behavioral Change also includes ten techniques and strategies for bringing about change:

1. **Consciousness-raising.** Different methods that are used to raise awareness of healthier choices.
2. **Dramatic Relief.** The use of emotions through testimonials, role-playing, and the media to support change.
3. **Environmental Reevaluation.** Helping people become aware of how they affect others, and how a change on their part can

also help those around them.
4. **Social Liberation.** Helping individuals realize that society may be more welcoming if they change their behavior.
5. **Self-Liberation.** Allowing people to believe in their ability to change, and make a commitment to it.
6. **Helping Relationships.** Providing connections between people seeking positive change with others who support their efforts.
7. **Counterconditioning.** Finding healthier substitutes for the unhealthy behavior.
8. **Reinforcement Management.** Increasing rewards for healthy behavior and reducing those for negative behavior.
9. **Stimulus Control.** Being aware of and eliminating cues for unhealthy behavior, and replacing them with cues for healthy choices.
10. **Self-reevaluation.** Changing your self-image to fit with a newer, healthier lifestyle.

Prochaska and colleagues state that their research related to the transtheoretical model shows that interventions to change behavior are more effective if they are "stage-matched," that is, "matched to each individual's stage of change (Figure 11.9.2).

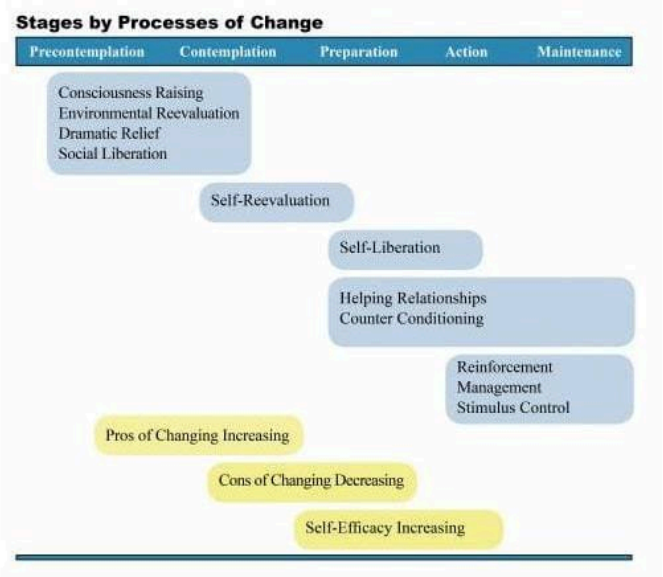


Figure 11.9.2: Processes of Change. from Wikipedia

Some of these processes of change are more effective at different points in the process. A person who is not even contemplating change could tune out emotional appeals or reinforcement management. However, combining knowledge of the change process with the effective use of strategies can help everyone turn their good intentions into healthier lifestyles.Center for Health Communications Research. “Transtheoretical Model (Stages of Change).” © 2009 The Regents of University of Michigan. Accessed December 21, 2011. chcr.umich.edu/how_we_do_it/h..._document_view.

Key Takeaways

Living a sustainable lifestyle can help you to work toward achieving optimal health. There are a number of steps you can take to promote sustainable practices, such as buying locally grown food, eating a plant-based diet, and becoming aware of food and nutrition issues in your community. The Transtheoretical Model of Behavioral Change outlines the different stages of the process of change, and provides tools and techniques to enable major changes.

Discussion Starter

1. Think of a change you might want to make in your life to become healthier, and discuss ways you can use the transtheoretical model to make this change.

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11.10: Genetically Modified Foods (GMO's)

In this section we will explore the topic of Genetically Modified Organisms (GMO's) and specifically the genetic modification of plants and animals for food.

Please watch the video "NOVA Frontline: Harvest of Fear"

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INDEX

A

anaerobic exercise
10.3: Anaerobic Exercise

ascorbic acid
7.3I: Vitamin C (Ascorbic acid)

B

biotin
7.3F: Vitamin B_7 (Biotin)

C

carbohydrates
4: Carbohydrates

chloride
8.6G: Chloride

cholesterol
5.5: Understanding Blood Cholesterol and Heart Attack Risk

clotting
7.2D: Vitamin K

cobalamin
7.3H: Vitamin B_{12} (Cobalamin)

D

dietary reference intakes
2.9: The Dietary Reference Intakes - How much of a Nutrient should we Consume?

F

fluoride
8.7I: Fluoride

folic acid
7.3G: Vitamin B_9 (Folic acid)

G

goiter
8.7E: Iodine

H

heart attack
5.5: Understanding Blood Cholesterol and Heart Attack Risk

I

iodine
8.7E: Iodine

iron
8.7B: Iron

M

Molybdenum
8.7H: Molybdenum

N

niacin
7.3C: Vitamin B_3 (Niacin)

P

phosphorus
8.6C: Phosphorus

S

selenium
8.7J: Selenium

sodium
8.6F: Sodium

steroids
10.4: Fitness Supplements and Steroids

sulfur
8.6D: Sulfur

T

thiamine
7.3A: Vitamin B_1 (Thiamine)

V

vitamin A
7.2A: Vitamin A

vitamin E
7.2C: Vitamin E

vitamin K
7.2D: Vitamin K

vitamins
7: Vitamins

Z

zinc
8.7D: Zinc

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GLOSSARY

A

Acceptable Macronutrient Distribution Range (AMDR) | The value of the energy-yielding nutrients carbohydrates, protein, and fat, expressed as percentages of total daily calorie intake, sufficient to provide total adequate energy needs; staying within the AMDR is associated with reducing the risks for developing chronic disease.

Acidic amino acids | Hydrophilic amino acids that are negatively charged.

added sugars | Sugars and other sweeteners (such as high-fructose corn syrup, honey, maple syrup, and molasses), that are added to food at the table, and are also ingredients in food products.

adequate | A dietary term signifying a diet that provides all nutrients, fiber, and energy in amounts sufficient to maintaining good health and body weight.

Adequate Intakes (AI) | If scientific data is insufficient to establish an EAR value, an AI is established based on the scientific data that is available. As with the RDA, the AI serves a nutrient-intake goal.

adipose tissue | Fatty tissue in the body that consists of masses of fat-storing cells.

adolescence | The period of the human life cycle between ages fourteen to eighteen, nutritionally speaking.

Age-related macular degeneration (AMD) | The progressive loss of central vision resulting from damage to the center of the retina, referred to as the macula.

albumin | A butterfly-shaped protein that plays a role in fluid balance, acid-base balance, and the transport of biological molecules.

Alcoholic Liver Disease (ALD) | Liver problems linked to excessive alcohol intake including fatty liver, alcoholic hepatitis, and cirrhosis.

Alcohols | In chemistry, alcohols refer to a group of similar organic compounds, but in beverages the only alcohol consumed is ethanol.

Amino acids | Simple monomers composed of the elements carbon, oxygen, hydrogen, and nitrogen.

amphiphilic | A compound that has both water-loving and fat-loving properties.

anabolism | All metabolic processes involved in building bigger molecules, which consume energy.

Anaphylaxis | A life-threatening, extreme immune response to a food allergen. Anaphylaxis can result in difficulty breathing, swelling in the mouth and throat, decreased blood pressure, shock, and death.

Anorexia nervosa | A psychiatric illness in which a person obssesses over their weight and the food that they eat. Anorexia results in extreme nutrient inadequacy and, eventually, organ malfunction.

Anorexia nervosa | A psychiatric illness in which a person obssesses over their weight and the food that they eat. Anorexia results in extreme nutrient inadequacy and, eventually, organ malfunction.

anorexia of aging | A condition that affects the elderly and is characterized by poor food intake.

antibodies | A protein that protects against unwanted intruders.

antioxidant | Any molecule that can block free radicals from stealing electrons.

arachidonic acid (ARA) | An omega-6 essential fatty acid that is a precursor to the synthesis of eicosanoids.

atherosclerosis | Disease that is characterized by the deposition of plaques and fatty material in the walls of the body's artery, vein and blood vessel network.

atoms | The basic building blocks of all matter, living and nonliving.

B

balanced diet | A balanced diet supplies various types of foods in proportion to one another. With balance, foods rich in one nutrient leave room for foods that are rich in other nutrients.

basal metabolism | Metabolic pathways necessary to support and maintain the basic functions of the body (e.g. breathing, heartbeat, liver, and kidney function) while at rest.

Basic amino acids | Hydrophilic amino acids that are positively charged.

bile | A substance secreted by the liver that aids in the absorption and digestion of fats.

binge-eating disorder | A nonpsychiatric disorder characterized by periodic losses of control over eating. The periods of excessive overeating are not followed by fasting or purging. People who have this disorder are often overweight or obese.

biomarker | A measurable molecule or trait that is connected with a specific disease or health condition.

blood alcohol concentration (BAC) | A measurement of the level of alcohol in the blood stream, in terms of percentages; used to determine if an individual is legally intoxicated and driving while impaired.

Body mass index (BMI) | A measurement that associates height and weight, and is a more comprehensive measurement of body fatness than weight alone.

bone remodeling | Process in which bone tissue is broken down and then rebuilt at the same location.

bone resorption | Process in which osteoclasts secrete hydrogen ions, which acidify the local environment and dissolve the minerals in the bone tissue matrix.

Bulimia | A psychiatric illness characterized by frequent episodes of eating large amounts of food followed by purging.

C

Caffeine | 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.

calcitonin | This hormone has the opposite effect of calcitriol and parathyroid hormone and aids in the maintenance of blood calcium levels by decreasing the calcium level as necessary.

calcium | The most abundant mineral in mineralized bone tissue. Good dietary sources of calcium are dairy products and many vegetables with low oxalate content, such as kale, collard greens, and okra.

calorie | A unit of energy; equivalent to the amount of energy required to heat 1 gram of water 1 degree Celsius.

Calorie control | Controlling energy intake so that energy requirements are being met but not exceeded.

Carbohydrates | Organic molecules composed of carbon, hydrogen, and oxygen. There are two basic forms: simple sugars and complex sugars.

cardiorespiratory endurance | The cardiovascular system's ability to deliver oxygen and nutrients efficiently to fuel physical activity.

cardiovascular disease | A disease of the heart or blood vessels.

Celiac disease | An autoimmune disorder caused by an abnormal reaction of cells in the small intestine to a type of protein, called gluten.

cell theory | Cells are the most basic building units of life, all living things are composed of cells, and new cells are made from preexisting cells, which divide into two.

cellular respiration | The process by which the stored chemical energy in nutrients is transformed into cellular energy.

central nervous system | Neurons form the core of the central nervous system, which consists of the brain, spinal cord, and other nerve bundles. The main function of the central nervous system is to sense changes in the external environment and create a reaction to them.

chemical energy | Potential energy in chemical bonds.

chylomicron | Chylomicron clusters form when lipids are combined with carrier proteins in the cells of the intestinal lining. Chylomicron is a vehicle of transport for fats throughout the watery environment of the body to the liver and other tissues.

Chyme | A semiliquid mass of partially digested food that also contains gastric juices.

circulatory system | Comprised of the heart, blood, and blood vessels. Its main functions are to transport nutrients to all cells and transport wastes from all cells.

cis fatty acid | A fatty acid with the hydrogen atoms bonded to the same side of the carbon chain.

cofactors | Minerals that make up part of enzymes required for converting a substrate to an end-product.

collagen | A strong, fibrous protein made up of mostly glycine and proline amino acids.

complementary foods | A combination of foods that when consumed together (though not necessarily at the same time) contain all nine essential amino acids at adequate levels.

complete protein sources | Foods that contain all nine of the essential amino acids.

Concentration | The amount of particles in a set volume of water.

conditionally essential amino acids | Amino acids that become essential during certain times in life, such as child growth.

conditionally essential nutrients | Nutrients that are supplied only under special conditions or circumstances, such as pregnancy, stress, illness, or aging.

cortical bone | Dense, strong bone that surrounds trabecular bone tissue. Also called compact bone.

D

Dehydration | Water loss from the body without adequate replacement.

Dementia | A disorder of the nervous system characterized by changes in the normal activity of the brain.

Dementia | A disorder of the nervous system characterized by changes in the normal activity of the brain.

Denaturation | The physical changes that take place in a protein when it is exposed to abnormal conditions in the environment.

determinants of health approach | These are the conditions reflective of the circumstances in which people are born, live, work, and age. It assesses the conditions that shape circumstances such as money, power, and resources at the local, national and global levels.

determinants of health approach | These are the conditions reflective of the circumstances in which people are born, live, work, and age. It assesses the conditions that shape circumstances such as money, power, and resources at the local, national and global levels.

Dietary fibers | Polysaccharides that are highly branched and cross-linked and only found in plant-based foods, with the exception of chitin (which forms the exoskeletons of some animals).

Dietary fibers | Polysaccharides that are highly branched and cross-linked and only found in plant-based foods, with the exception of chitin (which forms the exoskeletons of some animals).

Dietary Reference Intakes (DRI) | A set of nutrient recommendations that includes the Estimated Average Requirements (EAR), Recommended Dietary Allowances (RDA), Adequate Intakes (AI), Tolerable Upper Intake Levels (UL) and Acceptable Macronutrient Distribution Range (AMDR).

diglycerides | A product of lipid digestion, consisting of a glycerol molecule that has two fatty acids attached.

Disaccharides | Two monosaccharides joined together.

Disease | Any abnormal condition that affects the health of an organism and is characterized by specific signs and symptoms.

Diverticulitis | A condition that occurs when the out-pocketings in the lining of the colon become inflamed. Symptoms include lower abdominal pain, nausea, and alternating between constipation and diarrhea.

docosahexaenoic acid (DHA) | An omega-3 fatty acid that is especially important for brain growth and development in infants.

dual energy X-ray absorptiometry (DEXA) | A procedure during which two X-ray beams pass through a person and calculate the amount of calcified tissue in grams per unit area of bone.

E

early childhood caries | A dental disorder characterized by decay within the primary teeth.

eating disorder | A behavioral condition that involves extreme attitudes and behaviors toward food and nutrition. These disorders are characterized by overeating or undereating, and include anorexia nervosa, binge-eating disorder, and bulimia nervosa.

eating disorder | A behavioral condition that involves extreme attitudes and behaviors toward food and nutrition. These disorders are characterized by overeating or undereating, and include anorexia nervosa, binge-eating disorder, and bulimia nervosa.

eicosanoids | Compounds derived from polyunsaturated fatty acids that control several body functions.

eicosapentaenoic acid (EPA) | An omega-3 fatty acid made from linolenic acid, found in fish.

embolism | Blood vessel obstruction caused by a mass, such as a detached blood clot or other foreign body, that circulates in the bloodstream.

emulsifiers | Compound that allow two immiscible liquids to combine so that no separation occurs.

Energy | The quantity of work a particular system can perform.

Energy | The quantity of work a particular system can perform.

energy balance | When energy intake is equal to energy expended.

energy drinks | Beverages containing extremely high levels of caffeine, which can augment the effects of the drug.

Energy metabolism | The metabolic pathways that release or store energy.

Enzymes | Proteins that conduct a specific chemical reaction in order to transform substrates into a product.

Epidemiological studies | Scientific investigations that define frequency, distribution, and patterns of health events in a population.

Epigenetics | A rapidly advancing scientific field, in which researchers study how non-gene factors affect gene expression.

Epigenetics | A rapidly advancing scientific field, in which researchers study how non-gene factors affect gene expression.

essential fatty acids | A fatty acid that the body cannot synthesize and must be supplied through the diet.

essential fatty acids | A fatty acid that the body cannot synthesize and must be supplied through the diet.

Estimated Average Requirements (EAR) | Average daily intake levels for nutrients estimated to meet the needs of 50 percent of the target group. Used in nutrition research and policy-making. EARs form the basis for which RDA values are set.

Estimated Energy Requirement (EER) | Energy intake values that have been established to preserve energy balance in healthy adults of a specific age, gender, weight, and height, and category of physical activity concurrent with good health.

Estrogen | Primary female reproductive hormone.

extrusion reflex | An involuntary reflex that causes infants to push food out of their mouths with their tongues.

F

failure-to-thrive (FTT) | A condition that is characterized by inadequate growth or weight gain due to any cause.

Fatty acids | An organic compound that contains a carboxylic acid (–COOH) group at one end and a methyl group at the other ($–CH_3$).

fermentable sugars | Sugars such as glucose, fructose, and maltose that are easily metabolized by bacteria in a process known as fermentation.

Flexibility | Capability of joints to move in a whole, wide range of motion.

Fluoride | A mineral that blocks tooth decay and is part of mineralized bone tissue. The primary dietary source is fluoridated water.

food additives | Natural or man-made substance added to a food product during the processing stage to improve its quality.

food allergy | After eating certain kinds of food, the immune system reacts shortly thereafter producing symptoms such as digestive troubles, swollen airways, hives, or possible death.

food allergy | After eating certain kinds of food, the immune system reacts shortly thereafter producing symptoms such as digestive troubles, swollen airways, hives, or possible death.

food desert | A location that does not provide access to affordable nutritious food.

food infections | Foodborne illness caused by bacteria, viruses, or parasites.

food infections | Foodborne illness caused by bacteria, viruses, or parasites.

food insecurity | The state of not having continual access to sufficient, safe, and nutritious food to achieve an active, healthy lifestyle.

food intoxications | Foodborne illness caused by natural toxins or harmful chemicals.

food intoxications | Foodborne illness caused by natural toxins or harmful chemicals.

food jag | A behavior exhibited by a young child who insists upon eating the same foods over and over again.

Food security | A state in which all persons in a community's population obtain a nutritionally adequate diet that is culturally acceptable throughout the year that is not dependent on emergency aid sources, but more so from local production.

Food security | A state in which all persons in a community's population obtain a nutritionally adequate diet that is culturally acceptable throughout the year that is not dependent on emergency aid sources, but more so from local production.

functional foods | Foods which do more than meet basic nutritional needs and could provide additional health benefits.

functional foods | Foods which do more than meet basic nutritional needs and could provide additional health benefits.

G

gastroesophageal reflux | A disorder that occurs when stomach acid rises into the esophagus. In infancy, it is characterized by coughing, choking, or vomiting after feeding.

Gastroesophageal reflux disease (GERD) | A persistant form of acid reflux, in which acidic contents of the stomach leak backward into the esophagus and cause irritation.

Genetically modified foods | Food products made from animals or plants that have undergone genetic engineering.

genome | Entire genetic information contained in an individual which is inherited from their parents.

gestational diabetes | A metabolic condition similar to Type 2 diabetes that occurs in some pregnant women.

Gestational hypertension | A possible complication of pregnancy characterized by raised blood pressure levels.

glycemic index (GI) | A measurement of the effects of carbohydrate-containing foods on blood-glucose levels.

glycogen | A highly branched macromolecule consisting of thousands of glucose monomers held together by chemical bonds.

glycogen | A highly branched macromolecule consisting of thousands of glucose monomers held together by chemical bonds.

Glycolysis | The first stage of glucose breakdown; a ten-step enzymatic process that splits glucose into two three-carbon molecules and yields two molecules of ATP.

H

HDLs | High-density lipoproteins are also known as "good cholesterol." It contains the maximum percentage of protein and a lower percentage of cholesterol and collects and transports excess cholesterol, returning it to the liver for reuse or excretion.

Healthy Eating Index (HEI) | A standardized tool based on a simple scoring system of dietary components used to assess whether the diets of Americans are improving and adhering to the dietary guidelines.

heat capacity | The capability of a substance to store heat.

hormones | Biological molecules transported in the blood that regulate cellular processes in other target tissues.

human life cycle | The span of a human life, which consists of different stages, including childhood, adolescence, adulthood, and old age.

Hyperlipidemia | A term that refers to any number of conditions characterized by excessive amounts of fat in the blood.

hypertension | Medical condition in which the force of blood against the arterial walls is high enough that it could lead to heart disease or other health problems.

I

IDLs | Intermediate-density lipoproteins transport a variety of fats and cholesterol in the bloodstream and are a little under half triacylglycerol in composition.

immune system | The immune system is made up of several different types of white blood cells and other components that act as barricades to foreign invaders. The functions of the immune system are to barricade, seek, recruit, attack, and destroy foreign invaders, such as bacteria and viruses.

immunoglobulins | Proteins produced by plasma cells that function as antibodies. In infancy, immunoglobulins pass from mother to infant via breast milk and provide passive immunity for the baby.

Interventional clinical trial studies | Scientific investigations in which a variable is changed between groups of people.

iron-deficiency anemia | A condition characterized by inadequate hemoglobin in the blood due to low iron levels.

Iron-deficiency anemia | 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. Signs and symptoms include fatigue, weakness, pale skin, shortness of breath, dizziness, swollen and sore tongue, and abnormal heart rate.

irradiation | The application of radiation for the purpose of sterilization and the removal of harmful pathogens.

Irritable bowel syndrome (IBS) | A disorder characterized by muscle spasms in the colon that result in abdominal pain, bloating, constipation, and/or diarrhea. There is no permanent structural damage to the large intestine.

K

keratin | A fibrous protein that provides skin, hair, and nails with structure.

kilocalorie (Calorie) | A kilocalorie is the amount of heat generated by a particular macronutrient that raises the temperature of 1 kilogram of water 1 degree Celsius (this is what is denoted on the Nutrition Facts panel).

Kinetic energy | Energy associated with motion.

Kwashiorkor | A syndrome of severe protein and micronutrient deficiency, characterized by swelling (edema) of the feet and abdomen, poor skin health, growth retardation, low muscle mass, and liver malfunction.

L

Lactation | The medical term for the process of producing and secreting breast milk.

lactose intolerance | A condition in which there is incomplete digestion of lactose. It is caused by a deficiency in the enzyme, lactase. Symptoms include diarrhea, bloating, and abdominal cramps.

LDLs | Low-density lipoproteins are also known as “bad cholesterol.” It contains higher concentrations of triacylglycerols and lower concentrations of protein and is responsible for delivering cholesterol to the body’s tissues.

life cycle | The stages of life one passes through until death.

lifestyle | Components of lifestyle are dietary habits, physical activity level, recreational drug use, and sleeping patterns, all of which play a role in health and impact nutrition.

linoleic acid | An omega-6 fatty acid that is essential for human health.

lipase | An enzyme responsible for the breakdown of triacylglycerols and phospholipids.

Lipids | A family of organic compounds composed of carbon, hydrogen, and oxygen. They are insoluble in water. The three main types of lipids are triglycerides, phospholipids, and sterols.

M

macronutrients | Nutrients that are needed in large amounts. Includes carbohydrates, lipids, proteins, and water.

macronutrients | Nutrients that are needed in large amounts. Includes carbohydrates, lipids, proteins, and water.

magnesium | A mineral that is part of mineralized bone tissue. The dietary sources are meat, fish, dairy products, whole grains, nuts, chocolate, and coffee.

magnesium | A mineral that is part of mineralized bone tissue. The dietary sources are meat, fish, dairy products, whole grains, nuts, chocolate,

and coffee.

marasmic kwashiorkor | The combined syndrome of severe protein and energy deficiency, characterized by variable edema, emaciation, poor skin health, and growth retardation.

marasmic kwashiorkor | The combined syndrome of severe protein and energy deficiency, characterized by variable edema, emaciation, poor skin health, and growth retardation.

marasmus | A syndrome of severe protein and energy deficiency, characterized by emaciation, poor skin health, and growth retardation.

marasmus | A syndrome of severe protein and energy deficiency, characterized by emaciation, poor skin health, and growth retardation.

Mechanical breakdown | Includes mastication (chewing) and the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal.

Mechanical breakdown | Includes mastication (chewing) and the muscular contractions of the stomach and small intestine that mash, mix, slosh, and propel food down the alimentary canal.

metabolic fitness | Ability to provide energy to the muscles during physical activity.

Metabolic homeostasis | The nutrients consumed and absorbed matches the energy required to carry out life's biological processes.

Metabolic syndrome | A medical condition in which people have three or more risk factors for Type 2 diabetes and cardiovascular disease.

metastasis | Spread of cancerous cells from an original location to one or more new sites within the body.

metastasis | Spread of cancerous cells from an original location to one or more new sites within the body.

Micronutrients | Nutrients needed in smaller amounts. Includes vitamins and minerals.

Moderation | Not eating to the extremes, neither too much nor too little.

monoglycerides | A product of lipid digestion, consisting of a glycerol molecule with one fatty acid attached.

monosaccharide | The simplest unit of a carbohydrate.

muscle endurance | Quality of a muscle, or a group of muscles, to perform repetitive movements for a lengthy period of time.

muscular system | The muscular system allows voluntary movement as well as involuntary movements of other organ systems. It consists of skeletal muscle, the heart muscle, and smooth muscles.

mycotoxins | Natural, poisonous substance produced by certain molds and mushrooms that can cause foodborne illness.

myosin | A contractile protein in muscle cells.

N

Newborn jaundice | A condition that can occur within a few days of birth and is characterized by yellowed skin or yellowing in the whites of the eyes.

nitrogen balance | When the amount of protein input into the body equals the amount used up and excreted.

Nonpolar amino acids | Hydrophobic amino acids with side groups that are long or bulky.

Nutrient-dense foods | Foods that contain many nutrients per calorie.

nutrients | Substances required by the body that must be obtained from the diet.

Nutrition Facts panel | Found on most packaged foods, it contains specific amounts of nutrients and also compares the amounts of nutrients in the food and the recommended intake values. These comparisons are reported as percent DV.

Nutritional science | The investigation of how an organism is nourished, and how nourishment affects personal health, population health, and planetary health.

nutritionists | Health-care professional who works in the field of nutrition, but does not have registered credentials.

O

Obese | Having excess body fat (BMI greater than 30).

obesity | A metabolic disorder that leads to the overaccumulation of fat tissue, compromising overall health.

oligosaccharides | A carbohydrate that is a chain of a few (between three and ten) monosaccharides.

Organ systems | Two or more organs that support a specific physiological function.

organelles | A structural or functional unit in a cell that is constructed from several macromolecules bonded together.

organism | The complete living system capable of conducting all basic life processes.

Organs | A group of tissues arranged in a specific manner to support a common function.

osmolality | The total number of dissolved particles in a solvent, such as water.

osmosis | The movement of water through a selectively permeable membrane from an area where it is highly concentrated to an area where it is not as concentrated.

osmotic pressure | The force exerted by solutes at different concentrations on either side of a selectively permeable membrane.

Osteocytes | Star-shaped cells that are the most abundant cell type in bone tissue.

Osteoid | Bone tissue that is not mineralized.

osteomalacia | Similar to nutritional rickets, in adults this disease involves softening and weakening of the bones due to a lack of vitamin D or a problem metabolizing the vitamin.

osteopenia | Lower than normal bone mass.

Oxidation | The interaction between oxygen molecules and all the different substances they may contact. Can be more precisely defined as the loss of at least one electron when two or more substances interact and these substances may or may not include oxygen.

Oxidative stress | An imbalance in any cell, tissue, or organ between the amount of free radicals and the capablilities of its detoxifying and repair systems.

P

pancreatic amylase | Enzyme secreted by the pancreas that breaks down carbohydrates in the small intestine by breaking the glycosidic bonds between monomers.

peak bone mass | The greatest amount of bone mass that a person reaches during their lifetime.

pepsin | An enzyme secreted by stomach cells. It breaks the peptide bonds between amino acids, producing much shorter protein fragments.

peptide bond | The chemical bond that connects amino acids in a sequence.

percentage of Daily Value (percent DV) | The percentage of the amount of the nutrient in relationship to the DV. They are applicable only for a 2,000-calorie daily diet (not 2,500 calories).

peristalsis | Waves of smooth muscle contraction that propel food down the digestive tract.

Phospholipids | The second most common of the three basic lipids. Similar to triacylglycerols, phospholipids have an acid containing phosphorus in place of one of the fatty acids. These lipids appear in all cell membranes.

Phosphorus | A mineral that makes up a substantial part of mineralized bone tissue. The dietary sources are meat, fish, and dairy products, as well as processed foods, and cola beverages.

phytochemicals | Nonessential plant compounds considered to have a beneficial impact on human health.

pincer grasp | A grip that involves picking up an object with the fingers.

Platelets | Fragments of cells that, when stimulated by blood vessel injury, rush to plug up the wound.

point of unsaturation | The place on a molecule where additional hydrogen atoms can attach.

Polar amino acids | Hydrophilic amino acids that are not charged.

polysaccharides | A long chain of monosaccharides that may be branched or not branched.

polyunsaturated fatty acid | A fatty acid that contains two or more points of unsaturation.

prediabetes | A metabolic condition in which people have moderately high glucose levels, but do not meet the criteria for diagnosis as a diabetic.

preeclampsia | A possible complication of pregnancy marked by elevated blood pressure and high levels of protein in the urine.

preventive nutrition | The use of dietary practices to reduce disease and promote health and well-being.

primary prevention | Actions taken to avoid developing a disease before it starts.

protein folding | A sequence of amino acids transforms into its dictated shape.

protein turnover | The processes of continually breaking down proteins and building new ones.

Proteins | Macromolecules composed of chains of organic monomeric subunits, called amino acids. Amino acids are simple monomers composed of carbon, oxygen, hydrogen, and nitrogen.

R

Randomized clinical interventional trial studies | Scientific investigations which incorporate a change in the variable being tested between groups of people and are therefore capable of determining a causal relationship.

reactive oxygen species | Molecules containing oxygen that have unpaired electrons and are highly reactive.

Recommended Dietary Allowances (RDA) | Based upon the EAR, these are nutrient-intake goals designed to meet the requirements of 97 to 98 percent of the target group for a given nutrient.

risk factor | A variable that is linked to an increased probability of developing a disease or adverse outcome.

S

sarcopenia | The age-related decline in muscle mass.

satiety | The sensation of feeling full; determined by mechanical and chemical signals relayed from the periphery.

scientific method | The process of inquiry that involves making an observation, coming up with a hypothesis, conducting a test of that hypothesis, evaluating results, gathering more supporting evidence, and coming up with a conclusion.

secondary prevention | Strategies focused on halting or reversing a disease after it has developed.

Sedentary behavior | Activity during which energy expenditure is no more than one and one-half times the amount of energy expended while at rest (examples include sitting, reclining, or lying down while awake).

smoking point | The temperature at which fat gives off a pungent blue gas.

Socioeconomic status | A measurement dependent on three variables; income, occupation, and education.

SoFAS | An acronym for solid fats and added sugars.

SoFAS | An acronym for solid fats and added sugars.

Soluble fiber | Fiber that attracts water and turns to gel, which slows digestion. Soluble fiber is readily fermented in the colon by bacteria into gases and waste byproducts.

Solutes | Any dissolved substances in a fluid.

subsidies | Federal funding given to an agricultural producer to provide assistance and support.

Sugar alcohols | Carbohydrates that occur naturally in some fruits and vegetables; however they are industrially synthesized by yeast and other microbes for use as food additives.

supplements | Vitamins, minerals, and herbs which are taken in addition to your regular diet to promote healthy body functions or to target specific body parts.

sustainable food system | A system that can meet the needs of the current generation while providing food for generations to come without negatively impacting the environment.

T

T-score | Compares the patient's BMD to the averaged BMD of a healthy thirty-year-old population of the same sex.

taste threshold | Minimum concentration at which taste sensitivity to a food or substance can be perceived.

Thirst | An osmoregulatory mechanism to increase water input.

Tissues | A group of cells that share a common structure and function and that work together.

Tolerable Upper Intake Levels (UL) | The highest average daily nutrient-intake level at which a nutrient can be consumed before it poses a risk of toxicity.

trans fatty acid | A fatty acid that has hydrogens attached on opposite sides of the carbon chain.

Triacylglycerols | The most common of the three basic classes of lipids and the main form fat takes in both diet and the human body. A triacylglycerol is made up of three molecules of fatty acids and one molecule of glycerol.

Type 1 diabetes | A metabolic disease in which cells in the pancreas are killed by an abnormal response of the immune system, causing a lack of insulin in the body.

Type 2 diabetes | A metabolic disease of insulin insufficiency; also caused by muscle, liver, and fat cells no longer responding to the insulin in the body.

Type 2 diabetes | Occurs when the pancreas produces enough insulin initially, but the body is unable to use the hormone properly (insulin resistance).

V

Variety | Consuming an abundance of foods from different food groups on a regular basis.

visceral fat | Fat deposited in the abdominal cavity.

Vitamin D | Both a vitamin and a hormone, vitamin D plays an essential role in maintaining calcium homeostasis. A deficiency in vitamin D compromises bone health.

Vitamin K | A vitamin that acts as a coenzyme that modifies proteins important for bone health. The dietary sources are green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce.

VLDLs | Very low-density lipoproteins formed in the liver from the remains of the chylomicron.

W

waist-to-hip ratio | Waist circumference divided by hip circumference.

wellness | Achieving balance and integration of aspects that affect quality of life, including physical, mental, emotional, social, environmental, and spiritual dimensions.

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    - 1.1: Defining Nutrition, Health, and Disease - *CC BY-NC-SA 3.0*
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    - 3.1: Chapter Introduction - *CC BY-NC-SA 3.0*
    - 3.2: The Basic Structural and Functional Unit of Life- The Cell - *CC BY-NC-SA 3.0*
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    - 3.5: Energy and Calories - *CC BY-NC-SA 3.0*
    - 3.6: Disorders That Can Compromise Health - *CC BY-NC-SA 3.0*
    - 3.E: Nutrition and the Human Body (Exercises) - *CC BY-NC-SA 3.0*
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    - 4.1: Introduction to Carbohydrates - *CC BY-NC-SA 3.0*
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    - 4.3: Digestion and Absorption of Carbohydrates - *CC BY-NC-SA 3.0*
    - 4.4: The Functions of Carbohydrates in the Body - *CC BY-NC-SA 3.0*
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    - 4.7: Carbohydrates and Personal Diet Choices - *CC BY-NC-SA 3.0*
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  - 6.1: Prelude to Proteins - *CC BY-NC-SA 3.0*
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  - 7.2: Fat Soluble Vitamins - *CC BY-NC-SA 3.0*
    - 7.2A: Vitamin A - *CC BY-NC-SA 3.0*
    - 7.2B: Vitamin D - *CC BY-SA 3.0*
    - 7.2C: Vitamin E - *CC BY-NC-SA 3.0*
    - 7.2D: Vitamin K - *CC BY-NC-SA 3.0*
  - 7.3: Water Soluble Vitamins - *CC BY-NC-SA 3.0*
    - 7.3A: Vitamin B_1 (Thiamine) - *CC BY-NC-SA 3.0*
    - 7.3B: Vitamin B_2 (Riboflavin) - *CC BY-NC-SA 3.0*
    - 7.3C: Vitamin B_3 (Niacin) - *CC BY-SA 3.0*
    - 7.3D: Vitamin B_5 (Pantothenic acid) - *CC BY-NC-SA 3.0*
    - 7.3E: Vitamin B_6 (Pyridoxine) - *CC BY-NC-SA 3.0*
    - 7.3F: Vitamin B_7 (Biotin) - *CC BY-NC-SA 3.0*
    - 7.3G: Vitamin B_9 (Folic acid) - *CC BY-NC-SA 3.0*
    - 7.3H: Vitamin B_{12} (Cobalamin) - *CC BY-NC-SA 3.0*
    - 7.3I: Vitamin C (Ascorbic acid) - *CC BY-NC-SA 3.0*
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  - 8.1: Water - *CC BY-NC-SA 3.0*
  - 8.2: Minerals - Basic Concepts - *CC BY-NC-SA 3.0*
  - 8.3: Overview of Fluid and Electrolyte Balance - *CC BY-NC-SA 3.0*
  - 8.4: Water's Importance to Vitality - *CC BY-NC-SA 3.0*
  - 8.5: Regulation of Water Balance - *CC BY-NC-SA 3.0*
  - 8.6: Major Minerals - *CC BY-NC-SA 3.0*
    - 8.6A: Introduction to Major Minerals - *CC BY-NC-SA 3.0*
    - 8.6B: Calcium - *CC BY-NC-SA 3.0*
    - 8.6C: Phosphorus - *CC BY-NC-SA 3.0*
    - 8.6D: Sulfur - *CC BY-NC-SA 3.0*
    - 8.6E: Magnesium - *CC BY-NC-SA 3.0*
    - 8.6F: Sodium - *CC BY-NC-SA 3.0*
    - 8.6G: Chloride - *CC BY-NC-SA 3.0*
    - 8.6H: Potassium - *CC BY-NC-SA 3.0*
  - 8.7: Trace Minerals - *CC BY-NC-SA 3.0*
    - 8.7A: Prelude to Trace Minerals - *CC BY-NC-SA 3.0*
    - 8.7B: Iron - *CC BY-NC-SA 3.0*
    - 8.7C: Copper - *CC BY-NC-SA 3.0*
    - 8.7D: Zinc - *CC BY-NC-SA 3.0*
    - 8.7E: Iodine - *CC BY-NC-SA 3.0*
    - 8.7F: Chromium - *CC BY-NC-SA 3.0*
    - 8.7G: Manganese - *CC BY-NC-SA 3.0*
    - 8.7H: Molybdenum - *CC BY-NC-SA 3.0*
    - 8.7I: Fluoride - *CC BY-NC-SA 3.0*
    - 8.7J: Selenium - *CC BY-NC-SA 3.0*
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  - 9.1: Prelude to Energy Balance and Body Weight - *CC BY-NC-SA 3.0*
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  - 9.4: Too Little or Too Much Weight? - *CC BY-NC-SA 3.0*
  - 9.5: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management - *CC BY-NC-SA 3.0*
  - 9.E: Energy Balance and Body Weight (Exercises) - *CC BY-NC-SA 3.0*
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  - 10.1: Introduction to Nutrition and Physical Fitness - *CC BY-NC-SA 3.0*
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  - 10.3: Anaerobic Exercise - *CC BY-SA 3.0*
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    - 4.4: The Functions of Carbohydrates in the Body - *CC BY-NC-SA 3.0*
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  - 7.2: Fat Soluble Vitamins - *CC BY-NC-SA 3.0*
    - 7.2A: Vitamin A - *CC BY-NC-SA 3.0*
    - 7.2B: Vitamin D - *CC BY-SA 3.0*
    - 7.2C: Vitamin E - *CC BY-NC-SA 3.0*
    - 7.2D: Vitamin K - *CC BY-NC-SA 3.0*
  - 7.3: Water Soluble Vitamins - *CC BY-NC-SA 3.0*
    - 7.3A: Vitamin B_1 (Thiamine) - *CC BY-NC-SA 3.0*
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    - 7.3C: Vitamin B_3 (Niacin) - *CC BY-SA 3.0*
    - 7.3D: Vitamin B_5 (Pantothenic acid) - *CC BY-NC-SA 3.0*
    - 7.3E: Vitamin B_6 (Pyridoxine) - *CC BY-NC-SA 3.0*
    - 7.3F: Vitamin B_7 (Biotin) - *CC BY-NC-SA 3.0*
    - 7.3G: Vitamin B_9 (Folic acid) - *CC BY-NC-SA 3.0*
    - 7.3H: Vitamin B_{12} (Cobalamin) - *CC BY-NC-SA 3.0*
    - 7.3I: Vitamin C (Ascorbic acid) - *CC BY-NC-SA 3.0*
- 8: Water and Minerals - *CC BY-NC-SA 3.0*
  - 8.1: Water - *CC BY-NC-SA 3.0*
  - 8.2: Minerals - Basic Concepts - *CC BY-NC-SA 3.0*
  - 8.3: Overview of Fluid and Electrolyte Balance - *CC BY-NC-SA 3.0*
  - 8.4: Water's Importance to Vitality - *CC BY-NC-SA 3.0*
  - 8.5: Regulation of Water Balance - *CC BY-NC-SA 3.0*
  - 8.6: Major Minerals - *CC BY-NC-SA 3.0*
    - 8.6A: Introduction to Major Minerals - *CC BY-NC-SA 3.0*
    - 8.6B: Calcium - *CC BY-NC-SA 3.0*
    - 8.6C: Phosphorus - *CC BY-NC-SA 3.0*
    - 8.6D: Sulfur - *CC BY-NC-SA 3.0*
    - 8.6E: Magnesium - *CC BY-NC-SA 3.0*
    - 8.6F: Sodium - *CC BY-NC-SA 3.0*
    - 8.6G: Chloride - *CC BY-NC-SA 3.0*
    - 8.6H: Potassium - *CC BY-NC-SA 3.0*
  - 8.7: Trace Minerals - *CC BY-NC-SA 3.0*
    - 8.7A: Prelude to Trace Minerals - *CC BY-NC-SA 3.0*
    - 8.7B: Iron - *CC BY-NC-SA 3.0*
    - 8.7C: Copper - *CC BY-NC-SA 3.0*
    - 8.7D: Zinc - *CC BY-NC-SA 3.0*
    - 8.7E: Iodine - *CC BY-NC-SA 3.0*
    - 8.7F: Chromium - *CC BY-NC-SA 3.0*
    - 8.7G: Manganese - *CC BY-NC-SA 3.0*
    - 8.7H: Molybdenum - *CC BY-NC-SA 3.0*
    - 8.7I: Fluoride - *CC BY-NC-SA 3.0*
    - 8.7J: Selenium - *CC BY-NC-SA 3.0*
- 9: Energy Balance and Healthy Weight - *CC BY-NC-SA 3.0*
  - 9.1: Prelude to Energy Balance and Body Weight - *CC BY-NC-SA 3.0*
  - 9.2: Indicators of Health- Body Mass Index, Body Fat Content, and Fat Distribution - *CC BY-NC-SA 3.0*
  - 9.3: Balancing Energy Input with Energy Output - *CC BY-NC-SA 3.0*
  - 9.4: Too Little or Too Much Weight? - *CC BY-NC-SA 3.0*
  - 9.5: Dietary, Behavioral, and Physical Activity Recommendations for Weight Management - *CC BY-NC-SA 3.0*
  - 9.E: Energy Balance and Body Weight (Exercises) - *CC BY-NC-SA 3.0*
- 10: Physical Fitness - *CC BY-NC-SA 3.0*
  - 10.1: Introduction to Nutrition and Physical Fitness - *CC BY-NC-SA 3.0*
  - 10.2: Aerobic Exercise - *CC BY-SA 3.0*
  - 10.3: Anaerobic Exercise - *CC BY-SA 3.0*
  - 10.4: Fitness Supplements and Steroids - *CC BY-SA 4.0*
  - 10.5: How do my muscles get the Energy to perform work? - *CC BY-NC-SA 3.0*
  - 10.6: Nutrients that are critical to athletes - *CC BY-NC-SA 3.0*
  - 10.7: Creating your own fitness plan - *CC BY-*

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- 11: Food Safety and the Future of our Food - *CC BY-NC-SA 3.0*
  - 11.1: Protecting Our Food - *CC BY-NC-SA 3.0*
  - 11.2: Microbes in Food - *CC BY-NC-SA 3.0*
  - 11.3: Foodborne Illness - *CC BY-NC-SA 3.0*
  - 11.4: Common Food-Borne Pathogens - *CC BY-NC-SA 3.0*
  - 11.5: Foodborne Illness and Food Safety - *CC BY-NC-SA 3.0*
  - 11.6: Food Preservation - *CC BY-NC-SA 3.0*
  - 11.7: Preparing for Disasters - *CC BY-NC-SA 3.0*
  - 11.8: Food Additives - *CC BY-NC-SA 3.0*
  - 11.9: Start Your Sustainable Future Today - *CC BY-NC-SA 3.0*
  - 11.10: Genetically Modified Foods (GMO's) - *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*
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