CHAPTER 27 The Human Body

27.1 Organization of the Human Body

27.2 Human Systems I

27.3 Human Systems II

27.4 Immunity and Disease

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The human body is made up of complex systems that interact with each other to maintain homeostasis.

HS-LS1-2, HS-LS1-3, HS-ETS1-1, HS-ETS1-3

CASE STUDY

What's wrong with the water?

Public water systems that produce plenty of clean, healthful drinking water have always been one of the hallmarks of progress in developed societies, and America is no exception. Recently, however, many parts of the country have realized that their water systems are no longer as safe as they should be.

In 2014, the people of Flint, Michigan, began to notice disturbing changes in the appearance, the taste, and even the smell of their tap water. The water had become discolored and at times had a rancid odor. Testing revealed that the water had been contaminated by a number of dangerous chemicals, including lead. In one home, the drinking water had a lead level of more than 13,000 ppb (parts per billion). Water with a lead level greater than 5000 ppb is actually classified as hazardous waste!

The likely cause of the contamination was a change in the source of the water pumped into the system. The new water leached lead out of many of the old pipes used in the water supply system. Lead was once commonly used in pipes, as well as in paint, gasoline, and other materials. However, due to lead's negative health effects, especially in young children, it can no longer be used in these products.

Unfortunately, other communities across the country are suffering from similar problems. Water can be polluted from fertilizers and pesticides, from industrial chemicals, and from spilled oil. In some towns in rural Kentucky, the water has been unsafe for decades. When residents take a bath or shower with tap water, their skin burns or develops rashes. Coal mining is a leading cause of the problem. Among the byproducts of mining are metals such as arsenic, lead, and nickel, all of which are harmful to human health.

As these troubles demonstrate, the human body depends on the natural environment to work in peak condition and stay healthy. The body depends on clean air to breathe, clean water to drink, and nutritious food to eat. Polluted air can lead to diseases of the lungs and respiratory system, as can the use of tobacco products. A poor diet can lead to unhealthful weight loss or weight gain, as well as to diabetes and heart disease. When the environment contains toxic materials such as lead, chances are high that the toxins will enter the body, too.

How do the systems of the human body work together to keep the body functioning and healthy? How does the body defend itself from bacteria and other agents that can cause harm? If an illness does strike, how does the body recover from it?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 27.1

Organization of the Human Body

KEY QUESTIONS

- *How is the human body organized?*
- *What is homeostasis?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

VOCABULARY
epithelial tissue
connective tissue
nervous tissue
muscle tissue
homeostasis
feedback inhibition

READING TOOL

As you read, identify the main idea and supporting details under each main heading. Complete the table in your **Biology Foundations Workbook.**

The batter slaps a ground ball to the shortstop, who fields it cleanly and throws the ball toward you at 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 worked together to make this "routine" play.

Organization of the Body

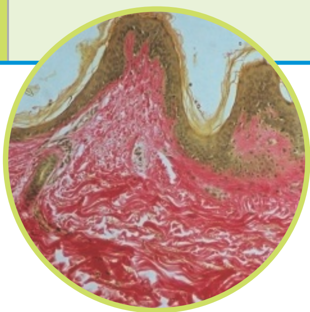
Every cell in the human body is both an independent unit and a part of a larger community—the entire organism. To complete a successful play, a player at first base has to use her eyes to watch the ball and use her brain to figure out how to position her body. With the support of her bones, muscles move 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 earlier, 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. **Figure 27-1** shows examples of each of the four basic types of tissues in the human body.

	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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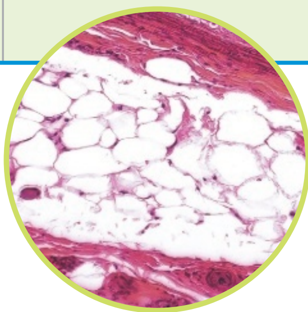

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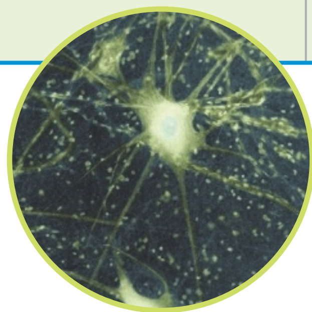

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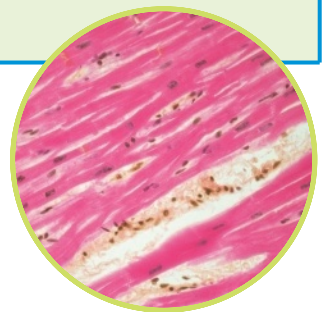

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Figure 27-1

Types of Tissues

The four major types of tissues in the human body are epithelial tissue, connective tissue, nervous tissue, and muscle 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 fiberlike protein that gives tissues strength and resiliency.

Nervous Tissue Nerve impulses are transmitted throughout the body by **nervous tissue**. Neurons, the cells that carry these impulses, are 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 in **Figure 27-2**.

INTERACTIVITY

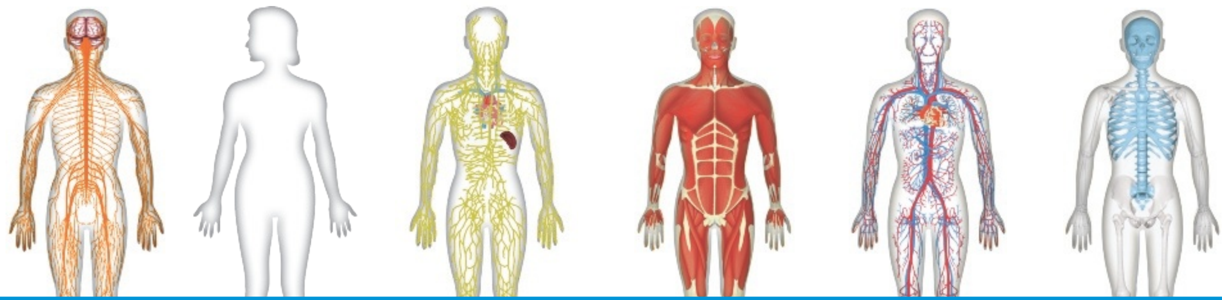
Investigate the organization of the human body.

Visual Summary

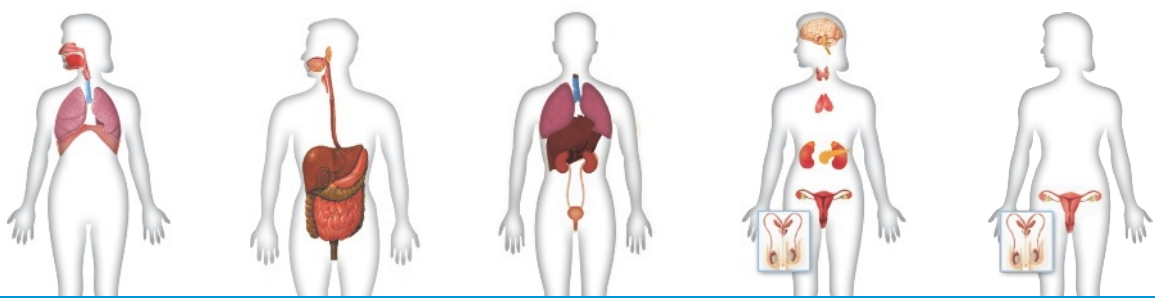
Figure 27-2

Human Body Systems

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

Some things about human activity are easy to observe. When you run or swim or write the answer to a test question, you can see your body at work. But behind the scenes, your body works constantly to do something that is difficult to see—maintaining a controlled, stable internal environment. This process is called **homeostasis**, which means "keeping things the same." ***Homeostasis describes the relatively constant internal conditions that organisms maintain despite changes in internal and external environments.*** Homeostasis may not be obvious, but for a living organism, it's a matter of life or death.

BUILD VOCABULARY

Root Words The root word *stasis* means "a state of balance or equilibrium."

Feedback Inhibition

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

VIDEO

Learn how feedback inhibition is used to return the body to its normal, homeostatic state.

A Nonliving Example One way to understand homeostasis is to look at a nonliving system that keeps conditions within a certain range, such as a home heating system. In many homes, heat is supplied by a furnace. 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 example is 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 27-3** 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.

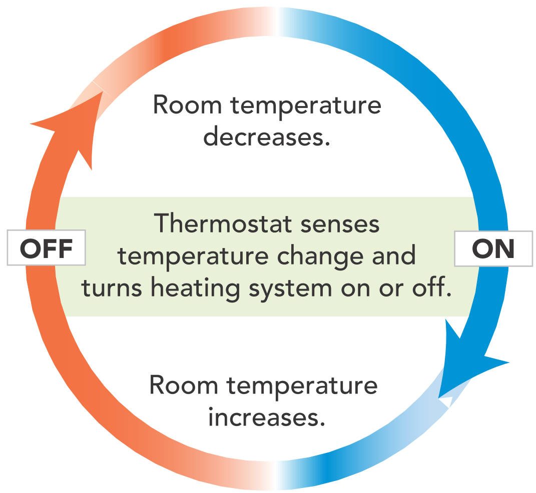
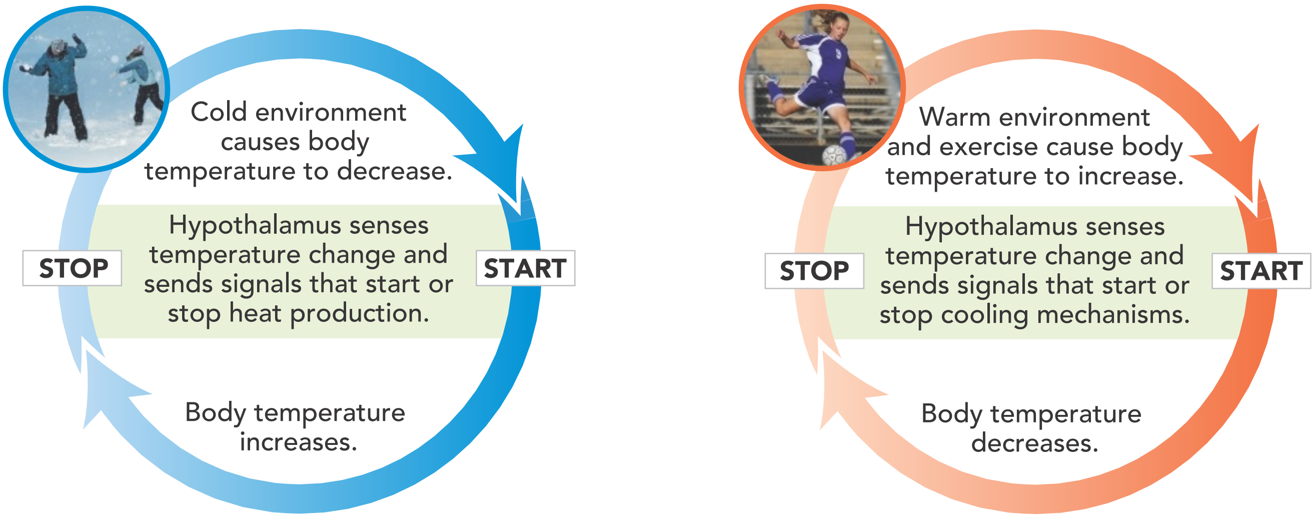


Figure 27-3

Feedback Inhibition

A home heating system uses a feedback loop to maintain a stable, comfortable environment within a house.

READING CHECK **Apply Concepts** Describe another example of a nonliving system that requires constant adjustment.



INTERACTIVITY

Figure 27-4

Body Temperature Control

In the human body, temperature is controlled through various feedback inhibition mechanisms.

A Living Example Could biological systems achieve homeostasis through feedback inhibition? Absolutely. One example is the maintenance of body temperature. **Figure 27-4** shows how the body regulates temperature in a way similar to that of a home heating system.

A part of the brain called the hypothalamus contains nerve cells that monitor body temperature. 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 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.

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.

HS-LS1-2

Quick Lab **Guided Inquiry**

How Do You Respond to an External Stimulus?

1. Have your partner put on safety goggles.
2. Crumple up a sheet of scrap paper into a ball.
3. Watch your partner's eyes carefully as you toss the paper ball toward his or her face.
4. Repeat step 3, three times.
5. Exchange roles and repeat steps 1, 3, and 4.

ANALYZE AND CONCLUDE

1. **Observe** Describe your partner's reaction to step 3.
2. **Compare and Contrast** Did you see any change in behavior as you repeated step 3? Explain.
3. **Infer** What is the function of the blink reflex?
4. **Develop Models** Draw a model to show how different systems of the body interacted.

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, 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 discover 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 blood 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 the failure of homeostasis with respect to blood glucose levels.

READING TOOL

Draw a diagram or flowchart to show how the liver helps control blood glucose levels, both when blood glucose is too low and when it is too high.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 27.1 Review

KEY QUESTIONS

1. Describe the relationship among cells, tissues, organs, and organ systems in the human body.
2. What is homeostasis? Describe an example of how the body maintains homeostasis.

CRITICAL THINKING

3. **Infer** After a large meal, blood glucose levels increase only moderately. Describe an action of the body that helps keep glucose levels within tolerable limits.
4. **Construct an Explanation** How does feedback inhibition help the body maintain homeostasis?
5. **Synthesize Information** Describe how a person uses many organ systems to accomplish a simple task such as brushing his or her teeth.

LESSON 27.2

Human Systems I

KEY QUESTION

- *What are the structures and functions of the digestive system, excretory system, circulatory system, lymphatic system, and respiratory system?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

READING TOOL

Complete the chart in your **Biology Foundations Workbook** to show the sequence of events in which food is digested.

Imagine a luscious peach, so perfectly ripe that you can smell its sweetness even as you bring it up to your mouth for the first delicious bite. The fuzz tickles your lips as you sink your teeth into the fruit. You savor the tangy sweetness as you chew and then swallow. It doesn't get much better than this! And you take another bite. What's your favorite food? Whether you're a fan of fruit or pizza, the food you eat becomes fuel and materials for your body.

The Digestive System

The need for food presents every animal with at least two challenges—how to obtain it and how to convert that food into molecules the body can use. 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.***

Digestion The first step in the process is ingestion, the act of putting food into your mouth. Food in the digestive system 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. During chemical digestion, enzymes break down food molecules. **Figure 27-5** summarizes the process of digestion.

Mechanical digestion occurs in your mouth as your teeth break up and grind your food. Chemical digestion occurs as enzymes in saliva start to break down carbohydrates. Once you swallow, that clump of food, now called a *bolus*, travels down the esophagus to your stomach, where more mechanical and chemical digestion occur. Muscles in the stomach wall cause a churning motion. Meanwhile, enzymes and hydrochloric acid continue the chemical breakdown of food. Chemical digestion is completed in the small intestine. Now the food is reduced to molecules that can be absorbed.

VIDEO

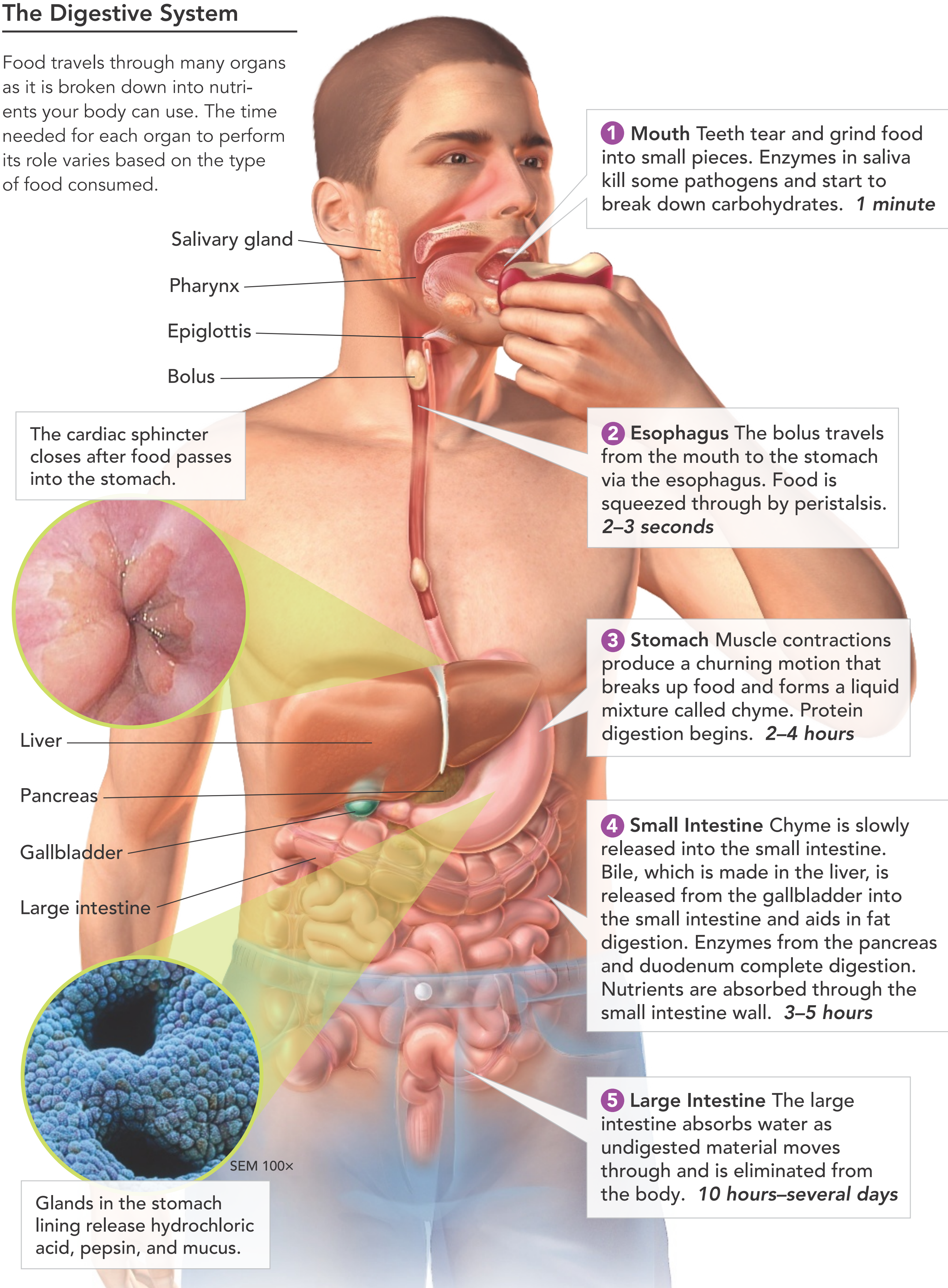
Learn how geography can be an advantage or a disadvantage for athletes.

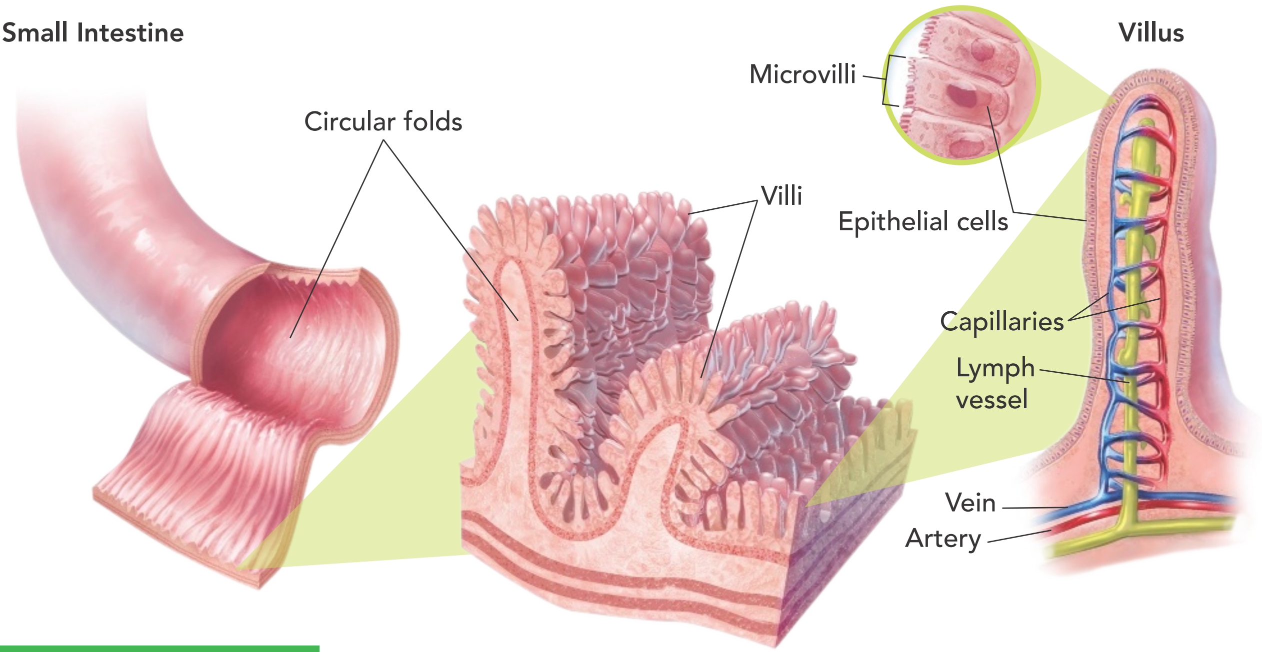
Visual Summary

Figure 27-5

The Digestive System

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.





Up Close

Figure 27-6

Absorption in the Small Intestine

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.

Absorption From the Small Intestine After leaving the first section of the small intestine, called 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. The small intestine's folded surface provides a large surface area for absorption. Its finger-like projections, called villi (singular: villus), are covered with tiny projections known as microvilli, which absorb the nutrients. **Figure 27-6** illustrates villi and microvilli.

Nutrient molecules then pass into the circulatory system. Sugars and amino acids go into capillaries, while most fats and fatty acids are absorbed by lymph vessels. By the time chyme leaves the small intestine, most nutrients have been absorbed, leaving only water, cellulose, and other indigestible substances behind.

Absorption and Elimination Chyme next 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. The primary function of the large intestine is to remove water from the material that is left. Bacteria in the large intestine break down some of the indigestible substances in the chyme and then produce compounds that the body is able to absorb and use, including vitamin K.

The concentrated waste material, called feces, forms after most of the water has been removed. Feces passes into the rectum and is eliminated from the body through the anus. You usually become aware of any problems with water removal in the large intestine. Diarrhea occurs when not enough water is absorbed, while constipation is the result of too much water absorption.

READING CHECK **Interpret Diagrams** How do the circular folds in the small intestine allow for more surface area for digestion?

The Excretory System

The chemistry of the human body is a marvelous thing. However, every living thing produces chemical waste products, some of which are toxic and must be expelled from the system. Ammonia, one of the most toxic of these waste compounds, is produced when 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 is called excretion.

The excretory system includes the skin, lungs, liver, and kidneys. This system excretes metabolic wastes from the body. The ureters, urinary bladder, and urethra are also involved in excretion. **Figure 27-7** shows the major organs of excretion.

BUILD VOCABULARY

Prefixes The Latin prefix *ex-* means "out." The process of moving wastes *out* of the body is excretion. When you exhale, or breathe out, you excrete the waste product carbon dioxide.

Skin

Many excretory organs are part of other body systems as well. The skin removes 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.

Lungs

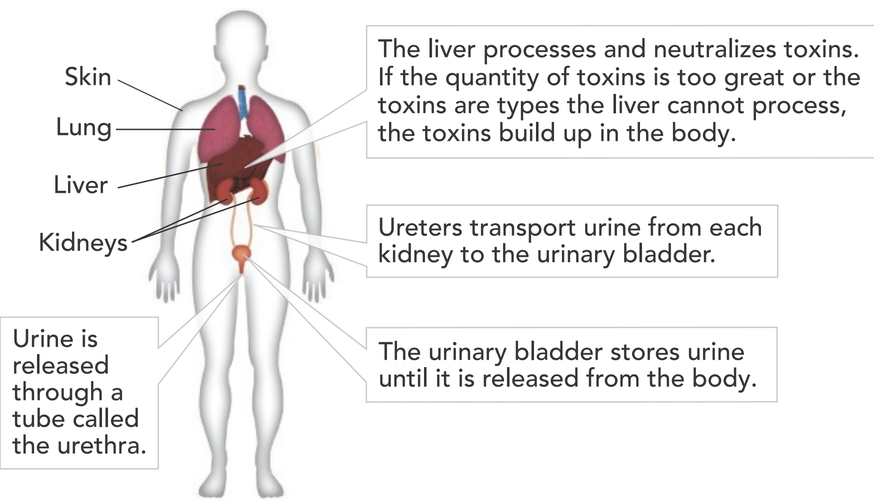
The blood transports carbon dioxide, a waste product of cellular respiration, from the body cells to the lungs. When you exhale, your lungs excrete carbon dioxide and small amounts of water vapor.

Liver

The liver plays many important roles in excretion. One of its principal activities is to convert dangerous nitrogen-based wastes into urea, which is a less toxic compound. Urea is then transported through the blood to the kidneys for elimination from the body.

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. 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 urine is stored until it is released through the urethra.

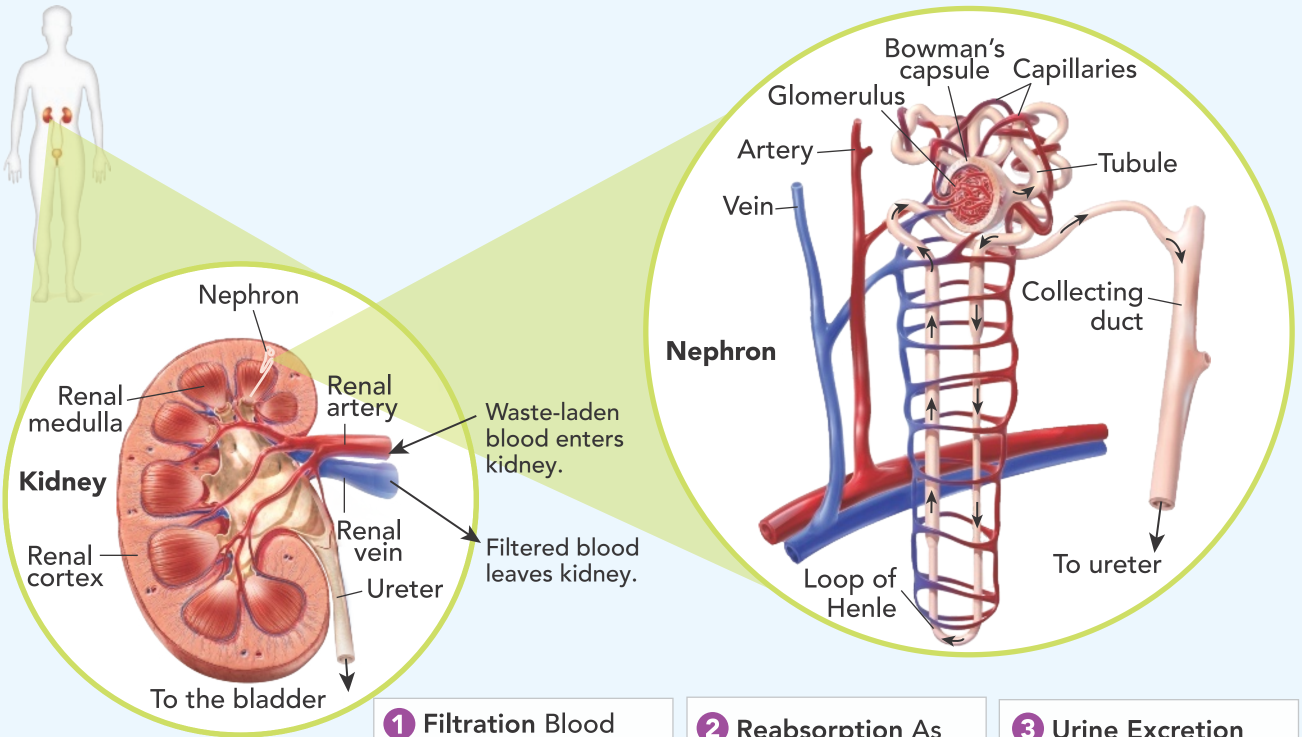


CASE STUDY

Figure 27-7

The Excretory System

The excretory system removes metabolic wastes and can also neutralize some toxins.



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.

Up Close

Figure 27-8

Structure and Function of the Kidneys

Kidneys are made up of nephrons. Blood enters a nephron, where impurities are filtered out and emptied into the collecting duct. Purified blood leaves a nephron through a vein.

To a large extent, the activity of the kidneys is controlled by the composition of the blood itself. **Figure 27-8** summarizes how the kidneys function. The kidneys respond directly to the composition of the blood. They are also influenced by the endocrine system. 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 signs of diabetes, a disease caused by the body's inability to control the concentration of glucose in the blood.

Endocrine glands release hormones that also influence kidney function. For example, if the amount of water in your blood drops, the pituitary gland releases antidiuretic hormone (ADH) into the blood. This 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.

READING CHECK **Identify** What role do the lungs play in removing waste from the body?

The Circulatory System

Some animals are so small that all of their cells are in direct contact with the environment. Diffusion and active transport across cell membranes supply their cells with oxygen and nutrients and remove waste products. The human body, however, contains billions of cells that are not in direct contact with the external environment. Because of this, humans need a circulatory system. ***The circulatory system transports oxygen, nutrients, and other substances throughout the body, and it removes wastes from tissues.***

Blood is pumped through the body by the heart. An adult's heart contracts on average 72 times a minute, pumping about 70 milliliters of blood with each contraction. As **Figure 27-9** shows, the heart is divided into four chambers. A wall called the septum separates the right side of the heart from the left side. The septum prevents oxygen-poor and oxygen-rich blood from mixing. On each side of the septum is an upper and lower chamber. Each upper chamber, or atrium (plural: atria), receives blood from the body. Each lower chamber, or ventricle, pumps blood out of the heart.

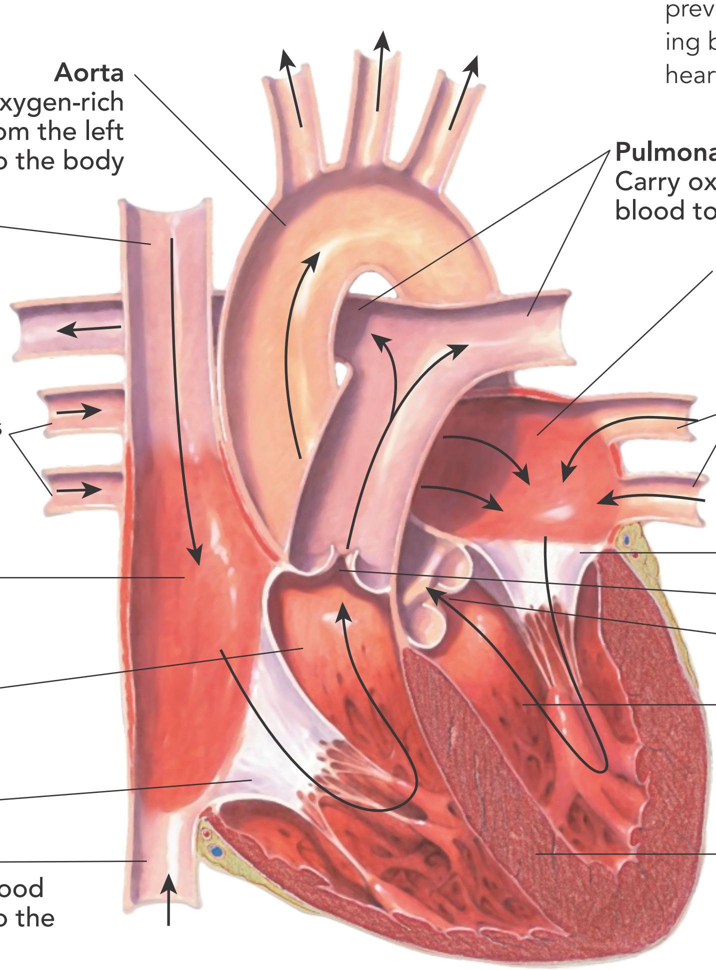
READING TOOL

Before you read this section, preview the diagrams associated with the circulatory system. Write down any questions that you have.

Figure 27-9

The Heart

Valves located between the atria and ventricles and between the ventricles and vessels leaving the heart prevent blood from flowing backward between heartbeats.



INTERACTIVITY

Explore the digestive, excretory, and circulatory systems.

Circulation

Circulation The heart functions as two pumps. As shown in **Figure 27-10**, one pump pushes blood to the lungs, while the other pump pushes blood to the rest of the body.

The right side of the heart pumps oxygen-poor blood from the heart to the lungs through the pulmonary circulation. In the lungs, carbon dioxide diffuses from the blood, and oxygen is absorbed into the blood. Oxygen-rich blood then flows to the left side of the heart.

The left side of the heart pumps oxygen-rich blood to the rest of the body through the systemic circulation. Cells absorb the oxygen that they need and load the blood with carbon dioxide by the time it returns to the heart.

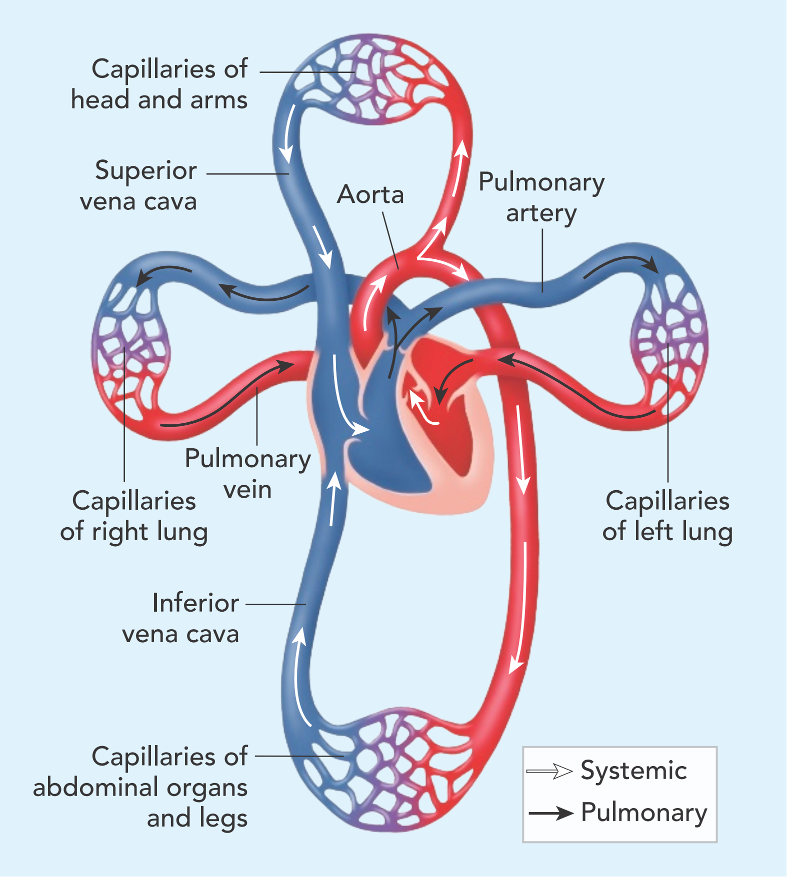
Blood leaves the heart to go to the rest of the body through the aorta, the first of a series of vessels that carries blood through the systemic circulation. As blood flows through the circulatory system, it moves through three types of blood vessels—arteries, capillaries, and veins.

Arteries Large vessels, or arteries, carry blood from the heart to the tissues of the body. Except for the pulmonary arteries, all arteries carry oxygen-rich blood. Arteries have thick elastic walls that help them withstand the powerful pressure produced when the heart contracts and pumps blood through them. **Figure 27-11** describes the layers of tissue found in the walls of arteries and veins—connective tissue, smooth muscle, and endothelium.

Figure 27-10

Circulation

Pulmonary circulation carries blood between the heart and lungs. Systemic circulation carries blood between the heart and the rest of the body.



INTERACTIVITY

Figure 27-11

Blood Vessels

The three basic types of blood vessels are arteries, capillaries, and veins. The scanning electron micrograph shows red blood cells and a few white blood cells inside a ruptured venule.

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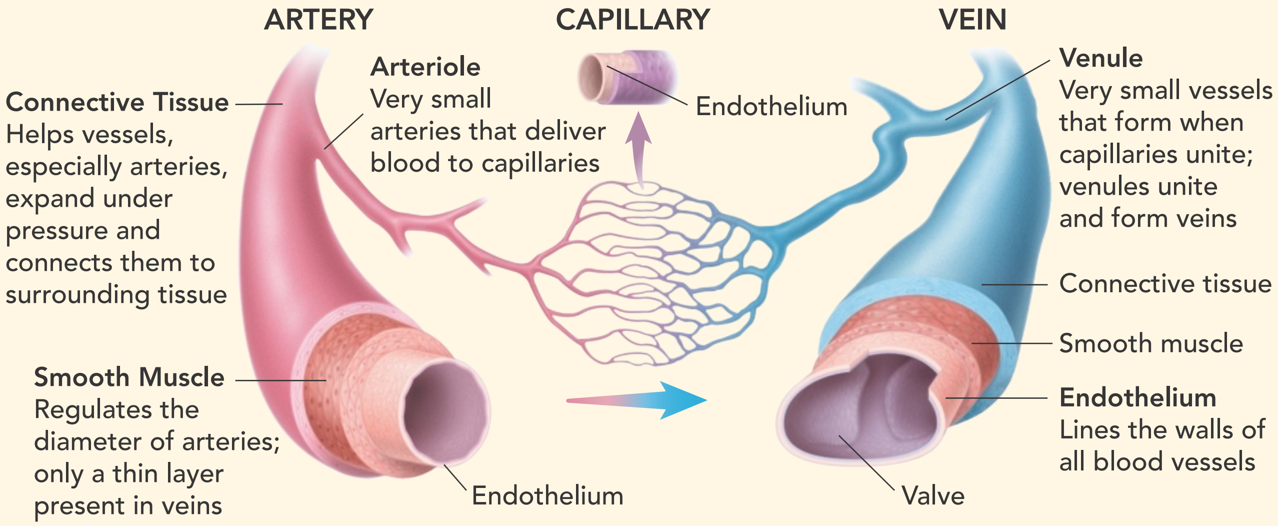


Capillaries The smallest blood vessels are the capillaries. Most capillaries are so narrow that blood cells pass through them in a single file. Their thin walls allow oxygen and nutrients to diffuse from blood into tissues and allow carbon dioxide and other waste products to move from tissues into blood.

Veins After blood passes through the capillaries, it returns to the heart through veins. Many veins are located near and between skeletal muscles. When you move, the contracting skeletal muscles squeeze the veins. Many veins contain valves, which ensure blood flows in one direction through these vessels toward the heart.

READING CHECK **Compare and Contrast** How are arteries and veins alike and different?

HS-LS1-3

Exploration Lab Open Ended Inquiry

Exercise and Heart Rate

Problem How does exercise affect heart rate?

Heart rate is the number of times per minute that the heart contracts, or beats, to push blood through the circulatory system. In this lab, you will investigate how the body maintains homeostasis during exercise. You will plan and carry out an investigation to show how exercise affects heart rate, and then construct an explanation for the data that the class obtains.

You can find this lab in your digital course.

Blood In addition to serving as the body's transportation system, components of blood also help regulate body temperature, fight infections, and produce clots to minimize the loss of body fluids from wounds.

The human body contains 4 to 6 liters of blood. About 55 percent of total blood volume is a fluid called plasma. Plasma is about 90 percent water and 10 percent dissolved gases, salts, nutrients, enzymes, plasma proteins, cholesterol, and other compounds. Plasma proteins consist of three types—albumin, globulins, and fibrinogen. Albumin and globulins transport substances such as fatty acids, hormones, and vitamins. Albumin also plays an important role in balancing osmotic pressure between blood plasma and surrounding tissues. Some globulins fight viral and bacterial infections. Fibrinogen is necessary for blood to clot.

The most numerous cells in blood are red blood cells, or erythrocytes (eh RITH roh syts). The main function of red blood cells is to transport oxygen. Red blood cells are produced by cells in the bone marrow. As they mature and fill with hemoglobin, nuclei and other organelles are forced out.

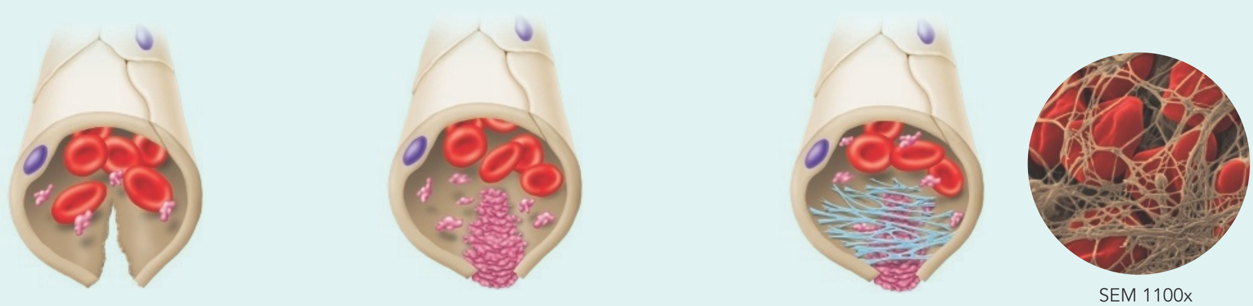
White blood cells, or leukocytes (LOO koh syts), are the "army" of the circulatory system. These cells guard against infection, fight parasites, and attack bacteria. Different types of white blood cells perform different protective functions. For example, macrophages engulf pathogens. Lymphocytes are involved in the immune response. B lymphocytes produce antibodies that fight infection and provide immunity. T lymphocytes help fight tumors and viruses. In a healthy person, red blood cells outnumber white blood cells by almost 1000 to 1.

Minor cuts and scrapes bleed for a bit and then stop. Why? Because platelets and plasma proteins cause blood to clot. Platelets are formed when the cytoplasm of particular bone marrow cells breaks apart into tiny membrane-enclosed fragments that then enter the blood. **Figure 27-12** explains the clotting process.

Figure 27-12

Blood Clotting

Platelets help blood to clot and thereby seal wounds. As shown in the scanning electron micrograph of a blood clot, filaments of fibrin form a netlike structure that traps blood cells.



1 Capillary Wall Breaks A blood vessel is injured by a cut or scrape.

2 Platelets Take Action Platelets clump at the site and release the clotting factor thromboplastin, which triggers a series of reactions. Thromboplastin converts the protein prothrombin into the enzyme thrombin.

3 Clot Forms Thrombin converts the soluble protein fibrinogen into sticky fibrin filaments. These form a clot that seals the break until the capillary wall can regrow and heal.

The Lymphatic System

The human circulatory system is not a perfect closed system. As blood circulates, some blood cells and plasma leak out through the capillary walls. Each day, about 3 liters of fluid leave the blood in this way. Most of this fluid, known as lymph, is reabsorbed into capillaries, but not all of it. The rest goes into the lymphatic system, which is shown in **Figure 27-13**. ***The lymphatic system is a network of vessels, nodes, and organs that collects the lymph that leaves capillaries, "screens" it for microorganisms, and returns it to the circulatory system.***

Role in Circulation Lymph collects in a system of capillaries that slowly conducts it into larger lymph vessels. Pressure on lymph vessels from surrounding skeletal muscles helps move lymph through the system into larger and larger ducts. Like veins, lymph vessels have valves that prevent lymph from flowing backward. These ducts return lymph to the blood through openings in veins just below the shoulders. When injury or disease blocks lymphatic vessels, lymph can accumulate in tissues, causing swelling called edema.

Role in Immunity Hundreds of small lymph nodes are scattered along lymph vessels throughout the body. Lymph nodes act as filters, trapping microorganisms, stray cancer cells, and debris. White blood cells inside lymph nodes destroy this cellular "trash." When large numbers of microorganisms are trapped in lymph nodes, the nodes become enlarged. The "swollen glands" that are symptoms of certain kinds of infections are actually swollen lymph nodes.

The thymus and spleen also play important roles in the immune functions of the lymphatic system. T lymphocytes mature in the thymus before they can function in the immune system. The functions of the spleen are similar to those of lymph nodes. However, instead of lymph, blood flows through the spleen, where it is cleansed of microorganisms, damaged cells, and other debris.

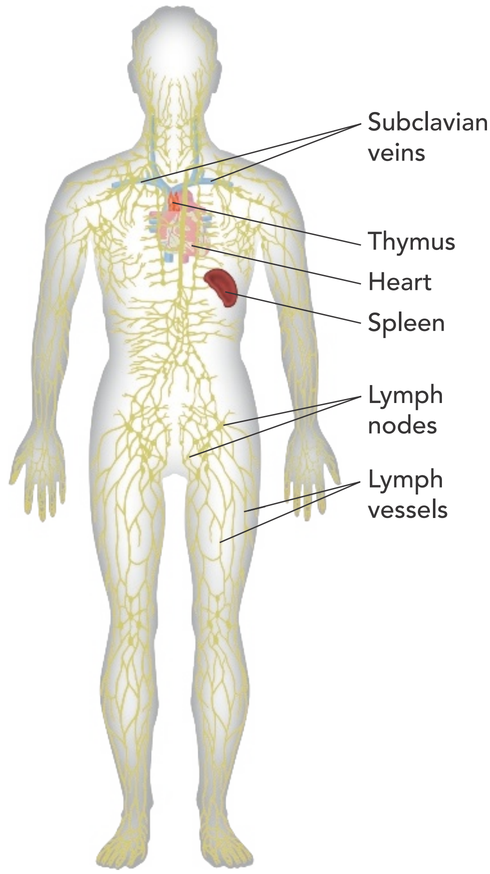
Role in Nutrient Absorption The lymphatic system also plays an important role in the absorption of nutrients. A system of lymph vessels runs alongside the intestines. The vessels pick up fats and fat-soluble vitamins from the digestive tract and transport these nutrients into the bloodstream.

READING CHECK Summarize What are three roles of the lymphatic system?

Figure 27-13

The Lymphatic System

The lymphatic system is a network of vessels, nodes, and organs that recycles fluids from tissues and plays a role in nutrient absorption and immunity. If the lymphatic system isn't working well, fluid can build up in tissues, causing swelling.



The Respiratory System

Breathing involves two opposite processes: inhaling and exhaling. You might complete both processes without much thought, but the singer shown in **Figure 27-14** should pay close attention to his breathing. Both inhaling and exhaling exchange gases with the environment, which is called respiration. ***The respiratory system picks up oxygen from the air as we inhale and releases carbon dioxide as we exhale.*** With each breath, air enters the body through the air passageways and fills the lungs. In the lungs, gas exchange takes place and oxygen enters the circulatory system. As shown in **Figure 27-15**, the respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, and lungs.

Figure 27-14

Breathing and Singing

Professional singers try to time their breathing to avoid pauses in a song. The vocal cords vibrate and make sounds when air rushes by them during an exhalation.

Air Flow As air enters the respiratory system, it is warmed and filtered in the inner nasal cavity and sinuses. Air then moves from the nose to a cavity at the back of the mouth called the pharynx, or throat, and then into the trachea, or windpipe. A flap of tissue called the epiglottis covers the entrance to the trachea, ensuring that food or liquid goes into the esophagus instead of the trachea. Between the pharynx and the trachea is the larynx, which contains two highly elastic folds of tissue known as the vocal cords. Your ability to speak, shout, and sing comes from these tissues. Mucus produced in the trachea traps inhaled particles, which cilia then sweep away from the lungs toward the pharynx.

From the trachea, air moves into two large tubes called bronchi (singular: bronchus) leading to the lungs. These tubes divide into smaller bronchi, and then into even smaller bronchioles. Bronchi and bronchioles are surrounded by smooth muscles that regulate the size of air passageways. The bronchioles lead to several hundred million tiny air sacs called alveoli (singular: alveolus). A delicate network of capillaries surrounds each alveolus.

Gas Exchange and Transport When you inhale, a muscle called the diaphragm contracts and flattens, creating a partial vacuum inside the tightly sealed chest cavity. Atmospheric pressure does the rest, filling the lungs as air rushes into the breathing passages. As air enters the alveoli, oxygen diffuses across thin capillary walls into the blood. Meanwhile, carbon dioxide diffuses in the opposite direction.

Diffusion of oxygen from alveoli into capillaries is a passive process. Oxygen dissolves into the bloodstream, and then becomes bound to hemoglobin in red blood cells. The ability of hemoglobin to bind oxygen increases the blood's oxygen-carrying capacity more than 60 times.

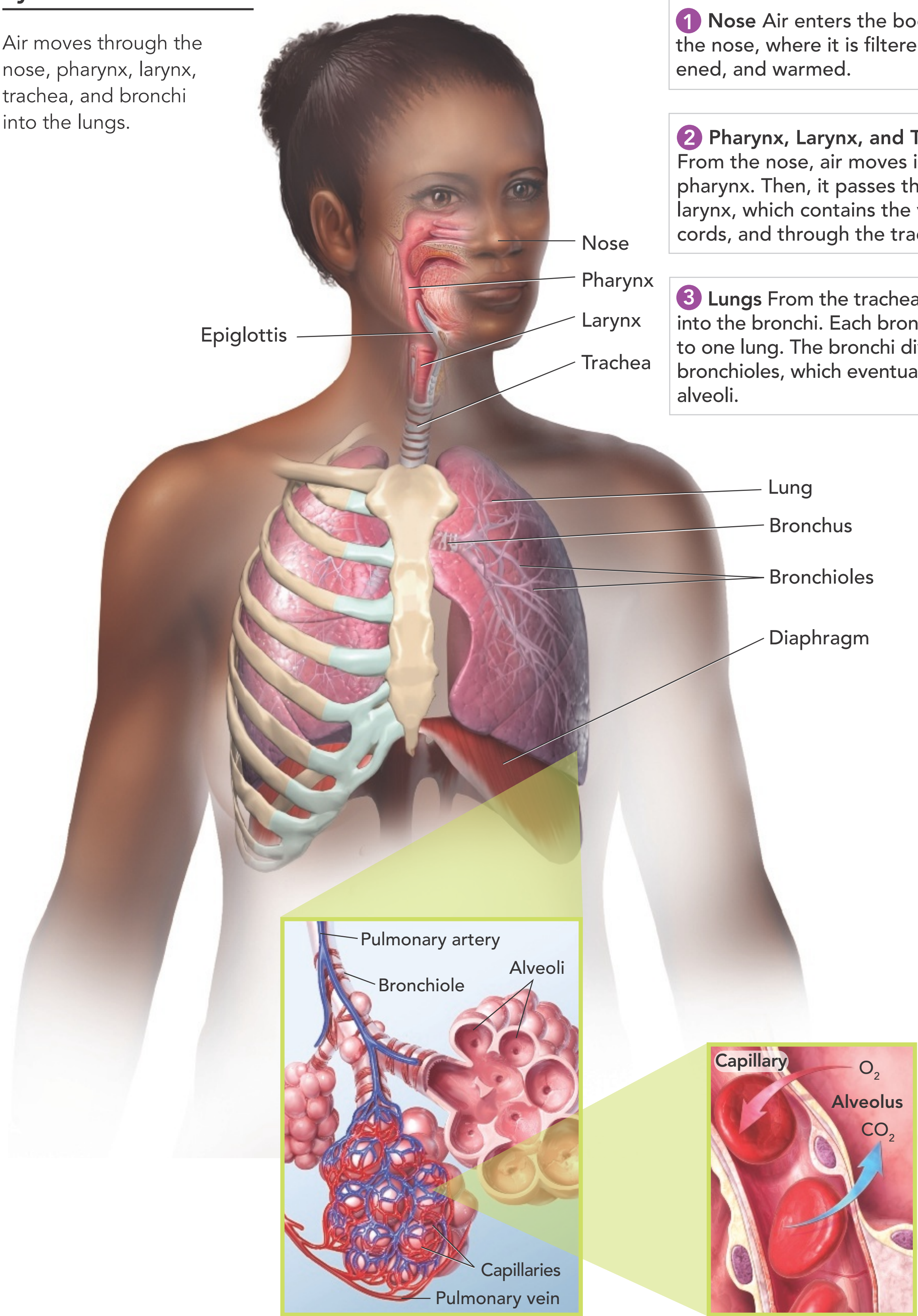
When carbon dioxide diffuses from body tissues to capillaries, most of it enters red blood cells and combines with water, forming carbonic acid and then bicarbonate. The rest of it dissolves in plasma or binds to hemoglobin and proteins in plasma. These processes are reversed in the lungs before the carbon dioxide is exhaled.

Visual Summary

Figure 27-15

The Respiratory System

Air moves through the nose, pharynx, larynx, trachea, and bronchi into the lungs.



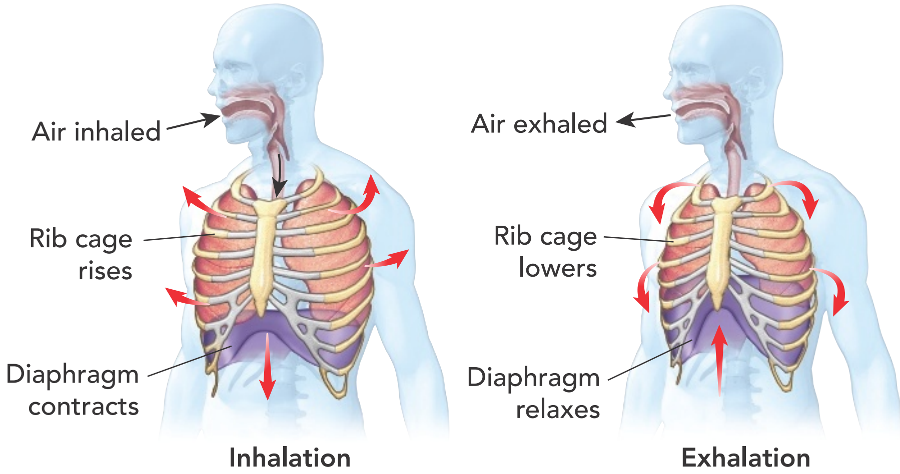
1 **Nose** Air enters the body through the nose, where it is filtered, moistened, and warmed.

2 **Pharynx, Larynx, and Trachea** From the nose, air moves into the pharynx. Then, it passes through the larynx, which contains the vocal cords, and through the trachea.

3 **Lungs** From the trachea, air moves into the bronchi. Each bronchus leads to one lung. The bronchi divide into bronchioles, which eventually end at alveoli.

Figure 27-16
Breathing

During inhalation, the rib cage rises and the diaphragm contracts, increasing the size of the chest cavity. During exhalation, the rib cage lowers and the diaphragm relaxes, decreasing the size of the chest cavity.



INTERACTIVITY

Survey the structures and functions of the digestive, excretory, cardiovascular, lymphatic, and respiratory systems.

Breathing Surprisingly, there are no muscles in our lungs or connected directly to them that participate in breathing. The force that drives air into the lungs comes from ordinary air pressure, the diaphragm, and muscles associated with the ribs. Movements of the diaphragm and rib cage change air pressure in the chest cavity during inhalation and exhalation, as shown in **Figure 27-16**.

Breathing and Homeostasis You can control your breathing almost any time you want, to blow up a balloon or to play a trumpet. But this doesn't mean that breathing is purely voluntary. Your nervous system has final control of your breathing muscles even when you are unconscious. Breathing is initiated by the breathing center in the part of the brain stem called the medulla oblongata. Sensory neurons in or near the medulla and in some large blood vessels gather information about carbon dioxide levels in the body and send the information to the breathing center. When stimulated, the breathing center sends nerve impulses that cause the diaphragm and chest muscles to contract, bringing air into the lungs. The higher the blood carbon dioxide level, the stronger the impulses. If the blood carbon dioxide level reaches a critical point, the impulses become so powerful that you cannot keep from breathing.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 27.2 Review

KEY QUESTIONS

1. What happens to food after it is ingested?
2. Describe the organs involved in excreting different types of metabolic wastes.
3. Describe how the heart circulates blood through the body.
4. How does the lymphatic system interact with the circulatory system?
5. Describe the pathway of air as it travels into and out of the respiratory system.

CRITICAL THINKING

6. **Predict** How would the rate of digestion be affected if the various organs and glands did not release enzymes?
7. **Apply Concepts** How do the circulatory and excretory systems work together to eliminate nitrogen-containing wastes?
8. **Construct an Explanation** Muscles are required for all movement within the body. How do muscles move blood through the circulatory system? How do they move air through the respiratory system?

Human Systems II

LESSON 27.3

KEY QUESTION

- *What are the structures and functions of the nervous system, skeletal system, muscular system, integumentary system, endocrine system, and the male and female reproductive systems?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

READING TOOL

As you read, connect to the visuals in this lesson by completing the chart in your **Biology Foundations Workbook.**

The billions of messages sent through your body at any given moment may tell you to laugh at a joke or tell you that it's cold outside. These messages enable the organs of the body to act together and also to react to external conditions.

The Nervous System

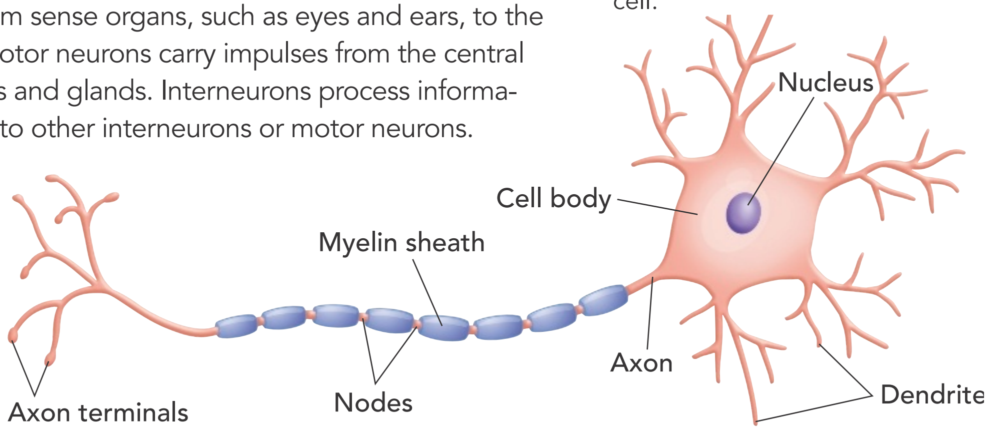
The nervous system is our window on the world. ***The nervous system collects information about the internal and external environment, processes that information, and responds to it.*** All of these messages are carried by electrical signals, called impulses, through nerve cells called neurons. A neuron is shown in **Figure 27-17**. The neurons and supporting cells that form the peripheral nervous system collect information about the body's external and internal environments. The brain and spinal cord form the central nervous system, which processes and creates a response to that information. This response is carried to muscles, glands, and other tissues by the peripheral nervous system.

Neurons Neurons are classified as one of three types. Sensory neurons carry impulses from sense organs, such as eyes and ears, to the central nervous system. Motor neurons carry impulses from the central nervous system to muscles and glands. Interneurons process information and send commands to other interneurons or motor neurons. Neurons have certain features in common, including a cell body, multiple dendrites, and an axon. Some axons are covered by a myelin sheath.

Figure 27-17

Neurons

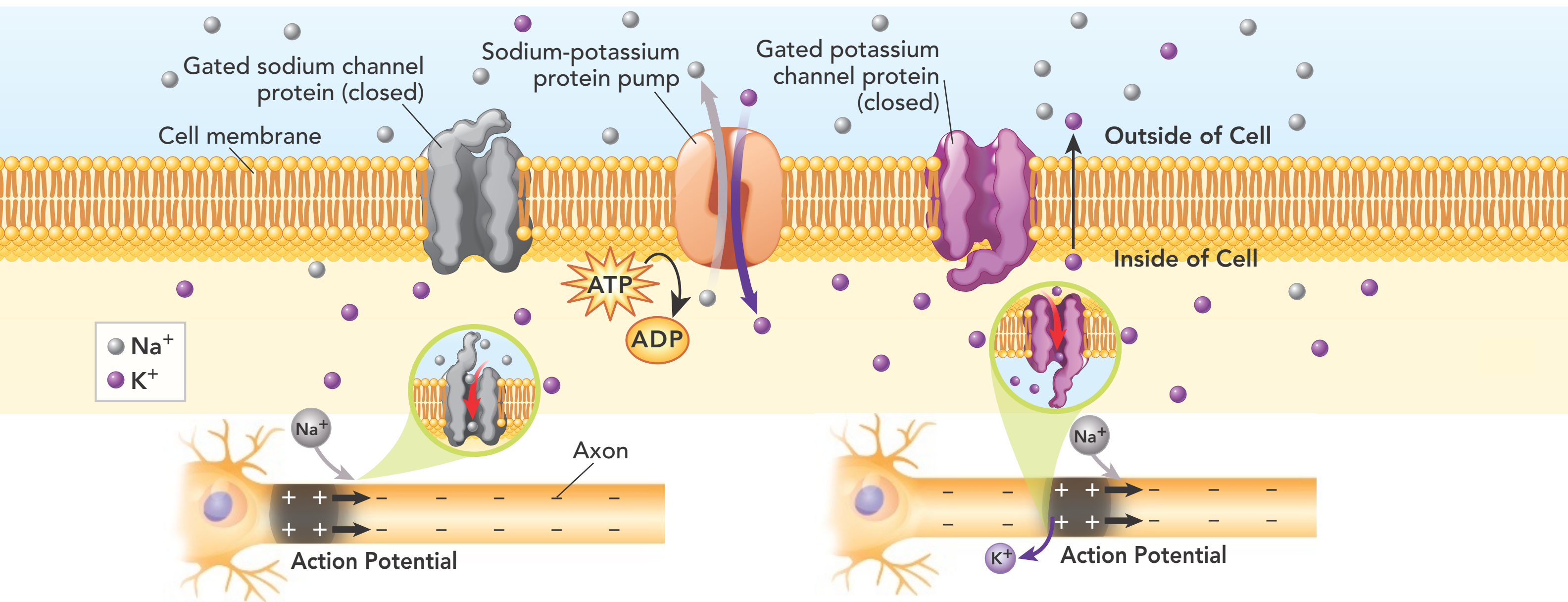
The basic unit of the nervous system is the neuron, or nerve cell.



The Nerve Impulse Neurons carry information by using specialized proteins in their cell membranes to create small electrical currents. But nerve cells do *not* carry electric currents the way that telephone wires do. Neurons at rest have an electrical charge of –70 millivolts (mV), called the resting potential, between the inside and outside of their cell membranes. The charge is produced by membrane proteins that pump sodium ions (Na^+) out of the cell and potassium ions (K^+) into it. Separate potassium channel proteins make it easier for K^+ ions than Na^+ ions to diffuse back across the membrane. Because the pumps create a higher concentration of K^+ ions inside the cell, positively charged K^+ ions diffuse out of the cell. The inside of the cell therefore becomes negatively charged compared to the outside.

When a neuron receives a large enough stimulus, this resting potential changes suddenly, producing a nerve impulse called an action potential. The smallest stimulus that can produce an action potential is called a threshold stimulus. Stimuli weaker than the threshold will not produce an action potential.

Nerve impulses are not created by a flow of electrons down the axon. Instead, each action potential is produced by a sudden reversal of the resting potential, as shown in **Figure 27-18**. This charge reversal travels down the axon like ripples passing down the surface of a stream. The impulse travels faster through an axon with a myelin sheath than through an axon with no myelin sheath.



2 At the leading edge of the impulse, gated sodium channels open. Na^+ ions flow into the cell, reversing the potential between the cell membrane and its surroundings. This rapidly moving reversal of charge is called an action potential.

3 As the action potential passes, gated potassium channels open, allowing K^+ ions to flow out and restoring the resting potential inside the axon.

ANIMATION

Figure 27-18

The Resting Neuron and the Nerve Impulse

In a resting neuron, sodium-potassium pumps use ATP to pump Na^+ from the cell and to pump K^+ in. Some K^+ ions diffuse out of the cell, but gated channels block Na^+ from flowing into the resting neuron. Once a nerve impulse begins, it will move through an axon until it reaches the end.

The Central Nervous System

As shown in **Figure 27-19**, the central nervous system, which includes the brain and the spinal cord, is contained almost entirely inside the bony structures of the skull and vertebral column. Sensations from various body areas are "felt" by specific brain regions. Commands to muscles originate in other brain areas. The spinal cord, which contains most neurons that enter and leave the brain, links the brain to the rest of the body.

The Peripheral Nervous System

The peripheral nervous system contains nerves and associated cells that are not part of the brain or spinal cord. It has two major divisions—sensory and motor. The sensory division consists of receptor cells, which gather information, and sensory neurons, which transmit impulses from sense organs to the central nervous system. The motor division transmits impulses from the central nervous system to the muscles and glands. These messages are relayed through networks called the somatic nervous system and the autonomic nervous system.

Somatic Nervous System

The somatic nervous system regulates activities such as movement of skeletal muscles. Some somatic nervous system actions are under voluntary control. When you lift your finger or wiggle your toes, impulses originating in the brain are carried through the spinal cord to motor neurons, which stimulate muscles. Other somatic nervous system actions occur automatically. If you step on a tack with your bare foot, your leg may recoil before you are aware of the pain. This rapid response (a reflex) is produced by impulses that travel through a pathway known as a reflex arc. Reflex arcs produce fast responses because the pain signal does not have to travel all the way to the brain. An interneuron in the spinal cord processes the information and sends a response to leg muscles via motor neurons.

Autonomic Nervous System

The autonomic nervous system regulates activities that are not under conscious control. For instance, when you start to run, the autonomic nervous system speeds up your heart rate and blood flow to skeletal muscles, stimulates sweat glands, and slows down contractions of smooth muscles in the digestive system.

The autonomic nervous system consists of two equally important parts, the sympathetic nervous system and the parasympathetic nervous system, which usually have opposite effects. This division enables precise control of body systems, in the same way that using both the gas pedal and the brake enables a driver to control the speed of a car. In general, the sympathetic system prepares the body for intense activity—often called a "fight or flight" reaction. The parasympathetic system produces the "rest and digest" response.

READING CHECK **Classify** In which division of the nervous system would you find an interneuron?

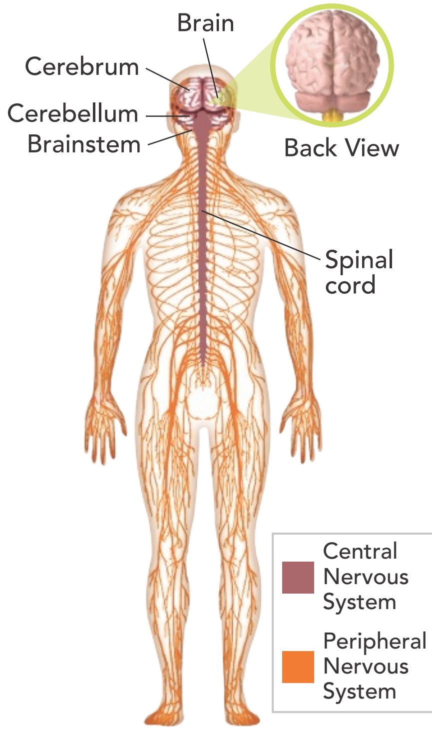


Figure 27-19

The Nervous System

The nervous system is comprised of the central nervous system and the peripheral nervous system. The central nervous system includes the brain and spinal cord.

INTERACTIVITY

Explore the lobes of the brain to discover how the brain functions.

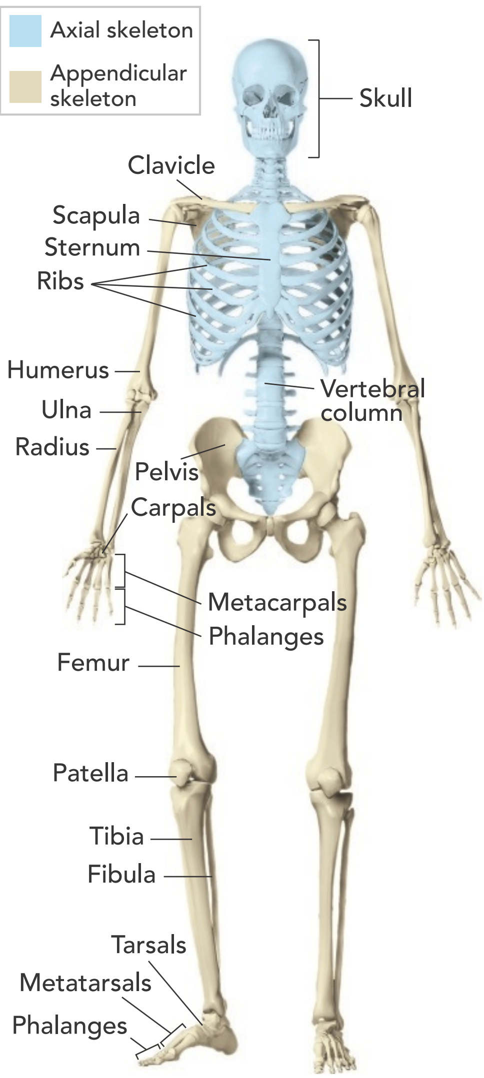
INTERACTIVITY

Investigate the skeletal and muscular systems.

Figure 27-20

The Skeleton

The human skeleton is divided into the axial skeleton and the appendicular skeleton. The skeleton consists of living tissue that has many roles in the body. **Summarize** What are four functions of the skeletal system?



The Skeletal System

The skeletal system, shown in **Figure 27-20**, supports and shapes the body the way an internal wooden frame supports a house. ***The skeleton supports the body, protects internal organs, assists in movement, stores minerals, and is a site of blood cell formation.*** Bones also act as rigid rods on which muscles exert force to produce movement. In addition, bones contain reserves of minerals, such as calcium salts.

The 206 bones in the adult human skeleton form the axial skeleton and the appendicular skeleton. The axial skeleton—the skull, the vertebral column, and the rib cage—supports the body's central axis. The bones of the arms, legs, pelvis, and shoulder area make up the appendicular skeleton.

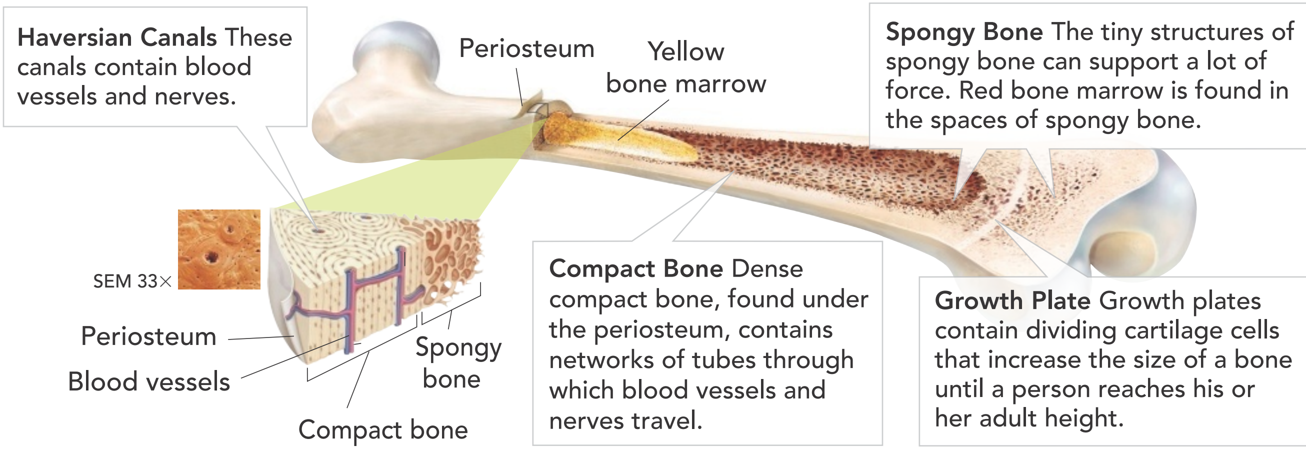
Bones Bones are living tissue made up of a solid network of cells and protein fibers surrounded by deposits of calcium salts. **Figure 27-21** shows the structure of a bone. Bones are surrounded by tough connective tissue called periosteum (pehr ee AHS tee um). Beneath the periosteum is a thick layer of compact bone. Nerves and blood vessels run through compact bone in channels called Haversian canals. A less dense tissue known as spongy bone may be found under the compact bone, especially in the ends of long bones. Despite its name, spongy bone is quite strong.

Near the ends of bones where force is applied, spongy bone forms latticework structures that resemble supporting girders in a bridge. These structures add strength without excess mass.

Inside many bones are cavities containing one of two types of bone marrow. Yellow marrow consists primarily of cells that store fat. Red marrow contains stem cells that produce most types of blood cells.

READING CHECK **Use Visuals** Use Figure 27-21 to provide evidence for the statement that bones are living tissue.

Functions of the Skeleton
Support The bones of the skeleton support and give shape to the human body.
Protection Bones protect the delicate internal organs of the body. For example, the ribs form a basketlike cage around the heart and lungs.
Movement Bones provide a system of levers on which muscles produce movement.
Mineral Storage Bones contain reserves of minerals, including calcium, that are important to many body processes. When blood calcium levels are low, some reserves are released from the bones.
Blood Cell Formation Many types of blood cells are produced in soft tissue that fills the internal cavities of some bones.



Up Close

Figure 27-21

Structure of a Bone

A typical long bone, such the femur, contains spongy bone and compact bone. Within compact bone are Haversian canals, which contain blood vessels and nerves.

Joints A place where two or more bones meet each other is called a joint. Joints contain connective tissue that holds bones together and permits bones to move without damaging each other. Joints can be classified as immovable, slightly movable, or freely movable.

Immovable joints, often called fixed joints, allow no movement. The bones at an immovable joint are interlocked and grow together until they are fused. Most bones in the skull meet at immovable joints.

Slightly movable joints permit a small amount of movement. Unlike the bones of immovable joints, the bones of slightly movable joints are separated from each other. The joints between the two bones of the lower leg and the joints between vertebrae in the spine are examples of slightly movable joints.

Freely movable joints, like the shoulder joint, permit movement in two or more directions. Freely movable joints are grouped according to the shapes of the surfaces of the adjacent bones. Several types of freely movable joints are shown in **Figure 27-22.**

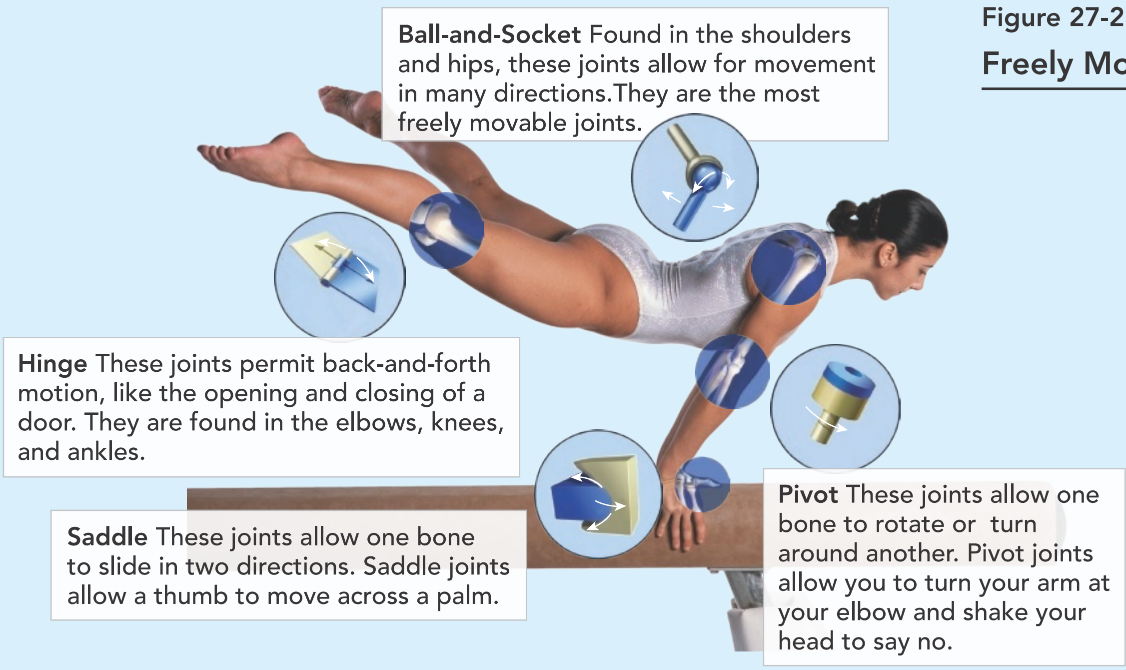


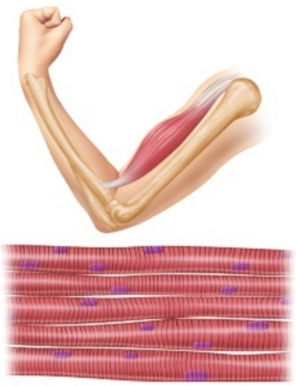
Figure 27-22

Freely Movable Joints

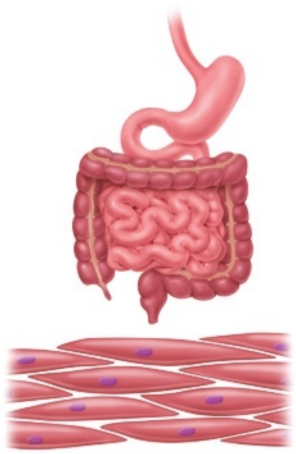
Figure 27-23

Types of Muscle

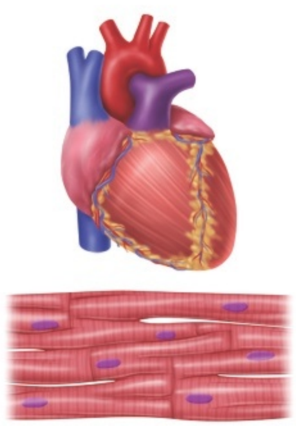
Skeletal muscle is striated, and smooth muscle is not. Although cardiac muscle is striated like skeletal muscle, it is not under voluntary control.



Skeletal muscle



Smooth muscle



Cardiac muscle

The Muscular System

Despite the animations you may have likely seen in horror films, a skeleton cannot move by itself. Muscles generate the force needed to power movement—from a leap in the air to the hint of a smile. ***There are three different types of muscle tissues that are specialized for different functions: skeletal, smooth, and cardiac muscle.*** The three types of muscles and their locations in the body are shown in **Figure 27-23**.

Skeletal muscles are usually attached to bones. They are responsible for voluntary movements. When viewed under a microscope at high magnification, skeletal muscle appears to have alternating light and dark bands called "striations." For this reason, skeletal muscle is said to be striated. Most skeletal muscle movements are consciously controlled by the central nervous system. Skeletal muscle cells are large, have many nuclei, and vary in length.

Smooth muscle cells are so named because they don't have striations and, therefore, look "smooth" under the microscope. These cells are spindle-shaped and usually have a single nucleus. Smooth muscle movements are usually involuntary. They are found throughout the body and form part of the walls of hollow structures such as the stomach, blood vessels, and intestines. Most smooth muscle cells can function without direct stimulation by the nervous system.

Cardiac muscle is found in just one place in the body—the heart. Cardiac muscle is striated like skeletal muscle, although its cells are smaller and usually have just one or two nuclei. Cardiac muscle is similar to smooth muscle because the cells can contract on their own without stimulation by the nervous system.

Muscle Contraction and Movement

Muscles produce movements by shortening, or contracting, from end to end. Skeletal muscle fibers contain units called sarcomeres, which contain filaments composed of the proteins myosin and actin. Interactions between myosin and actin make it possible for muscles to generate force.

Together, myosin and actin form tiny force-producing engines. During a muscle contraction, myosin filaments form cross-bridges with actin filaments, as shown in **Figure 27-24**. The cross-bridges then change shape, pulling the actin filaments toward the center of the sarcomere. This action decreases the distance between the ends of the sarcomere, so the fiber shortens. Then the cross-bridge detaches from actin and repeats the cycle by binding to another site on the actin filament. This is called the sliding-filament model of muscle contraction.

A muscle produces force by contracting in one direction. We can use our muscles to push as well as pull because muscles work in opposing pairs around joints. When one muscle in the pair contracts, the other muscle in the pair relaxes.

READING CHECK **Summarize** How do muscles cause movement?

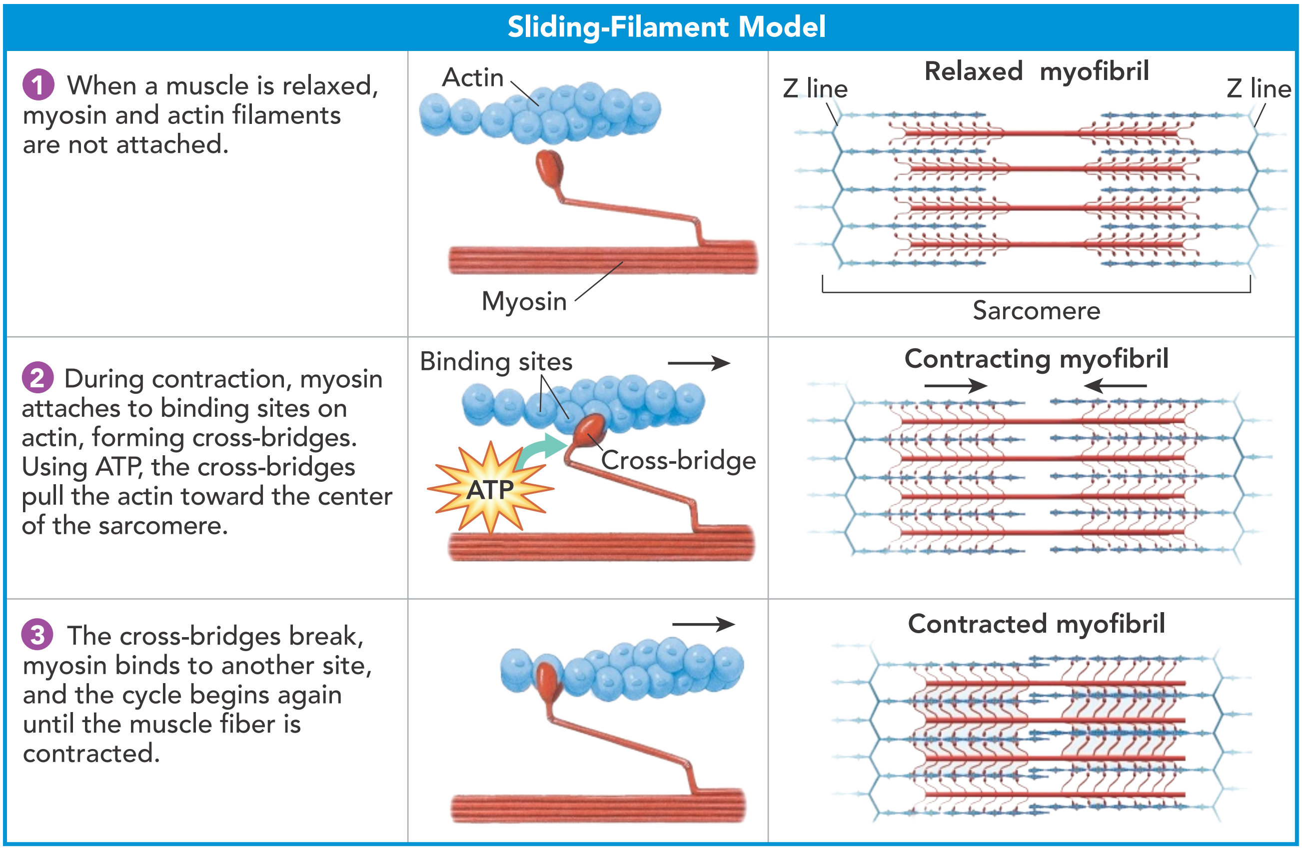


Figure 27-24

Sliding-Filament Model

Myosin ratchets along the actin in a sarcomere, causing a muscle to contract.

The Integumentary System

Skin and its related structures—the hair, nails, and glands—make up the integumentary system. The integumentary system serves as a barrier against infection and injury, helps to regulate body temperature, removes wastes, gathers sensory information, and produces vitamin D.

The outer layer of the skin is the epidermis, which has two layers. The outer layer is made of dead cells. The inner layer consists of stem cells that divide rapidly and push to the top. These cells eventually lose their organelles and become the tough, dead cells that protect your body from invading pathogens and injuries. Other cells in the epidermis produce melanin, which protects the skin by absorbing ultraviolet radiation from the sun.

The dermis lies below the epidermis. It contains blood vessels, nerve endings, glands, sensory receptors, smooth muscles, and hair follicles. Blood vessels in the dermis narrow when it is cold to conserve heat. The blood vessels widen on warm days to help the body lose heat. Excess heat and wastes are released when sweat glands produce perspiration. Beneath the dermis is a layer of fat and loose connective tissue that helps to insulate the body.

The basic component of human hair and nails is a protein called keratin. Hair on the head protects the scalp from ultraviolet radiation. Hair in the nostrils, around the eyes, and in ear canals prevents dirt from entering the body. Nails protect fingertips and toes from damage.

The Endocrine System

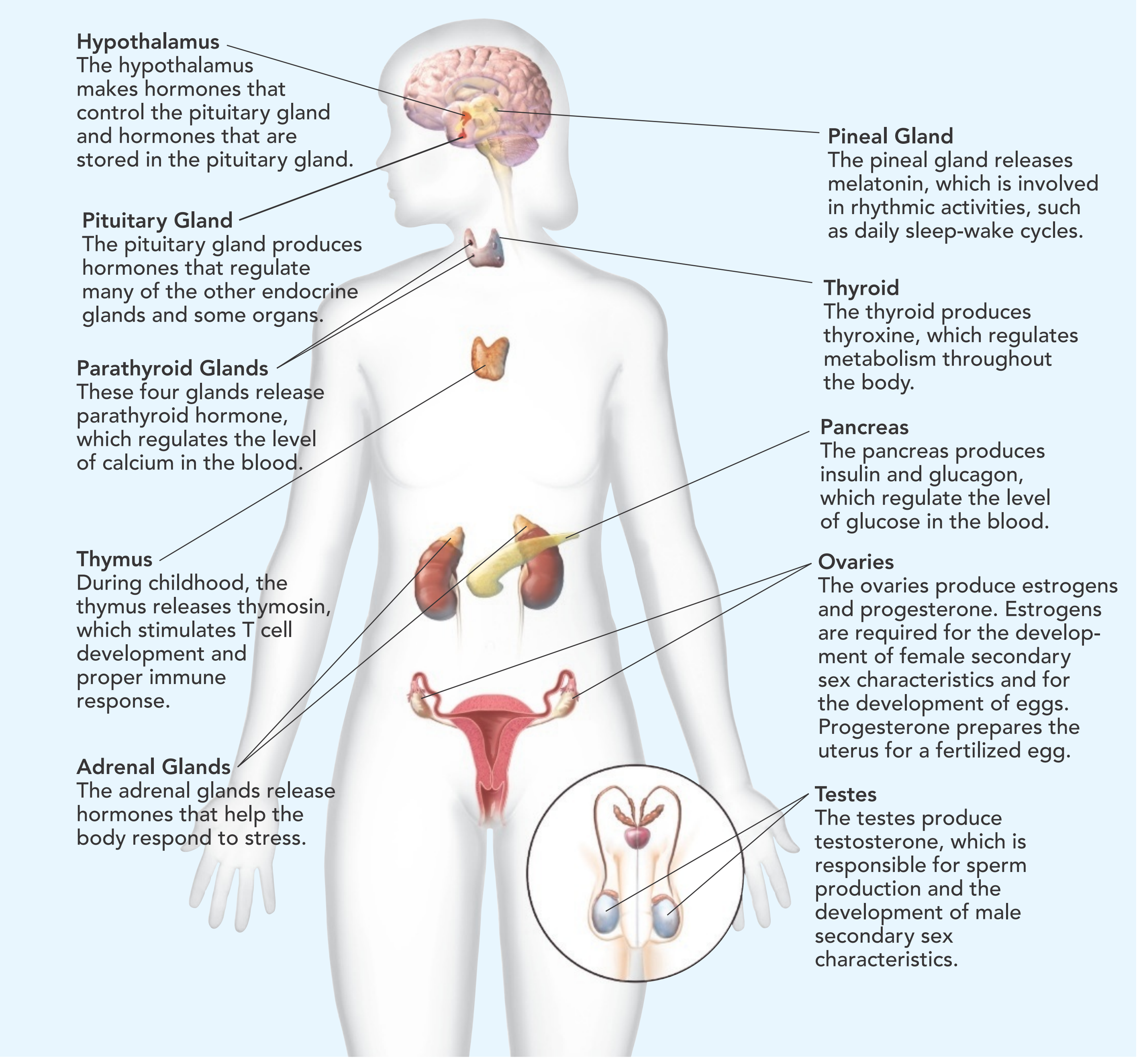
How are you feeling today? A major influence on your well-being is the endocrine system, which helps to regulate mood and metabolism, tissue function, growth and development, and reproductive processes. The endocrine system produces chemicals called hormones that affect many parts of the body. ***The glands of the endocrine system release hormones that travel through the blood and control the actions of cells, tissues, and organs.*** Most endocrine glands release their hormones directly into the blood. The major endocrine glands are shown in **Figure 27-25**.

READING CHECK Explain How does the endocrine system depend on the circulatory system?

Figure 27-25

The Endocrine System and Its Organs

Endocrine glands produce hormones that affect many parts of the body.



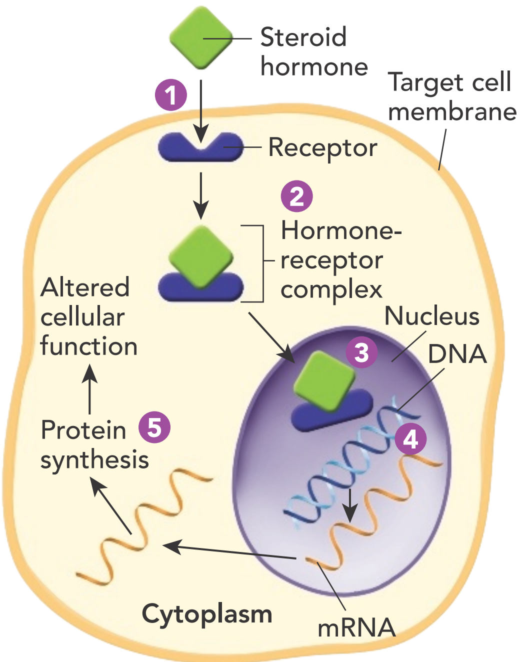
Hormone Action Hormones fall into two general groups—steroid hormones and nonsteroid hormones. Steroid and nonsteroid hormones work in different ways, but both affect cells by binding to specific chemical receptors located either on cell membranes or within cells. Cells that have receptors for a particular hormone are called target cells. If a cell does not have receptors for a particular hormone, the hormone has no effect on it. **Figure 27-26** shows how the two types of hormones act upon their target cells.

Figure 27-26

Hormones

Steroid hormones act by entering the nucleus of a cell and changing the pattern of gene expression. Nonsteroid hormones bind to receptors on a target cell membrane and cause the release of secondary messengers that affect cell activities.

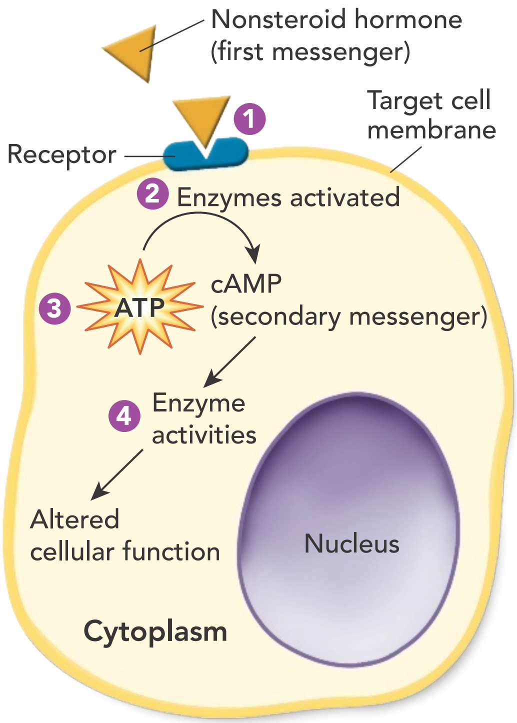
Steroid Hormone Action



Steroid Hormones

1. Because steroid hormones are lipids, they can pass directly across the cell membrane.
2. Once inside, the hormone binds to a receptor (found only in the hormone's target cells) and forms a hormone-receptor complex.
3. The hormone-receptor complex enters the nucleus, where it binds to regions of DNA that regulate gene expression.
4. This binding initiates the transcription of specific genes to messenger RNA (mRNA).
5. The mRNA moves into the cytoplasm and directs protein synthesis. This ability to alter gene expression makes the effects of many steroid hormones especially powerful and long lasting.

Nonsteroid Hormone Action



Nonsteroid Hormones

1. The binding of the hormone activates enzymes on the inner surface of the cell membrane.
2. These enzymes release secondary messengers such as calcium ions, nucleotides, and fatty acids to relay the hormone's message within the cell.
3. One common secondary messenger is cAMP (cyclic AMP), which is produced from ATP.
4. These secondary messengers can activate or inhibit a wide range of cell activities.

Control of the Endocrine System

The endocrine system is one of the master control systems of the body. Like most body systems, the endocrine system is regulated by negative feedback mechanisms that function to maintain homeostasis. Recall that negative feedback, also called feedback inhibition, occurs when an increase in a substance "feeds back" in a way that inhibits the system. Concentrations of hormones, and their effects on other body systems, are controlled in similar ways.

BUILD VOCABULARY

Prefixes The prefixes *anti-* and *ante-* can be easily confused. *Anti-*, as in *antidiuretic,* means "against." *Ante-*, as in *anterior,* means "before."

Maintaining Water Balance Water balance in the body is one example of how the endocrine system maintains homeostasis. When you exercise, you sweat and lose water. If this water loss continued, your body would soon become dehydrated. But your hypothalamus contains cells that monitor blood water content. As you lose water, concentrations of dissolved materials in blood rise. The hypothalamus responds in two ways. First, it signals the posterior pituitary gland to release antidiuretic hormone (ADH). ADH molecules are carried to the kidneys, where they slow the removal of water from blood. Second, the hypothalamus generates nerve impulses that produce a sensation of thirst to which we respond if water is available.

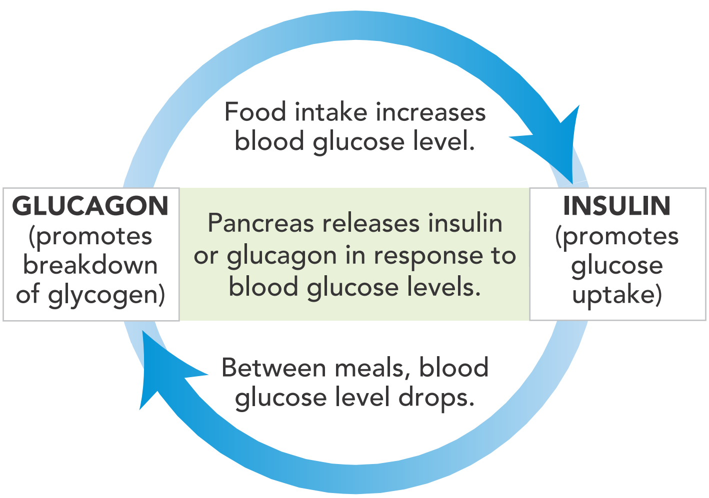
When concentrations of dissolved materials fall, as it might after you drink several glasses of water, the pituitary releases less ADH. As ADH concentrations fall, the kidneys remove more water from the blood, restoring its proper concentration. This homeostatic system sets both upper and lower limits for blood water content.

Blood Glucose Regulation Glucose concentration in the bloodstream is controlled by insulin and glucagon. When blood glucose concentration rises, the pancreas releases insulin. Insulin stimulates liver and skeletal muscle cells to convert blood glucose to glycogen, and it stimulates fat cells to convert glucose to lipids. These actions together prevent blood glucose concentrations from rising too rapidly. They also store energy for future use. In between meals, when blood glucose concentration drops, the pancreas releases glucagon. Glucagon stimulates liver and skeletal muscle cells to break down glycogen and release glucose into the blood. These actions raise blood glucose concentrations back to normal. **Figure 27-27** shows this feedback loop.

Figure 27-27

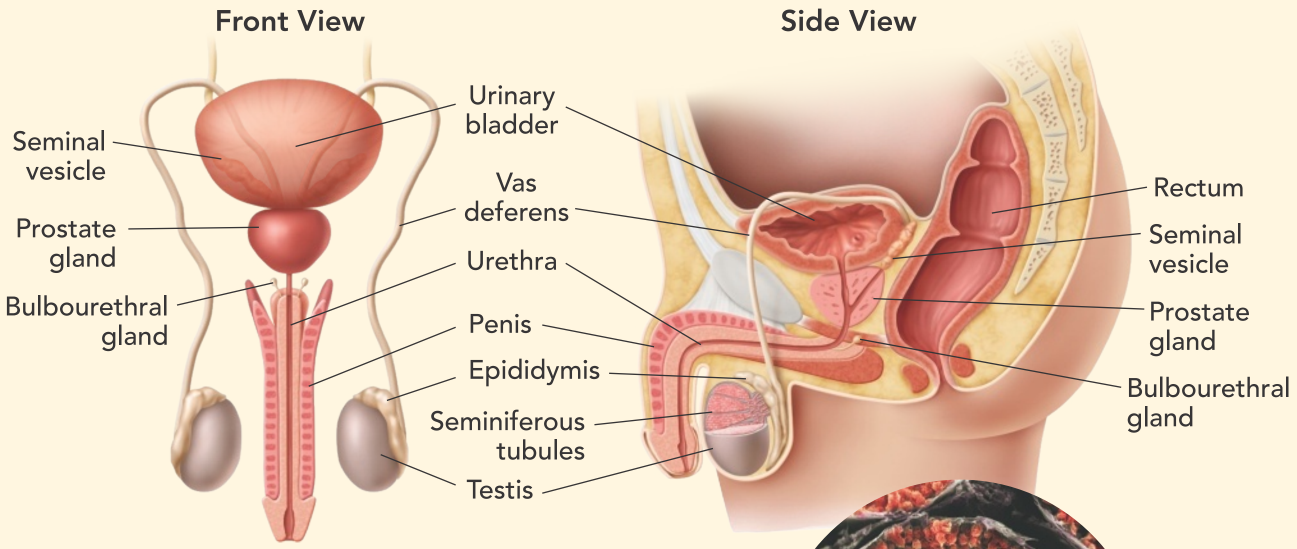
Glucagon and Insulin

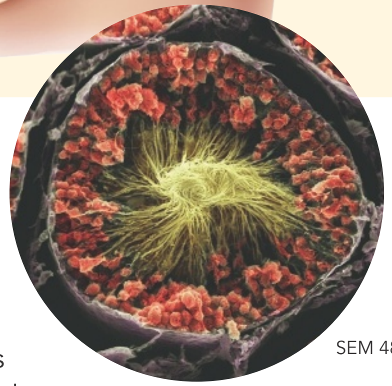
Insulin and glucagon are opposing hormones that ensure that blood glucose levels stay within a normal range.



READING CHECK

Summarize How does the endocrine system respond to rising or falling blood glucose levels?





The Male Reproductive System

As a male approaches puberty, the hypothalamus signals the pituitary to produce two hormones—luteinizing hormone (LH) and follicle stimulating hormone (FSH). LH stimulates the testes to produce testosterone. Testosterone directs the male physical changes associated with puberty and, together with FSH, stimulates sperm development. ***When puberty is complete, the male reproductive system is fully functional, meaning that it can produce and release active sperm.*** The male reproductive system is shown in **Figure 27-28**.

Figure 27-28

Male Reproductive System

The main structures of the male reproductive system produce and deliver sperm. The micrograph shows a cross section of one tiny seminiferous tubule containing developing sperm.

The testes (singular: testis) are located in a sac called the scrotum outside the body cavity, where a slightly lower temperature promotes sperm development. Specialized cells within the testes undergo meiosis to form haploid sperm nuclei. Sperm then move into the epididymis, where they mature and are stored. A mature sperm cell consists of a head, which contains a highly condensed nucleus; a midpiece, packed with mitochondria; and a tail, or flagellum, which propels the cell forward. Some sperm are moved into tubes called vas deferens, which empty into the urethra.

Glands lining the reproductive tract produce nutrient-rich seminal fluid that nourishes the sperm. The combination of sperm and seminal fluid is known as semen. Between 20 million and 150 million sperm are present in 1 milliliter of semen. That's about 3 million sperm per drop! When a male is sexually aroused, the autonomic nervous system stimulates the penis to become erect. Semen is ejected through the urethra by contractions of smooth muscles lining the reproductive tract in a process called ejaculation.

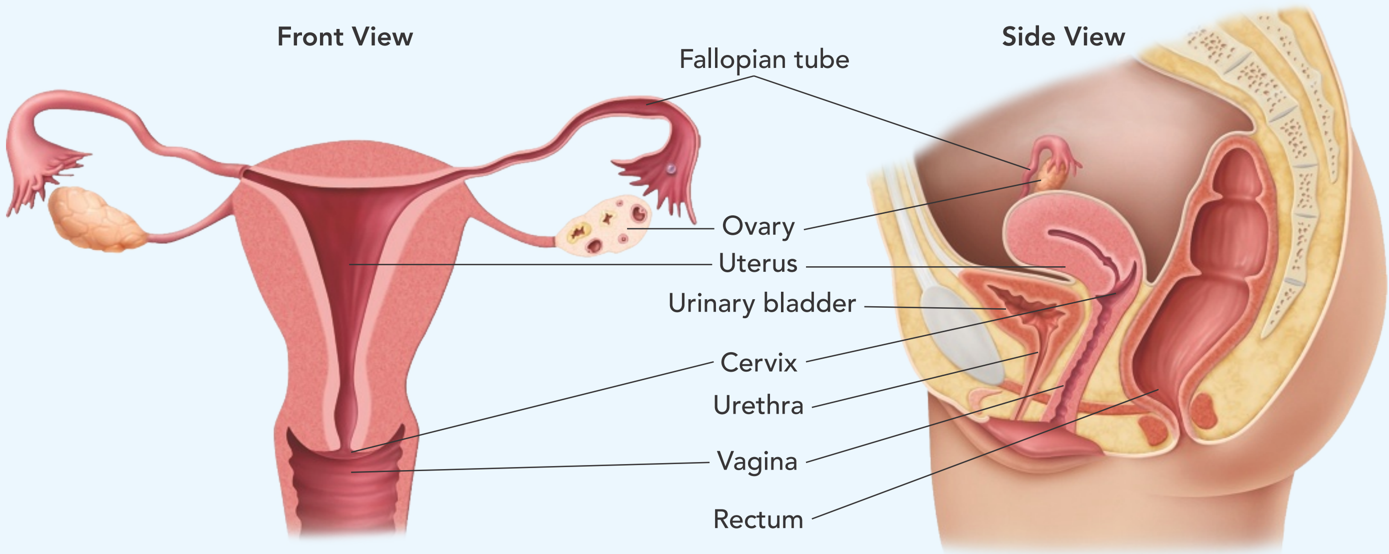


Figure 27-29

Female Reproductive System

The ovaries are the main organs of the female reproductive system.

The Female Reproductive System

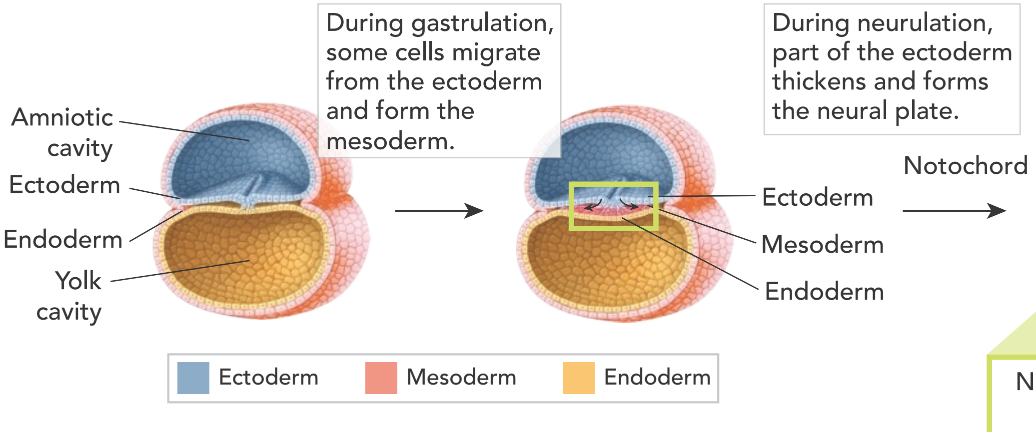
The primary reproductive organs of the female are the ovaries. As in males, puberty in females starts when the hypothalamus signals the pituitary gland to release FSH and LH. FSH stimulates cells within the ovaries to produce increased amounts of estrogens and to start producing egg cells. ***The main functions of the female reproductive system are to produce egg cells, or ova (singular: ovum), and to prepare the body to nourish a developing embryo.*** The female reproductive system is shown in **Figure 27-29**.

FSH and LH together stimulate the maturation of clusters of cells within the ovary, known as follicles. Each follicle contains a developing egg cell. Other cells within the follicle respond to these pituitary hormones by producing estrogens.

At puberty each ovary contains about 400,000 follicles. However, a female's ovaries only release about 400 eggs during her lifetime. One ovary releases an egg every 28 days or so. Egg release is part of the menstrual cycle, a regular sequence of events involving the interaction of the reproductive system and the endocrine system. Meanwhile, estrogens stimulate the uterus to grow new blood vessels in preparation for receiving a fertilized egg.

If an egg is not fertilized, or if a fertilized egg fails to attach to the uterine wall, it is discharged. The new blood vessels and the lining of the uterus deteriorate and are also discharged. A new menstrual cycle then begins. If an egg is fertilized, embryonic development begins. If the developing fertilized egg successfully attaches to the wall of the uterus, the menstrual cycle ceases, and tissues from both the developing embryo and the mother's uterus form a new organ called the placenta.

READING CHECK **Identify** Which organ in the female reproductive system produces egg cells?



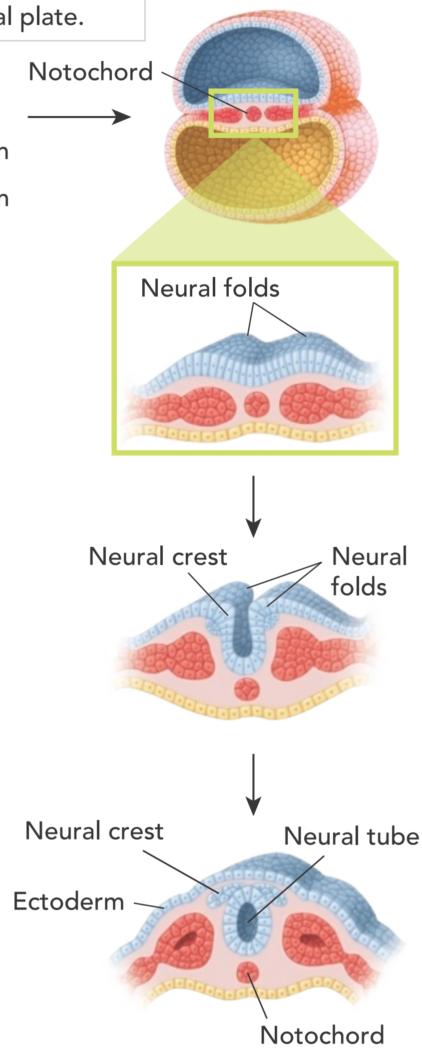


Figure 27-30

Gastrulation and Neurulation

The cells of human embryos, like those of other animal embryos, go through a series of complex changes during early development.

Fertilization and Early Development Human development begins with fertilization, the fusion of sperm and egg. During intercourse, semen containing millions of sperm is released into the vagina. Sperm swim through the uterus into the Fallopian tubes. The outer layer of an egg contains binding sites to which sperm can attach. The haploid (N) sperm nucleus enters the haploid egg, and their two nuclei fuse to form a single diploid (2N) nucleus.

The fertilized egg then undergoes multiple rounds of mitosis. A cavity forms in the center, and the embryo becomes a hollow ball of cells known as a blastocyst. About a week after fertilization, the blastocyst attaches to the wall of the uterus and grows into the mother's tissues. Cells in the blastocyst then begin to differentiate, producing different body tissues. A cluster of cells within the blastocyst cavity develops into the body of the embryo. Other blastocyst cells differentiate into tissues that support and protect the embryo.

Gastrulation The result of gastrulation is the formation of three cell layers called the ectoderm, mesoderm, and endoderm. As shown in **Figure 27-30**, the ectoderm and endoderm form first. The ectoderm develops into skin and the nervous system. Mesoderm cells develop into many of the body's internal structures, including bones, muscles, and blood cells. The endoderm forms the lining of organs in the digestive, respiratory, and excretory systems.

Neurulation The process of neurulation marks the beginning of the nervous system development. Some mesodermal tissue differentiates into a notochord. Nearby ectoderm thickens and forms the neural plate, neural folds, and neural crest. The neural folds form the neural tube, from which the spinal cord and brain develop. Neural crest cells become nerve cells, skin pigment cells, and other structures, such as the lower jaw.

READING TOOL

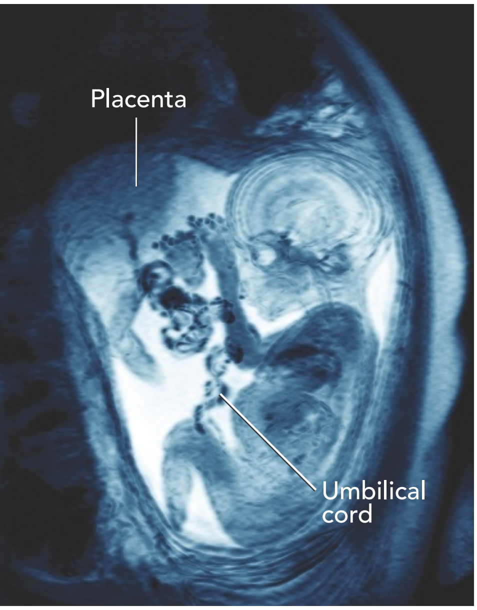
Record the sequence of events that occur during fertilization and development.

The Placenta As the embryo develops, specialized membranes form to protect and nourish the embryo. The amnion, a sac filled with fluid, cushions and protects the developing embryo. Another sac, the chorion, just outside the amnion, makes contact with the uterus. Small fingerlike projections form on the outer surface of the chorion and grow into the uterine lining to form the placenta, the vital connection between mother and embryo. The mother's blood and the embryo's blood flow past each other in the placenta, but they do not mix. Oxygen and nutrients diffuse from the mother's blood to the embryo's blood, and carbon dioxide and metabolic wastes diffuse from the embryo's blood to the mother's blood. The umbilical cord connects the embryo to the placenta.

Figure 27-31

Fetus

This MRI of a full-term fetus shows the umbilical cord and placenta.



Later Development

At about 5 weeks, a week after neurulation is complete, the embryo is about 7 millimeters long. The pharyngeal pouches and tail that characterize chordates are visible. After 8 weeks, the embryo is called a fetus. At this point, it is about 25 millimeters long and has eyes, fingers and toes, ears, and most major organs. Throughout the rest of the first trimester, or first three months of pregnancy, the fetus continues to grow and become more human in appearance.

During the second trimester, the tissues and organs of the fetus become more complex and begin to function. The fetal heart becomes large enough that it can be heard with a stethoscope. Bone continues to replace the cartilage that forms the early skeleton. A layer of soft hair grows over the skin of the fetus, and the eyes, ears, and nose move to their final positions.

During the third trimester, the last three months before birth, the fetus doubles in mass. Fat deposited beneath the skin makes the fetus look less wrinkled and skinny and more like a baby. The soft hair vanishes from the face and then from the rest of the body. The central nervous system and lungs continue developing throughout the third trimester, and complete their development at about 40 weeks, just before birth. A full-term fetus is shown in **Figure 27-31**.

HS-LS1-1, HS-LS1-2, HS-LS1-3

LESSON 27.3 Review

KEY QUESTIONS

1. What is the role of neurons in the nervous system?
2. List the different functions of the skeletal system.
3. What are the differences among the three types of muscle tissue?
4. List the functions of the integumentary system.
5. How do endocrine glands send messages to other organs?
6. How does puberty affect the male and female reproductive systems?

CRITICAL THINKING

7. **Synthesize Information** Describe how the muscular and skeletal systems work together to move the body.
8. **Compare and Contrast** How are the actions of the nervous and endocrine systems alike? How are they different?
9. **Relate Cause and Effect** How do the outcomes of gastrulation and neurulation contribute to human development?

Immunity and Disease

LESSON 27.4

What causes disease? People once believed that diseases were caused by curses, evil spirits, or bad behavior. Today, however, we know the causes of many diseases, and that has made it possible to prevent and cure many of them.

Classifying Diseases

A disease is an abnormal condition that harms an organism. Throughout most of human history, the causes of most diseases and how they were spread were a baffling mystery. This lack of knowledge led to "cures" that often did more harm than good. In the mid-nineteenth century, French chemist Louis Pasteur and German bacteriologist Robert Koch proposed the germ theory of disease, which is that **infectious diseases** occur when microorganisms disrupt normal body functions. Today, we call such microorganisms **pathogens**, meaning "sickness producers." ***Infectious diseases are caused by viruses, bacteria, fungi, "protists", and other pathogens.***

How Infectious Disease Spreads Many bacteria and viruses are spread through coughing, sneezing, and physical contact. When pathogens are released into the air, someone else may inhale them. Or the droplets may land on a surface, such as a doorknob. When an uninfected person touches the doorknob, he or she will pick up the pathogen.

Other types of diseases are spread through the exchange of body fluids that occurs during sexual intercourse or through blood transfusions. Donated blood is tested for a range of diseases before it becomes part of the blood supply.

Many pathogens that infect the digestive tract are spread through contaminated water. Contaminated water may be consumed, or it may carry pathogens onto fruit or vegetables that are later eaten.

KEY QUESTIONS

- *What causes infectious disease?*
- *What are the body's nonspecific defenses against pathogens?*
- *What is the function of the immune system's specific defenses?*
- *What health problems result when the immune system does not function properly?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

VOCABULARY

infectious disease
pathogen
inflammatory response
antigen
humoral immunity
cell-mediated immunity

READING TOOL

As you read, complete the table with information about the causes and effects of disease and prevention in your **Biology Foundations Workbook.**

CASE STUDY

Figure 27-32

Minamata Disease

Minamata disease, named after the Japanese city in which the condition was first discovered, results from severe mercury poisoning. Unfortunately, Minamata is not the first or last city in which citizens have been injured or killed by industrial pollution.

VIDEO

Learn about the strange actions of the pathogen that causes Lyme disease.

Disease Caused by Toxins

Another important category of diseases involves toxic chemicals that may be found in food or drinking water. For example, in the 1950s, a chemical plant in Minamata, Japan, released large amounts of methyl mercury into local waters. The mercury contaminated the fish that people ate.

The results were tragic, as shown in **Figure 27-32**. More than 2000 people were affected, suffering convulsions or paralysis. Like many heavy metals, mercury binds to proteins and blocks enzyme activity. In particular, mercury ions attack enzymes in the central nervous system that usually prevent cells from being damaged by oxidation. Eventually, nearly 1800 people in Minamata died from mercury poisoning.

Other chemicals found in water that can damage the body include compounds of arsenic, lead, and chromium. Some of these compounds occur naturally at low levels in streams and groundwater. However, some are released into the environment by mining or industrial activities. Public water systems are vulnerable as well, especially those built many decades ago when water pipes were made with lead.

Nonspecific Defenses

With pathogens all around us, how do we stay healthy most of the time? The reason is that our bodies have a series of defenses that protect us against infection. Some of these act against a wide range of pathogens and are called nonspecific defenses. ***Nonspecific defenses include the skin, tears, and other secretions; the inflammatory response; and fever.***

First Line of Defense

The most widespread nonspecific defense is the skin, a physical barrier that keeps most pathogens out of the body. Even the openings in the skin are protected. Saliva, mucus, and tears contain lysozyme, an enzyme that breaks down bacterial cell walls, while stomach secretions destroy many pathogens in food or water.

Second Line of Defense If pathogens do make it into the body, a second line of defense swings into action. Its mechanisms include the inflammatory response and fever. The **inflammatory response**, which is illustrated in **Figure 27-33,** causes infected areas to become red and painful, or inflamed. The response begins when pathogens stimulate cells called mast cells to release chemicals known as histamines that increase the flow of blood to the affected area. White blood cells then move into infected tissues, engulfing and destroying bacteria.

The immune system also releases chemicals that increase body temperature, producing a fever. Increased body temperature may slow down or stop the growth of some pathogens. Higher body temperature helps to speed up the immune response.

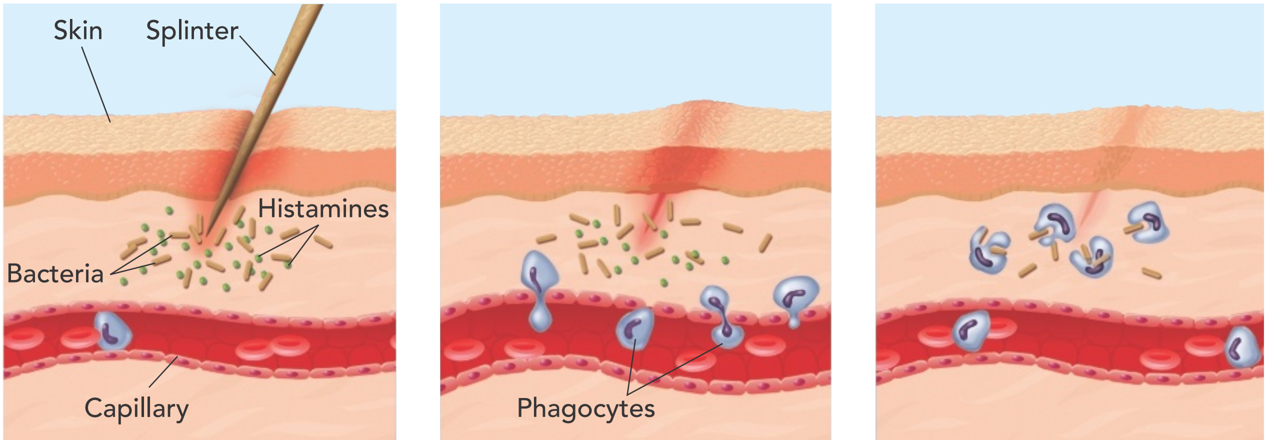
BUILD VOCABULARY

Related Word Forms The verb *inflame* means "to make sore, red, and swollen."

Figure 27-33

Inflammatory Response

The inflammatory response is a nonspecific defense reaction to tissue damage caused by injury or infection. **Infer** What part of the inflammatory response leads to redness around a wounded area?



1 In response to the wound and invading pathogens, mast cells release histamines, which stimulate increased blood flow to the area.

2 Local blood vessels dilate. Fluid leaves the capillaries and causes swelling. Phagocytes move into the tissue.

3 Phagocytes engulf and destroy the bacteria and damaged cells.

Specific Defenses: The Immune System

The body also has specific defenses, which respond to particular pathogens. ***The immune system's specific defenses distinguish between "self" and "other," inactivating or killing foreign substances or cells.***

INTERACTIVITY

Explore the different responses of the immune system to invading pathogens.

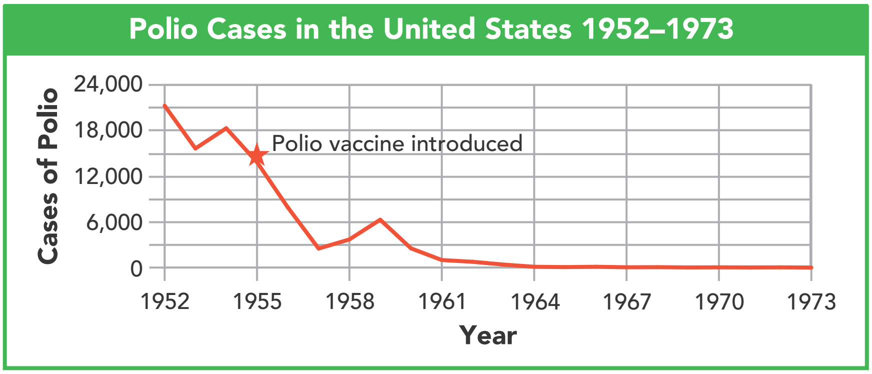
Recognizing "Self" and "Nonself" The immune system recognizes cells that belong in the body and treats these as "self." These cells carry chemical markers that act as passwords, saying, "I belong here. Don't attack me!" However, once the immune system recognizes a bacterium or virus as "other," it uses cellular and chemical weapons to attack it. In addition, after encountering an invader, the immune system "remembers" it. This immune "memory" enables a more rapid and effective response if the same pathogen attacks again.

INTERACTIVITY

Figure 27-34

Effectiveness of the Polio Vaccine

The polio vaccine greatly reduced the number of cases of polio in the United States. This in turn decreased the number of people who were paralyzed or died from the disease.



SOURCE: Pre-1962 data from Poliomyelitis. U.S. Department of Health, Education, and Welfare. Public Health Service. Health Information Series, No. 8. Public Health Service Publication No. 74. Rev. 1963. Data post-1962 from Centers for Disease Control.

Analyzing Data

Impact of the Polio Vaccine

Polio is an infectious viral disease that spreads from person to person by contact or through contaminated water. It infects the brain and spinal cord and can cause paralysis and death. The graph shows the number of polio cases in the United States over time.

1. **Analyze Graphs** Why might the number of cases have decreased in 1953 and then increased in 1954?
2. **Evaluate a Solution** How effective was the vaccine in eliminating polio in the short and long term?
3. **Construct a Counter-Argument** Some parents choose not to vaccinate their children. These parents claim that vaccines are unnecessary because the diseases they protect against are no longer prevalent in modern society. What might the consequences be if a significant number of people did not receive the vaccine?

How does the immune system recognize "others"? Specific immune defenses are triggered by molecules called antigens. An **antigen** is any foreign substance that can stimulate an immune response. Typically, antigens are molecules on the outer surfaces of bacteria, viruses, or parasites. The immune system responds to antigens by producing cells that attack the invaders directly or that produce proteins called antibodies that tag them for destruction.

Vaccines work by taking advantage of antigens and immunological memory. Vaccines contain the antigens of pathogens that cause diseases, such as smallpox, diphtheria, and polio. When a person is vaccinated with these antigens, the immune system generates antibody-producing cells. If the person comes in contact with this antigen again, the body is ready to fight. As **Figure 27-34** shows, within a few years of its introduction, the polio vaccine virtually eliminated this disease in the United States.

Fighting Infections The main working cells of the immune response are B lymphocytes (B cells) and T lymphocytes (T cells). B cells are produced in the bone marrow. T cells are produced in the bone marrow but mature in the thymus. Each B cell and T cell is capable of recognizing one specific antigen. Although both types of cells recognize antigens, they go about it differently.

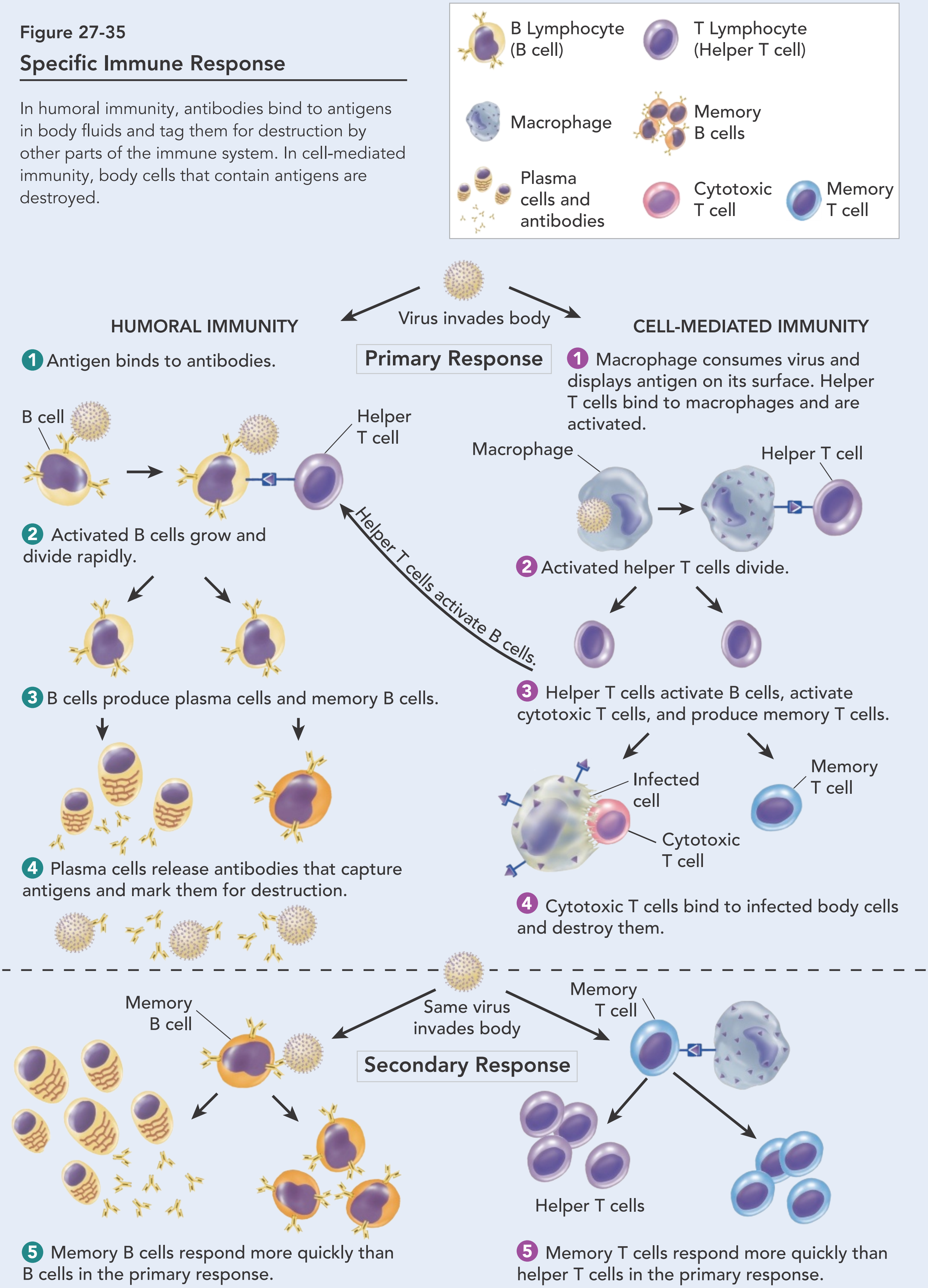
Both B cells and T cells continually search the body for signs of antigens. The specific immune response has two main styles of action: humoral immunity and cell-mediated immunity. **Humoral immunity** depends on the action of antibodies that circulate in the blood and lymph. **Cell-mediated immunity** defends the body against some viruses, fungi, and single-celled pathogens. The two types of immune response are shown in **Figure 27-35**.

READING CHECK **Explain** How do vaccines prevent disease?

Figure 27-35

Specific Immune Response

In humoral immunity, antibodies bind to antigens in body fluids and tag them for destruction by other parts of the immune system. In cell-mediated immunity, body cells that contain antigens are destroyed.



INTERACTIVITY

Explore how blood cell counts can help doctors diagnose leukemia.

Figure 27-36

Allergies

Ragweed pollen is a well-known allergen.

SEM 306x

Immune System Disorders

Failure of the immune system to react to pathogens can be life threatening. But the immune system can also cause problems when it overreacts to harmless antigens found in pollen, dust mites, pet dander, and even one's own cells. ***Problems with immune system function can result in allergies, asthma, autoimmune disease, and AIDS.***

Allergies Antigens that cause allergic reactions, such as the ragweed pollen shown in **Figure 27-36,** are called allergens. Allergens can trigger an inflammatory response, causing sneezing, watery eyes, a runny nose, and other irritations. Drugs called antihistamines help relieve allergy symptoms by counteracting these effects.

Asthma Allergic reactions in the respiratory system can create a dangerous condition called asthma, in which air passages narrow, causing wheezing and difficulty breathing. Asthma attacks can be triggered by respiratory infections, exercise, and stress as well as by allergens. Inhaled medications can relax smooth muscles around the airways and relieve asthma symptoms, preventing lung damage.

Autoimmune Disease When the immune system attacks the body's own cells, it produces an autoimmune disease. Type I diabetes is an autoimmune disease in which the immune system attacks insulin-producing cells in the pancreas. Other autoimmune diseases include rheumatoid arthritis and lupus. People with Type I diabetes can take insulin, while other autoimmune diseases can be treated with medications that suppress the immune response.

HIV and AIDS Medical progress has helped eradicate many once-deadly diseases, but new ones can always arise. During the late 1970s, physicians began reporting serious infections produced by microorganisms that didn't normally cause disease. Researchers concluded that these illnesses were symptoms of a new disorder they called acquired immunodeficiency syndrome (AIDS).

In 1983, researchers identified the cause of AIDS, which is the human immunodeficiency virus (HIV). HIV attacks key cells within the immune system, leaving the body with inadequate protection against pathogens. HIV is a retrovirus that carries its genetic information in RNA, rather than DNA. **Figure 27-37** shows how HIV attacks an immune system cell. Over time, HIV destroys T cells, crippling the ability of the immune system to fight HIV itself and other pathogens, which leads to AIDS.

HIV is deadly, but it is not transmitted through coughing, sneezing, sharing clothes, or other forms of casual contact. The four main ways that HIV is transmitted are sexual intercourse with an infected person; sharing needles with an infected person; contact with infected blood or blood products; or transmission from an infected mother to her child during pregnancy, birth, or breast-feeding.

READING TOOL

While reading about HIV and AIDS, write down any questions you have about how HIV is transmitted and how it replicates itself inside a cell. Look for answers as you read, or conduct additional research.

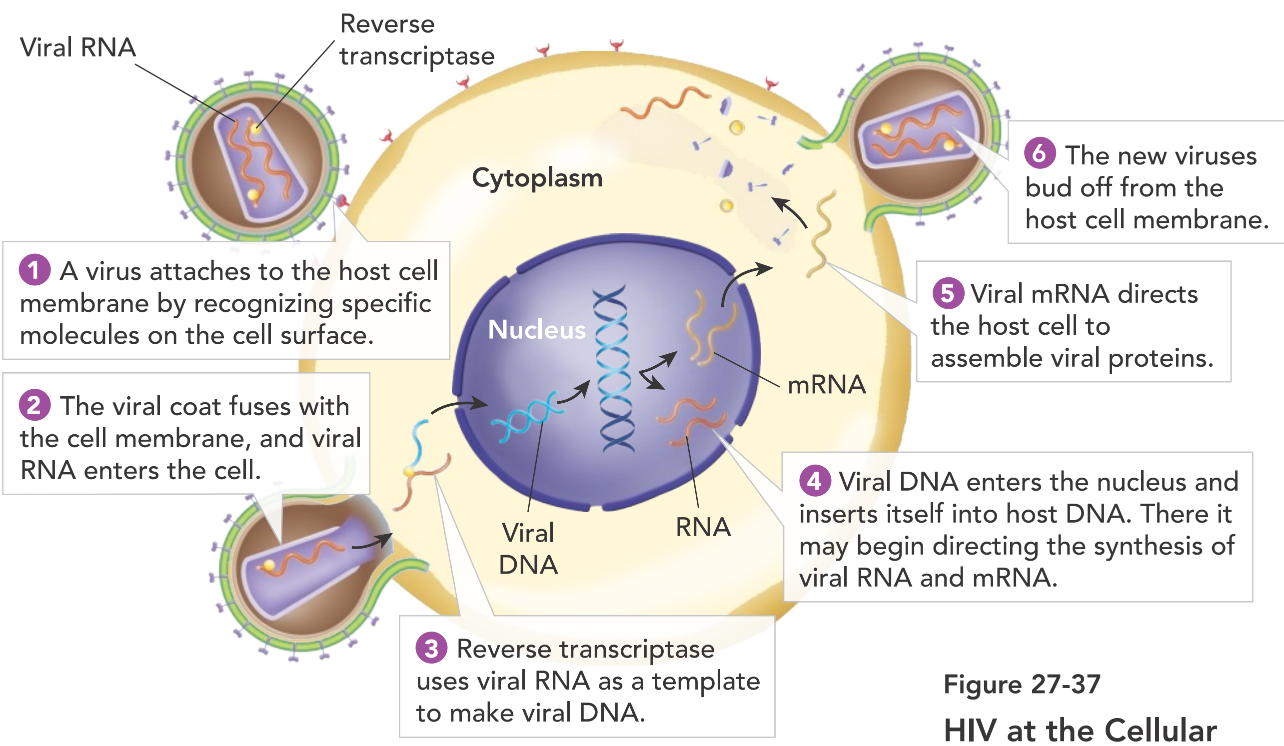


Figure 27-37

HIV at the Cellular Level

HIV travels through the blood, where it binds to receptors on a helper T cell. Inside the cell, the viral DNA directs the cell to produce many new viruses. These new viruses are quickly released back into the blood, where they infect more cells.

You can choose behaviors that reduce your risk of becoming infected with HIV. The best ways to avoid HIV infection are abstinence from sexual activity and avoidance of illegal intravenous drug use. Within a committed relationship, sexual fidelity between two uninfected partners presents the least risk of becoming infected with HIV.

At present, there is neither a cure for nor a reliable vaccine against AIDS. However, a steady stream of new drugs makes it possible to survive HIV infection for years. Unfortunately, these successful drugs have given some people the misconception that HIV is not serious. That idea is dead wrong. Each year in the United States about 40,000 people are diagnosed with HIV, and another 7,000 die from AIDS-related complications.

HS-LS1-1, HS-LS1-2

LESSON 27.4 Review

KEY QUESTIONS

1. What are the ways in which infectious diseases are spread?
2. Describe three of the nonspecific defenses against infection.
3. Why is it important for the immune system to distinguish "self" from "other"?
4. How does HIV damage the immune system?

CRITICAL THINKING

5. **Classify** Why can AIDS be classified as both an infectious disease and an immune system disorder?
6. **Compare and Contrast** How are nonspecific defenses against disease different from the immune system?
7. **Construct an Explanation** How can toxic chemicals cause disease? Cite a specific example.

CASE STUDY WRAP-UP

What's wrong with the water?

Fertilizers, pesticides, heavy metals, and a variety of harmful chemicals can all contaminate drinking water. Human health depends on keeping drinking water free of pollution.

HS-ETS1-1, HS-ETS1-3, CCSS.ELA-LITERACY.RST.9-10.8, CCSS.ELA-LITERACY.WHST.9-10.1, CCSS.ELA-LITERACY.WHST.9-10.7

Make Your Case

Our need for clean, safe water is one way that the environment and personal health are interrelated. In many communities in the United States and around the world, to drink water from the tap is to risk infection, cancer, or other diseases. When lead from old pipes leaches into drinking water, it causes some very serious health problems.

Evaluate a Solution

1. **Conduct Research** What is the source of drinking water for your home or community? How is the water treated before it reaches you? Research these questions and any issues that involve the community water supply.
2. **Engage in Argument** Evaluate the system that delivers water in your community. Argue that the system is sufficient for the community or that improvements are needed. Cite evidence from your research and this chapter to support your argument.


Flint River, Flint, Michigan

Technology on the Case

Get the Lead Out!

In the 1910s, chemist Thomas Midgley wanted to improve engine performance in automobiles. Midgley's solution was to add a compound called tetraethyl lead to the fuel. The lead compound proved to be wonderful for engines. Unfortunately, the lead also caused—and continues to cause—terrible health problems.

Even in Midgley's time, scientists knew that lead was toxic. Nevertheless, lead continued to be used for decades in gasoline, as well as in paints, pipes, and other products. As a result, lead spread throughout the environment. By the late 1970s, almost 90 percent of U.S. children ages 1 to 5 had elevated levels of lead in their blood.

The United States banned leaded gasoline in 1973, and the use of lead in paint and other products was phased out soon after. These actions greatly reduced the threat of lead. Over many years, the average blood levels of lead in children decreased significantly—although not to zero.

Today, lead persists in many homes and in the environment. The Environmental Protection Agency (EPA) has programs to help contractors remove lead paint safely. The EPA also helps homeowners test for lead in drinking water. However, as shown by the water crisis in Flint, Michigan, lead seems likely to cause trouble for years to come. The widespread use of lead in the previous century is a lesson about the side effects of a new technology. The effects can be unintended, harmful—and long lasting.

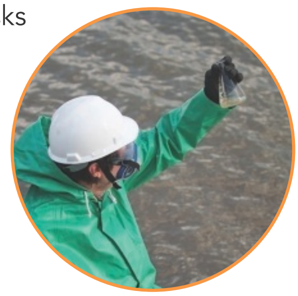
Careers on the Case

Work Toward a Solution

Toxicologists work closely with physicians and other healthcare providers to help prevent and treat the effects of poisons and toxins.

Toxicologist

This career specializes in the effects of chemicals on humans, wildlife, and ecosystems. Some toxicologists assess the risks to human health from a polluted environment. Others conduct research on potential toxins and poisons, such as new pesticides or industrial chemicals.



VIDEO

Learn more about toxicologists and other related careers.

STUDY GUIDE

Lesson Review

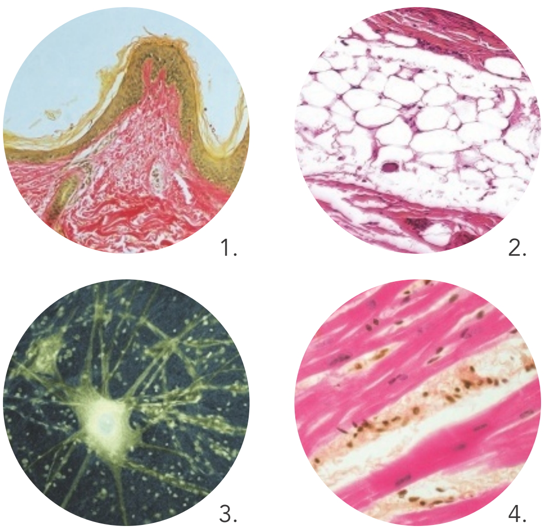
Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

27.1 Organization of the Human Body

The human body is an organization of cells, tissues, organs, and organ systems. At each level of organization, these parts work together to carry out the major body functions. The four basic types of tissues in the human body are epithelial, connective, nervous, and muscle.

The human body is constantly undergoing processes to maintain a controlled, stable internal environment called homeostasis. One way the body maintains homeostasis is through feedback inhibition. The liver is one of the body's most important organs for homeostasis.

- epithelial tissue
- connective tissue
- nervous tissue
- muscle tissue
- homeostasis
- feedback inhibition



Compare and Contrast Identify each type of tissue. What are some of the functions of each type of tissue?

27.2 Human Systems I

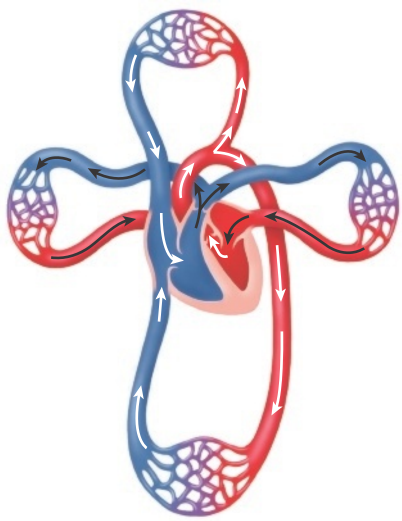
The digestive system converts food into small molecules that can be used by the cells of the body. The digestive system includes the mouth, esophagus, stomach, small intestine, and large intestine. The pancreas and gallbladder release substances that are involved in digestion.

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

The circulatory system uses blood to transport oxygen, nutrients, and other substances throughout the body. Blood also transports wastes from tissues. Blood is pumped through the body by the heart.

The lymphatic system is a network of vessels, nodes, and organs that collects lymph that leaves capillaries, "screens" it for microorganisms, and returns it to the circulatory system. The lymphatic system also plays an important role in the absorption of nutrients, especially fats.

The respiratory system picks up oxygen from the air we inhale and releases carbon dioxide as we exhale. The respiratory system includes the nose, pharynx, larynx, trachea, bronchi, and lungs.



Identify Which circulation pathway is indicated by the white arrows? By the black arrows? Briefly describe each pathway.

27.3 Human Systems II

The nervous system collects, processes, and responds to information about the internal and external environment. Neurons transmit nervous system signals. The central nervous system consists of the brain and spinal cord. The peripheral nervous system consists of nerves that transmit signals to and from the central nervous system.

The skeletal system supports the body, protects internal organs, assists in movement, stores minerals, and produces blood cells. Bones are a solid network of living cells. Joints permit bones to move without damaging each other.

There are three types of muscle tissue: smooth, skeletal, and cardiac. Skeletal muscles pull on body parts as they contract.

The integumentary system includes the skin, hair, and nails; serves as a barrier against infection and injury; and helps to produce vitamin D.

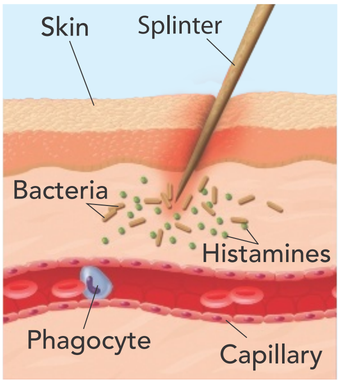
The endocrine system is made of glands that release hormones into the blood. The endocrine system is regulated by feedback mechanisms. The male and female reproductive systems produce sperm and eggs, respectively. The female reproductive system also prepares the female's body to nourish an embryo. The fusion of egg and sperm is called fertilization. A fertilized egg is a zygote that may develop into an embryo.

Review Draw a diagram of the nervous system. Label the spinal cord, cerebrum, brain stem, and peripheral nerves.

27.4 Immunity and Disease

Infectious diseases are caused by pathogens. Environmental chemicals can also cause damage to the human body. The body has a series of defenses to protect itself against infection. Nonspecific defenses include the skin, tears, and other secretions; the inflammatory response, and fever. The immune system's specific defenses distinguish between "self" and "other," and they inactivate or kill any foreign substance or cell that enters the body.

- infectious disease
- pathogen
- inflammatory response
- antigen
- humoral immunity
- cell-mediated immunity

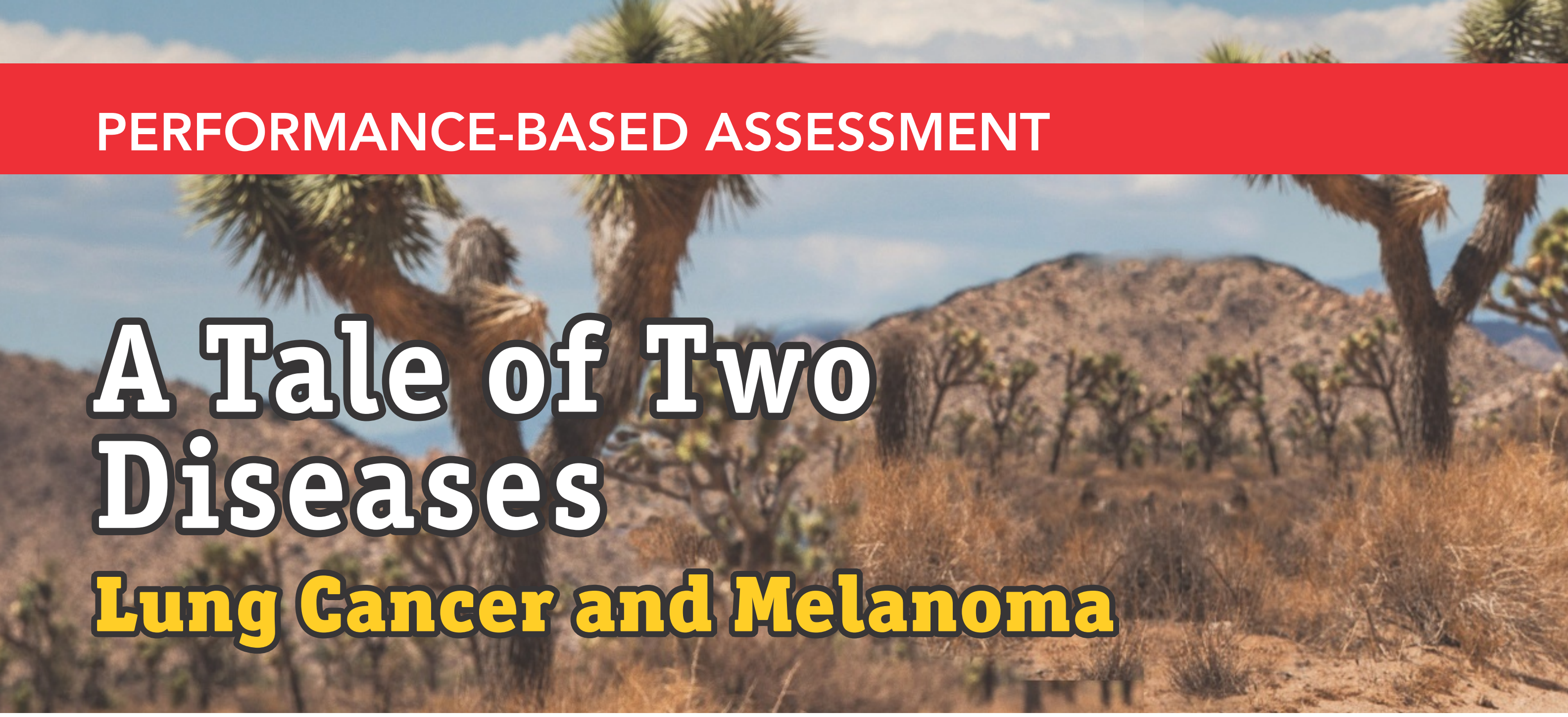


Interpret Visuals Develop a description of the process depicted in this diagram. In your description, use all of the labels shown in the diagram.

Organize Information

Complete the table by describing the function of the organ systems and listing their major organs.

Organ System	Function	Major Organs
Circulatory System	1.	Heart, blood vessels
Respiratory System	2.	3.
Nervous System	4.	5.
Muscular System	Movement of the body	6.
Endocrine System	7.	8.
Digestive System	9.	10.
Reproductive System	11.	12.



PERFORMANCE-BASED ASSESSMENT

A Tale of Two Diseases

Lung Cancer and Melanoma

Research a Problem

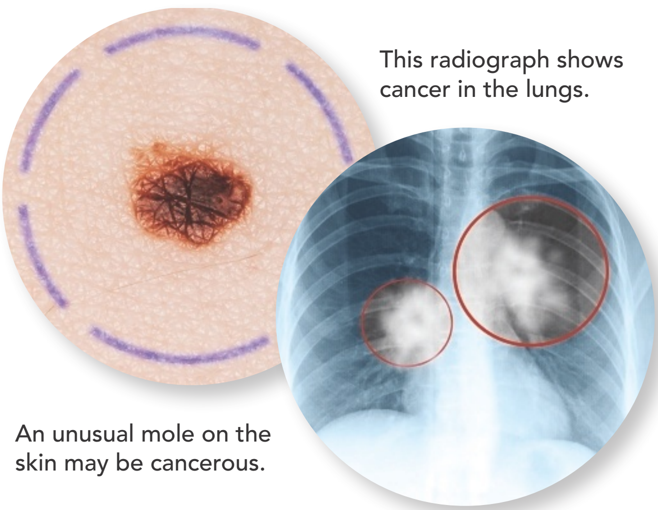
HS-ETS1-1, CCSS.ELA-LITERACY.RST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.4, CCSS.ELA-LITERACY.WHST.9-10.7, CCSS.ELA-LITERACY.WHST.9-10.8, CCSS.ELA-LITERACY.WHST.9-10.9

STEM Cancer can strike anyone and at any time in a person's life. Cancer also can strike any organ or organ system. However, the risk of developing cancer varies with age, and it varies from person to person. Many types of cancer are more common in some families than others, which means that genes play a role. Other cancers are linked to the environment.

For example, using tobacco products increases a person's risk for developing lung cancer. According to the Centers for Disease Control and Prevention (CDC), cigarette smoking is linked to 80 to 90 percent of lung cancers in the United States. Smokers are up to 30 times more likely than nonsmokers to develop lung cancer—as well as to die from it. Inhaling secondhand smoke, which is tobacco smoke exhaled by someone else, is also a risk factor for lung cancer.

Another cancer linked to the environment is melanoma, which is a dangerous form of skin cancer. Heavy exposure to ultraviolet (UV) rays causes damage to skin cells that can lead to melanoma. UV rays are emitted by the sun and by the artificial lights used in tanning beds.

At the CDC, researchers gather data on all types of cancer and their effects on the population. Their data were used to construct the two graphs displayed here. The graphs show the number of cases of lung cancer and melanoma by year and by sex. Use the graphs, your research skills, and scientific reasoning to answer the questions that follow.

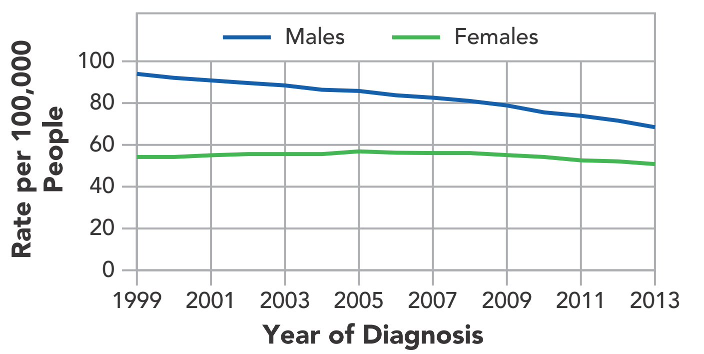


This radiograph shows cancer in the lungs.

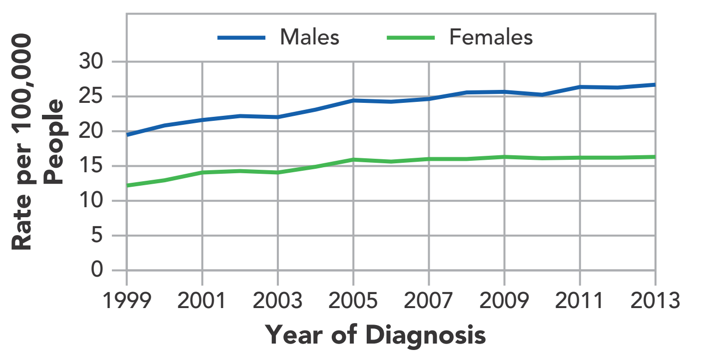
An unusual mole on the skin may be cancerous.

SCIENCE PROJECT

Lung and Bronchial Cancer Incidence Rates* for Males and Females, United States, 1999–2013**



Melanoma of the Skin Incidence Rates* for Males and Females, United States, 1999–2013**



* Rates are the number of cases per 100,000 persons and are age-adjusted to the 2000 U.S. standard population

** Data are compiled from cancer registries that meet the data quality criteria for all invasive cancer sites combined for all years, 1999–2013 (covering approximately 92% of the U.S. population).

Sources: CDC's National Program of Cancer Registries and National Cancer Institute's Surveillance, Epidemiology, and End Results program

1. **Interpret Graphs** For the time period shown in the graph, what are the trends in lung cancer cases for males and females? What are the trends for cases of melanoma?

2. **Form a Hypothesis** State reasonable hypotheses to explain the trends you identified.

3. **Ask Questions** What questions could you ask, and then investigate, to help you evaluate your hypotheses?

4. **Conduct Research** Choose either lung cancer or melanoma. Find trustworthy sources to research the answers to the questions you asked about the disease. Also research additional information about the risk factors of the disease, its treatments, and likely outcomes.

5. **Evaluate Evidence** Does the information you discovered support your hypothesis? If not, what other explanations can you propose for the trend you identified?

6. **Communicate** Share your findings in a written report, computer presentation, or poster. Include useful advice and the evidence that supports the prevention of the type of cancer you researched.

CHAPTER 27

ASSESSMENT

KEY IDEAS AND TERMS

27.1 Organization of the Human Body

HS-LS1-1, HS-LS1-2, HS-LS1-3

1. Which of the following is the correct order, from simplest to most complex, for the levels of organization in the human body?
   a. organ systems, tissues, organs, cells
   b. cells, tissues, organs, organ systems
   c. organ systems, organs, tissues, cells
   d. cells, organs, organ systems, tissues
2. Read the following statements. In maintaining homeostasis, what is the correct order in which these events occur?
   1) The liver removes glucose from the blood.
   2) The body absorbs food molecules after eating.
   3) As the body uses glucose for energy, the liver releases stored glucose into the blood.
   4) The levels of glucose in the blood rise.
   a. 3, 4, 1, 2
   b. 4, 1, 2, 3
   c. 2, 4, 1, 3
   d. 1, 2, 3, 4
3. Why is it important for an organism to maintain homeostasis?
4. Which tissues make voluntary movement possible?

27.2 Human Systems I

HS-LS1-1, HS-LS1-2, HS-LS1-3

5. Where does mechanical digestion begin?
   a. the esophagus
   b. the mouth
   c. the large intestine
   d. the small intestine
6. What structure removes excess water, urea, and metabolic waste from the blood?
   a. kidney
   b. renal vein
   c. urinary bladder
   d. ureter
7. What are the components of blood, and what are their functions?
8. What is the main muscle in the respiratory system?
9. What are alveoli, and in which organ system do they function?
10. How does the lymphatic system work?

Use the following table to answer questions 11 and 12.

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

11. Which enzymes are involved in the breakdown of sugar and starch?
12. Suppose you ate a peach. How and where would enzymes break down the proteins in the peach?

27.3 Human Systems II

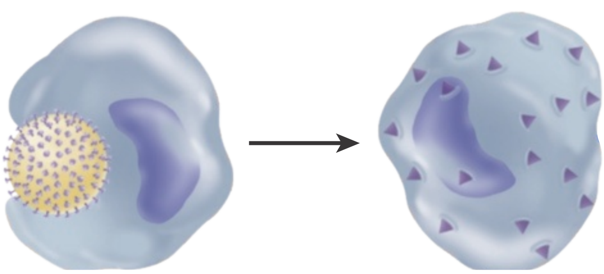
HS-LS1-1, HS-LS1-2, HS-LS1-3

13. Which division of the nervous system speeds up your heart rate?
    a. somatic
    b. autonomic
    c. central
    d. brain and spinal cord
14. Which type(s) of muscle can contract without stimulation from the nervous system?
    a. skeletal only
    b. skeletal and smooth
    c. smooth and cardiac
    d. cardiac only
15. What do bones do besides support the body and protect internal organs?
16. What are the functions of the skin?
17. How does a feedback mechanism regulate the activity of the endocrine system?
18. What are the major organs of the human reproductive system in males and females?

27.4 Immunity and Disease

HS-LS1-1, HS-LS1-2

19. The body's nonspecific defenses against invading pathogens include
    a. antibodies.
    b. mucus, sweat, and tears.
    c. antibiotics.
    d. cytotoxic T cells.
20. What causes asthma?
    a. Bacteria that are resistant to antibiotics infect the body.
    b. Particular antigens trigger muscle contractions that make it difficult to breathe.
    c. Antibodies and cytotoxic T cells attack cells in the tissues of the lungs.
    d. Mosquito-borne pathogens enter the bloodstream.
21. Which type of immune response involves redness and swelling around damaged cells?
    a. cell-mediated response
    b. humoral response
    c. inflammatory response
    d. autoimmune response
22. Explain the difference between a specific and a nonspecific immune response.
23. How do vaccines prevent disease?
24. What is an antigen, and how is it harmful?
25. What is HIV? What type of disease does it cause?
26. Explain what is happening in this image. Which type of immune response will this lead to—humoral immunity or cell-mediated immunity?



CRITICAL THINKING

HS-LS1-2, HS-LS1-3

27. **Classify** Is blood classified as a cell, a tissue, an organ, or an organ system? Explain the classification.
28. **Infer** Many people have had their stomachs either partially or completely removed. They survive by eating predigested food. Could a person survive without a small intestine? Explain your inference.
29. **Synthesize Information** How does the lymphatic system interact with the digestive, circulatory, and muscular systems?
30. **Predict** Explain how the removal of someone's lymph nodes can affect his or her ability to fight disease.
31. **Use Analogies** How is transmission of an action potential through a neuron similar to ripples spreading across a pond?
32. **Infer** Disks of cartilage are found between the vertebrae of the spinal column. Cartilage also lines many joints, including the shoulder and knee. What is the likely function of the cartilage?
33. **Use Scientific Reasoning** Tobacco smoke can damage white blood cells in the respiratory tract. These cells help clear airways of debris from the environment. How could this damage contribute to respiratory diseases?

The table shows the percentages of blood that flow through several organs of the human body. Use the table to answer questions 34 to 36.

Blood Flow Through Human Organs

Organ	Percentage of Total Flow
Brain	14%
Heart	5%
Kidneys	22%
Liver	13%
Lungs	100%
Skeletal muscles	18%
Skeletal muscles during exercise	75%

34. **Reason Quantitatively** How does exercise affect the flow of blood through skeletal muscles?
35. **Interpret Visuals** Refer to the diagram of the circulatory system in Figure 27-10. How does the diagram help explain the percentage of blood flow to the lungs?
36. **Infer** Which organ receives the lowest percentage of blood flow? Use your knowledge of human systems to suggest an explanation for this low percentage.

CHAPTER 27
ASSESSMENT

CROSSCUTTING CONCEPTS

37. **Stability and Change** Discuss how the body of a developing fetus is an example of both stability and change.

38. **Systems and System Models** The systems of a city are sometimes used to model the organ systems of the human body. Consider these three city systems: roads and vehicles, telephone wires, and sewage systems. How are they useful models of organ systems?

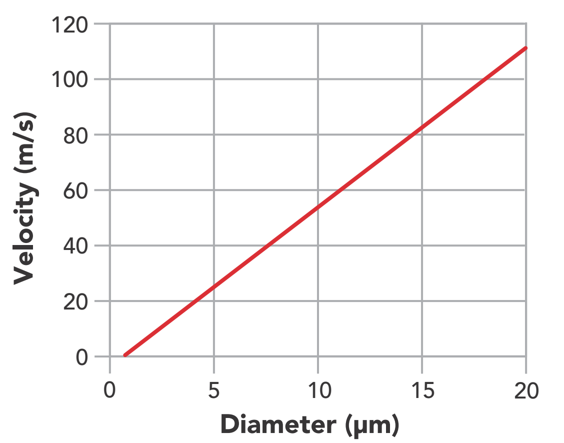
MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.MP2, CCSS.MATH.CONTENT.HSS.ID.A.1

The graph shows the relationship between neuron diameter and impulse conduction speed in a typical mammal nerve (myelinated). Use the graph to answer questions 39 and 40.

Conduction Speed and Neuron Diameter

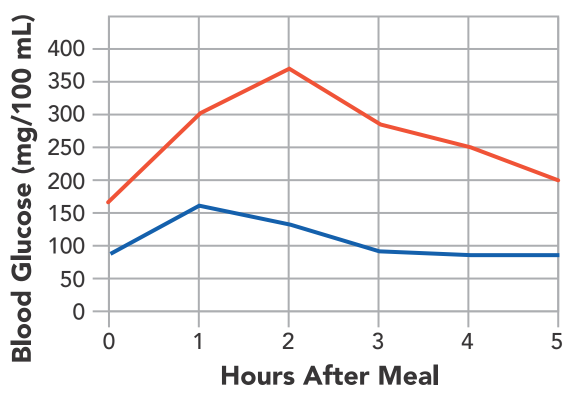


39. **Interpret Graphs** What conclusion about the speed of nerve conduction and the diameter of the neuron is supported by the graph?

40. **Calculate** In a reflex response, your hand touches a hot object and immediately pulls away. During this action, impulses travel a total distance of about 1.5 meters down neurons that are 5 μm in diameter. How much time is needed for the impulse to travel this distance?

The following line graph shows the levels of glucose in the blood of two people during a five-hour period immediately following the ingestion of a typical meal. Use the graph to answer questions 41 and 42.

Blood Glucose Level After Eating



41. **Interpret Graphs** How long does it take the blood glucose level of the person represented by the blue line to return to homeostatic value?

42. **Defend Your Claim** The body of a person with Type 2 diabetes does not use insulin properly. At first, the body makes extra insulin to make up for this. Over time, however, the body cannot make enough insulin to keep blood glucose at normal levels. Based on this information and the diagram of the feedback loop in Figure 27-27, which person probably has Type 2 diabetes? Justify your choice.

LANGUAGE ARTS CONNECTION

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

43. **Write Explanatory Texts** 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 food as it moves through the digestive system.

44. **Write Informative Texts** Choose a simple activity from everyday life, such as opening a door, eating a sandwich, or saying hello to a friend. Describe the actions of at least three organ systems that work together to complete this activity.

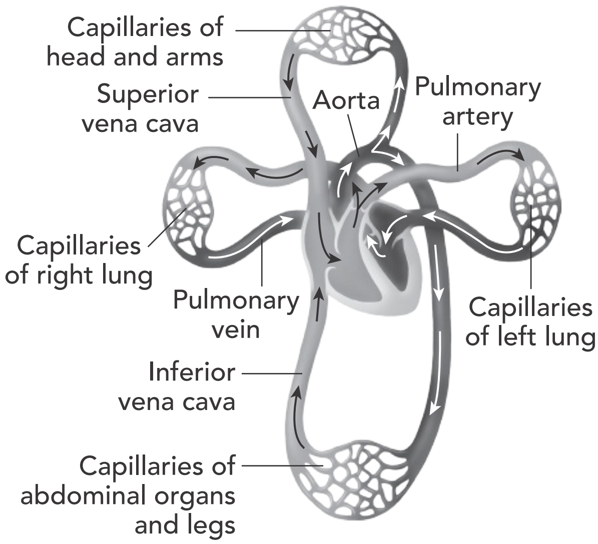
Read About Science

CCSS.ELA-LITERACY.RST.9-10.2

45. **Summarize Text** How does blood travel through the circulatory system? Identify the organs that blood passes through and the events that occur in these organs.

END-OF-COURSE TEST PRACTICE

1. The circulatory system transports substances throughout the body. The diagram shown summarizes blood flow through the circulatory system.



If a clot were to form in the pulmonary artery, how would this affect other systems?

A. Blood flow from the heart to the lungs would be reduced.
B. Blood flow from the heart to body tissues would be reduced.
C. Blood flow from the lungs to body tissues would increase.
D. Blood flow from the lungs to the heart would increase.
E. Blood flow from the aorta to the arms and legs would increase.

2. Ricardo is investigating ways that the human body maintains homeostasis. What is one way that the body can maintain homeostasis?

A. When the hypothalamus senses an increase in body temperature it sends signals for the body to produce sweat.
B. When the hypothalamus senses an increase in body temperature it sends signals for the body to increase cellular respiration.
C. When the hypothalamus senses a decrease in body temperature it sends signals for the kidneys to produce urine.
D. When the hypothalamus senses a decrease in body temperature it sends signals for the body to absorb nutrients from food.
E. When the hypothalamus senses a decrease in body temperature it sends signals for the liver to release stored glucose.

3. How does the immune system depend on other systems to produce an immune response?

A. B cells are produced in the bone marrow of the skeletal system.
B. Vaccines are produced in the blood vessels of the circulatory system.
C. Antigens are secreted by the endocrine system.
D. Allergens are secreted in the airways of the respiratory system.
E. Fever occurs when muscles in the muscular system contract.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With…			
Question	1	2	3
See Lesson	27.2	27.1	27.4
Performance Expectation	HS-LS1-2	HS-LS1-3	HS-LS1-2