The Human Body

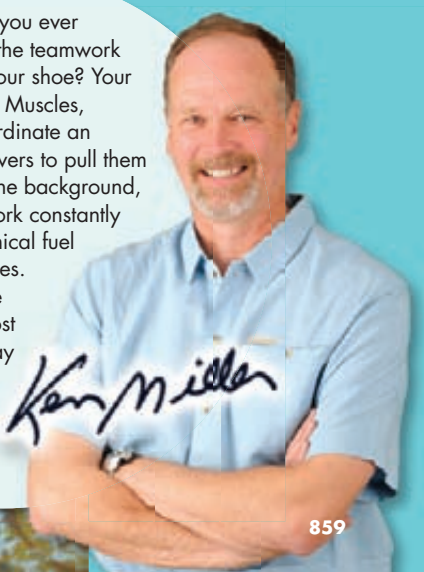
UNIT 8

Chapters

INTRODUCE the Big ideas

- **Homeostasis**
- **Structure and Function**

"Have you ever thought about the teamwork involved in tying your shoe? Your eyes locate the laces. Muscles, bones, and nerves coordinate an intricate series of maneuvers to pull them tight and tie the knot. In the background, lungs and bloodstream work constantly to bring oxygen and chemical fuel to those muscles and nerves. The body is an incredible machine, but what is most extraordinary is the way in which its systems and organs work together."



30 Digestive and Excretory Systems

Big idea

Homeostasis

Q: How are the materials that enter and leave your body related to the processes that maintain homeostasis?

Food sellers display their goods at a floating food market on Dal Lake in northern India.

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INSIDE:

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

THE TELLTALE SAMPLE

On the first day of summer football practice, all players were required to have a physical. Each student was handed a plastic cup and directed to the restroom. "Please provide me with a sample," the physician requested. The athletes had no idea how much could be learned about their health and behavior from a small urine sample.

Immediately after handing over their samples, Philip and Seth were sent home and told to drink plenty of water before practice the next day. The next day, Andrew was told to see his family physician because he could have diabetes. Several days later, another student was dropped from the team for violating the school's well-known antidrug policy. How was all of this information gained from a urine sample? As you read this chapter, look for clues to help you discover what can be learned about the body by simply examining what leaves it. Solve the mystery.

Never Stop Exploring Your World. Finding the solution to the Telltale Sample mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

Untamed Science™

30.1 Organization of the Human Body

Key Questions

How is the human body organized?

What is homeostasis?

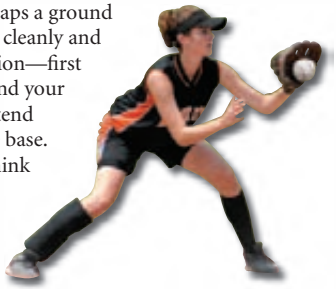
Vocabulary

epithelial tissue
connective tissue
nervous tissue
muscle tissue
homeostasis
feedback inhibition

Taking Notes

Preview Visuals Examine **Figure 30–2.** For each system, describe how you think it interacts with at least one other system.

THINK ABOUT IT The batter slaps a ground ball to the shortstop, who fields it cleanly and throws the ball toward your position—first base. In a single motion, you extend your glove hand, catch the ball, and extend your foot to touch the edge of the base. An easy out, a routine play. But think about how many systems of your body are involved in making this type of "routine" play. How do they all work together?



Organization of the Body

How is the human body organized?

Every cell in the human body is both an independent unit and an interdependent part of a larger community—the entire organism. To complete a winning play, a player at first base has to use her eyes to watch the ball and use her brain to figure out how to position her body. With the support of her bones, muscles move her body to first base. Meanwhile, the player's lungs absorb oxygen, which her blood carries to cells for use during cellular respiration. Her brain monitors the location of the ball and sends signals that guide her glove hand to make the catch.

How can so many individual cells and parts work together so efficiently? One way to answer this question is to study the organization of the human body. **The levels of organization in the body include cells, tissues, organs, and organ systems.** At each level of organization, these parts of the body work together to carry out the major body functions.

Cells A cell is the basic unit of structure and function in living things. As you learned in Chapter 7, individual cells in multicellular organisms tend to be specialized. Specialized cells, such as bone cells, blood cells, and muscle cells, are uniquely suited to perform a particular function.

Tissues A group of cells that perform a single function is called a tissue. There are four basic types of tissue in the human body—epithelial, connective, nervous, and muscle. **Figure 30–1** shows examples of each type of tissue.

	Epithelial Tissue	Connective Tissue	Nervous Tissue	Muscle Tissue
FUNCTIONS	Protection, absorption, and excretion of materials	Binding of epithelial tissue to structures, support, and transport of substances	Receiving and transmitting nerve impulses	Voluntary and involuntary movements
LOCATIONS	Skin, lining of digestive system, certain glands	Under skin, surrounding organs, blood, bones	Brain, spinal cord, and nerves	Skeletal muscles, muscles surrounding digestive tract and blood vessels, the heart

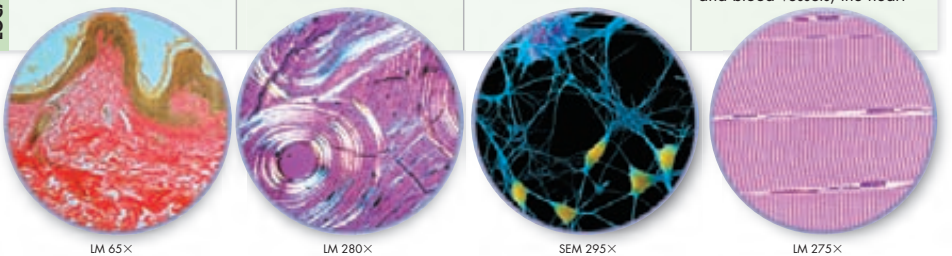


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FIGURE 30–1 Types of Tissues The four major types of tissues in the human body are epithelial tissue, connective tissue, nervous tissue, and muscle tissue. **Predict** *Which organ may not contain all four types of tissue?*

▶ ***Epithelial Tissue*** The tissue that lines the interior and exterior body surfaces is called **epithelial tissue.** Your skin and the lining of your stomach are both examples of epithelial tissue.

▶ ***Connective Tissue*** A type of tissue that provides support for the body and connects its parts is **connective tissue.** This type of tissue includes fat cells, bone cells, and even blood cells. Many connective tissue cells produce collagen, a long, tough fiber-like protein that is the most common protein in the body. Collagen gives tissues strength and resiliency, helping them to keep their shape even under pressure.

▶ ***Nervous Tissue*** Nerve impulses are transmitted throughout the body by **nervous tissue.** Neurons, the cells that carry these impulses, and glial cells, which surround and protect neurons, are both examples of nervous tissue.

▶ ***Muscle Tissue*** Movements of the body are possible because of **muscle tissue.** Some muscles are responsible for the movements you control, such as the muscles that move your arms and legs. Some muscles are responsible for movements you cannot control, such as the tiny muscles that control the size of the pupil in the eye.

Organs A group of different types of tissues that work together to perform a single function or several related functions is called an organ. The eye is an organ made up of epithelial tissue, nervous tissue, muscle tissue, and connective tissue. As different as these tissues are, they all work together for a single function—sight.

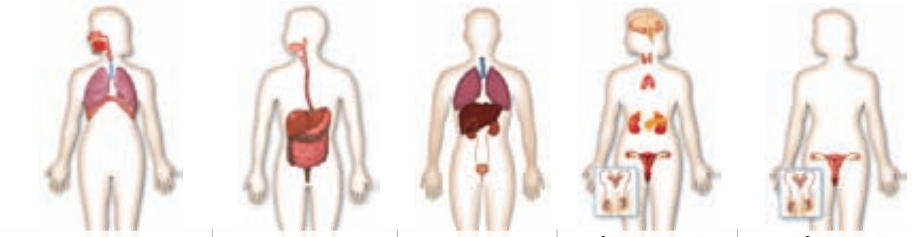
Organ Systems An organ system is a group of organs that perform closely related functions. For example, the brain and spinal cord are organs of the nervous system. The organ systems interact to maintain homeostasis in the body as a whole. The organ systems, along with their structures and main functions, are shown on the next page.

VISUAL SUMMARY

HUMAN BODY SYSTEMS

FIGURE 30–2 Although each of the organ systems shown here has a different set of functions, they all work together, as a whole, to maintain homeostasis.

	Nervous System	Integumentary System	Immune/ Lymphatic Systems	Muscular System	Circulatory System	Skeletal System
STRUCTURES	Brain, spinal cord, nerves	Skin, hair, nails, sweat and oil glands	White blood cells, thymus, spleen, lymph nodes, lymph vessels	Skeletal muscle, smooth muscle, cardiac muscle	Heart, blood vessels, blood	Bones, cartilage, ligaments, tendons
FUNCTIONS	Recognizes and coordinates the body's response to changes in its internal and external environments	Guards against infection and injury and ultraviolet radiation from the sun; helps to regulate body temperature	Helps protect the body from disease; collects fluid lost from blood vessels and returns it to the circulatory system	Works with skeletal system to produce voluntary movement; helps to circulate blood and move food through the digestive system	Transports oxygen, nutrients, and hormones to cells; fights infection; removes cell wastes; helps to regulate body temperature	Supports the body; protects internal organs; allows movement; stores mineral reserves; contains cells that produce blood cells



	Respiratory System	Digestive System	Excretory System	Endocrine System	Reproductive System
STRUCTURES	Nose, pharynx, larynx, trachea, bronchi, bronchioles, lungs	Mouth, pharynx, esophagus, stomach, small and large intestines, rectum	Skin, lungs, liver, kidneys, ureters, urinary bladder, urethra	Hypothalamus, pituitary, thyroid, parathyroids, adrenals, pancreas, ovaries (in females), testes (in males)	Testes, epididymis, vas deferens, urethra, and penis (in males); ovaries, Fallopian tubes, uterus, vagina (in females)
FUNCTIONS	Brings in oxygen needed for cellular respiration and removes excess carbon dioxide from the body	Breaks down food; absorbs nutrients; eliminates wastes	Eliminates waste products from the body	Controls growth, development, and metabolism; maintains homeostasis	Produces gametes; in females, nurtures and protects developing embryo

Homeostasis

What is homeostasis?

Some things are easy to observe. When you run or swim or even write the answer to a test question, you can see your body at work. But behind the scenes, your body's systems are working constantly to do something that is difficult to see and that few people appreciate—maintaining a controlled, stable internal environment. This stable environment is called **homeostasis,** which means "similar standing."

Homeostasis describes the relatively constant internal physical and chemical conditions that organisms maintain despite changes in internal and external environments. Homeostasis may not be obvious, but for a living organism, it's literally a matter of life or death.

Feedback Inhibition If you've ever watched someone driving a car down a relatively straight road, you may have noticed how the person constantly moves the wheel left or right, adjusting direction to keep the vehicle in the middle of the lane. In a certain sense, that's how the systems of the body work, too, keeping internal conditions within a certain range, and never allowing them to go too far to one side or the other.

▶ ***A Nonliving Example*** One way to understand homeostasis is to look at a nonliving system that automatically keeps conditions within a certain range like a home heating system. In most homes, heat is supplied by a furnace that burns oil or natural gas. When the temperature within the house drops below a set point, a thermostat sensor switches the furnace on. Heat produced by the furnace warms the house. When the temperature rises above the set point, the thermostat switches the furnace off, keeping the temperature within a narrow range.

A system like this is said to be controlled by feedback inhibition. **Feedback inhibition,** or negative feedback, is the process in which a stimulus produces a response that opposes the original stimulus. **Figure 30–3** summarizes the feedback inhibition process in a home heating system. When the furnace is switched on, it produces a product (heat) that changes the environment of the house (by raising the air temperature). This environmental change then "feeds back" to "inhibit" the operation of the furnace. In other words, heat from the furnace eventually raises the temperature high enough to trigger a feedback signal that switches the furnace off. Systems controlled by feedback inhibition are generally very stable.

In Your Notebook *Describe another example of a nonliving system that requires constant adjustment.*

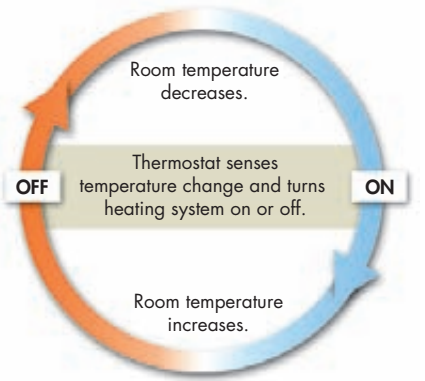


FIGURE 30–3 Feedback Inhibition
A home heating system uses a feedback loop to maintain a stable, comfortable environment within a house.
Interpret Diagrams ***What is the stimulus in this feedback loop?***

BUILD Vocabulary

ACADEMIC WORDS The noun **inhibition** means "the act of blocking the action of." Therefore, feedback inhibition refers to a response that blocks further actions of a stimulus.

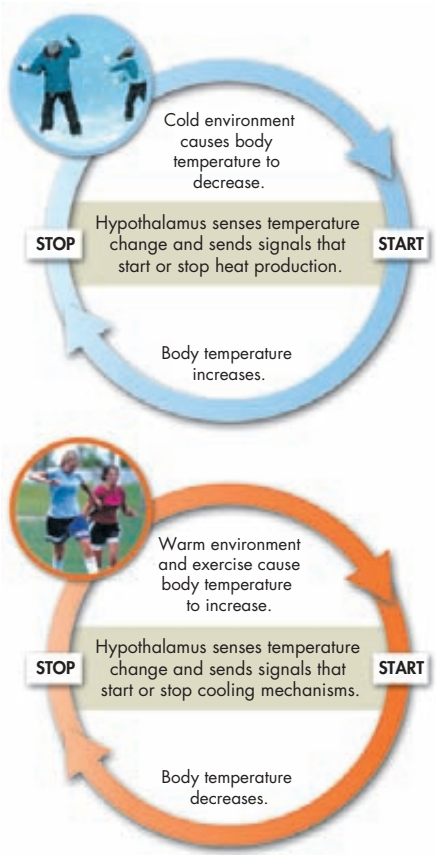


FIGURE 30–4 Body Temperature Control In the human body, temperature is controlled through various feedback inhibition mechanisms. **Infer** ***Why do you think moving around on a cold day helps to keep you warm?***

▶ ***A Living Example*** Could biological systems achieve homeostasis through feedback inhibition? Absolutely. All that is needed is a system that regulates some aspect of the cellular environment and that can respond to feedback from its own activities by switching on or off as needed. Such mechanisms are very common, not only in the human body, but in all forms of life.

One example is the maintenance of body temperature. The body regulates temperature by a mechanism that is remarkably similar to that of a home heating system. You can follow body temperature regulation in **Figure 30–4.** A part of the brain called the hypothalamus contains nerve cells that monitor both the temperature of the skin at the surface of the body and the temperature of organs in the body's core.

If the nerve cells sense that the core temperature has dropped much below 37°C, the hypothalamus produces chemicals that signal cells throughout the body to speed up their activities. Heat produced by this increase in activity, especially cellular respiration, causes a gradual rise in body temperature, which is detected by nerve cells in the hypothalamus.

Have you ever been so cold that you began to shiver? If your body temperature drops well below its normal range, the hypothalamus releases chemicals that signal muscles just below the surface of the skin to contract involuntarily—to "shiver." These muscle contractions release heat, which helps the body temperature to rise toward the normal range.

If body temperature rises too far above 37°C, the hypothalamus slows down cellular activities to reduce heat production. This is one of the reasons you may feel tired and sluggish on a hot day. The body also responds to high temperatures by producing sweat, which helps to cool the body surface by evaporation.

Quick Lab
OPEN-ENDED INQUIRY

Maintaining Temperature

You will receive a thermometer and three beakers of water at the following temperatures: 25°C, 35°C, and 40°C. Develop a method to keep the temperature of the 35°C water within one degree for a period of fifteen minutes. You may use the contents of the other two beakers.

Analyze and Conclude

1. Compare and Contrast Compare this experiment to what happens in your own body during temperature regulation.

2. Interpret Visuals Make a feedback loop similar to the ones in **Figure 30–4** that shows how feedback inhibition was involved in this activity.

The Liver and Homeostasis The liver is technically part of the digestive system because it produces bile, which aids in the digestion of fats. However, it is also fair to say that the liver is one of the body's most important organs for homeostasis.

For example, when proteins are broken down for energy, ammonia, a toxic byproduct, is produced. The liver quickly converts ammonia to urea, which is much less toxic. The kidneys, as you will read a bit later, then remove urea from the blood. The liver also converts many dangerous substances, including some drugs, into compounds that can be removed from the body safely.

One of the liver's most important roles involves regulating the level of a substance we take almost for granted as something completely harmless—the simple sugar, glucose. Glucose is obtained from the foods we eat, and cells take glucose from the blood to serve as a source of energy for their everyday activities. Naturally, right after a meal, as the body absorbs food molecules, the level of glucose in the blood begins to rise. That's where the liver comes in. By taking glucose out of the blood, it keeps the level of glucose from rising too much. As the body uses glucose for energy, the liver releases stored glucose to keep the level of the sugar from dropping too low.

The liver's role in keeping blood glucose levels within a certain range is critical. Too little glucose, and the cells of the nervous system will slow down to the point that you may lose consciousness and pass out. On the other hand, too much glucose gradually damages cells in the eyes, kidneys, heart, and even the immune system. Abnormally high levels of glucose are associated with a disease called diabetes. In diabetes, changes occur in either the pancreas or body cells that affect the cells' ability to absorb glucose. Diabetes, one of the fastest-growing health problems in the developed world, is the unfortunate result of failure of homeostasis with respect to blood glucose levels.

MYSTERY CLUE

The lab test of Andrew's urine sample showed an abnormal amount of a certain substance. What substance do you think it was?

30.1 Assessment

Review Key Concepts

1. a. Review What are the four types of tissues?

b. Explain Describe the function of three organ systems depicted in **Figure 30–2.**

c. Classify Compare the characteristics of two types of tissues. Identify parts of the body that contain these types of tissues.

2. a. Review What is homeostasis?

b. Explain What are two roles of the liver in maintaining homeostasis?

c. Apply Concepts Do you think that feelings of hunger and fullness are an example of feedback inhibition? Explain.

VISUAL THINKING

3. Draw a Venn diagram to relate the four basic levels of organization in the human body. Provide at least three examples for each level of organization. *Hint:* Your Venn diagram should have a nesting structure. One set of examples could be skin cells, epithelial tissue, skin, and the integumentary system.

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30.2 Food and Nutrition

Key Questions

- ***Why do we need to eat?***
- ***What nutrients does your body need?***
- ***What is meant by the term "balanced diet"?***

Vocabulary

Calorie
carbohydrate
fat
protein
vitamin
mineral

Taking Notes

Outline Before you read, make an outline of the major headings in the lesson. As you read, fill in main ideas and supporting details for each heading.

THINK ABOUT IT When you feel hungry, how would you describe the feeling? Do you feel full of energy and ready to go? Or do you feel weak and just a little bit lazy? Why? What do these sensations tell us about the purpose of food in the body?

Food and Energy

Why do we need to eat?

Have you ever wondered why you need food? The most obvious answer is energy. You need energy to climb stairs, lift books, run, and even to think. Just as a car needs gasoline, your body needs fuel, and food is that fuel. **Molecules in food contain chemical energy that cells use to produce ATP. Food also supplies raw materials your body needs to build and repair tissues.**

Energy The energy available in food can be measured in a laboratory in a surprisingly simple way—by burning it! When food is burned, most energy in the food is converted to heat, which is measured in terms of calories. A calorie is the amount of heat needed to raise the temperature of 1 gram of water by 1 degree Celsius. The "Calories" you've heard about in food are actually dietary Calories, written with a capital *C*. One dietary **Calorie** is equal to 1000 calories, or 1 kilocalorie (kcal). As you may recall, the energy stored in food molecules is released during cellular respiration and used to produce the ATP molecules that power cellular activities.

Raw Materials Chemical pathways, including cellular respiration, can extract energy from almost any type of food. So why does it matter which foods you eat? The reason is that food also supplies the raw materials used to build and repair body tissues. Some of these raw materials are needed to make enzymes, the lipids in cell membranes, and even DNA. In fact, food contains at least 45 substances that the body needs but cannot manufacture. A healthy diet ensures that your body receives all of these required substances.

In Your Notebook *Prepare a table to fill in with information about the nutrients. For each nutrient, include foods in which it is found and describe its role in the body.*

Nutrients

What nutrients does your body need?

Nutrients are substances in food that supply the energy and raw materials your body uses for growth, repair, and maintenance. **The nutrients that the body needs include water, carbohydrates, fats, proteins, vitamins, and minerals.**

Water The most important nutrient is water. Every cell in the human body needs water because many of the body's processes, including chemical reactions, take place in water. Water makes up the bulk of blood, extracellular fluid, and other bodily fluids. On hot days or when you take part in strenuous exercise, sweat glands remove water from your tissues and release it as sweat on the surface of your body. Water is also lost from the body in urine and with every breath you exhale.

Humans need to drink at least 1 liter of fluid each day. If enough water is not taken in to replace what is lost, dehydration can result. Dehydration leads to problems with many body systems, and under extreme conditions it can be fatal.

MYSTERY CLUE

Philip's and Seth's samples were both a very dark yellow. Neither boy drank water before or during practice. Why do you think they were sent home from practice?

Carbohydrates Simple and complex **carbohydrates** are a major source of energy for the body. **Figure 30–5** shows some of the foods that contain carbohydrates. The sugars found in fruits, honey, and sugar cane are simple carbohydrates, or monosaccharides and disaccharides. The starches found in grains, potatoes, and vegetables are complex carbohydrates, or polysaccharides. Starches are broken down by the digestive system into simple sugars. These molecules are absorbed into the blood and carried to cells throughout the body. Excess blood sugar is converted into glycogen, which is stored in the liver and in skeletal muscles. Excess sugar may also be converted to and stored as body fat.

Whole-grain breads, bran, and many fruits and vegetables contain the complex carbohydrate cellulose, often called fiber. Although the human digestive system cannot break down cellulose, you need fiber in your diet. The bulk supplied by fiber helps muscles move food and wastes through your digestive system. Fiber may also have other benefits, such as reducing the risk of heart disease and Type II diabetes.

Whole-grain products contain more fiber than processed grains.

Milk is one of few nonplant foods that is a rich source of carbohydrates.

Fruits contain simple sugars and fiber.

FIGURE 30–5 Carbohydrates Pastas and cereals are also foods that are rich in carbohydrates. Simple carbohydrates do not have to be digested or broken down. Complex carbohydrates, such as those found in whole grains, must be broken down before they can be used by the body. **Infer** ***Which type of carbohydrate—simple or complex—provides the body with quick energy?***

BUILD Vocabulary

PREFIXES The prefix *poly-* is Greek for "many." Polyunsaturated fats contain more than one double bond. The prefix *mono-* means "single." Monounsaturated fats, such as olive oil, contain only one double bond.

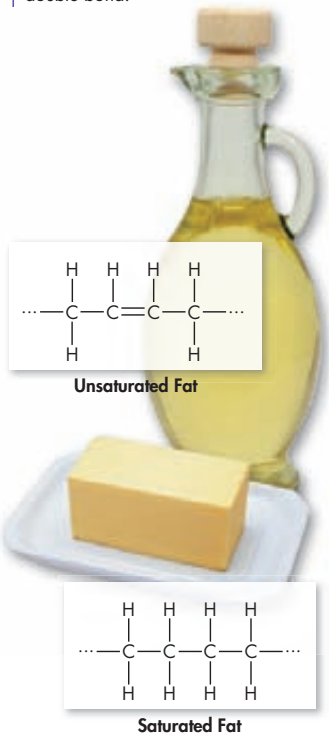

FIGURE 30–6 Fats At room temperature, most saturated fats are solid and most unsaturated fats are liquid. Saturated fats have been tied to many health problems. Consuming limited amounts of unsaturated fats, such as those found in avocados and olive oil, may have some benefits.

Fats Because our society places great emphasis on a trim appearance, the word "fat" has a bad reputation. But fats, or lipids, are an important part of a healthy diet. **Fats** help the body absorb fat-soluble vitamins and are a part of cell membranes, nerve cells, and certain hormones. Deposits of fat protect and insulate body organs and are a source of stored energy.

Fats usually form when a glycerol molecule combines with fatty acids. Some of these acids, called essential fatty acids, cannot be made in the body and are needed to perform many of fat's functions. Based on the structure of their fatty acid chains, fats are classified as saturated or unsaturated. When there are only single bonds between the carbon atoms in the fatty acids, each carbon atom has the maximum number of hydrogen atoms and the fat is said to be saturated. Most saturated fats, such as butter, are solids at room temperature.

Unsaturated fats have one or more double bonds between carbon atoms, which reduces the number of hydrogen atoms in their fatty acids. Unsaturated fats are usually liquids at room temperature. Because many vegetable oils contain more than one double bond, they are called polyunsaturated.

Food manufacturers often modify unsaturated fats in vegetable oils by adding hydrogen to them. These processed fats are called trans fats. Trans fats are solid at room temperature and have a longer shelf life than unsaturated fats. However, recent studies suggest that trans fats may be associated with serious health concerns, including heart disease.

Proteins Proteins have a wide variety of roles in the body. **Proteins** supply raw materials for growth and repair of structures such as skin and muscle. Many enzymes that control cellular chemistry by increasing the rates of chemical reactions are made of proteins. Proteins also have regulatory and transport functions. For example, the hormone insulin is a protein that regulates the level of sugar in the blood. Hemoglobin, a protein found in red blood cells, helps transport oxygen. Proteins can also be used as energy sources when other nutrients, such as carbohydrates and fats, are in short supply.

Proteins are polymers of amino acids. The body is able to synthesize only 12 of the 20 amino acids used to make proteins. The other eight are called essential amino acids. Essential amino acids must be obtained from the foods that you eat. Foods shown below, such as meat, fish, eggs, and milk, generally contain all eight essential amino acids. Foods derived from plants, such as grains and beans, do not. People who don't eat animal products must eat a combination of plant foods, such as beans and rice, to obtain all of the essential amino acids.

Vitamins Organic molecules that the body needs in very small amounts are called **vitamins.** Most vitamins are needed by the body to help perform chemical reactions. If we think of proteins, fats, and carbohydrates as the building blocks of the body, then vitamins are the tools that help to put them together. As shown in **Figure 30–7,** most vitamins must be obtained from food. However, the bacteria that live in the large intestine are able to synthesize vitamins K and B_{12}.

There are two types of vitamins: fat-soluble and water-soluble. The fat-soluble vitamins A, D, E, and K can be stored in the fatty tissues of the body. The body can build up small deposits of these vitamins for future use. The water-soluble vitamins, which include vitamin C and the B vitamins, dissolve in water and cannot be stored in the body. Therefore, they should be included in the foods you eat each day.

A diet lacking certain vitamins can have serious health consequences. Eating a variety of foods will supply the daily vitamin needs of most people. Large doses of vitamin supplements do not benefit the body. Excessive amounts of the fat-soluble vitamins A, D, and K can be toxic.

FIGURE 30–7 Vitamins This table lists the food sources and functions of 14 essential vitamins. The fat-soluble vitamins are listed in the first four rows. **Interpret Tables** ***What is the function of vitamin K?***

Vitamins

Vitamin	Sources	Function
A (retinol)	Yellow, orange, and dark-green vegetables; fortified dairy products	Important for growth of skin cells; important for night vision
D (calciferol)	Fish oils, eggs; made by skin when exposed to sunlight; added to dairy products	Promotes bone growth; increases calcium and phosphorus absorption
E (tocopherol)	Green leafy vegetables, seeds, vegetable oils	Antioxidant; prevents cellular damage
K 	Green leafy vegetables; made by bacteria that live in human intestine	Needed for normal blood clotting
B_1 (thiamine)	Whole grains, pork, legumes, milk	Metabolism of carbohydrates
B_2 (riboflavin)	Dairy products, meats, vegetables, whole grains	Growth; energy metabolism
Niacin	Liver, milk, whole grains, nuts, meats, legumes	Important in energy metabolism
B_6 (pyridoxine)	Whole grains, meats, vegetables	Important for amino acid metabolism
Pantothenic acid	Meats, dairy products, whole grains	Needed for energy metabolism
Folic acid 	Legumes, nuts, green leafy vegetables, oranges, broccoli, peas, fortified grains	Involved in nucleic acid metabolism; prevents neural-tube defects
B_{12} (cyanocobalamin)	Meats, eggs, dairy products, enriched cereals	Involved in nucleic acid metabolism; maturation of red blood cells
C (ascorbic acid) 	Citrus fruits, tomatoes, red or green peppers, broccoli, cabbage, strawberries	Maintains cartilage and bone; antioxidant; improves iron absorption; important for healthy gums and wound healing
Biotin	Legumes, vegetables, meat	Coenzyme in synthesis of fat; glycogen formation; amino acid metabolism
Choline	Egg yolk, liver, grains, legumes	Part of phospholipids and neurotransmitters

Important Minerals

Mineral	Sources	Function
Calcium	Dairy products, salmon, kale, tofu, collard greens, legumes	Bone and tooth formation; blood clotting; nerve and muscle function
Phosphorus	Dairy products, meats, poultry, grains	Bone and tooth formation; acid-base balance
Iron	Meats, eggs, legumes, whole grains, green leafy vegetables, dried fruit	Component of hemoglobin and of electron carriers used in energy metabolism
Chlorine	Table salt, processed foods	Acid-base balance; formation of gastric juice
Sodium	Table salt, processed foods	Acid-base balance; water balance; nerve and muscle function
Potassium	Meats, dairy products, fruits and vegetables, grains	Acid-base balance; water balance; nerve and muscle function
Magnesium	Whole grains, green leafy vegetables	Activation of enzymes in protein synthesis
Fluorine	Fluoridated drinking water, tea, seafood	Maintenance of bone and tooth structure
Iodine	Seafood, dairy products, iodized salt	Component of thyroid hormones
Zinc	Meats, seafood, grains	Component of certain digestive enzymes

FIGURE 30–8 Minerals A healthful diet should include small amounts of certain minerals to maintain a healthy body. **Infer** *Why do you think some cities and towns add fluoride to their water supplies?*

Minerals Inorganic nutrients that the body needs, usually in small amounts, are called **minerals.** **Figure 30–8** lists some of the minerals needed by the body. Calcium, for example, is required to produce the calcium phosphate that makes up bones and teeth. Iron is needed to make hemoglobin, the oxygen-carrying protein in red blood cells. A constant supply of minerals in the diet is needed to replace those lost in sweat, urine, and digestive wastes.

Nutrition and a Balanced Diet

What is meant by the term "balanced diet"?

The science of nutrition—the study of food and its effects on the body—tries to determine how food helps the body meet all of its various needs. Because of the work of nutritionists, many tools have been developed to help people plan healthful diets. **A balanced diet provides nutrients in adequate amounts and enough energy for a person to maintain a healthful weight.**

Balancing Your Diet Food labels can be used to choose healthful foods. Food labels provide general information about nutrition as well as specific information about the product. They can be used to determine if you are consuming enough of some of the important vitamins and minerals.

In Your Notebook *List seven types of information you can learn about a food from its food label.*

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Note on the food label shown in **Figure 30–9** that fat contains about 9 Calories per gram, while carbohydrate and protein contain 4 Calories per gram. Why the difference? The carbon atoms in fats generally have more C–H (carbon to hydrogen) bonds than the carbon atoms in carbohydrates or proteins. Oxidizing these C–H bonds releases a great deal of energy. Because of this, oxidizing a gram of fat releases more energy than does oxidizing a gram of protein or carbohydrate, giving fats a greater energy value in Calories per gram.

When using food labels, it is important to remember that Percent Daily Values are based on a 2000-Calorie diet. However, nutrient needs are affected by age, gender, and lifestyle. The daily energy needs of an average-sized teenager who exercises regularly are about 2200 Calories for females and about 2800 Calories for males. People who are more active than average have greater energy needs. When a person stops growing or becomes less active, energy needs decrease.

Maintaining a Healthful Weight Inactive lifestyles and high-Calorie diet are contributing factors to the growing rate of obesity in the United States during the last several decades. Exercising about 30 minutes a day and eating a balanced diet can help maintain a healthful weight. Regular physical activity helps to maintain a healthful weight by burning excess Calories. Other benefits of physical activity include strengthening of the heart, bones, and muscles.

The American Heart Association recommends a diet with a maximum of 30 percent of Calories from fat, of which only 7 percent should be from saturated fats and 1 percent from trans fats. Controlling fat intake is important for several reasons. Foods that contain a high amount of any type of fat are high in Calories. A diet high in saturated fats and trans fats increases the risk for developing heart disease, Type II diabetes, or both.

Nutrition Facts

Serving Size	1 cup (30g)
Servings Per Container	About 10
Amount Per Serving	
Calories 110	Calories from Fat 17
	% Daily Value*
Total Fat 2g	**3%**
Saturated Fat 0g	**0%**
Trans Fat 0.5g	
Cholesterol 0mg	**0%**
Sodium 280mg	**12%**
Total Carbohydrate 22g	**7%**
Dietary Fiber 3g	**12%**
Sugars 1g	
Protein 3g	
Vitamin A 10% • Vitamin C	20%
Calcium 4% • Iron	45%

* Percent Daily Values are based on a 2,000 Calorie diet. Your Daily Values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Fiber		25g	30g

Calories per gram: Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Whole grain oats, sugar, salt, milled corn, oat fiber, dried whey, hone… almonds, di…

FIGURE 30–9 Food Label Reading food labels can help you track how many Calories you consume in a day and if you are meeting your requirements for important nutrients.

30.2 Assessment

Review Key Concepts

1. a. Review What are the two reasons humans need to eat?

b. Infer Foods that contain many Calories but few raw materials are said to contain empty Calories. What do you think the phrase *empty Calories* means?

2. a. Review List six nutrients that the body needs.

b. Compare and Contrast How are saturated and unsaturated fats similar? How are they different?

3. a. Review How can food labels be used to plan a balanced diet?

b. Calculate One serving of a particular food contains 16 g of carbohydrates, 2 g of protein, and 10 g of fats. Approximately how many Calories does it contain? MATH

ANALYZING DATA

Examine **Figure 30–9** and answer the questions.

4. a. Calculate If you ate 2 cups of this product, how many grams of fat would you eat? How many total Calories would you eat? MATH

b. Evaluate This product's packaging advertises that it contains 0 g of trans fat. Does that mean the product contains no trans fat? Explain.

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Biology & Society

Who Should Solve America's Obesity Problem?

As old subway cars are replaced and new sport stadiums are built, a trend is obvious. Seats are much larger than they used to be. For example, in the old arena of the Indiana Pacers, seats were 18 inches wide. In the new arena, the *smallest* seats are 21 inches wide. Advertisers tout that the seats are more comfortable. But the reality is, larger seats are needed because Americans have become fatter.

From the late 1970s to the early 2000s, the percentage of adults in the United States who are obese increased from 15 percent to 32.9 percent. During the same time period, the percentage of adolescents (ages 12 to 19) who are overweight more than tripled, from 5 percent to 17.4 percent. The trend shows no sign of changing.

The causes for what has been called the "obesity epidemic" seem apparent—a lifestyle of high-Calorie diets and lack of exercise. But the solutions are not so obvious. Many state and local governments have tried to gain control of the epidemic by removing high-Calorie foods from schools. Some people support these efforts, but others believe the government is encroaching too closely on personal lives. Should the government play a role in fighting obesity by controlling the foods served in school?

Viewpoints

The Government Must Play a Role Obesity increases the risk of high blood pressure, Type II diabetes, stroke, arthritis, and some cancers. An increase in the rates of these diseases will strain the healthcare system and affect the economy by reducing the number of healthy adults in the workforce.

Overweight children are likely to become obese adults. Schools should play an active role in limiting students' exposure to high-Calorie foods that are not nutritious.

Many schools throughout the country have replaced vending machines that offered soda and other sugary drinks with those that offer only water, milk, or 100 percent juice.

The Government Should Not Play a Role
Food choices are a personal decision. Keeping unhealthful foods out of school will not prepare students for making healthful decisions in the real world. Parents and educators should teach children how to make healthful choices, rather than simply controlling their options.

Research and Decide

1. Evaluate Discuss changes that have been proposed or made recently in your school to address the obesity epidemic. Have some foods been removed from the cafeteria? Have the offerings in vending machines changed? Explain.

2. Form an Opinion Do you think that recent changes in your school menu, if any, are positive changes? Should more be done? Or should less be done? Explain.

30.3 The Digestive System

THINK ABOUT IT When you're hungry, your whole body needs food. But the only system in the body that food actually enters is the digestive system. So, how does food get to the rest of the body after the process of digestion?

Functions of the Digestive System

What are the functions of the digestive system?

The need for food presents every animal with at least two challenges. The first is how to obtain it. Once an animal has caught or gathered its food, its body faces a new challenge—how to convert the food into useful molecules. In humans and many other animals, this is the job of the digestive system. **The digestive system converts food into small molecules that can be used by the cells of the body. Food is processed by the digestive system in four phases—ingestion, digestion, absorption, and elimination.**

Ingestion Naturally, the first step in digestion is getting food into the system. Ingestion, as the process is called, is the process of putting food into your mouth—the opening to the digestive tract.

Digestion As food passes through the digestive system, it is broken down in two ways—by mechanical and chemical digestion. **Mechanical digestion** is the physical breakdown of large pieces of food into smaller pieces. These smaller pieces can be swallowed and accessed by digestive enzymes. During **chemical digestion,** enzymes break down food into the small molecules the body can use.

Absorption Once food has been broken into small molecules, it can be absorbed by cells in the small intestine. From the small intestine, the molecules enter the circulatory system, which transports them throughout the body.

Elimination The digestive system cannot digest and absorb all the substances in food that enter the body. Some materials, such as cellulose, travel through the large intestine and are eliminated from the body as feces.

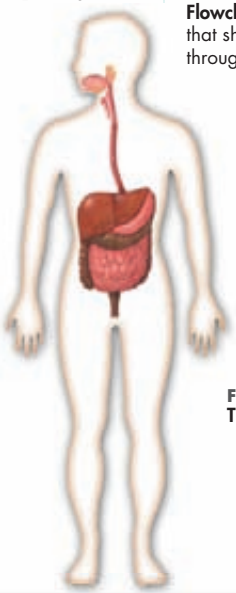

FIGURE 30–10
The Digestive System

Key Questions

- ***What are the functions of the digestive system?***
- ***What occurs during digestion?***
- ***How are nutrients absorbed and wastes eliminated?***

Vocabulary

mechanical digestion • chemical digestion • amylase • esophagus • peristalsis • stomach • pepsin • chyme • small intestine • villus • large intestine

Taking Notes

Flowchart Make a flowchart that shows the route food takes through the digestive system.

The Process of Digestion

What occurs during digestion?

The human digestive system, like those of other chordates, is built around an alimentary canal—a one-way tube that passes through the body. **During digestion, food travels through the mouth, esophagus, stomach, and small intestine. Mechanical digestion and chemical digestion are the two processes by which food is reduced to molecules that can be absorbed.** Both mechanical digestion and chemical digestion start in the mouth.

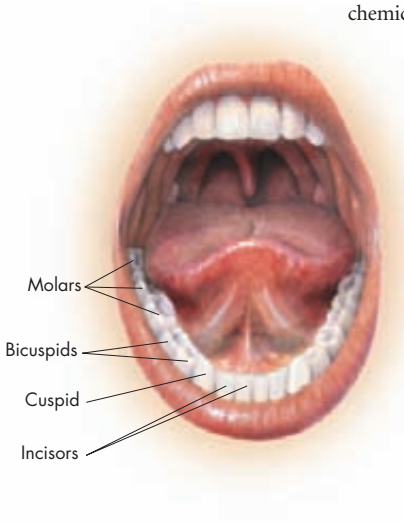

FIGURE 30–11 The Mouth
Digestion begins in the mouth, where the tongue, teeth, and saliva form food into a moist lump that can be swallowed. **Infer** *How do human teeth reflect an omnivorous diet?*

The Mouth As you take a forkful of food into your mouth, the work of the digestive system begins. Teeth and saliva start to work on your food first. Chewing begins the process of mechanical digestion. Chemical digestion begins as digestive enzymes in saliva start the breakdown of complex carbohydrates into smaller molecules.

▶ ***Teeth*** The teeth, shown in **Figure 30–11,** are anchored in the bones of the jaw. The surfaces of the teeth are protected by a coating of mineralized enamel. The teeth do much of the mechanical work of digestion. The incisors, cuspids, and bicuspids cut into and tear at food. The molars grind and crush food into a fine paste that can be swallowed. Meanwhile, your tongue moves food around so that it comes in contact with your teeth.

▶ ***Saliva*** As the teeth cut and grind the food, the salivary glands secrete saliva, which helps to moisten the food and make it easier to chew. The release of saliva is under the control of the nervous system and can be triggered by the scent of food—especially when you are hungry!

Saliva not only eases the passage of food through the digestive system but also begins the process of chemical digestion. Saliva contains an enzyme called **amylase** that begins to break the chemical bonds in starches, forming sugars. If you chew on a starchy food like a cracker long enough, it will begin to taste sweet—the result of amylase's work in breaking down starches into sugars. Saliva also contains lysozyme, an enzyme that fights infection by digesting the cell walls of many bacteria that may enter the mouth with food.

Once food is chewed, the combined actions of the tongue and throat muscles push the clump of food, called a bolus, down the throat. When you swallow, the bolus first enters the area at the back of the throat called the pharynx. As this occurs, a flap of connective tissue called the epiglottis closes over the opening to the trachea. This action prevents food from moving into the air passageways to the lungs as it passes through the pharynx and into the esophagus.

BUILD Vocabulary

WORD ORIGINS The prefix *amyl-* refers to starch and has both Greek (*amylon*) and Latin (*amylum*) origins. The suffix *-ase* is commonly used to indicate that a substance is an enzyme. **Amylase** is an enzyme that acts on starch.

In Your Notebook *Explain in your own words two protective functions of the mouth and throat.*

The Esophagus From the throat, the bolus passes through a tube called the **esophagus** into the stomach. You might think that gravity draws food down through the esophagus, but this is not correct. In fact, you can swallow quite well in zero gravity, as astronauts do, or even while standing on your head. The reason is that contractions of smooth muscles, known as **peristalsis** (pehr uh STAL sis), provide the force that moves food through the esophagus toward the stomach. Peristalsis in the esophagus is shown in **Figure 30–12.**

After food passes into the stomach, a thick ring of muscle called the cardiac sphincter closes the esophagus. This prevents the contents of the stomach from flowing back. Overeating or drinking excess caffeine can cause a backflow of stomach acid into the esophagus. The result is a burning sensation in the center of the chest known as heartburn. Despite its name, heartburn has nothing to do with the heart. Nonetheless, persistent heartburn can cause serious damage to the esophagus and is a reason to visit a doctor.

FIGURE 30–12 Peristalsis Muscles in the walls of the esophagus contract in waves. Each wave pushes the chewed clump of food, or bolus, in front of it. Eventually, the bolus is pushed into the stomach.

Chemical Digestion in the Stomach The **stomach** is a large muscular sac that continues the chemical and mechanical digestion of food. The lining of the stomach contains millions of microscopic gastric glands that release many substances into the stomach. Some of these glands produce hydrochloric acid. Other glands release an enzyme called pepsin that is activated in and functions best in acidic conditions. **Pepsin** breaks proteins into smaller polypeptide fragments.

Another stomach gland produces mucus, a fluid that lubricates and protects the stomach wall. If this protective layer fails, acids may erode the stomach lining and cause a sore called a peptic ulcer. For years, physicians thought that the primary cause of ulcers was too much stomach acid. They prescribed drugs that reduced symptoms but did not cure ulcers. Scientists have since discovered that most peptic ulcers are the result of infection with the bacterium *Helicobacter pylori.* Most peptic ulcers can now be cured with antibiotics that kill the bacteria.

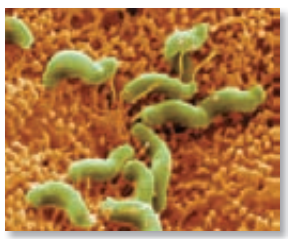

FIGURE 30–13 *Helicobacter pylori* After many years of blaming lifestyle factors for ulcers, researchers discovered that these bacteria are the cause. *H. pylori* burrow into the stomach wall and cause inflammation (SEM 6800×).

Mechanical Digestion in the Stomach Alternating contractions of the stomach's three smooth muscle layers thoroughly churn and mix the swallowed food. The churning causes further breakdown of the chunks of swallowed food and allows enzymes greater access to the food. Gradually, a mixture with an oatmeal-like consistency called **chyme** (KYM) is produced. After an hour or two, the pyloric valve, which is located between the stomach and small intestine, opens, and chyme begins to spurt into the small intestine.

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Quick Lab GUIDED INQUIRY

Modeling Bile Action

1. Add 10 mL of water and 2 drops of olive oil into two test tubes.
2. Add 3 mL of a 5 percent liquid soap solution to one test tube.
3. Stir the contents of both tubes. Record your observations.

Analyze and Conclude

1. Observe Describe the appearance of the liquid contents in both tubes.

2. Draw Conclusions Based on these observations, explain in your own words how bile aids fat digestion.

Digestion in the Small Intestine As chyme is pushed through the pyloric valve, it enters the duodenum (doo oh DEE num). The duodenum is the first part of the **small intestine,** and it is where almost all of the digestive enzymes enter the intestine. Most of the chemical digestion and absorption of the food you eat occurs in the small intestine. As chyme enters the duodenum from the stomach, it mixes with enzymes and digestive fluids from the pancreas, the liver, and even the lining of the duodenum itself. The pancreas and liver are shown in **Figure 30–15.**

▶ ***Pancreas*** Just behind the stomach is the pancreas, a gland that serves three important functions. One function is to produce hormones that regulate blood sugar levels. Within the digestive system, the pancreas has two other roles. It produces enzymes that break down carbohydrates, proteins, lipids, and nucleic acids. The pancreas also produces sodium bicarbonate, a base that quickly neutralizes stomach acid as chyme enters the duodenum. The enzymes produced by the pancreas, unlike those produced in the stomach, would be destroyed by strong acid, and therefore the sodium bicarbonate is necessary for digestion to proceed.

▶ ***The Liver and Gallbladder*** Assisting the pancreas in fat digestion is the liver. The liver produces bile, a fluid loaded with lipids and salts. Bile is stored in a small, pouchlike organ called the gallbladder. When fat is present in the duodenum, the gallbladder releases bile through a duct into the small intestine. Fats tend to glob together, which makes fat digestion by enzymes such as lipase difficult. Bile breaks up the globs of fat into smaller droplets that disperse in the watery environment of the small intestine. This action makes it possible for enzymes to reach the smaller fat droplets and break them down.

In Your Notebook *Summarize the two roles of the pancreas in fat digestion.*

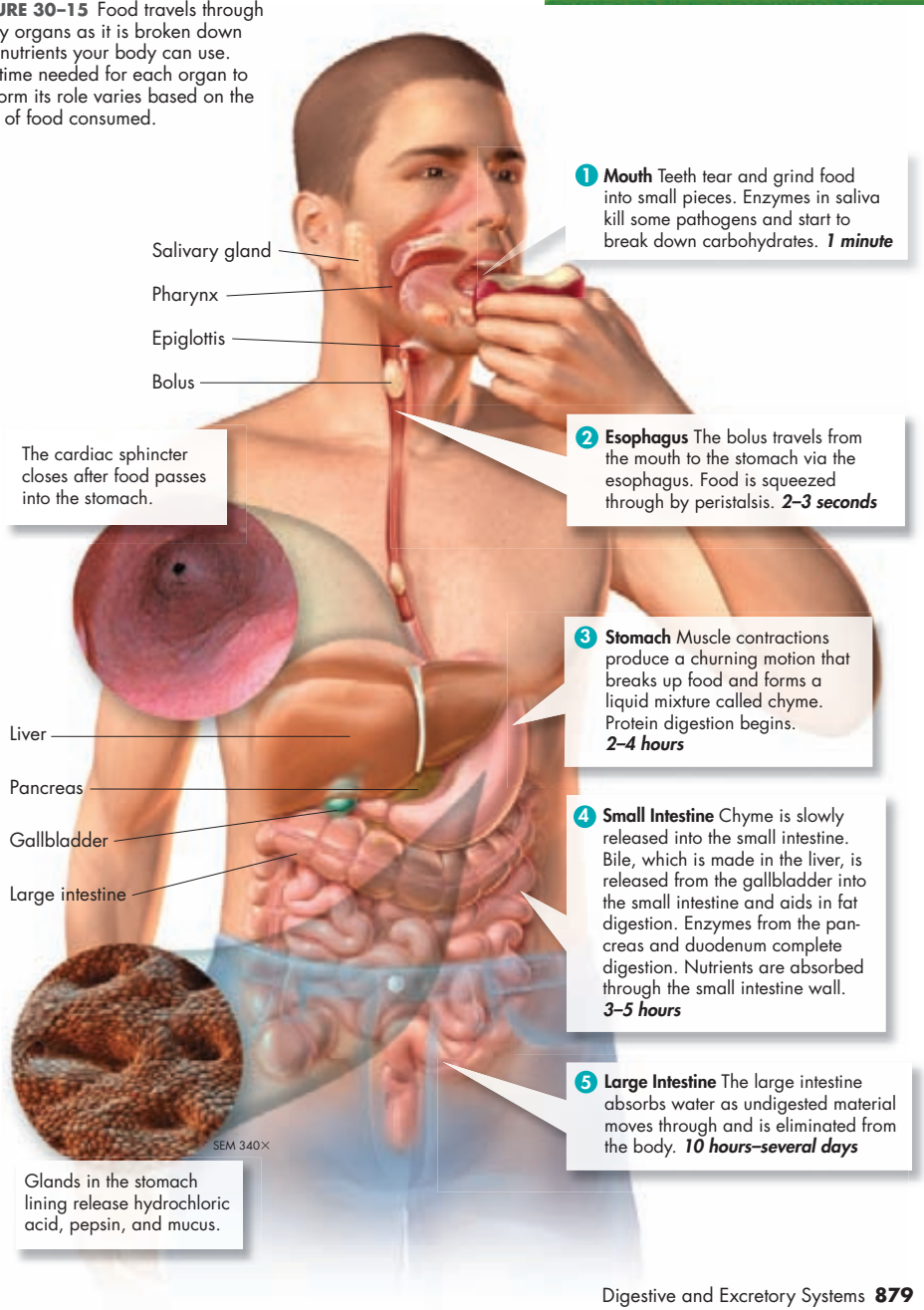
Effects of Digestive Enzymes

Active Site	Enzyme	Effect on Food
Mouth	Salivary amylase	Breaks down starches into disaccharides
Stomach	Pepsin	Breaks down proteins into large peptides
Small intestine (released from pancreas)	Pancreatic amylase	Continues the breakdown of starch
	Trypsin	Continues the breakdown of protein
	Lipase	Breaks down fat
Small intestine	Maltase, sucrase, lactase	Breaks down remaining disaccharides into monosaccharides
	Peptidase	Breaks down dipeptides into amino acids

FIGURE 30–14 Effects of Digestive Enzymes Digestive enzymes hasten the breakdown of foods and make nutrients available to the body. **Interpret Tables** ***Where in the body does the digestion of carbohydrates begin?***

THE DIGESTIVE SYSTEM

FIGURE 30–15 Food travels through many organs as it is broken down into nutrients your body can use. The time needed for each organ to perform its role varies based on the type of food consumed.



Absorption and Elimination

How are nutrients absorbed and wastes eliminated?

Once the small intestine has completed the digestive process, nutrients must be absorbed from the alimentary canal. **Most nutrients from food are absorbed through the walls of the small intestine. The large intestine absorbs water and several vitamins and prepares waste for elimination from the body.**

Absorption From the Small Intestine After leaving the duodenum, chyme moves along the rest of the small intestine. By this time, most of the chemical digestion has been completed. The chyme is now a rich mixture of small- and medium-sized nutrient molecules that are ready to be absorbed.

The small intestine is specially adapted for absorption of nutrients. Its folded surface and fingerlike projections provide an enormous surface area for absorption of nutrient molecules. The fingerlike projections, called **villi** (singular: villus), are covered with tiny projections known as microvilli. As slow, wavelike contractions move the chyme along the surface, microvilli absorb nutrients. **Figure 30–16** illustrates villi and microvilli.

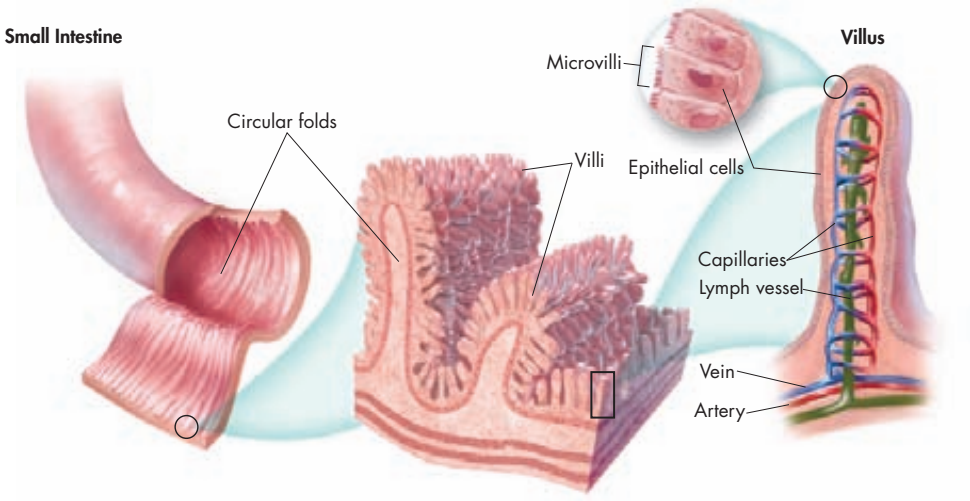
Nutrient molecules are rapidly absorbed into the cells lining the small intestine. Most of the products of carbohydrate and protein digestion are absorbed into the capillaries in the villi. Most fats and fatty acids are absorbed by lymph vessels.

By the time chyme is ready to leave the small intestine, it is basically nutrient-free. Complex organic molecules have been digested and absorbed, leaving only water, cellulose, and other undigestible substances behind.

ZOOMING IN

ABSORPTION IN THE SMALL INTESTINE

FIGURE 30–16 The lining of the small intestine consists of folds that are covered with tiny projections called villi. Within each villus there is a network of blood capillaries and lymph vessels that absorb and carry away nutrients.



As material leaves the small intestine and enters the large intestine, it passes by a small saclike organ called the appendix. In some mammals, the appendix processes cellulose and other materials. The only time humans notice their appendix is when it becomes clogged and inflamed, causing appendicitis. The remedy for appendicitis is to remove the infected organ by surgery—as quickly as possible—before it can rupture or break open.

Absorption From the Large Intestine When chyme leaves the small intestine, it enters the **large intestine,** or colon. The large intestine is actually much shorter than the small intestine. The large intestine gets its name due to its diameter, which is much greater than the small intestine's diameter. The primary function of the large intestine is to remove water from the undigested material that is left. Water is absorbed quickly across the wall of the large intestine, leaving behind the undigested materials. Rich colonies of bacteria present in the large intestine produce compounds that the body is able to absorb and use, including vitamin K. When large doses of antibiotics are given to fight an infection, they can destroy these bacteria, and vitamin K deficiency can occur.

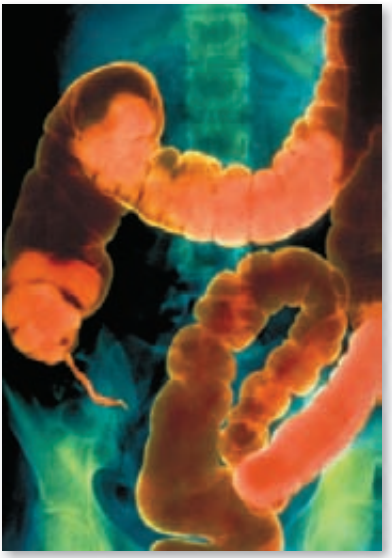


FIGURE 30–17 The Large Intestine This X-ray shows the large intestine and its contents.

Elimination The concentrated waste material—the feces—that remains after most of the water has been removed passes into the rectum and is eliminated from the body through the anus. When something happens that interferes with the removal of water by the large intestine, you usually become aware of it right away. If not enough water is absorbed, a condition known as diarrhea occurs. If too much water is absorbed from the undigested materials, a condition known as constipation occurs.

30.3 Assessment

Review Key Concepts

1. a. Review Explain the function of the digestive system.

b. Compare and Contrast What is the difference between mechanical digestion and chemical digestion?

2. a. Review List the structures that food travels through during digestion and give the function of each.

b. Relate Cause and Effect Some people have a disorder in which their stomach muscles cannot contract and churn food. What effect do you think this has on the length of time food stays in the stomach?

3. a. Review Explain how nutrients are absorbed.

b. Apply Concepts What impact do the folds and villi of the small intestine have on absorption?

Apply the Big idea

Matter and Energy

4. How would the rate of digestion be affected if the various organs and glands did not release enzymes? *Hint:* You may wish to refer to Chapter 2 for a review of enzyme action.

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30.4 The Excretory System

Key Questions

- ***What is the principal role of the structures of the excretory system?***
- ***How do the kidneys clean the blood?***
- ***How do the kidneys help maintain homeostasis?***

Vocabulary

excretion
ureter
urinary bladder
urethra
nephron
filtration
glomerulus
Bowman's capsule
reabsorption
loop of Henle

Taking Notes

Preview Visuals Examine **Figure 30–19.** What does this Figure reveal about the important functions of the kidneys?

THINK ABOUT IT It's a hot day, and you've been getting thirsty for hours. Finally, you get the chance to go inside, and you gulp down more than a liter of water. The water tastes great, but as you drink, you begin to wonder. Where's all that water going? Will it just dilute your blood, or is something in your body making sure that everything stays in balance?

Structures of the Excretory System

What is the principal role of the structures of the excretory system?

The chemistry of the human body is a marvelous thing. An intricate system of checks and balances controls everything from your blood pressure to your body temperature. Nutrients are absorbed, stored, and carefully released when they are needed. However, every living system, including the human body, produces chemical waste products, some of which are so toxic that they will cause death if they are not eliminated.

For example, as a normal consequence of being alive, every cell in the body produces waste compounds, including excess salts and carbon dioxide. Ammonia, one of the most toxic of these waste compounds, is produced when the amino acids from proteins are used for energy. Ammonia is converted to a less toxic compound called urea, but it, too, must be eliminated from the body. The process by which these metabolic wastes are eliminated to maintain homeostasis is called **excretion.** Excretion is one part of the many processes that maintain homeostasis.

The excretory system, which includes the skin, lungs, liver, and kidneys, excretes metabolic wastes from the body. The ureters, urinary bladder, and urethra are also involved in excretion. **Figure 30–18** shows the major organs of excretion.

In Your Notebook *Make a two-column table that lists the organs of excretion in the first column and their function in the second column.*

The Skin The skin excretes excess water, salts, and a small amount of urea in sweat. By releasing sweat in very small amounts, this process eliminates wastes even when you may not think you're sweating.

The Lungs The blood transports carbon dioxide, a waste product of cellular respiration, from the body cells to the lungs. When you exhale, your lungs excrete carbon dioxide and small amounts of water vapor.

The Liver The liver plays many important roles in excretion. As we have seen, one of its principal activities is the conversion of potentially dangerous nitrogen wastes, a product of protein breakdown, into less toxic urea. Urea, which is highly soluble, is then transported through the blood to the kidneys for elimination from the body.

The Kidneys The major organs of excretion are the kidneys, a pair of fist-sized organs located on either side of the spinal column near the lower back. Through a complex filtering process, the kidneys remove excess water, urea, and metabolic wastes from the blood. The kidneys produce and excrete a waste product known as urine. **Ureters** transport urine from the kidneys to the **urinary bladder,** where the urine is stored until it is released through the **urethra.**

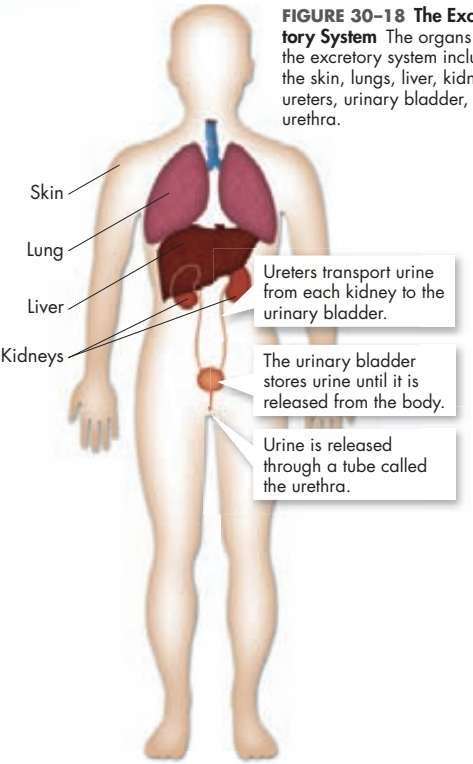


FIGURE 30–18 The Excretory System The organs of the excretory system include the skin, lungs, liver, kidneys, ureters, urinary bladder, and urethra.

Analyzing Data

The Composition of Urine

The kidneys are selective filters. As blood passes through them, urea, other impurities, and excess salts are removed from the blood. But important substances such as water, protein, and glucose remain in circulation. The collected waste products are excreted in urine. The concentrations of certain substances in the blood compared to their concentration in urine reveal the important work of the kidneys.

Concentrations of Selected Substances in Blood and Urine

Substance	Average Concentration in Blood (g/mL)	Average Concentration in Urine (g/mL)
Calcium	0.01	0.02
Glucose	0.10	0.00
Potassium	0.02	0.20
Sodium	0.32	0.60
Urea	0.03	2.00

1. Interpret Data Which substances listed have the highest and lowest concentrations in the blood? Which substances have the highest and lowest concentrations in the urine?

2. Calculate Approximately how many times more concentrated is urea in urine than in the blood? MATH

3. Infer Recall that urea is a byproduct of amino acid breakdown. How might the urea concentration vary in the blood and urine as the result of high protein diets? Explain.

Excretion and the Kidneys

How do the kidneys clean the blood?

What does a kidney do? **As waste-laden blood enters the kidney through the renal artery, the kidney removes urea, excess water and minerals, and other waste products.** The clean, filtered blood leaves the kidney through the renal vein and returns to circulation.

Each kidney contains nearly a million individual processing units called **nephrons.** These nephrons are where most of the work of the kidney takes place—impurities are filtered out, wastes are collected, and purified blood is returned to circulation. Blood purification in the kidneys is complex and involves two distinct processes: filtration and reabsorption.

BUILD Vocabulary

WORD ORIGINS The word **glomerulus** derives from the Latin words *glomus,* which means "ball of yarn," and *glomerare,* which means "to form into a ball." The twisted capillaries of a glomerulus resemble a ball of yarn.

Filtration Passing a liquid or gas through a filter to remove wastes is called **filtration.** The filtration of blood mainly takes place in the **glomerulus** (gloh MUR yoo lus). A glomerulus is a small but dense network of capillaries (very small blood vessels) encased in the upper end of each nephron by a hollow, cup-shaped structure called **Bowman's capsule.** A glomerulus is shown in **Figure 30–19.**

Because the blood is under pressure and the walls of the capillaries and Bowman's capsule are permeable, much of the fluid from the capillaries flows into Bowman's capsule. The material that is filtered from the blood is called the filtrate. The filtrate contains water, urea, glucose, salts, amino acids, and some vitamins. Large substances in the blood, such as proteins and blood cells, are too large to pass through the capillary walls.

Reabsorption Nearly 180 liters of filtrate pass from the blood into nephron tubules every day. That's the equivalent of 90 2-liter bottles of soft drink. Thank goodness, not all of those 180 liters are excreted. In fact, nearly all of the material that moves into Bowman's capsule makes its way back into the blood. The process by which water and dissolved substances are taken back into the blood is called **reabsorption.**

A number of materials, including salts, vitamins, amino acids, fats, and glucose, are removed from the filtrate by active transport and reabsorbed by the capillaries. Because water follows these materials by osmosis, almost 99 percent of the water that enters Bowman's capsule is actually reabsorbed into the blood. In effect, the kidney first throws away nearly everything and then takes back only what the body needs. This is how the kidney is able to remove drugs and toxic compounds from the blood—even chemicals the body has never seen before.

A section of the nephron tubule called the **loop of Henle** is responsible for conserving water and minimizing the volume of the filtrate. The waste material—now called urine—that remains in the tubule is emptied into a collecting duct.

Urine Excretion From the collecting ducts, urine flows to the ureter of each kidney. The ureters carry urine to the urinary bladder for storage until the urine leaves the body through the urethra.

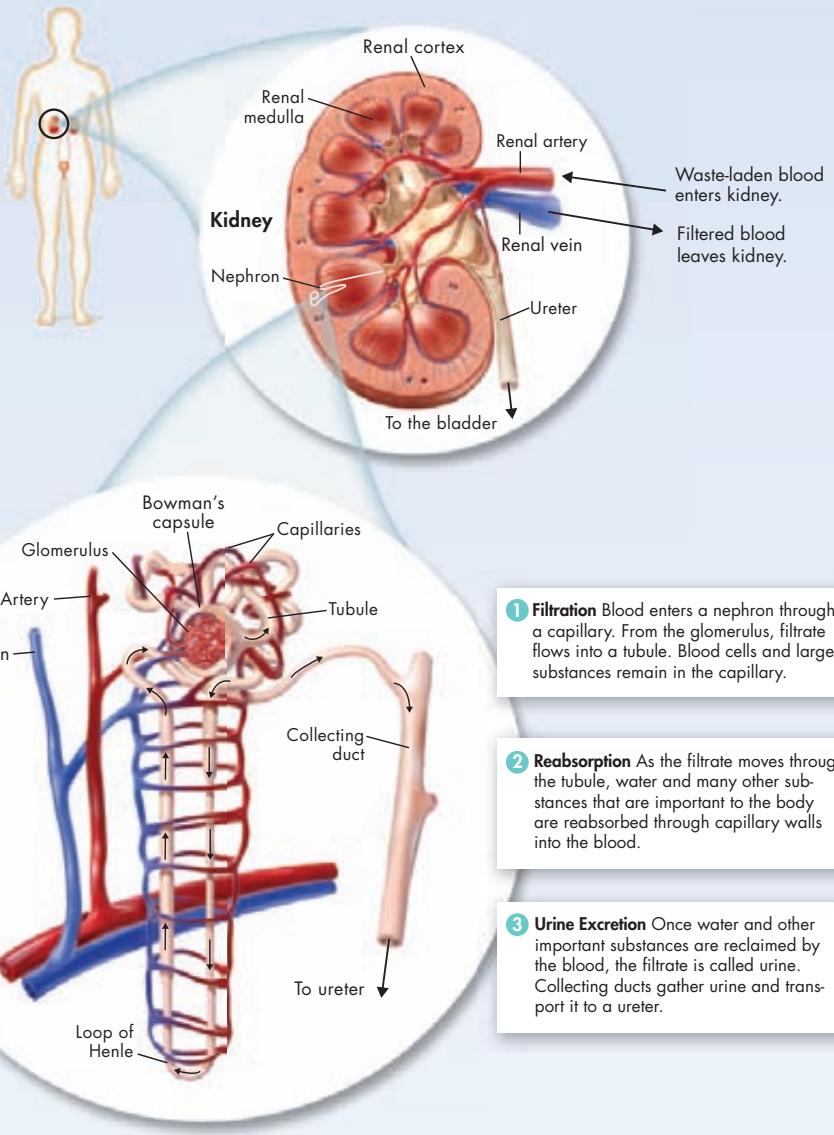
MYSTERY CLUE

The illegal drug taken by one of the athletes contained a synthetic compound never found in nature. How did his body remove the compound from his blood and eliminate it in urine?

ZOOMING IN

STRUCTURE AND FUNCTION OF THE KIDNEYS

FIGURE 30–19 Kidneys are made up of nephrons. Blood enters the nephron, where impurities are filtered out and emptied into the collecting duct. Purified blood leaves a nephron through a vein. **Interpret Visuals** ***List in order the structures that blood flows through in a kidney.***



1. **Filtration** Blood enters a nephron through a capillary. From the glomerulus, filtrate flows into a tubule. Blood cells and large substances remain in the capillary.

2. **Reabsorption** As the filtrate moves through the tubule, water and many other substances that are important to the body are reabsorbed through capillary walls into the blood.

3. **Urine Excretion** Once water and other important substances are reclaimed by the blood, the filtrate is called urine. Collecting ducts gather urine and transport it to a ureter.

The Kidneys and Homeostasis

How do the kidneys help maintain homeostasis?

The kidneys play an important role in maintaining homeostasis. Besides removing wastes, the kidneys also maintain blood pH and regulate the water content of the blood. **The kidneys respond directly to the composition of the blood. They are also influenced by the endocrine system. Disruption of proper kidney function can lead to serious health problems.**

Control of Kidney Function To a large extent, the activity of the kidneys is controlled by the composition of the blood itself. For example, if you eat salty food, the kidneys will respond to the excess salt in your blood by returning less salt to your blood during reabsorption. If the blood is too acidic, then the kidneys excrete more hydrogen ions in the urine. If your blood glucose levels rise past a certain point, the kidneys will even excrete glucose into the urine. This is one of the danger signals of diabetes, a disease caused by the body's inability to control the concentration of glucose in the blood.

Glands release hormones that also influence kidney function. For example, if you have not consumed enough fluids or if you have sweat excessively, your pituitary gland releases antidiuretic hormone (ADH) into your blood. This hormone causes the kidneys to reabsorb more water and to excrete less water in the urine. If the blood contains excess water, ADH secretion stops and more water is excreted.

Did you know that the color of your urine is an indicator of how hydrated you are? A pale yellow color indicates that you are well hydrated because your kidneys are releasing a good amount of water. A darker color indicates that the water level in your blood is low, causing your kidneys to conserve water.

MYSTERY CLUE

Would Seth's and Philip's blood contain a high level or low level of ADH?

Urine Testing Medical professionals can learn a lot about a person's health from a simple urine sample. The presence of protein or glucose in urine can be indicators of diseases such as dangerously high blood pressure or diabetes. Although many filtered substances are reabsorbed into the blood, drugs generally remain in the filtrate and are eliminated in urine. This is why the effects of many drugs wear off over time and why urine tests are often used to detect the use of illegal drugs.

In Your Notebook *Explain in your own words why urine can reveal a lot about a person's health.*

Kidney Disorders The kidneys are the master chemists of the blood supply. If anything goes wrong with the kidneys, serious medical problems will likely follow. Three of these problems are kidney stones, kidney damage, and kidney failure.

▶ ***Kidney Stones*** Sometimes substances such as calcium, magnesium, or uric acid salts in the urine crystallize and form kidney stones. When kidney stones block a ureter, they cause great pain. Kidney stones are often treated using ultrasound waves. The sound waves pulverize the stones into smaller fragments, which are eliminated with the urine.

▶ ***Kidney Damage*** Many diseases, injuries, and exposure to hazardous substances can lead to impaired kidney function. But most cases of kidney damage in the United States are related to high blood pressure and diabetes. Excessive blood pressure damages the delicate filtering mechanism, and high blood sugar levels cause the kidneys to filter more blood than normal. Over time, the tubules weaken, and the kidneys may fail to keep up with the demands placed upon them.

▶ ***Kidney Failure*** When kidneys can no longer cleanse the blood and maintain a state of homeostasis in the body, a person is said to be in kidney failure. A patient with kidney failure must receive dialysis or undergo a kidney transplant as shown in **Figure 30–20.**

During dialysis, a machine performs the role of the kidneys. The patient's blood is pumped through the machine, cleansed, and pumped back into the body. Although the procedure is painless, it is very time-consuming. Most patients receive dialysis treatments three times a week for about four hours each time. To prevent the buildup of fluid and harmful materials between treatments, patients must restrict their fluid intake and eat foods low in potassium, phosphorus, and salt.

In transplantation, a patient receives a kidney and ureter from a compatible donor. Fortunately for the donor, a person can survive with just one healthy kidney.

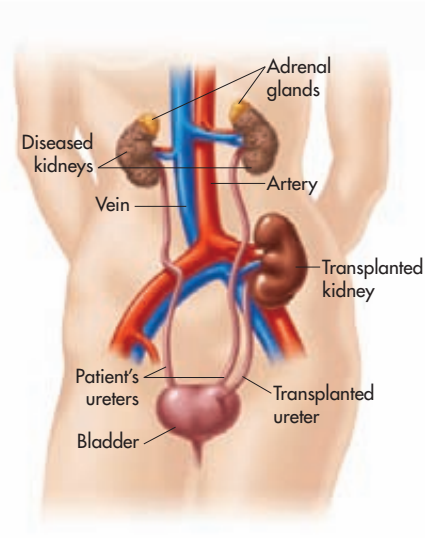


FIGURE 30–20 Kidney Transplantation Unless the patient's diseased kidneys are causing infection or high blood pressure, they are left in place when a healthy kidney and ureter are transplanted from a donor.

30.4 Assessment

Review Key Concepts

1. a. Review List the organs that are involved in excretion.

b. Classify Why is excretion important for homeostasis?

2. a. Review What substances do the kidneys remove from blood?

b. Sequence Explain what happens during filtration, reabsorption, and urine excretion.

3. a. Review Describe how the kidneys help maintain water balance.

b. Apply Concepts Why do you think protein and glucose in the urine are signs of kidney damage?

BUILD VOCABULARY

4. Two words that are often used interchangeably are *excretion* and *secretion*. They have two distinct meanings, however. An excretion is usually a waste product of metabolism that is expelled from an organism. A secretion is a useful substance that is released inside or outside an organism. Name one example each of an excretion and a secretion from this lesson.

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Pre-Lab: Digestion of Dairy Products

Problem How can an enzyme deficiency affect digestion?

Materials well plate, sheet of paper, glucose solution, milk, milk-digestion aid, toothpicks, glucose test strips

Lab Manual Chapter 30 Lab

Skills Focus Control Variables, Infer, Draw Conclusions

Connect to the Big idea Food is both a source of raw materials and a source of energy for your body. First the food must pass through your digestive system, where mechanical and chemical processes break the food down into smaller molecules. Enzymes play an essential role in chemical digestion. Different enzymes are needed to digest proteins, fats, and carbohydrates. In this lab, you will explore the role of enzymes in the digestion of milk and other dairy products.

Background Questions

a. **Review** What is an enzyme? Why are enzymes necessary for maintaining homeostasis?

b. **Review** Where do most digestive enzymes enter the digestive system?

c. **Compare and Contrast** Use glucose and sucrose to explain the difference between a monosaccharide and a disaccharide.

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Design an Experiment** What is the purpose of the glucose solution?
2. **Control Variables** What is the control in this lab?
3. **Communicate** Read the instructions on the package of glucose test strips. Then, briefly describe how you will test your samples for the presence of glucose.

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Visit Chapter 30 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hold your noses as you join the Untamed Science crew to learn what scientists can discover about animals by investigating their scat.

Data Analysis Use nutrient data to plan a lunch that meets your own personal requirements.

Tutor Tube Tune in to Tutor Tube for another perspective on how homeostasis works in the human body.

Art Review Review your understanding of human body systems.

Art in Motion Watch peristalsis in action in the esophagus.

30 Study Guide

Big idea Homeostasis

The foods you eat provide energy and materials to cells. Excretions contain the wastes produced as the result of cellular activities. Homeostasis requires an appropriate balance of these inputs and outputs.

30.1 Organization of the Human Body

The levels of organization in the body include cells, tissues, organs, and organ systems.

Homeostasis describes the relatively constant internal physical and chemical conditions that organisms maintain despite changes in internal and external environments.

epithelial tissue (863)
connective tissue (863)
nervous tissue (863)
muscle tissue (863)
homeostasis (865)
feedback inhibition (865)

30.2 Food and Nutrition

Molecules in food contain chemical energy that cells use to produce ATP. Food also supplies raw materials your body needs to build and repair tissues.

The nutrients that the body needs include water, carbohydrates, fats, proteins, vitamins, and minerals.

A balanced diet provides nutrients in adequate amounts and enough energy for a person to maintain a healthful weight.

Calorie (868)
carbohydrate (869)
fat (870)
protein (870)
vitamin (871)
mineral (872)

30.3 The Digestive System

The digestive system converts food into small molecules that can be used by the cells of the body. Food is processed by the digestive system in four phases—ingestion, digestion, absorption, and elimination.

During digestion, food travels through the mouth, esophagus, stomach, and small intestine. Mechanical digestion and chemical digestion are the two processes by which food is reduced to molecules that can be absorbed.

Most nutrients from food are absorbed through the walls of the small intestine. The large intestine absorbs water and several vitamins and prepares waste for elimination from the body.

mechanical digestion (875)
chemical digestion (875)
amylase (876)
esophagus (877)
peristalsis (877)
stomach (877)
pepsin (877)
chyme (877)
small intestine (878)
villus (880)
large intestine (881)

30.4 The Excretory System

The excretory system, which includes the skin, lungs, liver, and kidneys, excretes metabolic wastes from the body.

As waste-laden blood enters the kidney through the renal artery, the kidney removes urea, excess water and minerals, and other waste products.

The kidneys respond directly to the composition of the blood. They are also influenced by the endocrine system. Disruption of proper kidney function can lead to serious health problems.

excretion (882)
ureter (883)
urinary bladder (883)
urethra (883)
nephron (884)
filtration (884)
glomerulus (884)
Bowman's capsule (884)
reabsorption (884)
loop of Henle (884)

Visual Thinking

Create a flowchart that shows the path of a glucose molecule through a healthy nephron.

30 Assessment

30.1 Organization of the Human Body

Understand Key Concepts

1. The type of tissue that covers the body, lines internal surfaces, and forms glands is
   a. muscle tissue. **c.** epithelial tissue.
   b. connective tissue. **d.** nervous tissue.

2. The process of maintaining a relatively constant internal environment despite changes in the external environment is called
   a. regulation. **c.** synapse.
   b. homeostasis. **d.** stimulation.

3. What do all types of tissue have in common?
   a. They are all made of connective tissue.
   b. They are all made of cells.
   c. They are all found in every organ.
   d. They are all made of organs.

4. Why is it important for an organism to maintain homeostasis?

5. Name the four types of tissues and describe one characteristic of each.

Think Critically

6. **Classify** Would you classify blood as a cell, a tissue, or an organ? Explain.

7. **Predict** Infections may lead to an immune response that results in a high fever. Considering what you have learned about the action of enzymes, predict what may happen if a person's body temperature remains abnormally high.

30.2 Food and Nutrition

Understand Key Concepts

8. Energy in food is measured in
   a. ATP. **c.** Calories.
   b. fats. **d.** disaccharides.

9. Inorganic nutrients that your body needs, usually in small amounts, are called
   a. vitamins. **c.** proteins.
   b. minerals. **d.** amino acids.

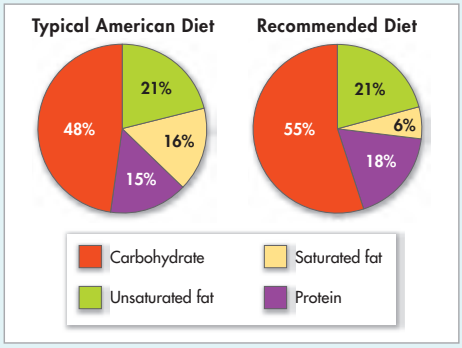
10. Which nutrients provide the body with energy?

11. In what three ways are proteins important to the body?

Think Critically

12. **Infer** Many food manufacturers have replaced trans fats in their foods with other types of fats that may not have the same level of heart disease risk. Some nutritionists fear that people will think foods such as French fries, doughnuts, and cookies are healthful if they are not made with trans fats. Explain why these foods are still not healthful choices.

13. **Calculate** If a person consumed 2000 Calories while following the typical diet, how many more of those Calories would be from saturated fat than if they were following the recommended diet? MATH



a. 320 **c.** 120
b. 200 **d.** 100

30.3 The Digestive System

Understand Key Concepts

14. Where does mechanical digestion begin?
   a. the esophagus
   b. the large intestine
   c. the mouth
   d. the small intestine

15. An enzyme in saliva that can break the chemical bonds in starch is
   a. pepsin. **c.** amylase.
   b. bile. **d.** chyme.

16. Explain why swallowed food does not normally enter the airway leading to the lungs.
17. What is the importance of enzymes during digestion?
18. Describe the functions of the pancreas.
19. How is the structure of the villi adapted to their function?

Think Critically

20. **Infer** Individuals who have had part, or even all, of their stomachs removed can survive if fed predigested food. Could these individuals also survive without a small intestine? Explain.
21. **Predict** Suppose that your doctor prescribed an antibiotic that killed all the bacteria in your body. What effect would this have on your digestive system?

30.4 The Excretory System

Understand Key Concepts

22. Which of the following is the basic functional unit in a kidney?
    a. nephron.
    b. glomerulus.
    c. Bowman's capsule.
    d. loop of Henle.
23. Urine is excreted from the body through the
    a. ureter.
    b. urinary bladder.
    c. urethra.
    d. renal vein.
24. What is the role of the skin in excretion?
25. What materials are filtered from blood in the kidney? What materials do not leave the bloodstream?
26. How is the water-regulating activity of the kidney controlled?

Think Critically

27. **Apply Concepts** Explain why kidney failure can be a fatal condition.
28. **Infer** When there is too much fluid in the blood, the heart must pump harder. Diuretics are substances that stimulate the kidneys to remove more fluid from the body. Why do you think diuretics are used to treat high blood pressure?

solve the CHAPTER MYSTERY

THE TELLTALE SAMPLE

For centuries, people have used urine for clues to health and disease. The Greeks, for example, knew that diabetics had excessive sugar in their urine and called the disease *diabetes mellitus*. Mellitus is the Greek word for honey.

- **Physical Examination** During this step, the color and clarity are examined. The shade of yellow indicates the amount of water being released by the kidneys. Urine of a color other than yellow could indicate the presence of blood. Or, it could simply indicate someone has eaten a lot of beets. Urine should be clear, rather than cloudy.
- **Microscopic Examination** The presence of mucus, white blood cells, or microorganisms in urine indicates a probable infection. Cloudy urine may also be caused by crystals, which could indicate kidney stones or a metabolic problem.
- **Chemical Examination** Hundreds of chemical tests can be performed on urine. Chemical dipsticks are used that change color in the presence of other chemicals. These tests can reveal a lot about kidney function, liver function, and overall homeostasis in the body.

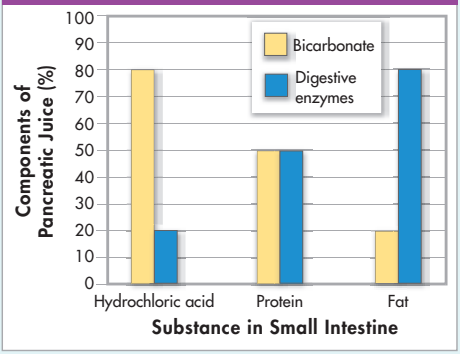
1. **Infer** How does urine reveal so much about the health of the human body?
2. **Form an Opinion** Most drug urine tests performed for schools do not test for alcohol or tobacco. Why do you think this is the case? Do you agree or disagree? Explain.
3. **Connect to the Big idea** Ketones are a product of the breakdown of fat for energy. Ketones in the urine can be an indication of diabetes. Why do you think this is?

Connecting Concepts

Use Science Graphics

Pancreatic secretions contain sodium bicarbonate and enzymes. The graph shows the secretions of the pancreas in response to three different substances in chyme. Use the graph to answer questions 29 and 30.

Pancreatic Secretions



29. Interpret Graphs Each pair of bars represents the response of the pancreas to a different variable. What are the three variables?

30. Analyze Data Compare the composition of pancreatic secretions in the presence of hydrochloric acid and fat.

Write About Science

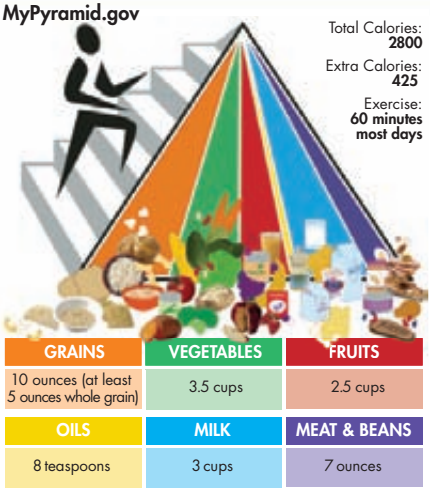
31. Creative Writing A children's television workshop wants to explain the process of digestion to young viewers. You are asked to write a script that describes the travels of a hamburger and bun through the digestive system. Write an outline of your script, including information about what happens to the different nutrients in each part of the digestive system.

32. Assess the Big idea Using **Figure 30–2,** choose five body systems that are involved in maintaining homeostasis in your body as you answer these assessment questions. Explain how these five body systems work together.

Analyzing Data

MyPyramid classifies food into six categories: grains, vegetables, fruits, milk, meat and beans, and oils. Personalized eating plans can be found at mypyramid.gov. This pyramid contains daily recommendations for Ryan, a 15-year-old male who weighs 140 pounds, is 5 feet 7 inches tall, and is physically active about 30 to 60 minutes a day.

MyPyramid.gov



33. Predict If Ryan were to become less active, what would happen to the number of extra Calories he could consume? Explain.

34. Infer For Ryan to meet his grain requirements, which group of foods would be his BEST choice in a single day?

a. sweetened cereal, pasta, white bread
b. whole-grain bagel, a doughnut, and pasta
c. whole-grain cereal, potato chips, and whole-grain bread
d. oatmeal, whole-grain bread, and a sweet potato

Standardized Test Prep

Multiple Choice

1. Which of the following is NOT a kind of tissue in the human body?
- **A** epithelial
- **B** connective
- **C** interstitial
- **D** nervous

2. Each of the following aids in the process of digestion EXCEPT the
- **A** teeth.
- **B** saliva.
- **C** stomach.
- **D** kidney.

3. In the human body, hydrochloric acid is responsible for the low pH of the contents of the
- **A** kidney.
- **B** gallbladder.
- **C** stomach.
- **D** liver.

4. Which is NOT a function of the kidneys?
- **A** removal of waste products from the blood
- **B** maintenance of blood pH
- **C** regulation of water content of the blood
- **D** excretion of carbon dioxide

5. The main function of the digestive system is to
- **A** break down large molecules into smaller molecules.
- **B** excrete oxygen and carbon dioxide.
- **C** synthesize minerals and vitamins needed for a healthy body.
- **D** remove waste products from the blood.

6. In the kidneys, both useful substances and wastes are removed from the blood by
- **A** reabsorption.
- **B** excretion.
- **C** dialysis.
- **D** filtration.

7. Which of the following is NOT a role of fats in the body?
- **A** Deposits of fat act as insulation.
- **B** They are components of cell membranes.
- **C** They help with absorption of fat-soluble vitamins.
- **D** They are hormones and enzymes.

Questions 8–9

A student is studying the effect of temperature on the action of an enzyme in stomach fluid. The enzyme digests protein. An investigation was set up using five identical test tubes. Each tube contained 40 mL of stomach fluid and 20 mm of glass tubing filled with gelatin. Each tube was subjected to a different temperature. After 48 hours, the amount of gelatin digested in each tube was measured in millimeters. The results for the five test tubes are shown in the table.

Effect of Temperature on Enzyme Action

Test Tube	Temperature (°C)	Amount of Digestion After 48 Hours
1	2	0.0 mm
2	10	3.0 mm
3	22	4.5 mm
4	37	8.0 mm
5	100	0.0 mm

8. Which is the manipulated (independent) variable in this investigation?
- **A** gastric fluid
- **B** length of glass tubing
- **C** temperature
- **D** time

9. Another test tube was set up that was identical to the other test tubes and placed at a temperature of 15°C for 48 hours. What amount of digestion would you expect to occur in this test tube?
- **A** less than 3.0 mm
- **B** between 3.0 mm and 4.5 mm
- **C** between 4.5 mm and 8.0 mm
- **D** more than 8.0 mm

Open-Ended Question

10. Fad diets that boast of rapid weight loss often become popular. Many of these diets involve eating only a limited variety of foods. Explain why these diets are an unhealthful way to lose weight.

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10
See Lesson	30.1	30.3	30.3	30.4	30.3	30.4	30.2	30.3	30.3	30.2