

35-1 Human Body Systems

7 5.a. Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organization. **BI 9.c.** Students know how feedback loops in the nervous and endocrine systems regulate conditions in the body.

As the missed shot bounces high in the air, one of the defenders decides to take a chance. She breaks for the other end of the court. Another defender grabs the rebound, glances upcourt, and throws a long, arching pass toward the basket. Wide open, her teammate grabs the pass, dribbles, and leaps into the air, laying the basketball carefully off the backboard and into the unguarded basket. The buzzer goes off, and the game is over.

Organization of the Body

Teamwork is a wonderful thing! Anyone watching the end of this game would be impressed at the way these two players worked together to make the winning play. But the real teamwork on this play involved a much larger number of players—the nearly one hundred trillion cells that make up the human body.

Every cell in the human body is both an independent unit and an interdependent part of a larger community—the entire organism. To make a winning basket, a basketball player has to use her eyes to watch the play and her brain to figure out how to score. With the support of her bones, her muscles propel her body up the court. As she sprints for a pass, her lungs absorb oxygen, which her blood carries to her cells. Her brain monitors the sensation of the ball on her fingertips and sends signals that guide her body into the air for the final play.

How does the body get so many individual cells to work together so beautifully? You can begin to answer this question by studying the organization of the human body. **The levels of organization in a multicellular organism include cells, tissues, organs, and organ systems.** Tissues are groups of similar cells that perform a single function, such as connecting a muscle to a bone. An organ is a group of tissues that work together to perform a complex function, such as sight. An organ system is a group of organs that perform closely related functions.

The eleven organ systems of the human body work together to maintain homeostasis in the body as a whole. The organ systems, including their main structures and functions, are shown in **Figure 35-2** on pages 892 and 893.

► **Figure 35-1** Each player on a basketball team has a different role, but together the team works toward a common goal—winning the game.

Guide for Reading

Key Concepts

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

Vocabulary

specialized cell
epithelial tissue
connective tissue
nervous tissue
muscle tissue
homeostasis
feedback inhibition

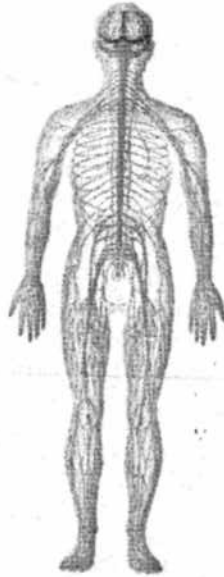
Reading Strategy:

Predicting Before you read, use **Figure 35-2** to predict how many organ systems help to regulate body temperature. As you read, look for evidence to support your prediction.



FIGURE 35-2 HUMAN ORGAN SYSTEMS

➤ The levels of organization in the human body include cells, tissues, organs, and organ systems. Although each of the eleven organ systems shown here has a different set of functions, they all work together, as a whole, to maintain homeostasis.



Nervous System

Structures: Brain, spinal cord, peripheral nerves

Function: Recognizes and coordinates the body's response to changes in its internal and external environments



Integumentary System

Structures: Skin, hair, nails, sweat and oil glands

Function: Serves as a barrier against infection and injury; helps to regulate body temperature; provides protection against ultraviolet radiation from the sun



Skeletal System

Structures: Bones, cartilage, ligaments, tendons

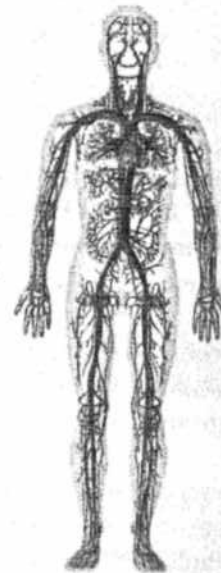
Function: Supports the body; protects internal organs; allows movement; stores mineral reserves; provides a site for blood cell formation



Muscular System

Structures: Skeletal muscle, smooth muscle, cardiac muscle

Function: Works with skeletal system to produce voluntary movement; helps to circulate blood and move food through the digestive system



Circulatory System

Structures: Heart, blood vessels, blood

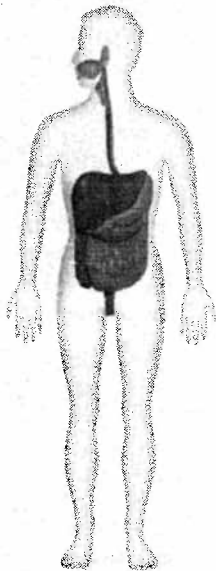
Function: Brings oxygen, nutrients, and hormones to cells; fights infection; removes cell wastes; helps to regulate body temperature



Respiratory System

Structures: Nose, pharynx, larynx, trachea, bronchi, bronchioles, lungs

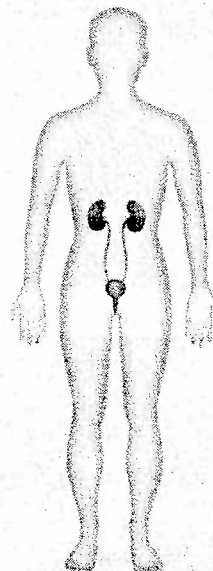
Function: Provides oxygen needed for cellular respiration and removes excess carbon dioxide from the body



Digestive System

Structures: Mouth, pharynx, esophagus, stomach, small and large intestines, rectum

Function: Converts foods into simpler molecules that can be used by the cells of the body; absorbs food; eliminates wastes



Excretory System

Structures: Skin, lungs, kidneys, ureters, urinary bladder, urethra

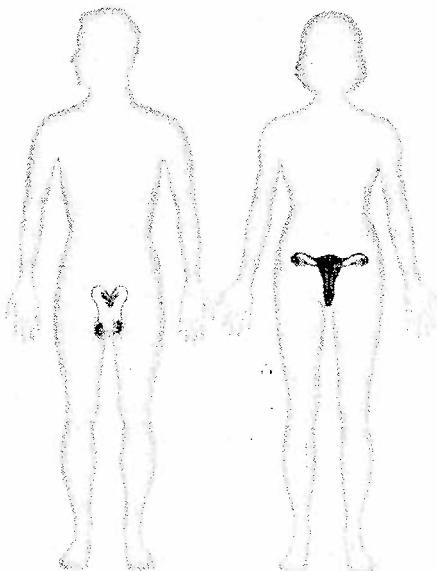
Function: Eliminates waste products from the body in ways that maintain homeostasis



Endocrine System

Structures: Hypothalamus, pituitary, thyroid, parathyroids, adrenals, pancreas, ovaries (in females), testes (in males)

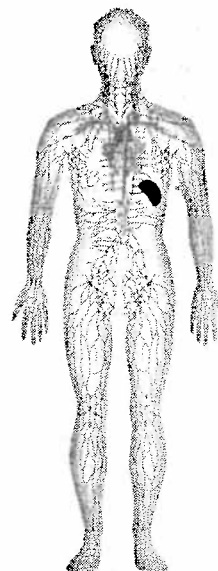
Function: Controls growth, development, and metabolism; maintains homeostasis



Reproductive System

Structures: Testes, epididymis, vas deferens, urethra, and penis (in males); ovaries, Fallopian tubes, uterus, vagina (in females)

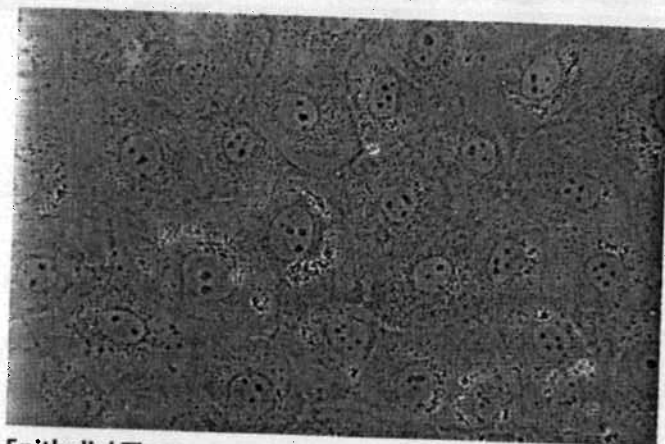
Function: Produces reproductive cells; in females, nurtures and protects developing embryo



Lymphatic/Immune Systems

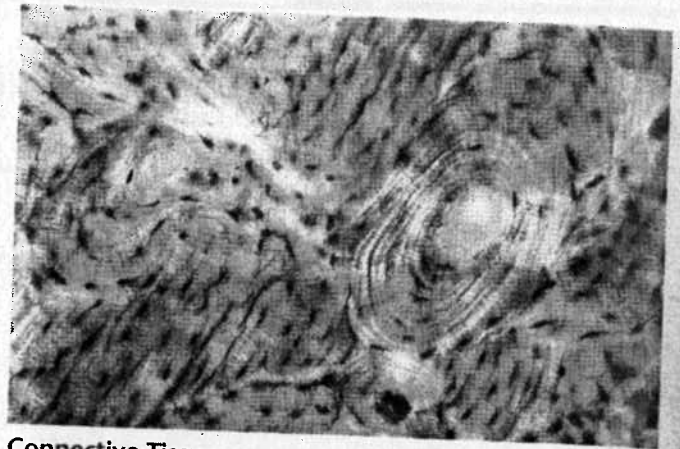
Structures: White blood cells, thymus, spleen, lymph nodes, lymph vessels

Function: Helps protect the body from disease; collects fluid lost from blood vessels and returns the fluid to the circulatory system



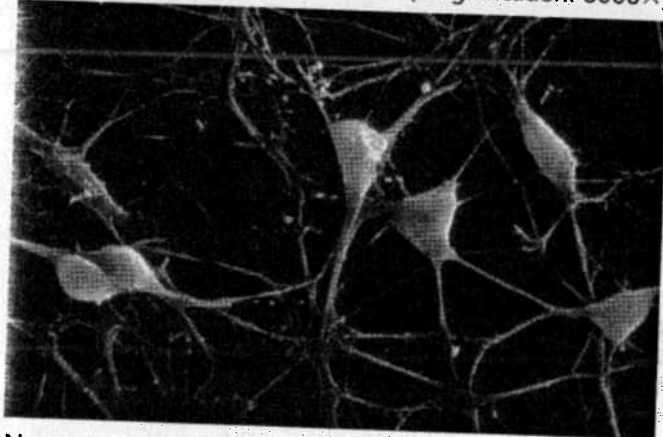
Epithelial Tissue

(magnification: 6000×)



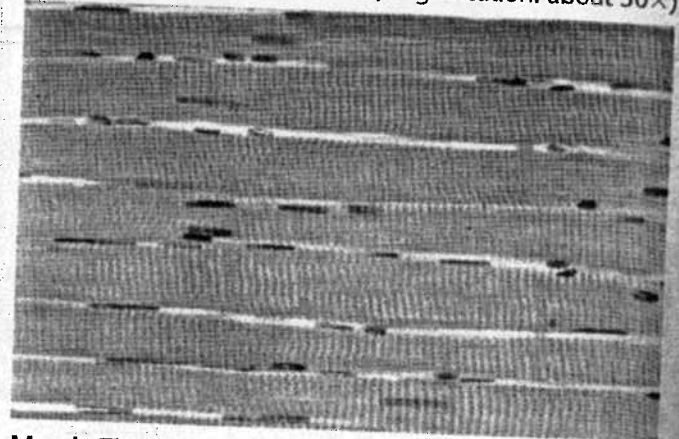
Connective Tissue

(magnification: about 50×)



Nervous Tissue

(magnification: 1100×)



Muscle Tissue

(magnification: 150×)

▲ **Figure 35-3** The four major types of tissues in the human body are epithelial tissue, connective tissue, nervous tissue, and muscle tissue. **Inferring** What kind of tissue is bone?

Cells A cell is the basic unit of structure and function in living things. Individual cells in multicellular organisms tend to be specialized. **Specialized cells** are uniquely suited to perform a particular function.


Tissues A group of cells that perform a single function is called a tissue. There are four basic types of tissue in the human body—epithelial, connective, nervous, and muscle. **Figure 35-3** shows examples of these tissues. **Epithelial tissue** includes glands and tissues that cover interior and exterior body surfaces. **Connective tissue** provides support for the body and connects its parts. **Nervous tissue** transmits nerve impulses throughout the body. And **muscle tissue**, along with bones, enables the body to move.

Organs A group of different types of tissues that work together to perform a single function 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 is one of the organs of the nervous system, which gathers information about the outside world and coordinates the body's response.


✓ **CHECKPOINT** What is the role of nervous tissue?

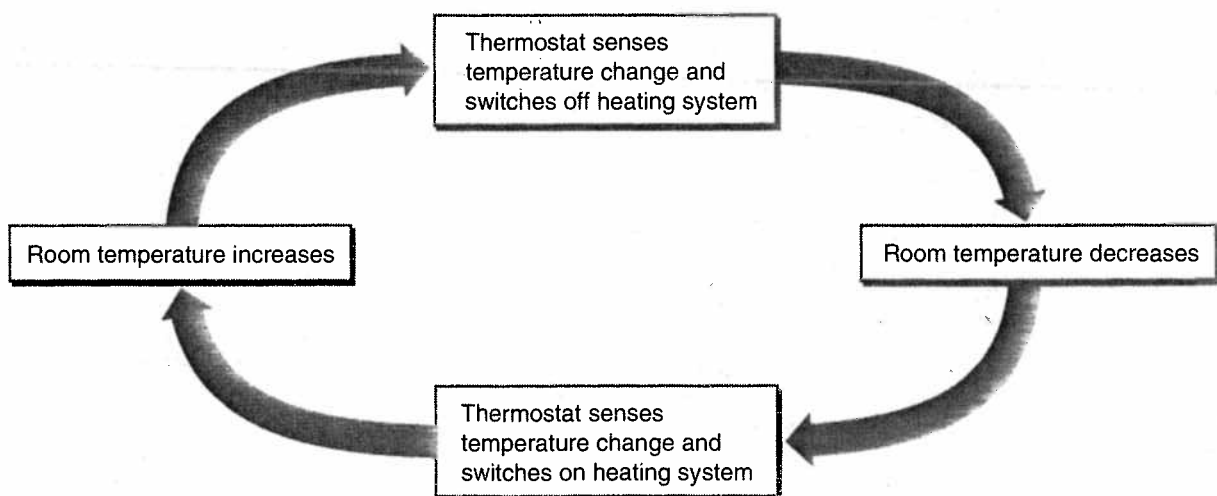
Maintaining Homeostasis

You can get a glimpse of the interrelationship of your body systems when you breathe deeply after climbing a steep hill or when your blood clots to seal a cut. Behind the scenes, your organ systems are working constantly to do something that few people appreciate—maintain a controlled, stable environment. This process is called **homeostasis**, which means “keeping things in balance.”  **Homeostasis is the process by which organisms keep internal conditions relatively constant despite changes in external environments. Homeostasis in the body is maintained by feedback loops.**

A Nonliving Example One way to understand homeostasis is to look at a nonliving system that also keeps environmental conditions within a certain range. The heating system of a house is a perfect example. In most houses, heat is supplied by a furnace that burns oil or natural gas. When the temperature within the house drops below a set point, a sensor in a device called a thermostat 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. Because the furnace runs only when it is needed, the temperature of the house is kept within a narrow range.

A heating system like the one described is said to be controlled by feedback inhibition. **Feedback inhibition**, or negative feedback, is the process in which a stimulus produces a response that opposes the original stimulus. **Figure 35-4** 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 enough to send a feedback signal to switch the furnace off. Systems controlled by feedback inhibition are generally fully automated and very stable.

Figure 35-4  Homeostasis is the process by which organisms keep internal conditions relatively constant despite changes in external environments. A home heating system uses a feedback loop to maintain a stable, comfortable environment within a house.



Word Origins

Thermometer comes from the Greek words *therme*, meaning "heat," and *metron*, meaning "measure." So, thermometer means an instrument used to measure heat. If *hypo-* is Greek for "under," what does *hypothermia* mean?

In the Body Could biological systems achieve homeostasis through feedback inhibition? Absolutely. All that is needed is a system that regulates some aspect of the cellular environment and that can respond to feedback from its own activities by switching on or off as needed.



Maintenance of homeostasis requires the integration of all organ systems at all times. One example is the maintenance of a stable body temperature. The body regulates temperature by a mechanism that is remarkably similar to that of a home heating system. A part of the brain called the hypothalamus contains nerve cells that monitor both the temperature of the skin at the surface of the body and the temperature of organs in the body's core. The temperature of the core is generally higher than the temperature of the skin.

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 cellular activity causes a gradual rise in body temperature, which is detected by nerve cells in the hypothalamus. This feedback inhibits the production of the chemicals that speed up cellular activity and keeps body temperature from rising to a dangerous level.

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 back toward the normal range.

If body temperature rises too far above 37°C, the hypothalamus slows down cellular activities, minimizing the production of heat. This is one of the main 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. Because heat from the body's core is carried by the blood to the skin, evaporation at the body surface also helps to lower the temperature of the core. When this temperature returns to its set point, the body stops producing sweat.

35-1 Section Assessment

1.  **Key Concept** Sequence the levels of organization in multicellular organisms.
2.  **Key Concept** What is homeostasis?
3. Describe the functions of each of the eleven organ systems.
4. What are the four types of tissue?

5. **Critical Thinking Inferring**
Look at the nervous tissue in **Figure 35-3**. Compare the cells of the nervous tissue to the cells of one of the other types of tissue. Which parts of an animal would contain these types of cells?

Thinking Visually

Making a Venn Diagram
Draw a Venn diagram to relate the four basic levels of organization in the human body. Provide at least three examples for each level included in your diagram.

35-2 The Nervous System

BI 9.b. Students know how the nervous system mediates communication between different parts of the body and the body's interactions with the environment. **BI 9.d.** Students know the functions of the nervous system and the role of neurons in transmitting electrochemical impulses. **BI 9.e.** Students know the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.

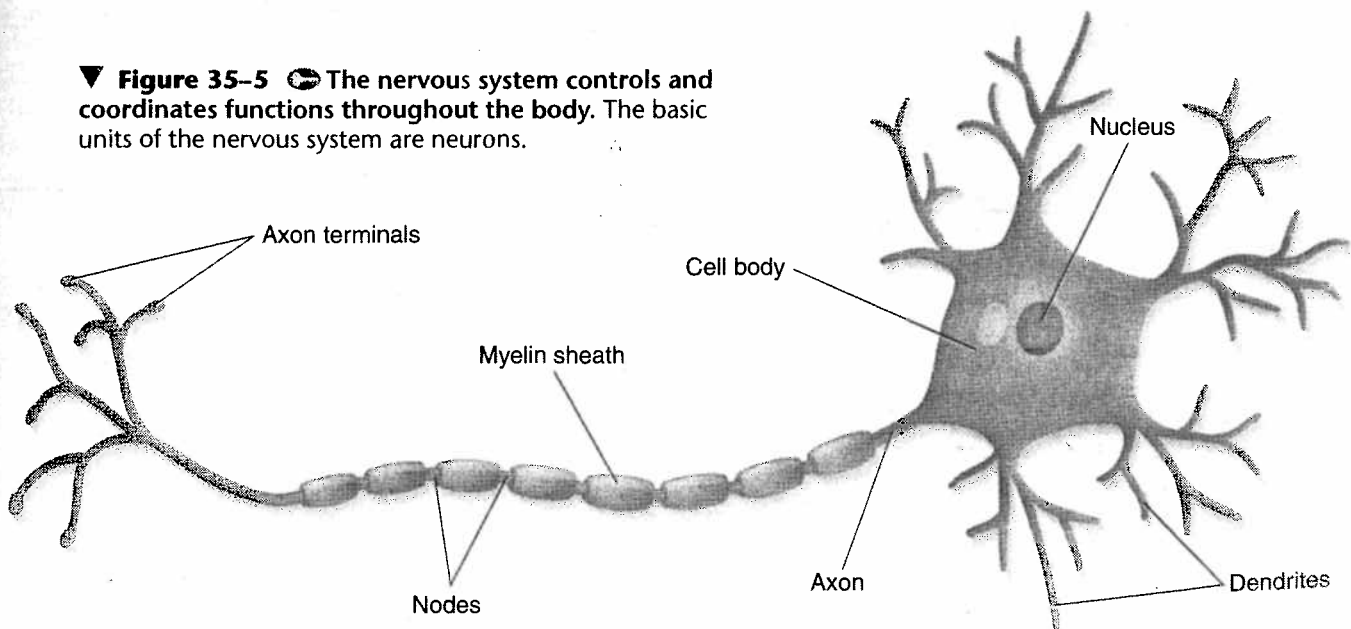
Play any team sport—basketball, softball, soccer—and you will discover that communication is one of the keys to success. Coaches call plays, players signal to one another, and the very best teams communicate in a way that enables them to play as a single unit. Communication can make the difference between winning and losing.

The same is true for living organisms. Nearly all multicellular organisms have communication systems. Specialized cells carry messages from one cell to another so that communication among all body parts is smooth and efficient. In humans, these cells include those of the nervous system. **The nervous system controls and coordinates functions throughout the body and responds to internal and external stimuli.**

Neurons

The messages carried by the nervous system are electrical signals called impulses. The cells that transmit these impulses are called **neurons**. Neurons can be classified into three types according to the direction in which an impulse travels. Sensory neurons carry impulses from the sense organs to the spinal cord and brain. Motor neurons carry impulses from the brain and the spinal cord to muscles and glands. Interneurons connect sensory and motor neurons and carry impulses between them. Although neurons come in all shapes and sizes, they have certain features in common. **Figure 35-5** shows a typical neuron. The largest part of a typical neuron is the **cell body**. The cell body contains the nucleus and much of the cytoplasm. Most of the metabolic activity of the cell takes place in the cell body.

▼ **Figure 35-5** The nervous system controls and coordinates functions throughout the body. The basic units of the nervous system are neurons.



Guide for Reading

Key Concepts

- What are the functions of the nervous system?
- How is a nerve impulse transmitted?

Vocabulary

neuron
cell body
dendrite
axon
myelin sheath
resting potential
action potential
threshold
synapse
neurotransmitter

Reading Strategy:

Summarizing As you read, find the main ideas for each paragraph. Write down a few key words from each main idea. Then, use the key words in your summary.

For: Links on the nervous system

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Spreading out from the cell body are short, branched extensions called **dendrites**. Dendrites carry impulses from the environment or from other neurons toward the cell body. The long fiber that carries impulses away from the cell body is called the **axon**. The axon ends in a series of small swellings called axon terminals, located some distance from the cell body. Neurons may have dozens of dendrites but usually have only one axon. In most animals, axons and dendrites are clustered into bundles of fibers called nerves. Some nerves contain only a few neurons, but many others have hundreds or even thousands of neurons.

In some neurons, the axon is surrounded by an insulating membrane known as the **myelin (MY-uh-lin) sheath**. The myelin sheath that surrounds a single long axon leaves many gaps, called nodes, where the axon membrane is exposed. As an impulse moves along the axon, it jumps from one node to the next, which increases the speed at which the impulse can travel.

The Nerve Impulse

A nerve impulse is similar to the flow of electrical current through a metal wire. The best way to understand a nerve impulse is to first look at a neuron at rest.

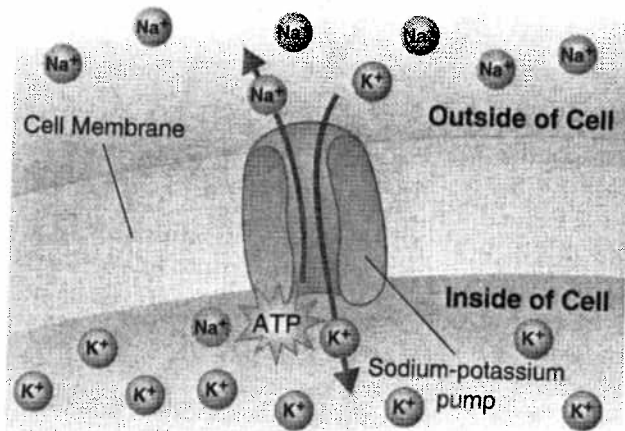
The Resting Neuron When a neuron is resting (not transmitting an impulse), the outside of the cell has a net positive charge, and the inside of the cell has a net negative charge. The cell membrane is said to be electrically charged because there is a difference in electrical charge between its outer and inner surfaces. Where does this difference come from? Some of the differences come from the selective permeability of the membrane. Most of the differences, however, are the result of active transport of ions across the cell membrane.

The nerve cell membrane pumps sodium (Na^+) ions out of the cell and potassium (K^+) ions into the cell by means of active transport. The active transport mechanism that performs this pumping action is called the sodium-potassium pump, shown in **Figure 35-6**.


As a result of active transport, the inside of the cell contains more K^+ ions and fewer Na^+ ions than the outside.

The neuron cell membrane allows more K^+ ions to leak across it than Na^+ ions. As a result, K^+ ions leak out of the cell to produce a negative charge on the inside of the membrane. Because of this, there is a positive charge on the outside of the membrane and a negative charge on the inside. The electrical charge across the cell membrane of a neuron in its resting state is known as the **resting potential** of the neuron. The neuron, of course, is not actually "resting," because it must produce a constant supply of ATP to fuel active transport.

▼ **Figure 35-6** The sodium-potassium pump in the neuron cell membrane uses the energy of ATP to pump Na^+ out of the cell and, at the same time, to pump K^+ in. This ongoing process maintains resting potential. **Applying Concepts** Is this process an example of diffusion or active transport?



CHECKPOINT What is resting potential?

The Moving Impulse A neuron remains in its resting state until it receives a stimulus large enough to start a nerve impulse. The impulse causes a movement of ions across the cell membrane.  **An impulse begins when a neuron is stimulated by another neuron or by the environment.** Once it begins, the impulse travels rapidly down the axon away from the cell body and toward the axon terminals. As **Figure 35-7** shows, an impulse is a sudden reversal of the membrane potential. What causes the reversal?

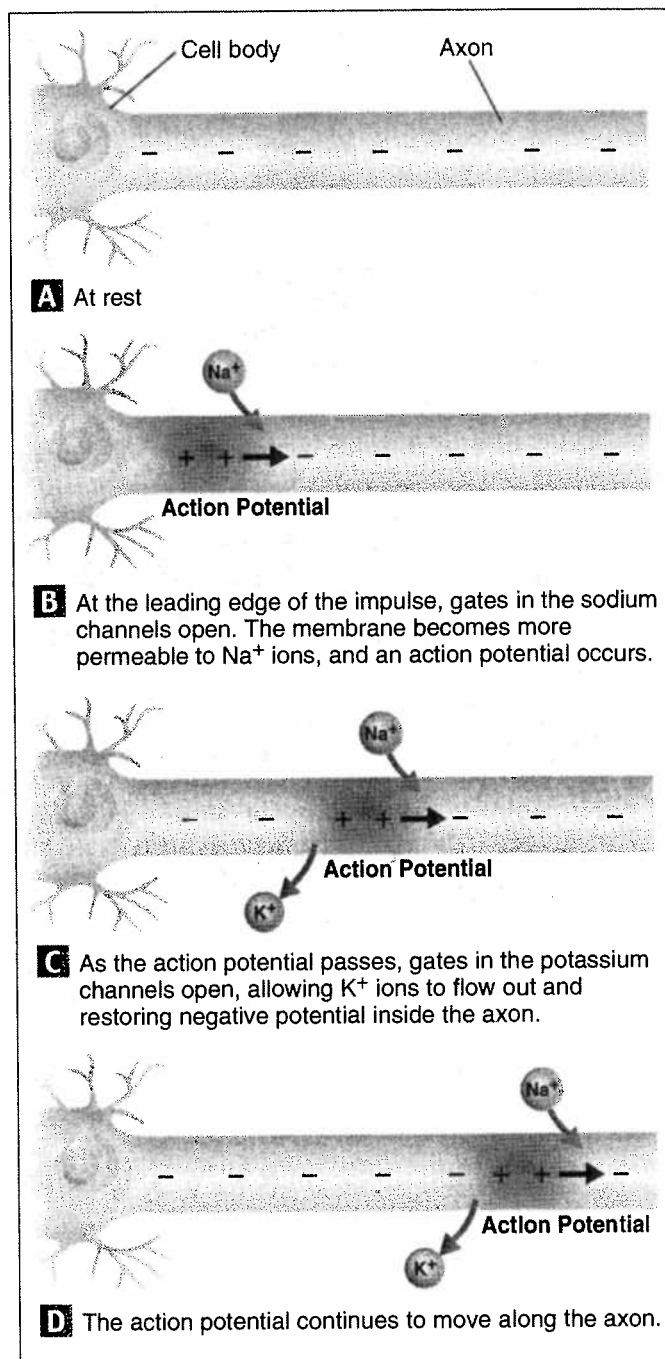
The cell membrane of a neuron contains thousands of protein channels that may allow ions to pass through, depending on the state of “gates” within the channels. Generally, the gates within these channels are closed. At the leading edge of an impulse, however, gates within the sodium channels open, allowing positively charged Na^+ ions to flow inside the cell membrane. The inside of the membrane temporarily becomes more positive than the outside, reversing the resting potential. This reversal of charges, from negative to positive, is called a nerve impulse, or an **action potential**.


As the impulse passes, gates within the potassium channels open, allowing K^+ ions to flow out. This restores the resting potential so that the neuron is once again negatively charged on the inside of the cell membrane and positively charged on the outside.

A nerve impulse is self-propagating; that is, an impulse at any point on the membrane causes an impulse at the next point along the membrane. You could compare the flow of an impulse to the fall of a row of dominoes. As each domino falls, it causes the next domino to fall.

Threshold The strength of an impulse is always the same—either there is an impulse in response to a stimulus or there is not. In other words, a stimulus must be of adequate strength to cause a neuron to transmit an impulse. The minimum level of a stimulus that is required to activate a neuron is called the **threshold**. Any stimulus that is stronger than the threshold will produce an impulse. Any stimulus that is weaker than the threshold will produce no impulse. Thus, a nerve impulse follows the all-or-none principle: Either the stimulus will produce an impulse, or it will not produce an impulse.

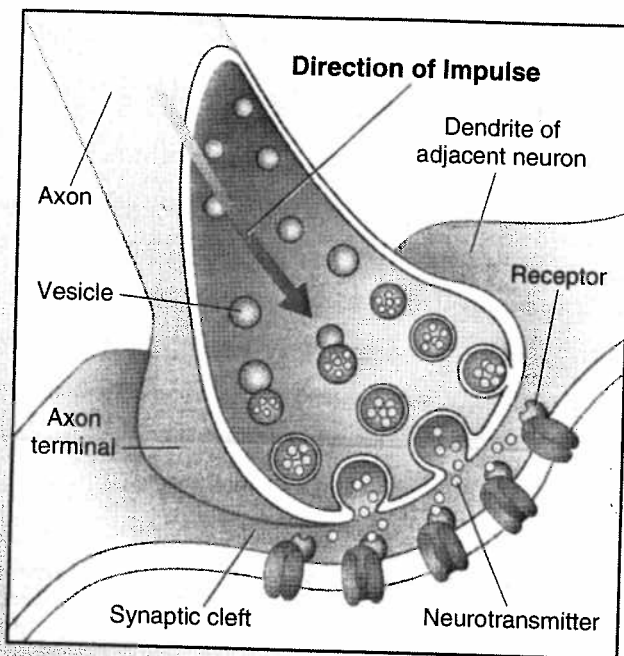
The all-or-none principle can be illustrated by using a row of dominoes. If you were to gently press the first domino in a row, it might not move at all. A slightly harder push might make the domino teeter back and forth but not fall. A slightly stronger push would cause the first domino to fall into the second. You have reached the threshold at which the row of dominoes would fall.



▲ Figure 35-7  An impulse begins when a neuron is stimulated by another neuron.

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▲ **Figure 35-8** When an impulse reaches the end of the axon of one neuron, neurotransmitters are released into the synaptic cleft. The neurotransmitters bind to receptors on the membrane of an adjacent dendrite. **Applying Concepts** *Is the adjacent cell always another neuron?*

The Synapse

At the end of the neuron, the impulse reaches an axon terminal. Usually the neuron makes contact with another cell at this location. The neuron may pass the impulse along to the second cell. Motor neurons, for example, pass their impulses to muscle cells.

The location at which a neuron can transfer an impulse to another cell is called a **synapse** (SIN-aps). As shown in **Figure 35-8**, a space, called the synaptic cleft, separates the axon terminal from the dendrites of the adjacent cell, in this case a neuron. The terminals contain tiny sacs, or vesicles, filled with neurotransmitters (noo-roh-TRANZ-mit-urs). **Neurotransmitters** are chemicals used by a neuron to transmit an impulse across a synapse to another cell.

When an impulse arrives at an axon terminal, the vesicles release the neurotransmitters into the synaptic cleft. The neurotransmitter molecules diffuse across the synaptic cleft and attach themselves to receptors on the membrane of the neighboring cell. This stimulus causes positive sodium ions to rush across the cell membrane, stimulating the second cell. If the stimulation exceeds the cell's threshold, a new impulse begins.

Only a fraction of a second after binding to their receptors, the neurotransmitter molecules are released from the cell surface. They may then be broken down by enzymes, or taken up and recycled by the axon terminal.

35-2 Section Assessment

Thinking Visually

Creating a Flowchart

Create a flowchart to show the events that occur as a nerve impulse travels from one neuron to the next. Include as much detail as you can. Use your flowchart to explain the process to a classmate.

1. **Key Concept** Describe the functions of the nervous system.
2. **Key Concept** What happens when a neuron is stimulated by another neuron?
3. Name and describe the three types of neurons.
4. Describe the role of the myelin sheath.
5. **Critical Thinking Applying Concepts** How can the level of pain you feel vary if a stimulus causes an all-or-none response?

35-3 Divisions of the Nervous System

BI 9.b. Students know how the nervous system mediates communication between different parts of the body and the body's interactions with the environment. **BI 9.e.** Students know the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.

Neurons do not act alone. Instead, they are joined together to form a complex network—the nervous system. The human nervous system is separated into two major divisions: the central nervous system and the peripheral nervous system.

The central nervous system is the control center of the body. The functions of the central nervous system are similar to those of the central processing unit of a computer. **The central nervous system relays messages, processes information, and analyzes information.** The peripheral nervous system receives information from the environment and relays commands from the central nervous system to organs and glands.

The Central Nervous System

The central nervous system consists of the brain, shown in **Figure 35-9**, and the spinal cord. The skull and vertebrae in the spinal column protect the brain and spinal cord. Both the brain and spinal cord are wrapped in three layers of connective tissue known as **meninges** (muh-NIN-jeez). Between the meninges and the central nervous system tissue is a space filled with cerebrospinal (sehr-uh-broh-SPY-nul) fluid. **Cerebrospinal fluid** bathes the brain and spinal cord and acts as a shock absorber that protects the central nervous system. The fluid also allows for the exchange of nutrients and waste products between blood and nervous tissue.

Guide for Reading

Key Concepts

- What are the functions of the central nervous system?
- What are the functions of the two divisions of the peripheral nervous system?

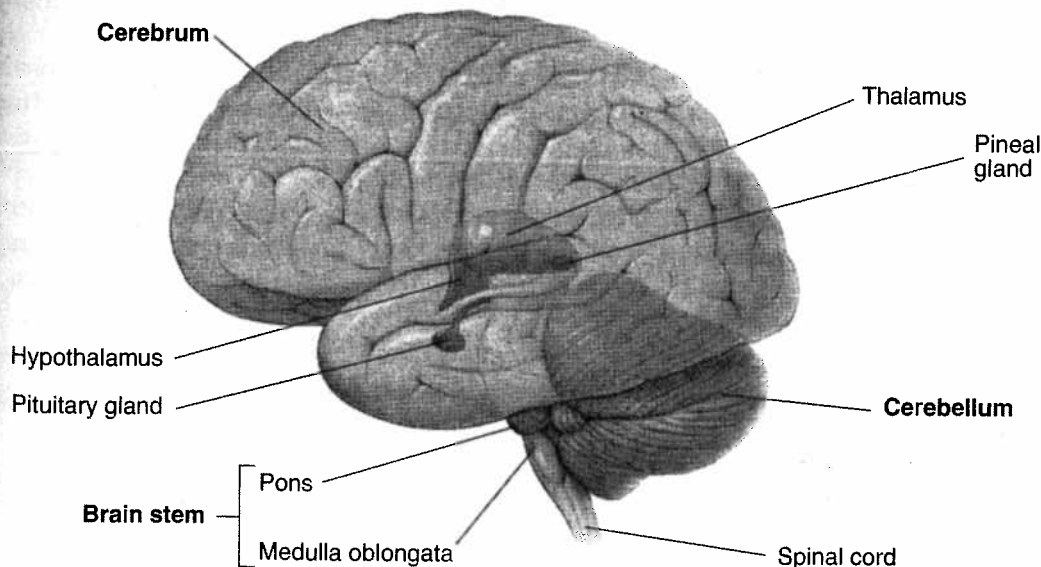
Vocabulary

meninges • cerebrospinal fluid
cerebrum • cerebellum
brain stem • thalamus
hypothalamus • reflex
reflex arc

Reading Strategy:

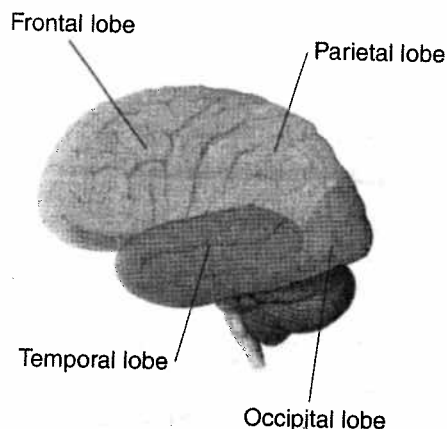
Asking Questions Before you read, rewrite the headings in the section as *how*, *why*, or *what* questions about the nervous system. As you read, write down the answers to your questions.

▼ **Figure 35-9** The brain helps to relay messages, process information, and analyze information. The brain consists of the cerebrum, cerebellum, and brain stem.



The Brain

The brain is the place to which impulses flow and from which impulses originate. The brain contains approximately 100 billion neurons, many of which are interneurons. The brain has a mass of about 1.4 kilograms.



▲ **Figure 35-10** This view of the cerebrum shows the four different lobes of the brain. Different functions of the body are controlled by different lobes of the brain.

Drawing Conclusions The frontal lobe controls voluntary muscle movements. What might happen if this part of the brain became injured?

The Cerebrum The largest and most prominent region of the human brain is the **cerebrum**. The cerebrum is responsible for the voluntary, or conscious, activities of the body. It is the site of intelligence, learning, and judgment. A deep groove divides the cerebrum into right and left hemispheres. The hemispheres are connected by a band of tissue called the corpus callosum.

Folds and grooves on the surface of each hemisphere greatly increase the surface area of the cerebrum. Each hemisphere of the cerebrum is divided into regions called lobes. The lobes are named for the skull bones that cover them. The locations of four lobes of the brain are shown in **Figure 35-10**.

Remarkably, each half of the cerebrum deals mainly with the opposite side of the body. Sensations from the left side of the body go to the right hemisphere of the cerebrum, and those from the right side of the body go to the left hemisphere. Commands to move muscles are generated in the same way. The left hemisphere controls the body's right side, and the right hemisphere controls the body's left side. Some studies have suggested that the right hemisphere may be associated with creativity and artistic ability, whereas the left hemisphere may be associated with analytical and mathematical ability.

The cerebrum consists of two layers. The outer layer of the cerebrum is called the cerebral cortex and consists of **gray matter**. Gray matter consists mainly of densely packed nerve cell bodies. The cerebral cortex processes information from the sense organs and controls body movements. The inner layer of the cerebrum consists of **white matter**, which is made up of bundles of axons with myelin sheaths. The myelin sheaths give the white matter its characteristic color. White matter connects the cerebral cortex and the brain stem.

The Cerebellum The second largest region of the brain is the **cerebellum**. The cerebellum is located at the back of the skull. Although the commands to move muscles come from the cerebral cortex, the cerebellum coordinates and balances the actions of the muscles so that the body can move gracefully and efficiently.

The Brain Stem The **brain stem** connects the brain and spinal cord. Located just below the cerebellum, the brain stem includes two regions known as the pons and the medulla oblongata. Each of these regions regulates the flow of information between the brain and the rest of the body. Some of the body's most important functions—including blood pressure, heart rate, breathing, and swallowing—are controlled in the brain stem.

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The Thalamus and Hypothalamus The thalamus and hypothalamus are found between the brain stem and the cerebrum. The **thalamus** receives messages from all of the sensory receptors throughout the body and then relays the information to the proper region of the cerebrum for further processing. Just below the thalamus is the hypothalamus. The **hypothalamus** is the control center for recognition and analysis of hunger, thirst, fatigue, anger, and body temperature. The hypothalamus also controls the coordination of the nervous and endocrine systems. You will learn more about the endocrine system in a later chapter.

The Spinal Cord


Like a major telephone line that carries thousands of calls at once, the spinal cord is the main communications link between the brain and the rest of the body. Thirty-one pairs of spinal nerves branch out from the spinal cord, connecting the brain to all of the different parts of the body. Certain kinds of information, including some kinds of reflexes, are processed directly in the spinal cord.

A **reflex** is a quick, automatic response to a stimulus. Sneezing and blinking are two examples of reflexes. A reflex allows your body to respond to danger immediately, without spending time thinking about a response. Animals rely heavily on reflex behaviors for survival.

 **CHECKPOINT** What is a reflex?

The Peripheral Nervous System

The peripheral nervous system lies outside of the central nervous system. It consists of all of the nerves and associated cells that are not part of the brain and the spinal cord. Included here are cranial nerves that pass through openings in the skull and stimulate regions of the head and neck, spinal nerves, and ganglia. Ganglia are collections of nerve cell bodies.

The peripheral nervous system can be divided into the sensory division and the motor division.  **The sensory division of the peripheral nervous system transmits impulses from sense organs to the central nervous system. The motor division transmits impulses from the central nervous system to the muscles or glands.** The motor division is further divided into the somatic nervous system and the autonomic nervous system.

The Somatic Nervous System The somatic nervous system regulates activities that are under conscious control, such as the movement of the skeletal muscles. Every time you lift your finger or wiggle your toes, you are using the motor neurons of the somatic nervous system. Some somatic nerves are also involved with reflexes and can act with or without conscious control.

Quick Lab

How do you respond to an external stimulus?

Materials sheet of scrap paper

Procedure

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. Record your partner's reaction.
4. Repeat step 3, three more times.
5. Exchange roles and repeat steps 1, 3, and 4.

Analyze and Conclude

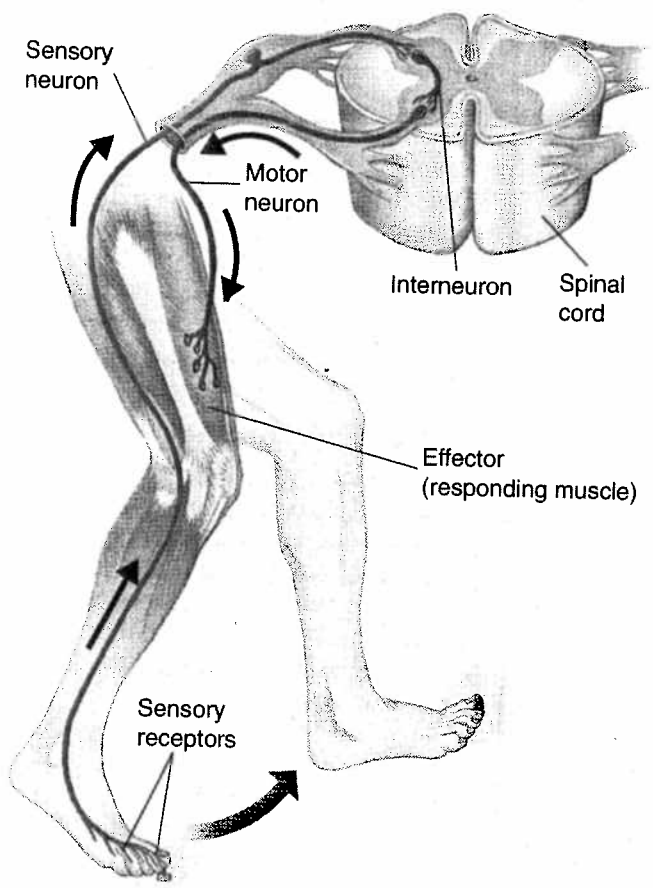
1. **Observing** What reaction did you observe when you tossed the ball at your partner's face?
2. **Observing** Was that reaction voluntary? What kind of reaction is this?
3. **Comparing and Contrasting** Did you see any change in behavior as you repeated step 3? If so, how would you describe this change?
4. **Inferring** What is the function of the blink reflex?



BI 9.e

If you accidentally 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 possible because receptors in your skin stimulate sensory neurons, which carry the impulse to your spinal cord. Even before the information is relayed to your brain, a group of neurons in your spinal cord automatically activates the appropriate motor neurons. These motor neurons cause the muscles in your leg to contract, pulling your foot away from the tack.

The pathway that an impulse travels from your foot back to your leg is known as a reflex arc. As shown in **Figure 35-11**, a **reflex arc** includes a sensory receptor (in this case, a receptor in your toe), sensory neuron, motor neuron, and effector (leg muscle). Some reflex arcs include interneurons. In other reflex arcs, a sensory neuron communicates directly with a motor neuron.



▲ **Figure 35-11** The peripheral nervous system transmits impulses from sense organs to the central nervous system and back to muscles or glands. When you step on a tack, sensory receptors stimulate a sensory neuron, which relays the signal to an interneuron within the spinal cord. The signal is then sent to a motor neuron, which in turn stimulates a muscle in your leg to lift your leg.

The Autonomic Nervous System The autonomic nervous system regulates activities that are automatic, or involuntary. The nerves of the autonomic nervous system control functions of the body that are not under conscious control. The influence exerted on other body systems by the autonomic nervous system is a good example of an interrelationship that is needed between systems for the body's well-being. For instance, when you are running, the autonomic nervous system speeds up your heart rate and the blood flow to the skeletal muscles, stimulates the sweat glands and adrenal glands, and slows down the contractions of the smooth muscles in the digestive system.

The autonomic nervous system is further subdivided into two parts—the sympathetic nervous system and the parasympathetic nervous system. Most organs controlled by the autonomic nervous system are under the control of both sympathetic and parasympathetic neurons.

The sympathetic and parasympathetic nervous systems have opposite effects on the same organ system. The opposing effects of the two systems help the body maintain homeostasis. For example, heart rate is increased by the sympathetic nervous system but decreased by the parasympathetic nervous system. The process of regulating heart rate can be compared to the process of controlling the speed of a car. One system is like the gas pedal and the other is like the brake. Because there are two different sets of neurons, the autonomic nervous system can quickly speed up the activities of major organs in response to a stimulus or slam on the brakes if necessary.

Quick Lab



BI 9.e, 6IIE 7.e, 8IIE 9.b, BIIE 1.d, BIIE 1.g

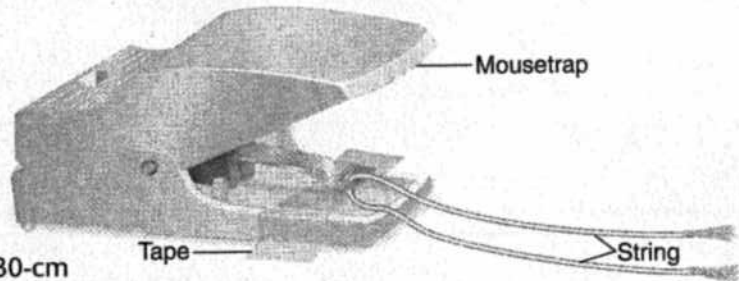
How do reflexes occur?

Materials string, scissors, 3 plastic mousetraps, packing tape, 30-cm ruler

Procedure



- Using Models** To model a synapse, cut a 30-cm piece of string. **CAUTION:** Handle scissors carefully.
- Hold a mousetrap open. Pull the string through the bait platform as shown. **CAUTION:** Do not let the mousetrap snap on your fingers. Slide a piece of tape under the bait platform and tape the trap to the table as shown. Label the trap "sensory neuron."
- Hold one end of the string in each hand. Gently pull one end without setting off the trap. Now gradually pull harder.
- To model a reflex arc, cut two more 30-cm pieces of string. Tie one end of each piece of string to the bait platform of a separate trap.
- Tape the 2 new traps to the table, 20 cm from the first trap. Label one new trap "motor neuron," and the other "brain."
- Reset the first trap, and then set the new ones. Tape both ends of the strings attached to the new traps to the top of the first trap. Leave these strings slightly slack.



- Pull the strings attached to the bait platform of the "sensory neuron."

Analyze and Conclude

- Drawing Conclusions** What was required for the trap to close in step 3? How does this behavior compare to the transmission of a nerve impulse?
- Applying Concepts** Does a stronger stimulus produce a stronger nerve impulse? Explain your answer.
- Evaluating** Do you consider this procedure an adequate model of a reflex arc? Explain your response by citing specific details. If not, propose an alternative model.
- SAFETY** Explain how you demonstrated safe practices as you carried out this investigation.

35-3 Section Assessment

- Key Concept** Discuss the overall function of the central nervous system.
- Key Concept** Describe the functions of the two divisions of the peripheral nervous system.
- How is the central nervous system protected from injury?
- What is the role of the hypothalamus?
- Is a reflex part of the central nervous system, the peripheral nervous system, or both? Explain.
- Critical Thinking Inferring** Would you expect the cerebrum of a bird to be more or less developed relative to its size than the cerebrum of a human? Explain. (*Hint:* You may want to review Section 33-3.)

Focus on the BIG Idea

Structure and Function

Using Section 34-1, decide which parts of the nervous system are most likely to be involved with innate, or inborn, behaviors. Which parts are likely to be involved with learned behaviors? Explain your reasoning.

35-4 The Senses



BI 9.e. Students know the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.

Guide for Reading

Key Concept

- What are the five types of sensory receptors?

Vocabulary

sensory receptor
pupil
lens
retina
rod
cone
cochlea
semicircular canal
taste bud

Reading Strategy:

Outlining Before you read, use the headings of the section to make an outline about the five sense organs. As you read, fill in the subtopics and smaller topics. Then, add phrases or a sentence after each to provide key information.

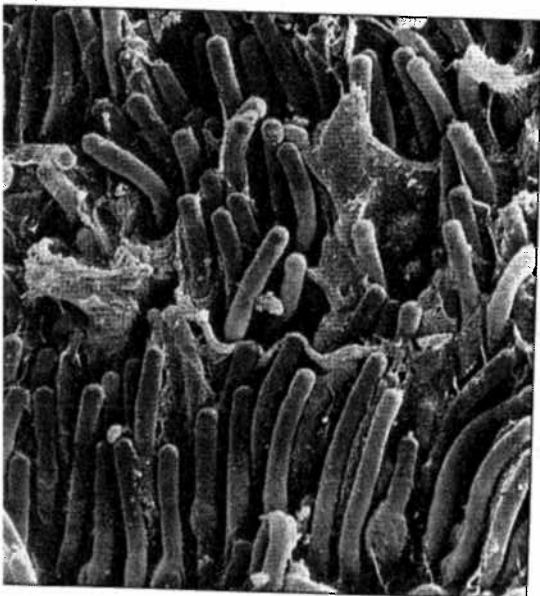
The body contains millions of neurons that react directly to stimuli from the environment, including light, sound, motion, chemicals, pressure, and changes in temperature. These neurons, known as **sensory receptors**, react to a specific stimulus such as light or sound by sending impulses to other neurons, and eventually to the central nervous system. Sensory receptors are located throughout the body but are concentrated in the sense organs. These sense organs include the eyes, the inner ears, the nose, the mouth, and the skin. Sensory receptors within each organ enable it to respond to a particular stimulus.

There are five general categories of sensory receptors: **pain receptors, thermoreceptors, mechanoreceptors, chemoreceptors, and photoreceptors**. Pain receptors are located throughout the body except in the brain. Pain receptors respond to chemicals released by damaged cells. Pain is important to recognize because it usually indicates danger, injury, or disease. Thermoreceptors are located in the skin, body core, and hypothalamus. Thermoreceptors detect variations in temperature. Mechanoreceptors are found in the skin, skeletal muscles, and inner ears. They are sensitive to touch, pressure, stretching of muscles, sound, and motion. Chemoreceptors, located in the nose and taste buds, are sensitive to chemicals in the external environment. Photoreceptors, found in the eyes, are sensitive to light. **Figure 35-12** shows how photoreceptor cells appear under a scanning electron microscope.

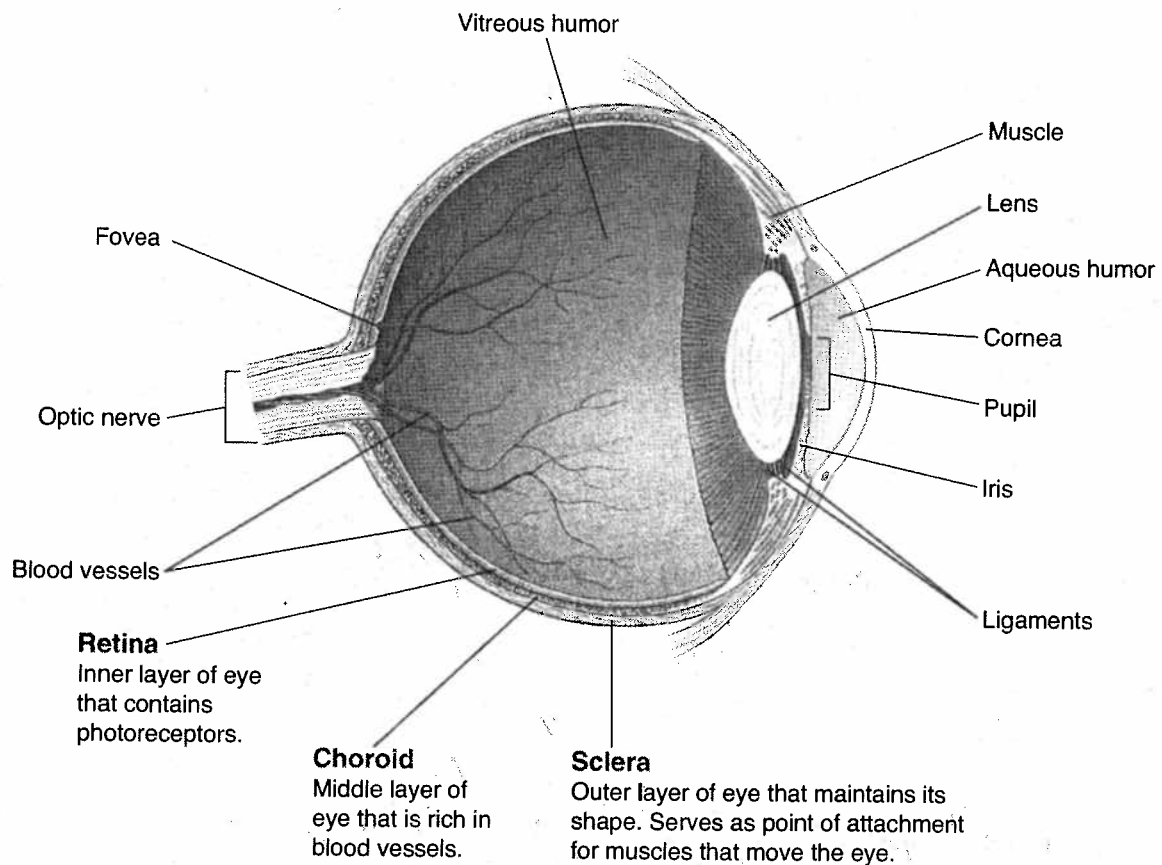
Vision

The world around us is bathed in light. The sense organs that we use to sense light are the eyes. The structures of the eye are shown in **Figure 35-13**. Light enters the eye through the cornea, a tough transparent layer of cells. The cornea helps to focus the light, which then passes through a chamber filled with a fluid called aqueous (AY-kwee-uhs) humor. At the back of the chamber is a disklike structure called the iris. The iris is the colored part of the eye. In the middle of the iris is a small opening called the **pupil**. Tiny muscles in the iris adjust the size of the pupil to regulate the amount of light that enters the eye. In dim light, the pupil becomes larger so that more light can enter the eye. In bright light, the pupil becomes smaller so that less light enters the eye.

◀ **Figure 35-12** There are two types of light-sensitive photoreceptor cells in the retina—rods and cones. This color-enhanced scanning electron micrograph shows the rod cells of an eye.



(magnification: 2000×)



▲ **Figure 35-13** The eye is a complicated sense organ. The sclera, choroid, and retina are three layers of tissue that form the inner wall of the eyeball. **Interpreting Graphics** What is the function of the sclera?

Just behind the iris is the **lens**. Small muscles attached to the lens change its shape to help you adjust your eyes' focus to see near or distant objects. Behind the lens is a large chamber filled with a transparent, jellylike fluid called vitreous (VIH-tree-uhs) humor.

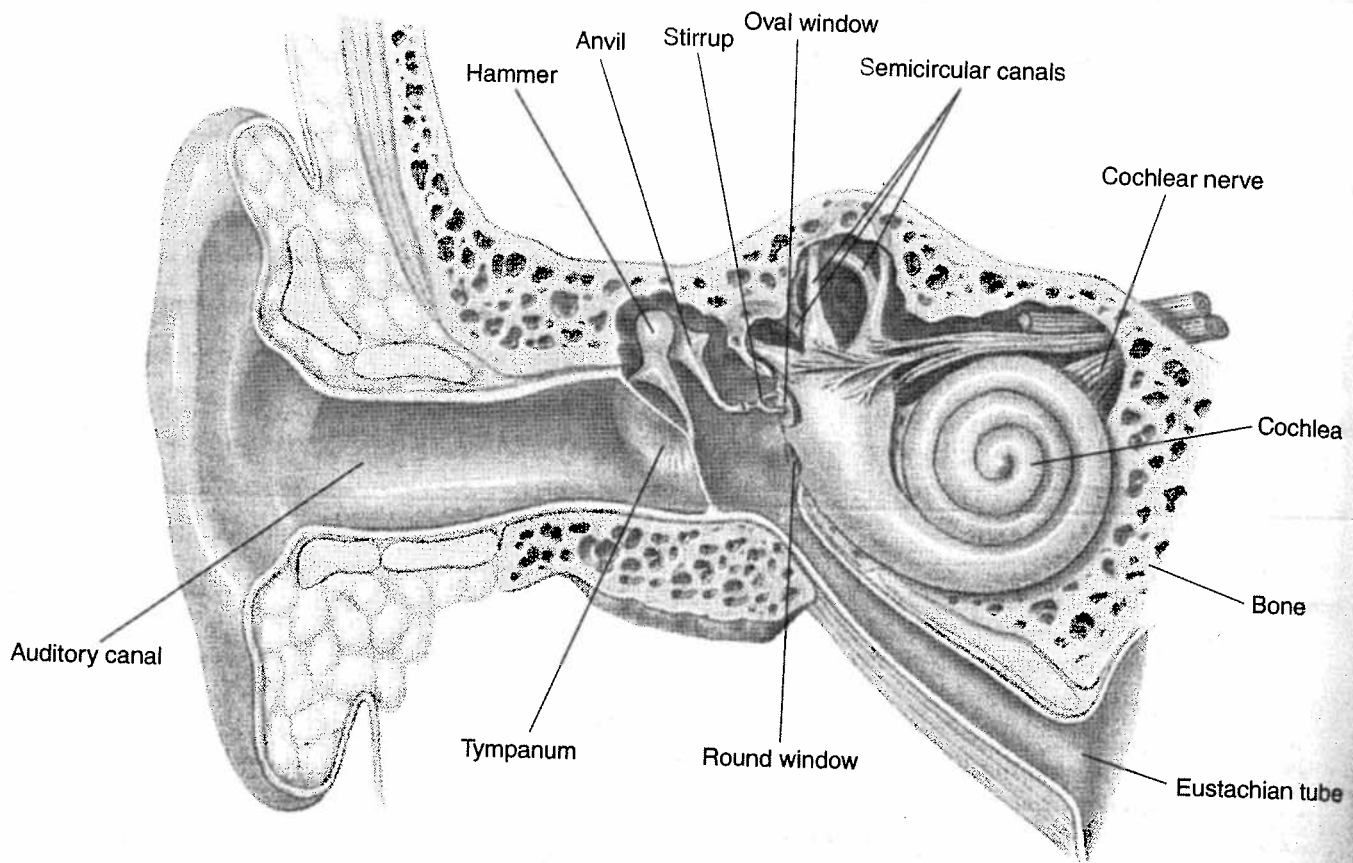
The lens focuses light onto the **retina**. Photoreceptors are arranged in a layer in the retina. The photoreceptors convert light energy into nerve impulses that are carried to the central nervous system. There are two types of photoreceptors: rods and cones. **Rods** are extremely sensitive to light, but they do not distinguish different colors. **Cones** are less sensitive than rods, but they do respond to light of different colors, producing color vision. Cones are concentrated in the fovea. The fovea is the site of sharpest vision. There are no photoreceptors where the optic nerve passes through the back of the eye. This place is called the blind spot.

The impulses assembled by this complicated layer of interconnected cells leave each eye by way of an optic nerve. The optic nerves then carry the impulses to the appropriate regions of the brain. The brain interprets them as visual images and provides information about the external world.

✓ **CHECKPOINT** Where are the photoreceptors located in the eye?

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Hearing and Balance

The human ear has two sensory functions. One of these functions is hearing. The other function is detecting positional changes associated with movement.

Hearing Sound is nothing more than vibrations in the air around us. The ears are the sensory organs that can distinguish both the pitch and loudness of those vibrations. The structure of the ear is shown in **Figure 35-14**.

Vibrations enter the ear through the auditory canal. The vibrations cause the tympanum (TIM-puh-num), or eardrum, to vibrate. These vibrations are picked up by three tiny bones, commonly called the hammer, anvil, and stirrup. The last of these bones, the stirrup, transmits the vibrations to the oval window. Vibrations of the oval window create pressure waves in the fluid-filled **cochlea** (KAHK-lee-uh) of the inner ear.

The cochlea is lined with tiny hair cells that are pushed back and forth by these pressure waves. In response to these movements, the hair cells produce nerve impulses that are sent to the brain through the cochlear nerve.

Balance Your ears contain structures that help your central nervous system maintain your balance, or equilibrium. Within the inner ear just above the cochlea are three tiny canals at right angles to one another. They are called **semicircular canals** because each forms a half circle. The semicircular canals and the two tiny sacs located behind them monitor the position of your body, especially your head, in relation to gravity.



(magnification: about 3500×)

Figure 35-14 The diagram (top) shows the structures in the ear that transmit sounds. The scanning electron micrograph shows hair cells (yellow) in the inner ear. The motion of these hairs produces nerve impulses that travel to the brain through the cochlear nerve.

Predicting How would frequent exposure to loud noise affect a person's threshold for detecting sound?

The semicircular canals and the sacs are filled with fluid and lined with hair cells. As the head changes position, the fluid in the canals also changes position. This causes the hair on the hair cells to bend. This action, in turn, sends impulses to the brain that enable it to determine body motion and position.

Smell and Taste

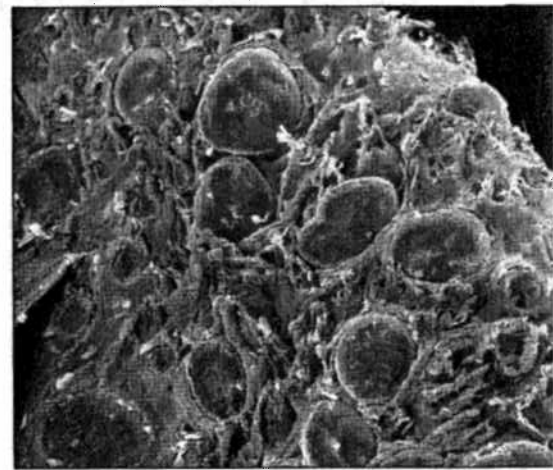
You may never have thought of it this way, but your sense of smell is actually an ability to detect chemicals. Chemoreceptors in the lining of the nasal passageway respond to specific chemicals and send impulses to the brain through sensory nerves.

Your sense of smell is capable of producing thousands of different sensations. In fact, much of what we commonly call the “taste” of food and drink is actually smell. To prove this to yourself, eat a few bites of food while holding your nose. You’ll discover that much of the taste of food disappears until you open your nose and breathe freely.

Like the sense of smell, the sense of taste is a chemical sense. The sense organs that detect taste are the **taste buds**. Most of the taste buds are on the tongue, but a few are found at other locations in the mouth. The surface of the tongue is shown in **Figure 35–15**. The tastes detected by the taste buds are classified as salty, bitter, sweet, and sour. Sensitivity to these different categories varies on different parts of the tongue.

Touch and Related Senses

The sense of touch, unlike the other senses you have just read about, is not found in one particular place. All of the regions of the skin are sensitive to touch. In this respect, your largest sense organ is your skin. Skin contains sensory receptors that respond to temperature, touch, and pain. Not all parts of the body are equally sensitive to touch, because not all parts have the same number of receptors. The greatest density of touch receptors is found on your fingers, toes, and face.



(magnification: 86×)

▲ **Figure 35–15** This color-enhanced scanning electron micrograph shows the surface of the tongue. The large pink objects are the taste buds. ● Chemoreceptors found in the taste buds are sensitive to chemicals in food.

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For: Links on the senses

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35–4 Section Assessment

1. ● **Key Concept** Name the five types of sensory receptors and list where they are found in the body.
2. Identify the functions of the cornea, pupil, lens, retina, and optic nerve.
3. What are the four basic tastes detected by the tongue?
4. Explain why you can’t “taste” food when you have a bad cold.
5. ● **Critical Thinking Applying Concepts** If you spin around for a time, the fluid in your semicircular canals also moves. When you stop suddenly, you feel as though you are still moving. Why do you think you might feel dizzy?

Writing in Science

Creative Writing

Imagine that you have to do without your sense of taste for one day. How would this influence your food choices? Write a 3- to 4-paragraph essay describing how the absence of this sense organ would affect your day.

35-5 Drugs and the Nervous System

Guide for Reading

Key Concepts

- What are the different classes of drugs that directly affect the central nervous system?
- What is the effect of alcohol on the body?

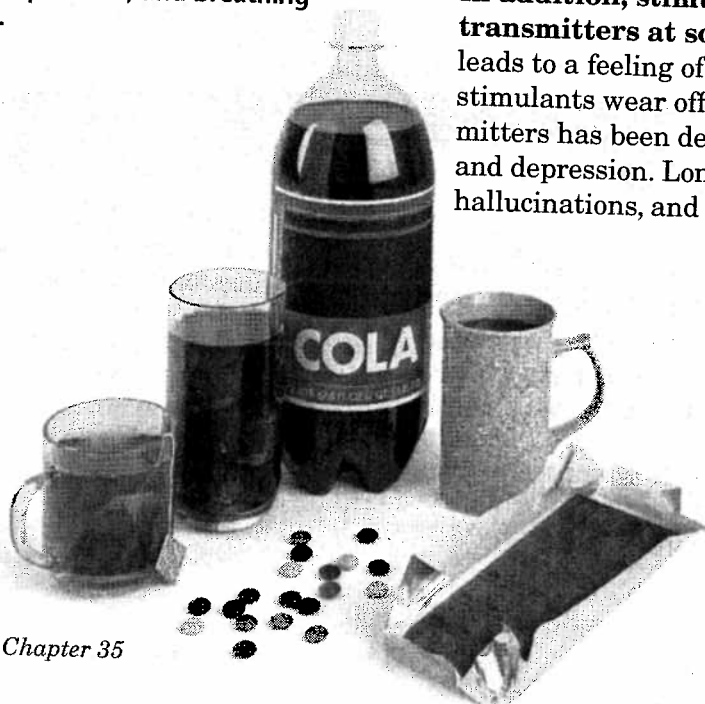
Vocabulary

drug
stimulant
depressant
fetal alcohol syndrome
drug abuse
addiction

Reading Strategy: Using Graphic Organizers

As you read, create a table that lists each of the drugs in this section and the effects that each drug has on the body.

Figure 35-16 Common stimulant drugs include amphetamines, cocaine, nicotine (found in cigarettes), and caffeine (found in coffee, tea, chocolate, and cola products). Stimulants increase heart rate, blood pressure, and breathing rate.



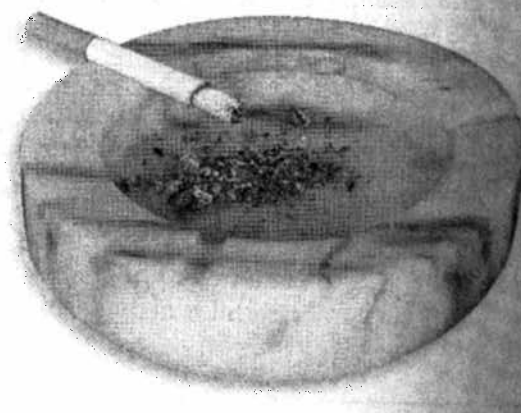
By definition, a **drug** is any substance, other than food, that changes the structure or function of the body. Some drugs, such as cocaine and heroin, are so powerful and dangerous that their possession is illegal. Other drugs, including penicillin and codeine, are prescription drugs and can be used only under the supervision of a doctor. Still other drugs, including cough and cold medicines, are sold over the counter. All drugs, both legal and illegal, have the potential to do harm if they are used improperly or abused.

Drugs differ in the ways in which they affect the body. Some drugs kill bacteria and are useful in treating disease. Other drugs affect a particular system of the body, such as the digestive or circulatory systems. Among the most powerful drugs, however, are the ones that cause changes in the nervous system, especially to the brain and the synapses between neurons.

Drugs That Affect the Synapse

The nervous system performs its regulatory functions through the transmission of information along pathways from one part of the body to another. Synapses are key relay stations along the way. The nervous system depends on neurotransmitters to bridge the gap between neurons or between a neuron and an effector. A drug that interferes with the action of neurotransmitters can disrupt the functioning of the nervous system.

Stimulants A number of drugs, called **stimulants**, increase the actions regulated by the nervous system. Stimulants increase heart rate, blood pressure, and breathing rate. In addition, stimulants increase the release of neurotransmitters at some synapses in the brain. This release leads to a feeling of energy and well-being. When the effects of stimulants wear off, however, the brain's supply of neurotransmitters has been depleted. The user quickly falls into fatigue and depression. Long-term use can cause circulatory problems, hallucinations, and psychological depression.



Depressants Some drugs, called **depressants**, decrease the rate of functions regulated by the brain. **Depressants slow down heart rate and breathing rate, lower blood pressure, relax muscles, and relieve tension.** Some depressants enhance the effects of neurotransmitters that prevent some nerve cells from starting action potentials. This calms parts of the brain that sense fear and relaxes the individual. As a result, the user comes to depend on the drug to relieve the anxieties of everyday life, which may seem unbearable without the drug. When depressants are used with alcohol, the results are often fatal because that combination can depress the activity of the central nervous system until breathing stops.

CHECKPOINT What is the general function of a depressant?

Cocaine Even stronger effects are produced by drugs that act on neurons in what are known as the pleasure centers of the brain. The effects of cocaine are so strong that they produce an uncontrollable craving for more of the drug. Cocaine is obtained from the leaves of coca plants. **Cocaine causes the sudden release in the brain of a neurotransmitter called dopamine.** Normally, this compound is released when a basic need, such as hunger or thirst, is fulfilled. By fooling the brain into releasing dopamine, cocaine produces intense feelings of pleasure and satisfaction. So much dopamine is released when the drug is used that the supply of dopamine is depleted when the drug wears off. Users quickly discover that they feel sad and depressed without the drug. The psychological dependence that cocaine produces is difficult to break.

Cocaine also acts as a powerful stimulant, increasing heart rate and blood pressure. The stimulation can be so powerful that the heart is damaged. Sometimes, even a first-time user may experience a heart attack after using cocaine.

A particularly potent and dangerous form of cocaine is crack. Crack becomes addictive after only a few doses. The intense "high" produced by crack wears off quickly and leaves the brain with too little dopamine. As a result, the user suddenly feels sad and depressed, and quickly seeks another dose of the drug. In time, the urge to seek this drug can be so strong that it leads users to commit serious crimes and to abandon their families and children.

Opiates The opium poppy, like the one shown in **Figure 35-17**, produces a powerful class of pain-killing drugs called opiates. **Opiates mimic natural chemicals in the brain known as endorphins, which normally help to overcome sensations of pain.** The first doses of these drugs produce strong feelings of pleasure and security, but the body quickly adjusts to the higher levels of endorphins. Once this happens, the body cannot do without the drug. A user who tries to stop taking these drugs will suffer from uncontrollable pain and sickness because the body cannot produce enough of the natural endorphins.



Figure 35-17 Many illegal drugs are found in nature. Cocaine comes from the South American *Erythroxylum coca* plant (top). The centers of opium poppies (below) contain pods from which opiate drugs are derived. **Opiates mimic endorphins, which help overcome pain.** For this reason, opiates are often used medically as painkillers.



Commonly Abused Drugs

Drug Type	Medical Use	Examples	Effects on the Body
Stimulants	Used to increase alertness, relieve fatigue	Amphetamines	Increases heart and respiratory rates, elevates blood pressure, dilates pupils, and decreases appetite
Depressants	Used to relieve anxiety, irritability, tension	Barbiturates Tranquilizers	Slows down the actions of the central nervous system; small amounts cause calmness and relaxation; larger amounts cause slurred speech and impaired judgment
Opiates	Used to relieve pain	Morphine Codeine	Acts as a depressant; causes drowsiness, restlessness, nausea

▲ **Figure 35-18** Legal drugs that are used for medical purposes can also be abused. **Applying Concepts** Do you think a person can become addicted to a legal drug?

Marijuana Statistically, the most widely abused illegal drug is marijuana. Marijuana comes from *Cannabis sativa*, a species of hemp plant. Hashish, or hash, is a potent form of marijuana made from the flowering parts of the plant. The active ingredient in all forms of marijuana is tetrahydrocannabinol (THC). Smoking or ingesting THC can produce a temporary feeling of euphoria and disorientation. Smoking marijuana is bad for the lungs. In fact, smoking marijuana is even more destructive to the lungs than smoking tobacco. Long-term use of marijuana can also result in loss of memory; inability to concentrate; and, in males, reduced levels of the hormone testosterone.

✓ **CHECKPOINT** What are the long-term effects of marijuana use?

Alcohol One of the most dangerous and abused legal drugs is alcohol. The most immediate effects of alcohol are on the central nervous system. **Alcohol is a depressant that slows down the rate at which the central nervous system functions.** Alcohol slows down reflexes, disrupts coordination, and impairs judgment. Heavy drinking fills the blood with so much alcohol that the central nervous system cannot function properly. People who have two or three drinks in the span of an hour may feel relaxed and confident, but their blood contains as much as 0.10 percent alcohol, making them legally drunk in most states. They usually cannot walk or talk properly, and they are certainly not able to safely control an automobile, as shown in **Figure 35-19**.

The abuse of alcohol has a frightening social price. About 40 percent of the 50,000 people who die on American highways in a typical year are victims of accidents in which at least one driver had been drinking. One third of all homicides can be attributed to the effects of alcohol. When health care, property damage, and lost productivity are considered, alcohol abuse costs the U.S. economy at least \$150 billion per year.



▲ **Figure 35-19** Alcohol slows down the rate at which the central nervous system functions. It slows down reflexes, disrupts coordination, and impairs judgment. For this reason, you should never get into a car with a driver who has been drinking.

But the toll of alcohol abuse does not stop there. Women who are pregnant and drink on a regular basis run the risk of having a child with fetal alcohol syndrome. **Fetal alcohol syndrome (FAS)** is a group of birth defects caused by the effects of alcohol on the fetus. Babies born with FAS can suffer from heart defects, malformed faces, delayed growth, and poor motor development. In the United States alone, more than 50,000 babies are born every year with alcohol-related birth defects, many of which are irreversible.

Alcohol and Disease People who have become addicted to alcohol suffer from a disease called alcoholism. Some alcoholics feel the need to have a drink before work or school—every day. They may drink so heavily that they black out and cannot remember what they have done while drinking. Some alcoholics, however, do not drink to the point where it is obvious that they have an alcohol-abuse problem. If a person cannot function properly without satisfying the need or craving for alcohol, that person is considered to have an alcohol-abuse problem.

Long-term alcohol use destroys cells in the liver, where alcohol is broken down. As liver cells die, the liver becomes less able to handle large amounts of alcohol. The formation of scar tissue, known as cirrhosis of the liver, occurs next. The scar tissue blocks the flow of blood through the liver and interferes with its other important functions. Eventually, a heavy drinker may die from liver failure.

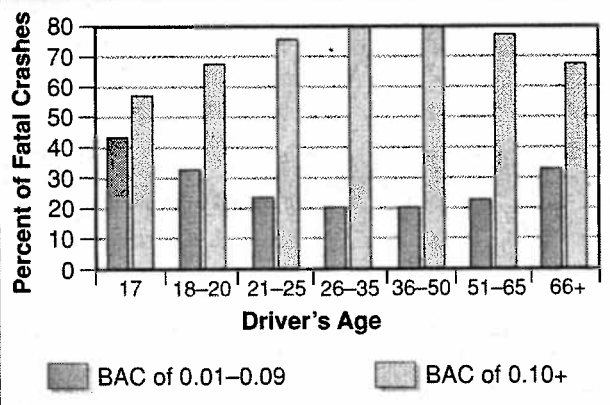
Analyzing Data

Blood Alcohol Concentration

Blood alcohol concentration (BAC) is a measure of the amount of alcohol in the bloodstream per 100 mL of blood. A BAC of 0.1 percent means that one tenth of 1.0 percent of the fluid in the blood is alcohol. In some states, if a driver has a BAC of 0.08 percent, he or she is considered legally drunk. In other states, drivers with a BAC of 0.10 percent are considered drunk. The graph shows the relative risk of being involved in a fatal accident as a result of the blood alcohol concentration of the driver.

- Using Tables and Graphs** What trends do you see in the number of fatal crashes from age 17 to age 66+ based on the two ranges of BAC?
- Using Tables and Graphs** How does the consumption of alcohol affect driving risk for the average driver?
- Drawing Conclusions** Is the effect of alcohol consumption on driving independent of the age of the driver? Are young drivers more affected by alcohol or less affected by it than older drivers?

BAC for Drivers Involved in Fatal Crashes, by Age, 1992–1995



- Making Judgments** All levels of alcohol consumption affect driving skills, although the effect increases dramatically as more drinks are consumed. To minimize accidents and fatalities due to drunk driving, what should be the legal limit of blood alcohol for drivers?

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and drug abuse

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As with other drugs, dealing with alcohol abuse is not simply a matter of willpower. Alcoholics often need special help and support to quit their drinking habit. Organizations such as Alcoholics Anonymous are available in most communities to help individuals and families deal with the problems created by alcohol abuse.

Drug Abuse



Each of the drugs discussed so far presents a danger to users. The misuse of either a legal or an illegal drug is a serious problem in modern society. **Drug abuse** can be defined as the intentional misuse of any drug for nonmedical purposes. With some drugs, such as cocaine, drug abuse causes serious physical damage to the body. With other drugs, such as marijuana, drug abuse produces psychological dependence that can be strong enough to disrupt family life and schoolwork.

An uncontrollable dependence on a drug is known as a drug **addiction**. Some drugs cause a strong psychological dependence. People who are psychologically dependent on a drug have a mental craving, or need, for the drug. Other drugs cause a strong physical dependence. Physical dependence occurs when the body cannot function without a constant supply of the drug. Any attempt at withdrawal, or stopping the use of the drug, will cause pain, nausea, chills, and fever.

Because many users inject drugs for maximum effect, there is another important consequence of drug use—the increased transmission of human immunodeficiency virus (HIV), the virus that causes AIDS. The virus can be spread rapidly from person to person when drug users share contaminated needles. Many of the new AIDS cases reported in the United States can be traced back to the use of injected drugs.

The best way to avoid the effects of drugs is to avoid drugs. The decision not to use drugs can be difficult when you are faced with pressure to take them. By deciding not to take drugs, you are acting to take control of your life.

35-5 Section Assessment

1.  **Key Concept** Describe the effects of stimulants, cocaine, depressants, and opiates on the central nervous system.
2.  **Key Concept** Explain the effects of alcohol on the body.
3. What is a drug?
4. Why is drinking and driving an extremely dangerous behavior?

5. **Critical Thinking Inferring**
Which do you think is a more difficult addiction to break: one in which a person is physically dependent on a drug, or one in which a person is psychologically dependent on a drug? Explain your answer.

Writing in Science

Persuasive Writing

Research one of the drugs mentioned in this section to find out more about the short- and long-term effects of the drug on the body. Then, develop an informational brochure trying to persuade someone not to take the drug. *Hint: Be sure to include specific facts.*



Modeling Corrective Lenses

The lenses of your eyes focus light on the retina. In people who are nearsighted, the lens focuses images in front of the retina, making distant objects appear blurry. In people who are farsighted, the lens focuses images behind the retina, making nearby objects difficult to see. To see more clearly, these people wear glasses or contact lenses. The shapes of these artificial lenses depend on the type of correction needed.

Problem What types of corrective lenses are needed by nearsighted individuals and by farsighted individuals?

Materials

- tape
- 2 cardboard photo easels
- black construction paper
- unruled white index card
- 6-V light bulb and socket
- 6-V battery and wires with alligator clips
- 2 convex lenses
- modeling clay
- meter stick
- concave lens

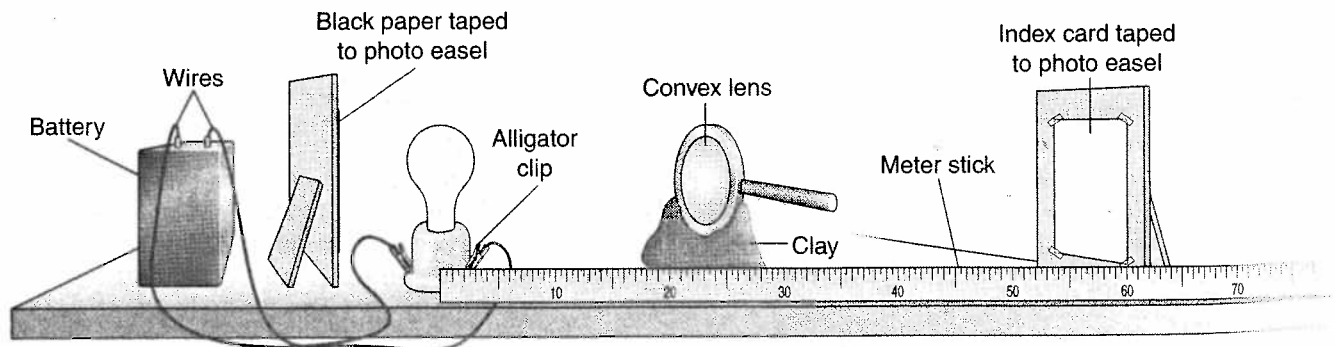
Skills Analyzing Data, Using Models

Procedure

- 1 Set up your equipment as shown in the diagram below. Place the white index card about 50 to 60 cm in front of the bulb.
- 2 Place a convex lens in front of the bulb and move the lens until an image of the bulb focuses clearly on the index card. Secure the lens in this position with modeling clay or tape. The distance between the fixed lens and the index card is the focal length of the lens.
- 3 Move the index card about 5 to 8 cm away from the fixed lens to simulate the formation of an image in front of the retina. Observe the image and record your observations.
- 4 Hold the concave lens between the light bulb and the fixed lens. Try to focus the image by moving the concave lens between the light bulb and the fixed lens.
- 5 Repeat step 4, but this time use the second convex lens. Record your observations.
- 6 Move the index card about 10 to 16 cm closer to the fixed lens to simulate image formation behind the retina. Record your observations.
- 7 Repeat steps 4 and 5.

Analyze and Conclude

1. **Drawing Conclusions** Does the lens in your eye focus an image right side up or upside down on your retina? Why does an image appear right side up when you look at objects?
2. **Drawing Conclusions** Which lens sharpened the image that formed in front of the retina? Behind the retina?
3. **Using Models** Which condition—long-focal length or short-focal length—do you think models the problem of nearsightedness? Which condition models farsightedness? Explain your answers.



Chapter 35 Study Guide

35-1 Human Body Systems



Key Concepts



7 5.a, BI 9.c

- The levels of organization in a multicellular organism include cells, tissues, organs, and organ systems.
- Homeostasis is the process by which organisms keep internal conditions relatively constant despite changes in external environments.

Vocabulary

specialized cell, p. 894
epithelial tissue, p. 894
connective tissue, p. 894
nervous tissue, p. 894
muscle tissue, p. 894
homeostasis, p. 895
feedback inhibition, p. 895

35-2 The Nervous System



Key Concepts



BI 9.b, BI 9.d, BI 9.e

- The nervous system controls and coordinates functions throughout the body and responds to internal and external stimuli.
- The basic structural units of the nervous system are neurons.
- A nerve impulse begins when a neuron is stimulated by another neuron or by its environment.

Vocabulary

neuron, p. 897 • cell body, p. 897
dendrite, p. 898 • axon, p. 898
myelin sheath, p. 898
resting potential, p. 898
action potential, p. 899
threshold, p. 899 • synapse, p. 900
neurotransmitter, p. 900

35-3 Divisions of the Nervous System



Key Concepts



BI 9.b, BI 9.e

- The central nervous system relays messages, processes information, and analyzes information. The central nervous system consists of the brain and the spinal cord.
- The peripheral nervous system can be divided into the sensory division and the motor division. The sensory division transmits impulses from sense organs to the central nervous system. The motor division transmits impulses from the central nervous system to the muscles or glands.

Vocabulary

meninges, p. 901 • cerebrospinal fluid, p. 901
cerebrum, p. 902 • cerebellum, p. 902
brain stem, p. 902 • thalamus, p. 903
hypothalamus, p. 903 • reflex, p. 903
reflex arc, p. 904

35-4 The Senses



Key Concept



BI 9.e

- There are five general categories of sensory receptors: pain receptors, thermoreceptors, mechanoreceptors, chemoreceptors, and photoreceptors.

Vocabulary

sensory receptor, p. 906 • pupil, p. 906
lens, p. 907 • retina, p. 907 • rod, p. 907
cone, p. 907 • cochlea, p. 908
semicircular canal, p. 908 • taste bud, p. 909

35-5 Drugs and the Nervous System



Key Concepts

- Stimulants increase heart rate, blood pressure, and breathing rate. In addition, stimulants increase the release of neurotransmitters at some synapses in the brain.
- Depressants slow down heart rate and breathing rate, lower blood pressure, relax muscles, and relieve tension.
- Cocaine causes the sudden release of a neurotransmitter in the brain called dopamine.
- Opiates mimic natural chemicals in the brain known as endorphins, which normally help to overcome sensations of pain.
- Alcohol is a depressant that slows down the rate at which the central nervous system functions.

Vocabulary

drug, p. 910
stimulant, p. 910
depressant, p. 911
fetal alcohol syndrome, p. 913
drug abuse, p. 914
addiction, p. 914

Thinking Visually

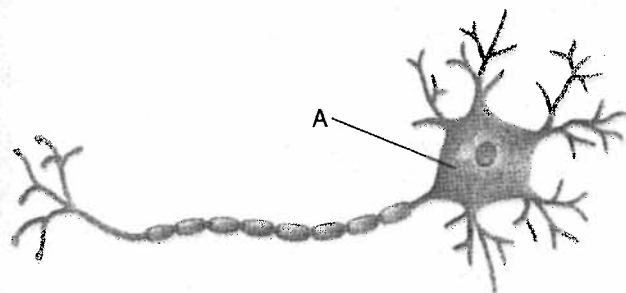
Develop a graphic organizer to show the relationship between the different divisions of the nervous system.

Chapter 35 Assessment

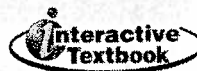
Reviewing Content

Choose the letter that best answers the question or completes the statement.

- The type of tissue that covers the body, lines internal surfaces, and forms glands is
 - muscle tissue.
 - connective tissue.
 - epithelial tissue.
 - nervous tissue.
- The process of maintaining a relatively constant internal environment despite changes in the external environment is called
 - regulation.
 - homeostasis.
 - synapse.
 - stimulation.
- The basic units of structure and function of the nervous system are
 - neurons.
 - axons.
 - dendrites.
 - neurotransmitters.
- In the diagram below, letter A is pointing to the
 - myelin sheath.
 - axon.
 - dendrite.
 - cell body.
- The place where a neuron transfers an impulse to another cell is the
 - synapse.
 - dendrite.
 - myelin sheath.
 - receptor.
- The central nervous system consists of the
 - sense organs.
 - reflexes.
 - brain and spinal cord.
 - sensory and motor neurons.



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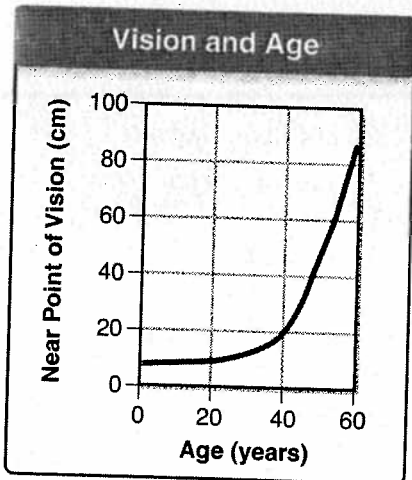
- Voluntary or conscious activities of the body are controlled by the
 - medulla oblongata.
 - cerebrum.
 - cerebellum.
 - brain stem.
- The sympathetic nervous system and the parasympathetic nervous system are divisions of the
 - peripheral nervous system.
 - central nervous system.
 - somatic nervous system.
 - autonomic nervous system.
- The semicircular canals and the two tiny sacs located behind them help maintain
 - night vision.
 - equilibrium.
 - respiratory rate.
 - temperature.
- Drugs that increase heart rate, blood pressure, and breathing rate are
 - stimulants.
 - depressants.
 - opiates.
 - barbiturates.

Understanding Concepts

- Sequence the following terms from simplest to most complex: organ system, tissue, organ, organism, cell.
- Why is it important for an organism to maintain homeostasis?
- Describe the structure and function of a neuron.
- What changes occur in the neuron during the resting potential? During an action potential?
- How does the all-or-none principle relate to the transmission of a nerve impulse?
- Describe the structure and function of the cerebrum.
- Describe the advantage of a reflex response in the survival of an organism.
- List the divisions of the autonomic nervous system and give the function of each.
- Trace the path of light through the eye.
- What are the functions of rods and cones?
- Trace the path of sound through the ear.
- Explain why a pregnant woman should avoid drinking alcohol.
- Define drug abuse in your own words.
- It has been said that no one can be cured of a drug dependence. Explain why.

Critical Thinking

25. **Designing Experiments** Design an experiment to determine the effects of fatigue on reaction time. Formulate a hypothesis and write down your procedure. Have your teacher check your experimental plan before you begin.
26. **Applying Concepts** Heat receptors of mammals are particularly concentrated on the tongue. These receptors keep humans from burning the mouth with hot food. What advantage is it for a wild mammal that doesn't cook its food to have so many heat receptors in its tongue?
27. **Inferring** Suppose a portion of an axon is cut so that it is no longer connected to its nerve cell body. What effect would that have on the transmission of impulses?
28. **Applying Concepts** A routine examination by a doctor usually includes a knee-jerk reflex test. What is the purpose of this test? What could the absence of a response indicate?
29. **Using Tables and Graphs** The graph below compares age to the nearest distance in centimeters that many people can see an object clearly. Describe the general trend of the graph. At what age does the slope of the graph begin to change rapidly? What do you think might explain this change?



30. **Predicting** Multiple sclerosis (MS) is a disease characterized by the destruction of myelin. Based on your knowledge of neuron structure and the function of various cell parts, predict the symptoms this destruction of myelin might produce.

31. **Applying Concepts** Constant exposure to loud noises may cause loss of hearing. What parts of the ear may be damaged? Can the loss of hearing be reversed?
32. **Using Analogies** How are a neuron and an electrical extension cord similar? How are they different?
33. **Inferring** What is the advantage of having a greater concentration of touch receptors and, therefore, greater sensitivity in the fingers, toes, and face?
34. **Classifying** Would you classify blood as a cell, a tissue, or an organ? Explain your answer.

Focus on the BIG Idea

Structure and Function Compare the nervous systems of nonvertebrate chordates and the human nervous system. What is the main difference between these systems? Refer to Section 30–1 and Section 33–3.

Writing in Science

At the beginning of this chapter, you read about how the systems of the body worked together toward a common goal—winning a basketball game. Imagine that you are playing soccer. Using **Figure 35–2** as a reference, pick five body systems that are most involved in the activity, and explain how the body systems are working together. Be sure to include your reasons for picking the five body systems that you chose.

Performance-Based Assessment

Making a Collage The left and right sides of the brain are responsible for different activities. Make a collage that shows examples of some right-brain activities and some left-brain activities. Attach to your collage a paragraph outlining what learning strategies would be useful for left-brain dominant individuals and for right-brain dominant individuals.

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Test-Taking Tip

Questions that begin with a list of lettered choices (A–D) followed by numbered statements are essentially multiple-choice questions. To solve these questions, use the same process that you use to solve standard multiple-choice questions.

Questions 1–4 Each of the lettered choices below refers to the following numbered statements. Select the best lettered choice. A choice may be used once, more than once, or not at all.

- A Synapse
- B Myelin sheath
- C Cerebrum
- D Cerebellum

1. The largest and most prominent part of the human brain
2. Carries out activities that are under voluntary control by the brain BI 9.b
3. Gap between two neurons
4. Insulating membrane surrounding some axons

Choose the letter that best answers the question or completes the statement.

5. The process by which organisms keep internal conditions relatively constant is called BI 9.b
 - A resting potential.
 - B positive feedback.
 - C feedback inhibition.
 - D homeostasis.
6. Which of the following is NOT a kind of tissue in the human body? 7 5.a
 - A epithelial
 - B connective
 - C neuron
 - D nervous
7. The part of a neuron that carries impulses away from the cell body is called a(an) BI 9.e
 - A axon.
 - B dendrite.
 - C node.
 - D vesicle.

8. Which of the following is NOT a structure of the human ear?
 - A tympanum
 - B cochlea
 - C stirrup bone
 - D vitreous humor

Questions 9–11

The table below lists the blood alcohol concentration (BAC) as alcohol consumption increases. Use the information in the table to answer the questions that follow.

Blood Alcohol Concentration (Percent)						
Drinks in One Hour	Body Mass					
	45 kg	54 kg	63 kg	72 kg	81 kg	90 kg
1	0.04	0.03	0.03	0.02	0.02	0.02
2	0.07	0.06	0.05	0.05	0.04	0.04
3	0.11	0.09	0.08	0.07	0.06	0.06
4	0.14	0.12	0.10	0.09	0.08	0.07
5	0.18	0.15	0.13	0.11	0.10	0.09
6	0.21	0.18	0.15	0.14	0.12	0.11
7	0.25	0.21	0.18	0.16	0.14	0.13
8	0.29	0.24	0.21	0.18	0.16	0.14
9	0.32	0.27	0.23	0.20	0.18	0.16
10	0.36	0.30	0.26	0.22	0.20	0.18

9. How many drinks in one hour would cause a 63-kg person to have a BAC percentage of 0.08?

A 1	C 3
B 2	D 4
10. If a 54-kg person had 3 drinks in one hour, what would his or her BAC percentage be?

A 0.06	C 0.09
B 0.08	D 0.11
11. If a 72-kg person had 4 drinks in two hours, what would his or her BAC percentage be?

A 0.03	C 0.08
B 0.05	D 0.13