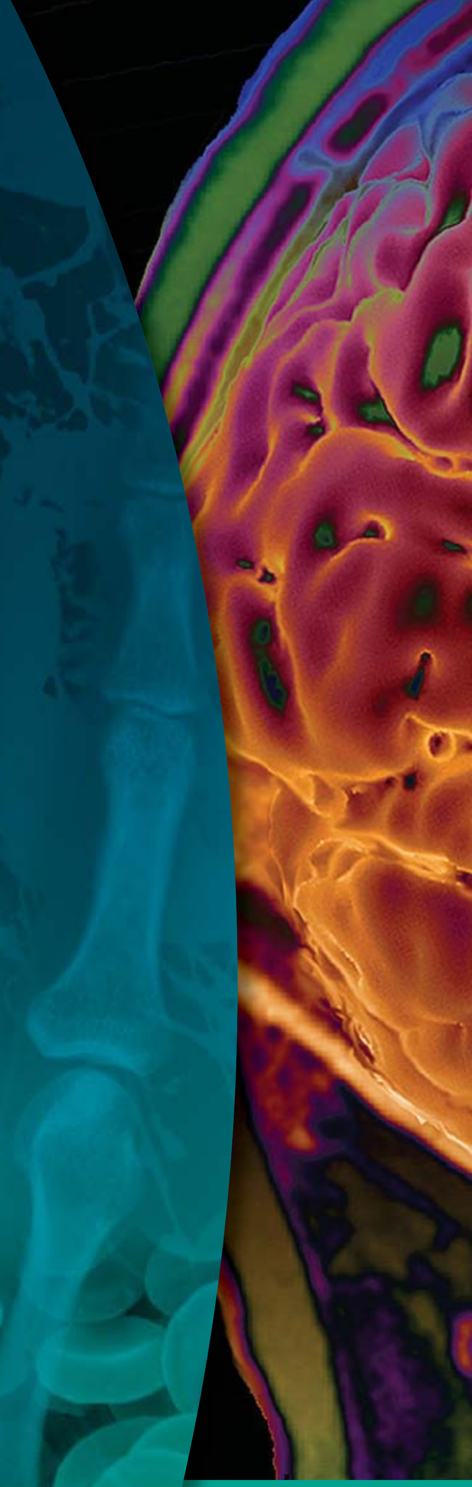
CHAPTER

29 Nervous and Endocrine Systems



KEY CONCEPTS

29.1 How Organ Systems Communicate

The nervous system and the endocrine system provide the means by which organ systems communicate.

29.2 Neurons

The nervous system is composed of highly specialized cells.

29.3 The Senses

The senses detect the internal and external environments.

29.4 Central and Peripheral Nervous Systems

The central nervous system interprets information, and the peripheral nervous system gathers and transmits information.

29.5 Brain Function and Chemistry

Scientists study the functions and chemistry of the brain.

29.6 Endocrine System and Hormones

The endocrine system produces hormones that affect growth, development, and homeostasis.

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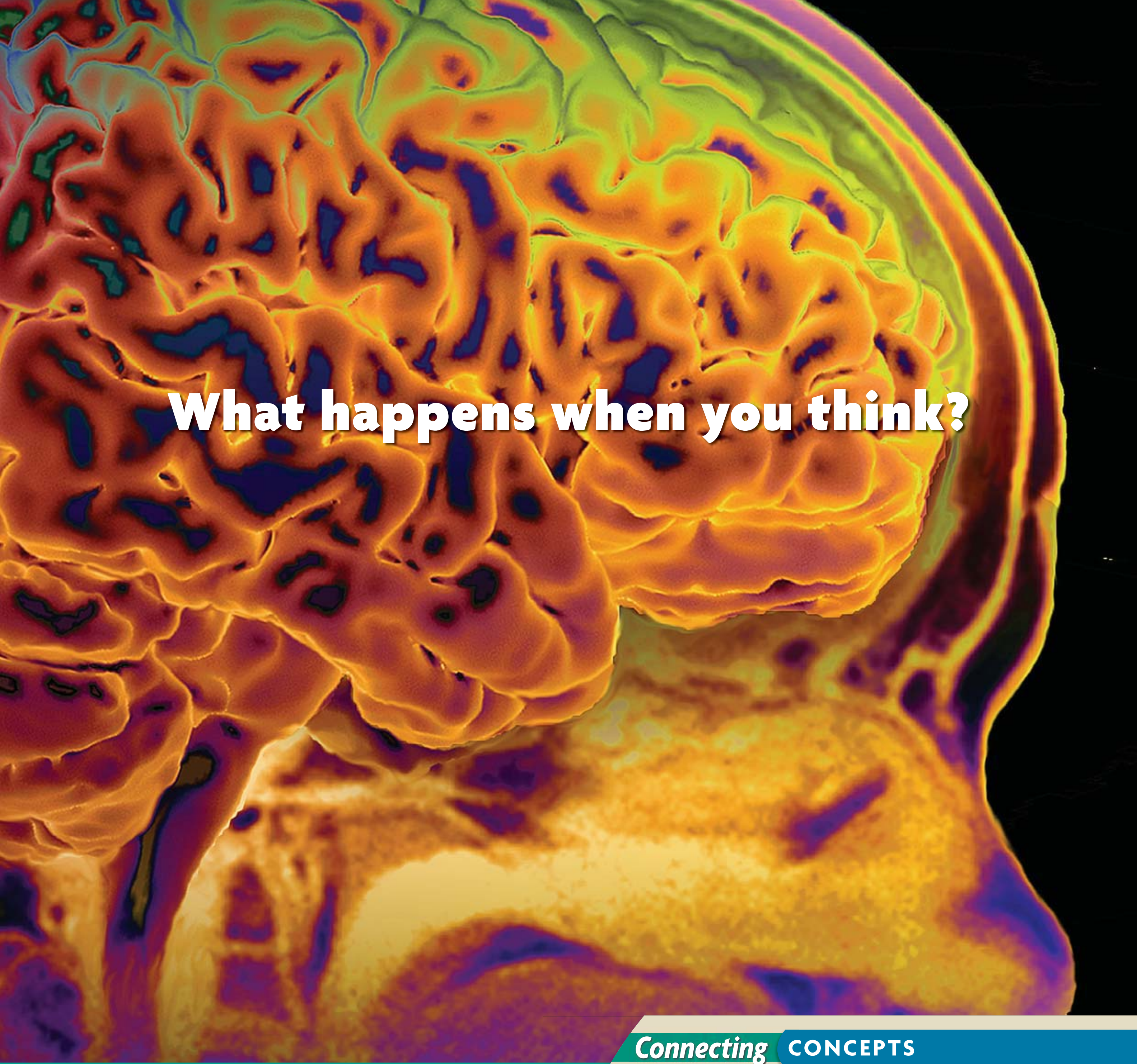
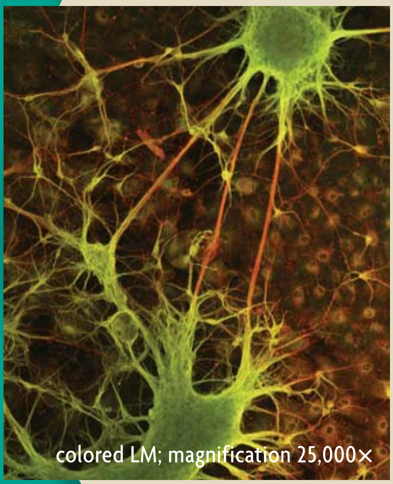
What happens when you think?



Some technology allows researchers to look into the body of a living person. As recently as the 1970s, there was no way for doctors and scientists to see inside of the body without putting a patient through surgery. Today, researchers and others use magnets and computer technology, such as the MRI scan above, to look at the internal organs of live patients.

Connecting CONCEPTS



colored LM; magnification 25,000×

Animals Although only vertebrates have a spinal column, most animals have neurons. Neurons are specialized cells that send signals to different organ systems throughout the body. Neurons connect the brain to muscles and other tissues, and some neurons send such fast signals that they can make a person blink in less than one one-hundredth of a second.

29.1 How Organ Systems Communicate

KEY CONCEPT The nervous system and the endocrine system provide the means by which organ systems communicate.

MAIN IDEAS

- The body's communication systems help maintain homeostasis.
- The nervous and endocrine systems have different methods and rates of communication.

VOCABULARY

nervous system, p. 874
endocrine system, p. 874
stimulus, p. 874
central nervous system (CNS), p. 875
peripheral nervous system (PNS), p. 875

REVIEW AT CLASSZONE.COM

Connect Scientists try to find new ways, such as MRI scans, to study the brain because the brain is so important. Your brain lets you think and move. It controls digestion, heart rate, and body temperature. Your brain does these things with help from the endocrine system and the rest of the nervous system.

MAIN IDEA

The body's communication systems help maintain homeostasis.

Homeostasis depends on the ability of different systems in your body to communicate with one another. To maintain homeostasis, messages must be generated, delivered, interpreted, and acted upon by your body. The nervous system and the endocrine system are the communication networks that allow you to respond to changes in your environment countless times each day.

- The **nervous system** is a physically connected network of cells, tissues, and organs that controls thoughts, movements, and simpler life processes such as swallowing. For example, when you walk outside without sunglasses on a sunny day, your nervous system senses the bright light coming into your eyes. It sends a message that tells your pupils to shrink and let in less light.
- The **endocrine system** (EHN-duh-krihn) is a collection of physically disconnected organs that helps to control growth, development, and responses to your environment, such as body temperature. For example, when you are outside on a hot day or you exercise, your body starts to feel warm. Your endocrine system responds by producing messages that tell your body to sweat more so that you can cool down.

Both of these systems, which are shown in **FIGURE 29.1**, let you respond to a stimulus in your environment and maintain homeostasis. A **stimulus** (STIHM-yuh-luhs) is defined most broadly as something that causes a response. In living systems, a stimulus is anything that triggers a change in an organism. Changes can be chemical, cellular, or behavioral.

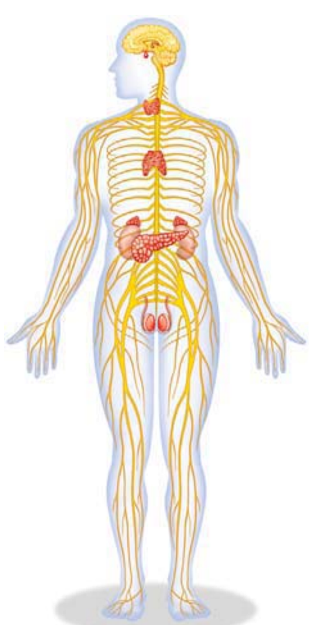


FIGURE 29.1 The nervous system (yellow) is a physically connected network, while the endocrine system (red) is made up of physically separated organs.

Analyze **What stimuli cause you to sweat and cause your pupils to shrink?**

MAIN IDEA

The nervous and endocrine systems have different methods and rates of communication.

You can think about your endocrine system as working like a satellite television system. A satellite sends signals in all directions, but only televisions that have special receivers can get those signals. Your endocrine system's chemical signals are carried by the bloodstream throughout the body, and only cells with certain receptors can receive the signals. On the other hand, your nervous system is like cable television. A physical wire connects your television to the cable provider. Similarly, your nervous system sends its signals through a network of specialized tissues.

The nervous and endocrine systems also have different rates of communication. Your endocrine system works slowly and controls processes that occur over long periods of time, such as hair growth, aging, and sleep patterns. The endocrine system also helps regulate homeostatic functions such as body temperature and blood chemistry. For example, as the day gradually warms, your endocrine system responds by releasing chemicals that stimulate sweat glands. The change in the temperature over the course of a day is slow so you do not need a rapid response from your body.

Your nervous system works quickly and controls immediate processes, such as heart rate and breathing. If you touch your hand to a hot stove, an immediate response from the nervous system causes you to jerk your hand away. Without a quick reaction, your hand would be badly burned.

Signals move from the skin on your hand to the muscles in your arm by passing through the two parts of the nervous system: the central and the peripheral. The **central nervous system (CNS)** includes the brain and spinal cord. The CNS interprets messages from other nerves in the body and stores some of these messages for later use. The **peripheral nervous system (PNS)** is a network of nerves that transmits messages to the CNS and from the CNS to other organs in the body. You can see some of the nerves of the PNS extending from the spinal cord toward the neck and shoulders in **FIGURE 29.2**.

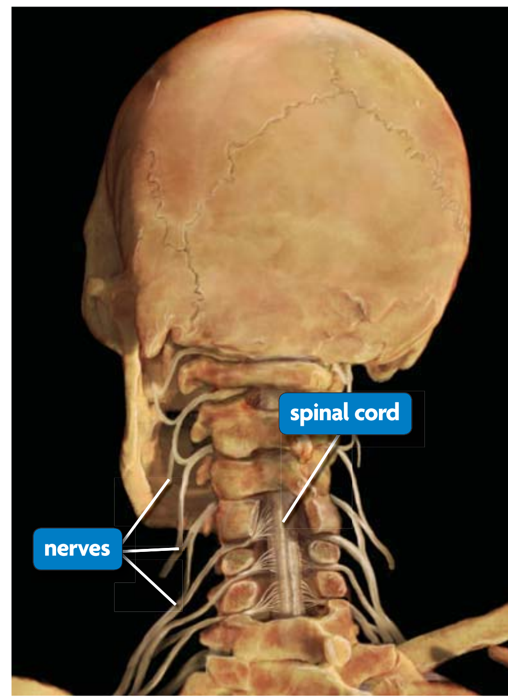


FIGURE 29.2 This medical illustration shows how the spinal cord connects the brain to the nerves that run throughout the body.

Infer **Which system controls the rate at which your fingernails grow?**

29.1 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. Why does your body need a communication system?
2. What are three differences between the ways in which the **endocrine system** and the **nervous system** work?

CRITICAL THINKING

3. **Apply** Which system, the endocrine or the nervous, controls the rate at which you blink? Explain.
4. **Predict** How might a clogged blood vessel affect the nervous system's and the endocrine system's abilities to deliver signals?

Connecting CONCEPTS

5. **Cell Structure** What structures on a cell membrane might ensure that the endocrine system's signals only affect the cells for which they are intended?

29.2 Neurons

KEY CONCEPT The nervous system is composed of highly specialized cells.

MAIN IDEAS

- Neurons are highly specialized cells.
- Neurons receive and transmit signals.

VOCABULARY

neuron, p. 876
dendrite, p. 876
axon, p. 876
resting potential, p. 877
sodium-potassium pump, p. 877
action potential, p. 878
synapse, p. 879
terminal, p. 879
neurotransmitter, p. 879

REVIEW AT CLASSZONE.COM

Connect When you eat a snack, you might flick crumbs off of your fingers without giving it much thought. The specialized cells of your nervous system, however, are hard at work carrying the messages between your fingers and your brain.

MAIN IDEA

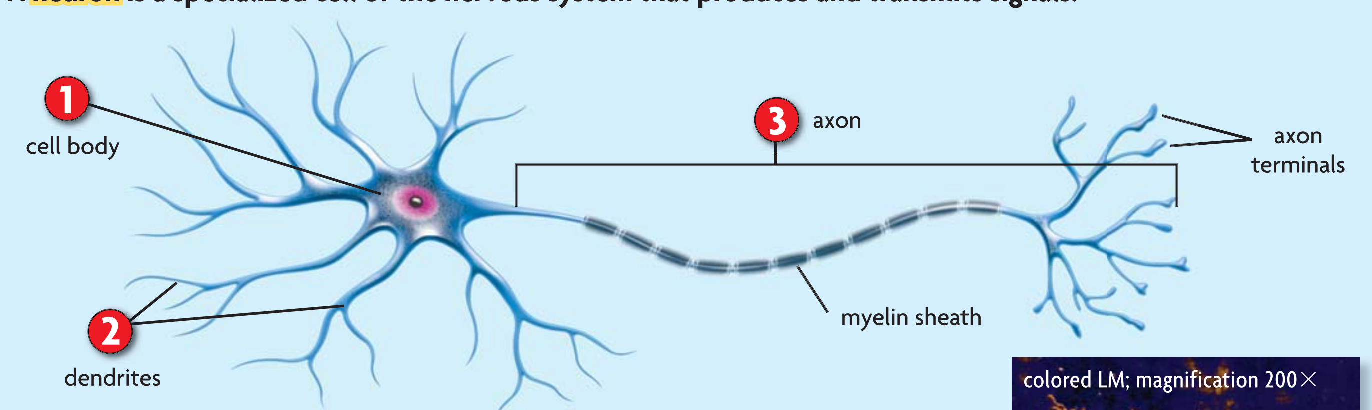
Neurons are highly specialized cells.

A **neuron** is a specialized cell that stores information and carries messages within the nervous system and between other body systems. Most neurons have three main parts, as shown in **FIGURE 29.3**.

1. The cell body is the part of the neuron that contains the nucleus and organelles.
2. **Dendrites** are branchlike extensions of the cytoplasm and the cell membrane that receive messages from neighboring cells. Neurons can have more than one dendrite, and each dendrite can have many branches.
3. Each neuron has one axon. An **axon** is a long extension that carries electrical messages away from the cell body and passes them to other cells.

FIGURE 29.3 Structure of a Neuron

A neuron is a specialized cell of the nervous system that produces and transmits signals.



Infer Why might it be beneficial for a neuron to have more than one dendrite?

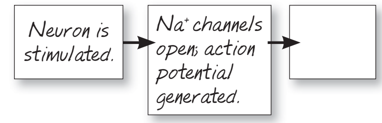
There are three types of neurons: (1) sensory neurons, (2) interneurons, and (3) motor neurons. Sensory neurons detect stimuli and transmit signals to the brain and the spinal cord, which are both made up of interneurons. Interneurons receive signals from sensory neurons and relay them within the brain and the spinal cord. They process information and pass signals to motor neurons. Motor neurons pass messages from the nervous system to other tissues in the body, such as muscles.

The nervous system also relies on specialized support cells. For example, Schwann cells cover axons. A collection of Schwann cells, called the myelin sheath, insulates neurons' axons and helps them to send messages.

Analyze How does a neuron's shape allow it to send signals across long distances?

TAKING NOTES

Use a flow chart to organize your notes on how a neuron transmits a signal.



MAIN IDEA

Neurons receive and transmit signals.

When your alarm clock buzzes in the morning, the sound stimulates neurons in your ear. The neurons send signals to your brain, which prompt you to either get out of bed or hit the snooze button. Neurons transmit information in the form of electrical and chemical impulses. When a neuron is stimulated, it produces an electrical impulse that travels only within that neuron. Before the signal can move to the next cell, it changes into a chemical signal.

Before a Neuron Is Stimulated

When a neuron is not transmitting a signal, it is said to be "at rest." However, this does not mean that the neuron is inactive. Neurons work to maintain a charge difference across their membranes, which keeps them ready to transmit impulses when they become stimulated.

While a neuron is at rest, the inside of its cell membrane is more negatively charged than the outside. The difference in charge across the membrane is called the **resting potential,** because it contains the potential energy needed to transmit an impulse. The resting potential occurs because there are unequal concentrations of ions inside and outside the neuron.

Two types of ions—sodium ions (Na^+) and potassium ions (K^+)—cause the resting potential. More Na^+ ions are present outside the cell than inside it. On the other hand, there are fewer K^+ ions outside the cell than inside it. Notice that both ions are positively charged. The neuron is negative compared with its surroundings because there are fewer positive ions inside the neuron.

Proteins in the cell membrane of the neuron maintain the resting potential. Some are protein channels that allow ions to diffuse across the membrane—Na^+ ions diffuse into the cell and K^+ ions diffuse out. However, the membrane has many more channels for K^+ than for Na^+, so positive charges leave the cell much faster than they enter. This unequal diffusion of ions is the main reason for the resting potential. In addition, the membrane also has a protein called the **sodium-potassium pump,** which uses energy to actively transport Na^+ ions out of the cell and bring K^+ ions into the cell. This process also helps maintain the resting potential.

Connecting CONCEPTS

Active Transport Recall from **Chapter 3** that energy and specialized membrane proteins are required to move molecules and ions against the concentration gradient.

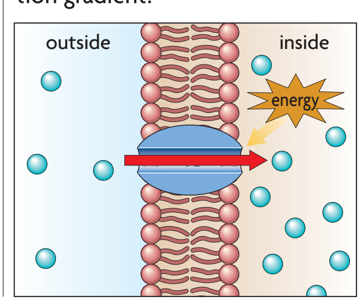
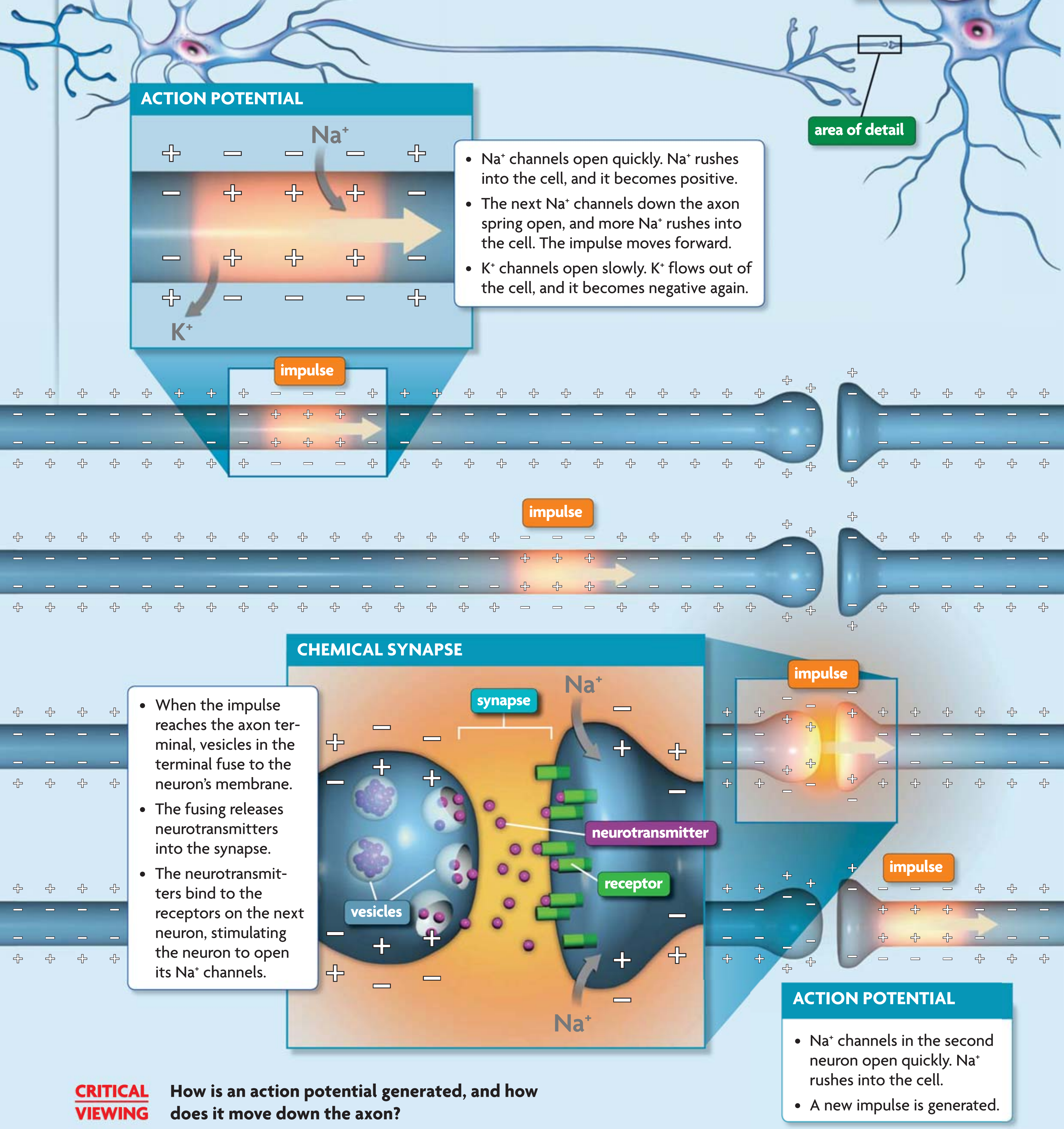


FIGURE 29.4 Transmission Through and Between Neurons

Once a neuron is stimulated, a portion of the inner membrane becomes positively charged. This electrical impulse, or action potential, moves down the axon. Before it can move to the next neuron, it must become a chemical signal.

Animated BIOLOGY View an animation of transmission at ClassZone.com.



CRITICAL VIEWING **How is an action potential generated, and how does it move down the axon?**

Transmission Within a Neuron

As you tap your finger on a desk, pressure receptors in your fingers stretch. The stretching causes a change in charge distribution that triggers a moving electrical impulse called an **action potential,** shown in **FIGURE 29.4**.

An action potential requires ion channels in the membrane that have gates that open and close. When a neuron is stimulated, gated channels for Na^+ open quickly, and Na^+ ions rush into the cell. This stimulates adjacent Na^+ channels down the axon to spring open. Na^+ ions rush into the cell, and then those ion channels snap shut. In this way, the area of positively charged membrane moves down the axon.

At the same time Na^+ channels are springing open and snapping shut, K^+ ion channels are opening and closing more slowly. K^+ ions diffuse out of the axon and cause part of the membrane to return to resting potential. Because K^+ channels are slow to respond to the change in axon's charge, they appear to open and close behind the moving impulse.

Transmission Between Neurons

Before an action potential moves into the next neuron, it crosses a tiny gap between the neurons called a **synapse.** The axon **terminal,** the part of the axon through which the impulse leaves that neuron, contains chemical-filled vesicles. When an impulse reaches the terminal, vesicles bind to the terminal's membrane and release their chemicals into the synapse. **Neurotransmitters** (NUR-oh-TRANS-miht-urz) are the chemical signals of the nervous system. They bind to receptor proteins on the adjacent neuron and cause Na^+ channels in that neuron to open, generating an action potential.

Typically, many synapses connect neurons. Before the adjacent neuron generates an action potential, it usually needs to be stimulated at more than one synapse. The amount a neuron needs to be stimulated before it produces an action potential is called a threshold.

Once neurotransmitters have triggered a new action potential, they must be removed from the synapse so that ion channels on the second neuron will close again. These neurotransmitters will be broken down by enzymes in the synapse, or they are transported back into the terminal that released them.

Contrast **How does signal transmission within and between neurons differ?**

29.2 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. What are the roles of the three types of **neurons**?
2. Draw a picture to illustrate **resting potential,** and explain how it helps transmit signals in neurons.

CRITICAL THINKING

3. **Infer** How does a threshold prevent a neuron from generating too many **action potentials**?
4. **Predict** What might happen if a drug blocked **neurotransmitter** receptors?

Connecting CONCEPTS

5. **Cell Chemistry** Hyponatremia occurs when people have very low amounts of sodium in their body. How might the nervous system be affected if a person had this condition?

29.3 The Senses

KEY CONCEPT The senses detect the internal and external environments.

MAIN IDEAS

- The senses help to maintain homeostasis.
- The senses detect physical and chemical stimuli.

VOCABULARY

rod cell, p. 881
cone cell, p. 881
hair cell, p. 882

REVIEW AT CLASSZONE.COM

Connect You may think that you hear sounds with your ear, smell with your nose, or taste with your tongue, but that is not true. Your sensory organs only collect stimuli and send signals to your brain. Your brain interprets these signals. Together, your sensory organs and your brain allow you to perceive stimuli as various sounds, sights, smells, tastes, and so forth.

MAIN IDEA

The senses help to maintain homeostasis.

You rely on your sensory organs to collect information about the world around you. Once your brain has information from sensory organs, it triggers a response that will maintain homeostasis. For example, eyes adjust to bright and dim light by changing the size of your pupils, as shown in **FIGURE 29.5**. If your skin feels cold, you might shiver. You might get goose bumps, or your arm hairs might stand up, trapping the heat that would otherwise escape from your skin.

Your sensory organs also influence your behavior. Although homeostasis is strictly defined as the regulation and maintenance of the body's internal condition, you could also think of behaviors that prevent death or injury as a kind of homeostatic mechanism.

Imagine that you are getting ready to cross a street, and you look both ways to see if it is safe. Light enters your eyes and the light receptors in your eyes are stimulated to produce impulses. The impulses travel down bundles of axons to your brain. Your brain filters these impulses and forwards some of them to the specific area of your brain that interprets visual information. Your brain then combines this information with that from your other sense organs. Your brain interprets the light that entered your eyes as a large truck speeding your way. With the help of your eyes, you will wait for the truck to pass before walking into the street.

Your senses influence many other behaviors that help protect your tissues from damage. For example, if automatic responses such as shivering and goose bumps don't warm you up, you might decide to put on a jacket. If the sun is too bright, you might decide to put on sunglasses. If a room is too dark, you might decide to turn on a light.

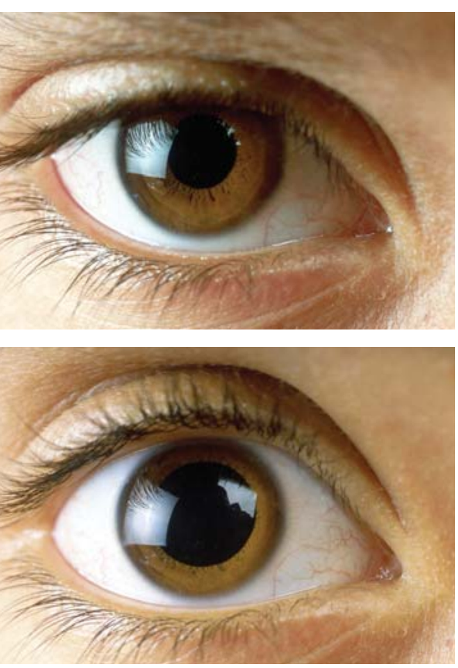

FIGURE 29.5 The size of your pupil changes depending on the amount of light around you. In bright light, your pupil constricts. In dim light, the pupil expands.

Summarize **How do your sensory organs help you to maintain homeostasis?**

MAIN IDEA

The senses detect physical and chemical stimuli.

Humans have specialized sensory organs that detect external stimuli. The information these organs collect helps to make up the five senses: vision, hearing, touch, taste, and smell. Five different types of sensory receptors help humans to detect different stimuli.

- Photoreceptors sense light.
- Mechanoreceptors respond to pressure, movement, and tension.
- Thermoreceptors monitor temperature.
- Chemoreceptors detect chemicals that are dissolved in fluid.
- Pain receptors respond to extreme heat, cold, and pressure, and to chemicals that are released by damaged tissues.

VOCABULARY

You can remember what kind of stimuli each receptor receives by remembering what their prefixes mean:
photo- = light
mechano- = machine, movement
thermo- = heat
chemo- = chemical

Vision

Humans rely on vision more than any of the other senses. In fact, the eye contains about 70 percent of all the sensory receptors in the body. Most of these are photoreceptors on the back inside wall of the eye. This layer of tissue, called the retina, is shown in **FIGURE 29.6**. Specialized cells called rods and cones are the photoreceptors. **Rod cells** detect light intensity and are used in black and white vision. **Cone cells** detect color. Rod cells are sensitive to low amounts of light, and cone cells need bright light to function. This is why you have difficulty seeing color when it is dark.

Because sight depends on the amount of light available, the eye must have a way to limit the amount of light from a bright source or allow more light to enter from a dim light source. Muscles around the iris—the colored part of the eye—control the size of the hole at its center, the pupil. The eye adjusts the amount of light that enters it by changing the size of the pupil. The larger the pupil, the more light that can enter.

Before light can stimulate the rod and cone cells in the retina, it must pass through structures at the front of the eye. Light enters the eye through a protective transparent layer called the cornea and moves through the pupil. After the pupil, light passes through the lens. The lens is behind the iris, and it focuses the light onto the retina. The light stimulates the rod and cone cells, which generate nerve impulses. The impulses travel along the bundle of axons that form the optic nerve. The nerve carries the impulses to the brain, where they are interpreted as images.

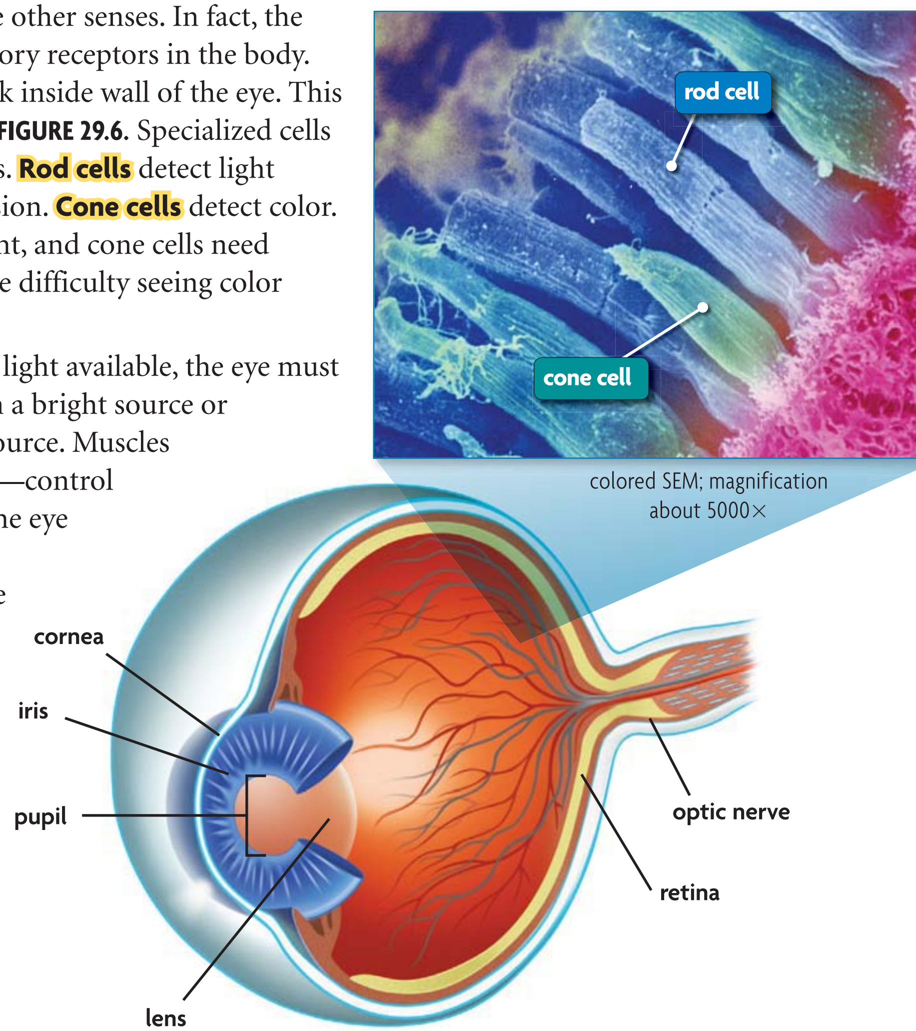

FIGURE 29.6 Light is focused by the lens onto the retina, where rod and cone cells generate impulses. These impulses travel through your optic nerve to your brain, where they are interpreted as images.

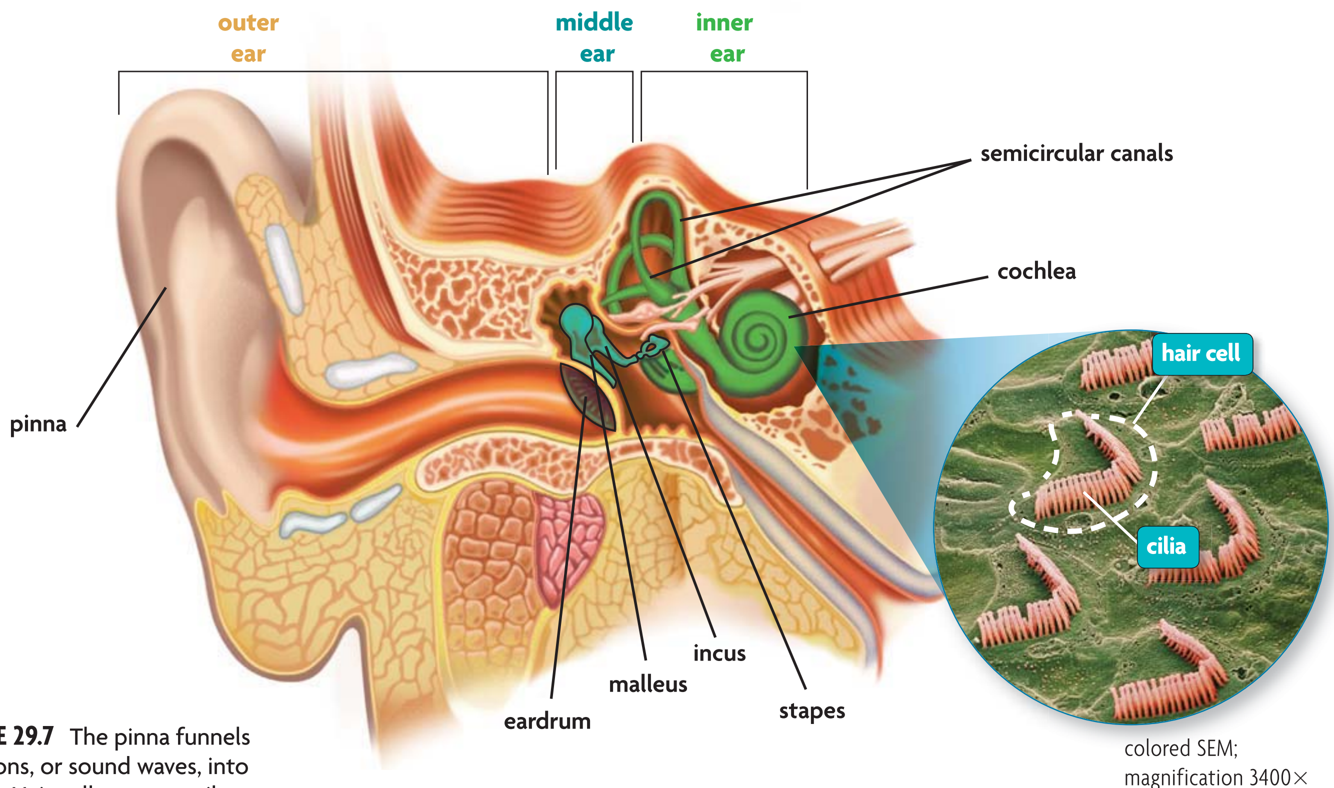

FIGURE 29.7 The pinna funnels vibrations, or sound waves, into the ear. Hair cells convert vibrations into impulses that are sent to the brain for interpretation.

Connecting CONCEPTS

Animal Behavior Sensory organs collect stimuli that influence human and animal behavior, as you read in **Chapter 27.**

Hearing

The ear collects vibrations—sound waves—from the air, amplifies them, and converts them into nerve impulses that are interpreted in the brain as sounds. **Hair cells** are specialized cells in the inner ear that contain mechanoreceptors that detect vibrations. Hair cells produce action potentials when they are bent.

Sound waves enter the body through the outer ear. The pinna, the part of the ear you can see, collects sound and funnels it into the auditory canal. Sound waves in the auditory canal hit the eardrum, or tympanic membrane, causing it to vibrate like the head of a drum. The vibrations are amplified by three small bones in the middle ear—the malleus, the incus, and the stapes.

As **FIGURE 29.7** shows, the amplified vibrations are transferred to the cochlea. The cochlea is a structure of fluid-filled canals in the inner ear where hair cells are located. The fluid in the cochlea moves in response to vibrations. This movement causes the hair cells to bend. When the hair cells bend, an impulse is produced. The impulse is carried by the auditory nerve to the brain, where it is perceived as a sound.

The ear also has organs that regulate balance. Balance is controlled by an organ in the inner ear called the semicircular canals. When your head moves, fluid inside the semicircular canals moves. The movement bends the hair cells in the canals. As the cells bend, they generate impulses that are transmitted to the brain.

Smell and Taste

You may have noticed that food seems to have less flavor when you have a cold. If you haven't, you can try holding your nose the next time you eat. It will have a similar effect. Your sense of taste is less sensitive when your nose is stuffed up because your smell and taste senses are closely related. Both the nose, which senses odors, and the tongue, which senses flavors, have chemoreceptors. These receptors detect molecules that are dissolved in liquid.

In smell, small airborne chemicals enter the nose. These chemicals dissolve in mucus in the nose, and they are detected by olfactory cells, which generate impulses. The olfactory nerve takes impulses to the brain.

Taste buds are chemoreceptors that detect tastes. They are found in bumps on the tongue called papillae. As in the nose, chemicals must be dissolved before they can be detected. The chemoreceptors generate impulses that are sent to the brain. Although your tongue can only detect five basic tastes—sweet, sour, salty, bitter, and savory—your brain interprets combinations of these as complex flavors.

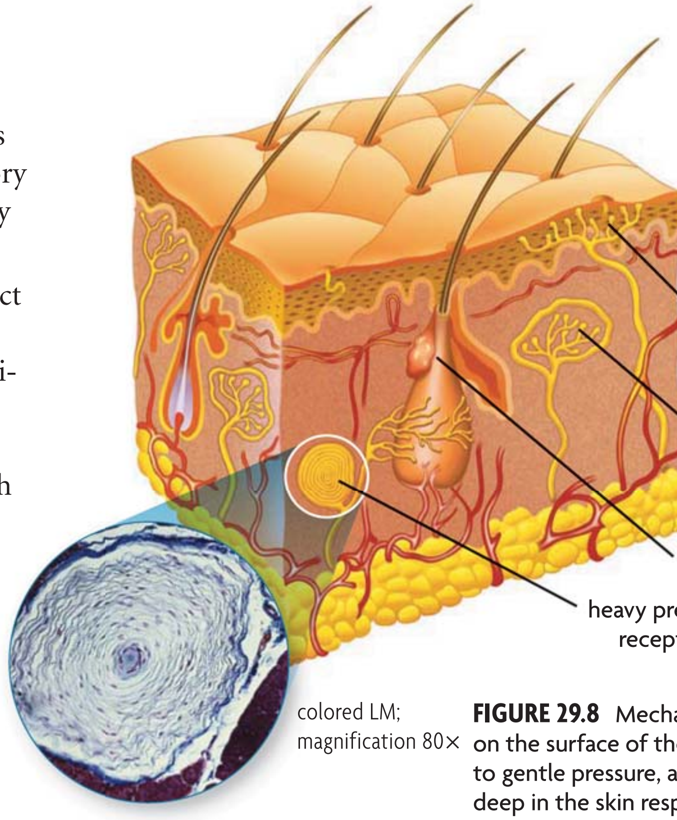

FIGURE 29.8 Mechanoreceptors on the surface of the skin respond to gentle pressure, and those deep in the skin respond to hard pressure. Pain receptors are close to the skin's surface.

Touch, Temperature, and Pain

Your skin contains receptors that sense touch, temperature, and pain. Touch is sensed by mechanoreceptors that detect pressure, movement, and tension. The skin has two general types of mechanoreceptors. Mechanoreceptors that detect gentle touch are located in the upper layer of the skin. Some of these are wrapped around hair follicles. They help you feel when these hairs move, as they might when a small fly lands on your arm. Mechanoreceptors that recognize heavy pressure are found deeper within the skin, as you can see in **FIGURE 29.8.**

Temperature and pain are sensed by thermoreceptors and pain receptors. Thermoreceptors detect heat and cold. Pain receptors detect chemicals that are released by damaged cells. Some pain receptors detect sharp pains, such as the pain you would feel by stepping on a nail. Other pain receptors sense blunt or throbbing pain, such as that caused by a bruise.

Summarize **To which senses do mechanoreceptors contribute?**

29.3 ASSESSMENT

ONLINE QUIZ
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REVIEWING MAIN IDEAS

1. How do your sensory organs work with your brain to help you perceive the world around you?
2. What kinds of receptors are **hair cells, rod cells,** and **cone cells,** and to which of your senses do these cells contribute?

CRITICAL THINKING

3. **Connect** Why do you think that you can perceive some sounds as loud and others as very soft?
4. **Predict** In the human eye, there are 20 rod cells for every 1 cone cell. How would your vision be different if you had 5 rod cells for every 20 cone cells?

Connecting CONCEPTS

5. **Evolution** For some invertebrates that live in water, the sense of taste and the sense of smell are identical. Why do you think separate organs for taste and smell might have evolved in animals that live on land but not in some animals that live exclusively in water?

MATERIALS
watch with second hand

PROCESS SKILLS
- Observing
- Collecting Data
- Inferring

The Stroop Effect

Psychologist John Stroop studied the processing of words and how these thought processes affected other mental tasks. He found that the brain must override an automatic response when it receives conflicting information, or interference. This is now called the Stroop Effect. In this lab, you will complete a task that demonstrates the Stroop Effect.

PROBLEM How does interference affect the completion of a task?

PROCEDURE

1. Have your partner time and record how long it takes for you to say aloud the color of ink in which each word in column 1 is printed (say the color, not the word itself). Give your responses as quickly as possible. Also record the number of incorrect responses.
2. Have your partner time and record how long it takes for you to say aloud the color of ink in which each word in column 2 is printed (say the color, not the word itself). Give your responses as quickly as possible. Also record the number of incorrect responses.
3. Switch roles and repeat steps 1 and 2.

TABLE 1. STROOP EFFECT COLOR TEST

COLUMN 1	COLUMN 2
blue	red
yellow	gray
red	orange
green	blue
black	black
purple	yellow
gray	green
orange	purple

ANALYZE AND CONCLUDE

1. **Analyze** Compare the times for naming the ink colors in both column 1 and column 2. Was there a difference between the two times? Explain why this difference exists.
2. **Infer** How many incorrect responses did you give for column 1? for column 2? Explain why incorrect responses might have occurred.
3. **Experimental Design** Design your own Stroop Effect test. For example, you could draw outlines of animals and write the name of a different animal in the drawing and test if interference occurs.

29.4 Central and Peripheral Nervous Systems

KEY CONCEPT The central nervous system interprets information, and the peripheral nervous system gathers and transmits information.

MAIN IDEAS

- The nervous system's two parts work together.
- The CNS processes information.
- The PNS links the CNS to muscles and other organs.

VOCABULARY

cerebrum, p. 886
cerebral cortex, p. 887
cerebellum, p. 888
brain stem, p. 888
reflex arc, p. 889
somatic nervous system, p. 889
autonomic nervous system, p. 890
sympathetic nervous system, p. 890
parasympathetic nervous system, p. 890

Review
central nervous system (CNS), peripheral nervous system (PNS)

REVIEW AT CLASSZONE.COM

Connect Imagine that you're watching television, and you want to turn up the volume. Without taking your eyes off the screen, you reach for the remote control on a table next to you. When you touch a glass of water or your homework that is sitting on the table, you will not pick it up because you know that it does not feel like the remote. Your brain is interpreting the stimuli gathered by your sense of touch. If you had no way to interpret each stimulus, you might pick up every item on the table before finding the remote.

MAIN IDEA

The nervous system's two parts work together.

Earlier in this chapter you read that your nervous system is divided into two parts—the central nervous system and the peripheral nervous system—which are shown in **FIGURE 29.9**.

- The central nervous system (CNS) includes the brain and spinal cord. The CNS is composed of interneurons that interact with other nerves in the body. The CNS receives, interprets, and sends signals to the PNS.
- The peripheral nervous system (PNS) is the collection of nerves that connects the CNS to all of your organ systems. The PNS uses sensory neurons to detect stimuli from inside and outside your body, and it uses motor neurons to carry signals from the CNS to other parts of the body and stimulate your muscles or other target organs.

Both the CNS and the PNS are made of several smaller parts. For example, the brain has several areas that control different functions. Divisions of the PNS influence voluntary responses, such as muscle contractions that occur while you walk, and involuntary responses, such as those that occur during digestion.

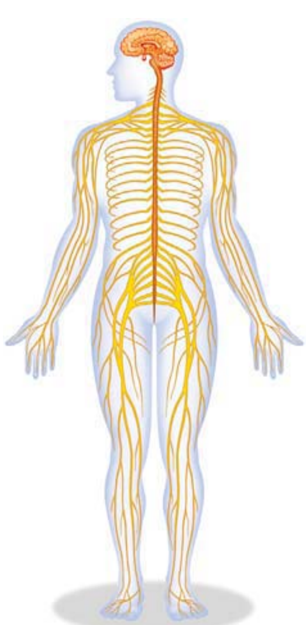


FIGURE 29.9 Your central nervous system (orange) and peripheral nervous system (yellow) are connected.

Summarize **How do the neurons of the CNS and PNS work together to produce responses to stimuli?**

QUICK LAB DESIGN YOUR OWN

The Primary Sensory Cortex

The primary sensory cortex is the part of your cerebrum that receives information about your sense of touch from different parts of your body. Each body part sends information to a different place in your primary sensory cortex. In this lab, you will determine the relationship between different body parts and the amount of space the brain devotes to receiving touch information from those body parts.

MATERIALS
- 3 toothpicks
- soft blindfold/bandana

PROBLEM Does your finger or your forearm have more space devoted to it in the primary sensory cortex?

PROCEDURE

1. Hypothesize which area will be more sensitive. Make a data table to record the information you gather during the lab.
2. Have your partner close his or her eyes. Gently, touch the tip of your partner's index finger with the tip(s) of one, two, or three toothpicks at the same time.
3. Ask your partner how many points he or she feels. Write down the number your partner says next to the number of toothpicks you used. Repeat three more times, varying the number of toothpicks used.
4. Repeat steps 2 and 3 on your partner's forearm.

TABLE 1. PRIMARY SENSORY CORTEX DATA

Area Tested	Number of Toothpicks	
	Used	Reported

ANALYZE AND CONCLUDE

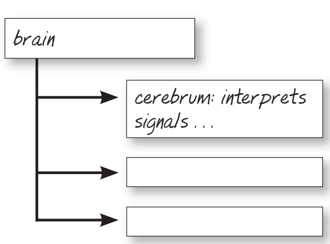
1. **Analyze** Did your partner's finger or forearm receive more sensory information? Do your data support your hypothesis? Why or why not?
2. **Infer** Which area likely has more space in the primary sensory cortex?

MAIN IDEA

The CNS processes information.

TAKING NOTES

Use a main idea diagram to study the parts of the brain.



The interneurons of the brain and spinal cord are arranged in a particular way. All of the neuron cell bodies are clustered together, and all of the axons are clustered together. The collection of neuron cell bodies is called gray matter because of its dark gray color. The collection of axons is called white matter because the myelin sheath on the axons give them a white appearance. In the brain, the gray matter is on the outside, and the white matter is on the inside. The spinal cord has the opposite arrangement.

The Brain

The entire brain weighs about half as much as a textbook and has more than 100 billion neurons. The brain is protected by three layers of connective tissue, called meninges (muh-NIHN-jeez), that surround it. Between the layers of meninges is a fluid. The fluid cushions the brain so that the brain will not bang up against the skull. The brain itself has three main structures: the cerebrum, the cerebellum, and the brainstem.

The **cerebrum** (SEHR-uh-bruhm) is the part of the brain that interprets signals from your body and forms responses such as hunger, thirst, emotions, motion, and pain. The cerebrum has right and left halves, or hemispheres.

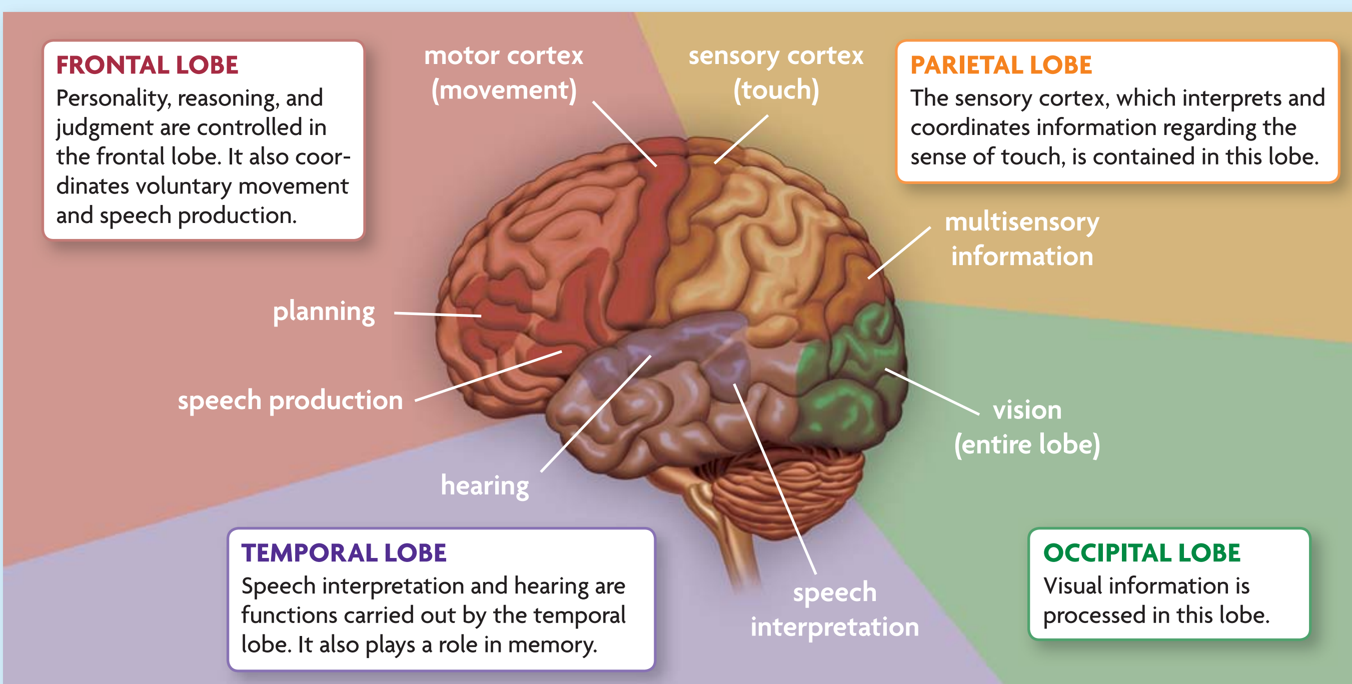
Each hemisphere controls the opposite side of the body. For example, the right hemisphere of your brain processes all of the stimuli received by your left hand. Similarly, the left side of your brain controls the muscles that kick your right leg. When the spinal cord brings a signal from the body, the signal crosses over to the opposite hemisphere in the corpus callosum. The corpus callosum is a thick band of nerves that connects the two hemispheres.

The outer layer of the cerebrum, called the **cerebral cortex,** interprets information from your sensory organs and generates responses. The cerebral cortex is about as thick as a pencil. Yet its size is deceptive because its folds give it a larger surface area than you might expect. If the cerebral cortex were unfolded, it would cover a typical classroom desk. This surface area is large enough to hold more than 10 billion neurons.

The neurons in the cerebral cortex are arranged in groups that work together to perform specific tasks. For example, movement is initiated by an area of the brain called the motor cortex, and the sense of touch is received by the sensory cortex. Scientists divide the cerebral cortex into different areas, or lobes, based on function. Each hemisphere of the human brain can be divided into four lobes—frontal, parietal, occipital, and temporal. The lobes and the cortical areas they contain are shown in **FIGURE 29.10**.

FIGURE 29.10 Lobes of the Brain

The various areas of the cerebral cortex process different types of information.



These scans of an actual brain (right) show which part of the brain is most active while a person does different activities.

Apply **Using the illustration as a guide, determine what type of information each scanned brain is processing.**

Underneath the cerebral cortex are many smaller areas with different functions. The limbic system, for example, is involved in learning and emotions and includes the hippocampus and the amygdala. The thalamus sorts information from your sensory organs and passes signals between the spinal cord and other parts of the brain. The hypothalamus gathers information about body temperature, hunger, and thirst. Then it sends signals that help the body adjust and maintain homeostasis, as you will see in Section 29.6.

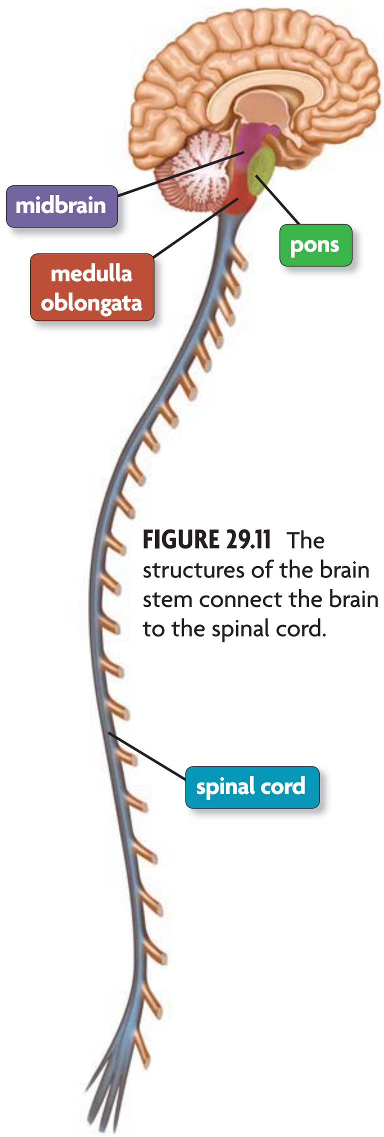
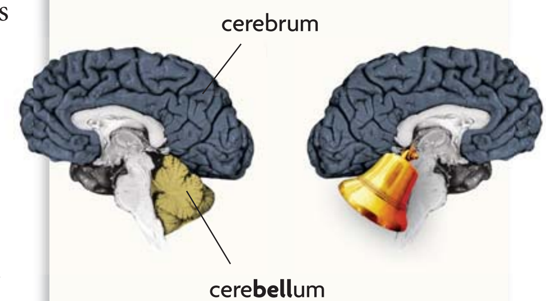


FIGURE 29.11 The structures of the brain stem connect the brain to the spinal cord.

The **cerebellum** (sehr-uh-BEHL-uhm) is the part of the brain that coordinates your movements. It helps you maintain your posture and balance, and it automatically adjusts your body to help you move smoothly. For example, when you brush your teeth, your cerebellum gets information about where your arm is positioned compared with the rest of your body. Your cerebellum plans how much your arm would need to move in order to brush your teeth. It sends this information to the motor cortex in your cerebrum, which signals your arm to move.

VISUAL VOCAB



You can learn the location of the **cerebellum** by remembering that it hangs below the large part of the brain, just as a bell hangs from the ceiling.

The **brain stem** connects the brain to the spinal cord and controls the most basic activities required for life, such as breathing and heartbeat. The brain stem has three major parts—midbrain, pons, and medulla oblongata—which are shown in **FIGURE 29.11**.

- The midbrain controls some reflexes, such as changing the size of the pupil to control the amount of light entering the eye.
- The pons regulates breathing and passes signals between the brain and the spinal cord.
- The medulla oblongata connects the brain to the spinal cord. It controls basic life-sustaining functions, such as heart function, vomiting, swallowing, and coughing.

The Spinal Cord

The spinal column consists of vertebrae, fluid, meninges, and the spinal cord. The spinal cord is a ropelike bundle of neurons that is about as wide as your thumb. It connects the brain to the nerves that are found throughout the body. All signals that go to or from the brain pass through the spinal cord.

Although movement is controlled by your cerebrum and cerebellum, your brain depends on your spinal cord to deliver messages to the proper muscles. When you are brushing your teeth, and you want to move your arm, the cerebrum sends an impulse down the spinal cord. The impulse is directed by an interneuron to the motor neuron that connects to the arm muscles. The motor neuron then carries the impulse to receptors in the arm muscle. When the receptors are stimulated by the impulse, your arm moves.

***Connecting* CONCEPTS**

Chordates The spinal cord is one anatomical feature that defines the phylum Chordata, which includes humans and many other animals. You can read more about chordates in **Chapter 25**.

If the spinal cord is damaged, messages cannot move between the brain and the rest of the body. This results in paralysis.

The spinal cord also controls involuntary movements called reflexes. **Reflex arcs,** as shown in **FIGURE 29.12**, are nerve pathways that need to cross only two synapses before producing a response. Because the signal never has to travel up the spinal cord to the brain, you react quickly.

For example, when the doctor taps your knee, tissues that connect your kneecap to your leg muscles stretch and stimulate a sensory neuron in your leg. The sensory neuron sends an impulse to your spinal cord. An interneuron in the spinal cord directs the impulse into motor neurons that cause your leg to jerk.

Reflex arcs play an important role in protecting your body from injury. When you put your hand on a hot stove, for example, you will jerk your hand away before you even have the chance to say "Ouch!" You do not feel the pain until moments after you jerk your hand away. If you did not have reflex arcs, your hand would remain on the stove until your brain interpreted the heat detected by thermoreceptors in your skin. Your hand would be badly burned before you ever reacted.

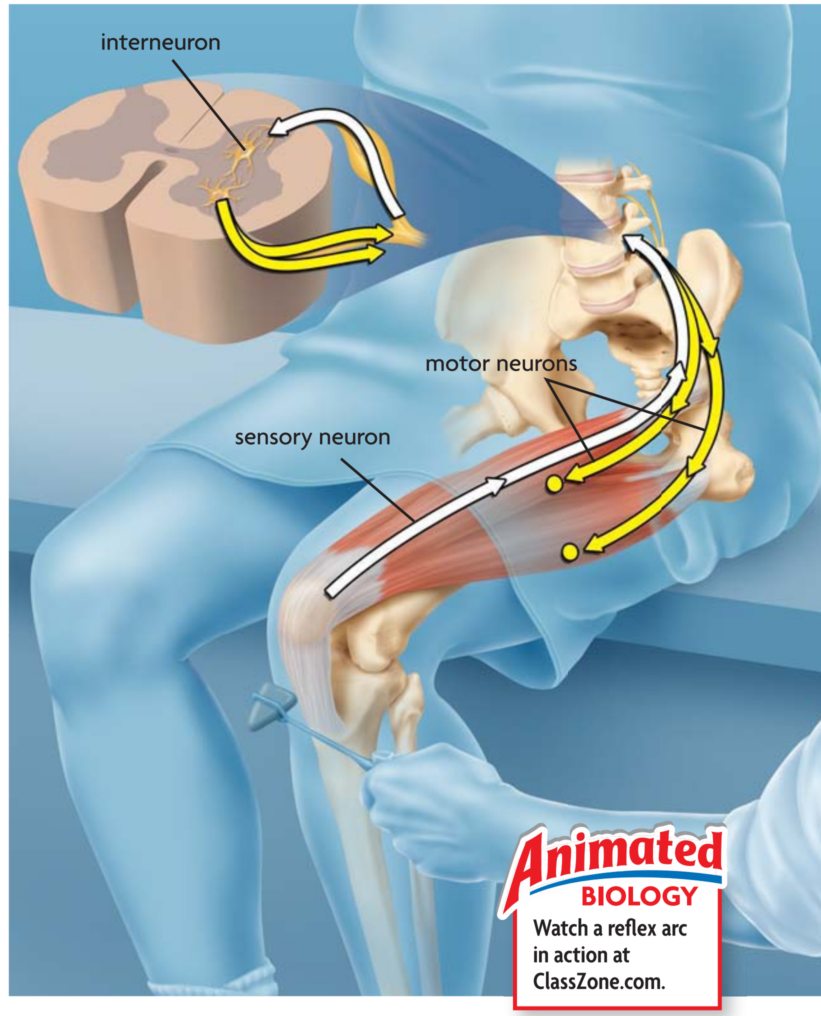


FIGURE 29.12 Reflex arcs allow your body to respond quickly and without thinking, as when your leg jerks after your doctor taps your knee with a mallet.

Summarize **How is a muscle movement caused by a reflex arc different from a voluntary muscle movement?**

MAIN IDEA

The PNS links the CNS to muscles and other organs.

The peripheral nervous system (PNS) includes 12 pairs of nerves in the head, such as the facial and olfactory nerves, and 31 pairs of spinal nerves. Most nerves contain axons from both sensory and motor neurons that carry information to and from the CNS. In general, the PNS is made up of a sensory system and a motor system. The system of sensory nerves collects information about the body and its surroundings. The system of motor nerves triggers voluntary and involuntary responses within the body.

When you are running, walking, or even sitting, you rely on your somatic nervous system to stimulate your muscles to maintain your movement, posture, and balance. The **somatic nervous system** is the division of the PNS that regulates all of the movements over which you have voluntary control. It connects the CNS to target organs.

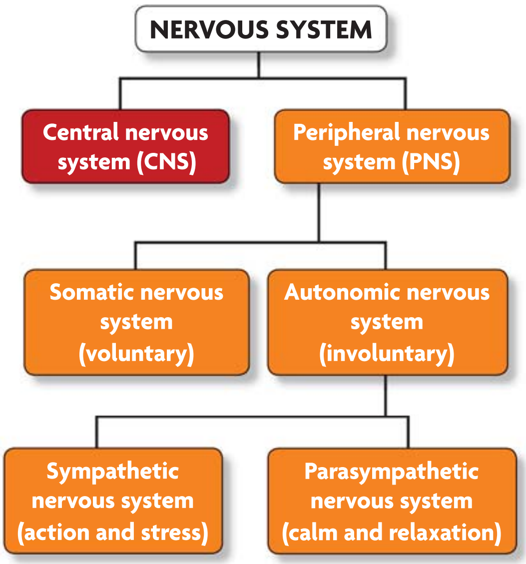


FIGURE 29.13 The nervous system can be divided into subsystems based on their functions.

The **autonomic nervous system** is the division of the PNS that controls automatic functions that you do not have to think about. For example, involuntary muscles help you to digest food by pushing it through your intestines. The autonomic nervous system is also important in maintaining homeostasis. It takes messages from the hypothalamus to organs in the circulatory, digestive, and endocrine systems.

Within the autonomic nervous system are two subdivisions: the sympathetic nervous system and the parasympathetic nervous system. **FIGURE 29.13** shows how these two systems relate to the rest of the nervous system. Although the two systems have opposite effects on the body, they both function continuously. If something happens to cause one system to produce more signals, the other system will become more active to balance the effects of the first. Together, the sympathetic and parasympathetic nervous systems help your body to maintain homeostasis.

The **sympathetic nervous system** is the part of the autonomic nervous system that prepares the body for action and stress. This is called the "fight or flight" response. When you become frightened or you are preparing to compete in a sport, your sympathetic nervous system is stimulated. Blood vessels going to the skin and internal organs contract, which reduces blood flow to those areas. Meanwhile, blood vessels going to the heart, brain, lungs, and skeletal muscles expand, increasing the blood supply in those areas. Heart rate increases. Airways enlarge, and breathing becomes more efficient. These changes improve your physical abilities and allow you to think quickly.

If something frightens you, your sympathetic nervous system activates. When the danger passes, the parasympathetic nervous system takes over to bring your body back to normal. The **parasympathetic nervous system** is the division of the autonomic nervous system that calms the body and helps the body to conserve energy. It does this by lowering blood pressure and heart rate. It is active when the body is relaxed.

Analyze Are reflex arcs part of the somatic or autonomic nervous system? Explain.

29.4 ASSESSMENT

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REVIEWING MAIN IDEAS

1. How do the types of neurons found in the CNS and PNS differ in their functions?
2. How does the **cerebral cortex** differ from the rest of the **cerebrum**?
3. What are some similarities and differences between the **somatic nervous system** and **autonomic nervous system**?

CRITICAL THINKING

4. **Apply** Why might a person with a brain injury be able to understand the speech of others but not be able to speak?
5. **Synthesize** You step on a sharp rock, your leg jerks upward, and a moment later you feel pain in your foot. Use the words *motor neuron, sensory neuron,* and *interneuron* to explain what happened.

Connecting CONCEPTS

6. **Evolution** Which part of the brain—the cerebrum, **cerebellum,** or **brain stem**—probably evolved first? (**Hint:** Consider which part is most important for basic life processes.)

29.5 Brain Function and Chemistry

KEY CONCEPT Scientists study the functions and chemistry of the brain.

MAIN IDEAS

- New techniques improve our understanding of the brain.
- Changes in brain chemistry can cause illness.
- Drugs alter brain chemistry.

VOCABULARY

addiction, p. 893
desensitization, p. 893
tolerance, p. 893
sensitization, p. 893
stimulant, p. 894
depressant, p. 894

Review
neurotransmitter, action potential

REVIEW AT CLASSZONE.COM

Connect When you take medicine for a headache, the drug alters your brain's chemistry. Aspirin, for example, stops your brain from making certain chemicals. In small amounts, it is beneficial to your health. However, even nonprescription drugs can cause permanent damage to your nervous system if taken incorrectly.

MAIN IDEA

New techniques improve our understanding of the brain.

For many years, the only way scientists could study brain function was by observing changes that occurred in people who had accidental brain injuries or by dissecting the brains of people who had died. A live patient would have to undergo surgery in order for scientists to learn about brain function.

Today, scientists use imaging technologies such as CT, MRI, and PET scans to study the brain in living patients without the need for surgery. These methods use x-rays, magnetic fields, or radioactive sensors and computer programs to form images of the brain, as shown in **FIGURE 29.14**.

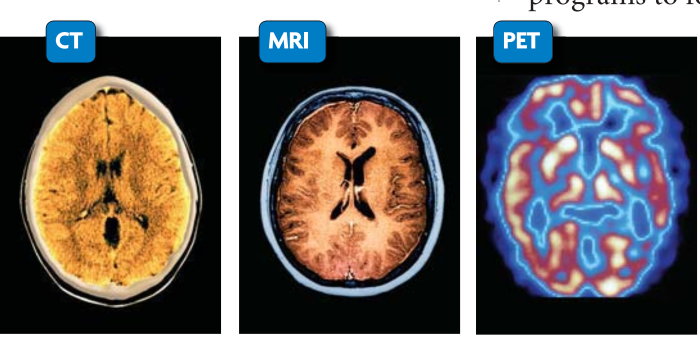


FIGURE 29.14 Modern technologies use computers and sensing devices to observe the brain without the need for surgery.

Computerized tomography (CT) scans use x-rays to view the brain. Magnetic resonance imaging (MRI) uses magnetic fields and radio waves. Both CT and MRI scans make images that show the structure of the brain. These scans are used to examine the brain's physical condition.

Positron emission tomography (PET) scans show which areas of the brain are most active. During PET scans, a person is injected with radioactive glucose. Recall from Chapter 4 that cells use glucose for energy. By measuring where the radioactive glucose collects in the brain, scientists can see which areas of the brain are using the most energy. In the image shown above, the bright red and yellow areas are the most active, and the dark blue areas are the least active.

Infer **Why are modern technologies for studying the brain safer for the patients being studied?**

MAIN IDEA

Changes in brain chemistry can cause illness.

Connecting CONCEPTS

Enzymes In **Chapter 2** you read that enzymes are like locks because only certain shaped molecules can fit into them. Neurotransmitters only affect certain areas of the brain because they are like keys that can only fit into certain neurons' receptors.

In Section 29.2, you learned that your nervous system cannot work without neurotransmitters. These chemicals regulate different functions in different areas of the brain. Neurotransmitters are specific to some areas of the brain because, like hormones, they only affect cells that have specific receptors. The function of neurotransmitters relates to the functions of the cells they stimulate.

- Acetylcholine is involved in learning and memory.
- Dopamine primarily influences your emotional behavior, but it also plays some role in stress and voluntary muscles.
- Serotonin is mainly found in the hypothalamus and midbrain. It also influences mood, some muscle functions, and hunger.
- Glutamate affects learning, memory, and brain development.
- Gamma amino butyric acid (GABA) is found throughout the brain. Unlike other neurotransmitters, when GABA binds to a neuron's membrane, it prevents the neuron from generating an impulse.

When your brain produces the correct amount of these neurotransmitters, homeostasis is maintained. If your body produces too much or too little of a neurotransmitter, the areas of your brain that are targeted by that chemical will be more or less active than normal. Because all of the areas of your brain work together, abnormal activity in one part of the brain can affect the whole brain and change the way you move, behave, and think. **FIGURE 29.15** shows that the brain activity of a healthy patient differs from that of patients with depression or schizophrenia, which are associated with chemical imbalances in the brain.

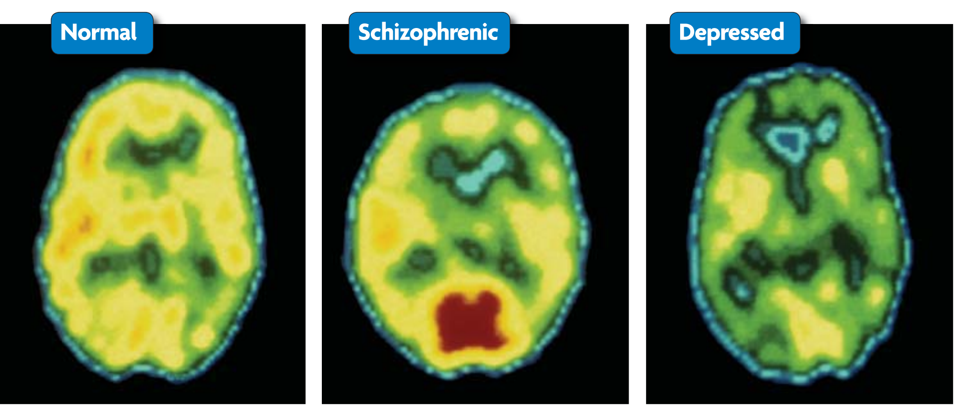


FIGURE 29.15 These PET images show the activity of a normal, a schizophrenic, and a depressed brain. Blue and green areas have low activity, and red areas are the most active.

Illnesses such as Parkinson's disease and schizophrenia are linked to abnormal amounts of dopamine. Parkinson's disease is caused by low amounts of dopamine in certain areas of the brain. People with Parkinson's disease have difficulty controlling their movements, maintaining their balance, and starting movements. Many patients with Parkinson's take drugs that increase the amount of dopamine in the brain. On the other hand, schizophrenia sometimes occurs when a person has too much dopamine. Schizophrenia is a mental disorder that causes hallucinations, irrational behavior, and illogical speech. It is treated with drugs that block dopamine receptors in the brain.

Depression is linked to low amounts of serotonin in parts of the brain. Depression causes extended periods of intense sadness, inability to sleep, and feelings of helplessness. One treatment for clinical depression uses drugs that extend the time that serotonin remains active in nerve synapses.

Summarize **How do treatments for neurological illnesses alter brain chemistry?**

MAIN IDEA

Drugs alter brain chemistry.

You may have noticed that some medicines come with warnings that say they may cause drowsiness so they should only be taken at night. People who use prescription, illegal, or other types of drugs can experience behavioral changes, such as changes in appetite, aggression, or sleep cycles. Drugs also cause changes in coordination or sensitivity to pain. Drugs might return one system in the body to homeostasis while pushing another system further out of balance. These changes occur because drugs change the way the brain works.

Many drugs affect the amount of neurotransmitter in synapses. Remember from Section 29.2 that a certain amount of neurotransmitter must be in the synapse before the threshold is reached and an action potential is generated. If a drug increases the amount of neurotransmitter released, impulses are more likely to occur. If a drug decreases the amount of neurotransmitter, action potentials are less likely to occur.

Some Drugs Cause Addiction

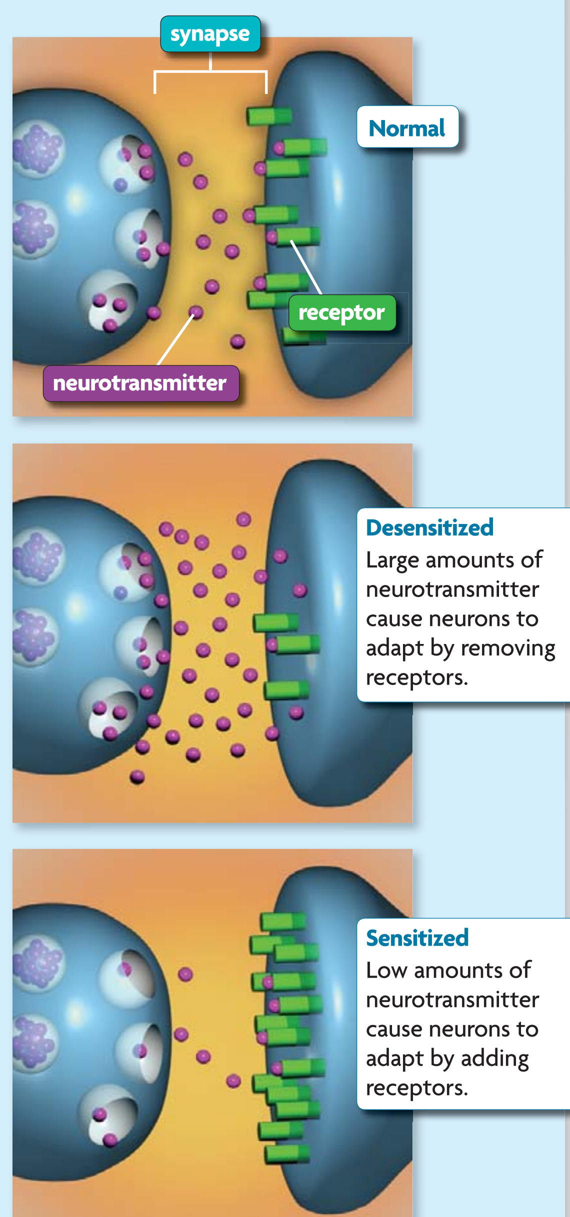
Many illegal, recreational, and prescription drugs can lead to addiction. **Addiction** is the physiological need for a substance. Through feedback loops, a person becomes addicted to a substance when the body changes the way it works so that it needs the drug in order to function normally. The brain adapts to drug exposure so that neurons will generate normal amounts of impulses despite abnormal levels of neurotransmitter.

Brain cells undergo **desensitization** when there is more neurotransmitter present in the synapse than usual. When a drug increases the amount of neurotransmitter in the synapses, the neuron generates more impulses than normal. The neuron responds by reducing the number of receptors on its cell membrane, as shown in **FIGURE 29.16**. With fewer receptors, less neurotransmitter can bind to the cell membrane and impulses are less likely to generate. Desensitization builds a person's tolerance. When someone has a **tolerance,** it takes larger doses of the drug to produce the same effect.

Sensitization occurs when low amounts of a neurotransmitter are in the synapses. When drugs lower the amount of a neurotransmitter, fewer action potentials are generated than normal. With less neurotransmitter than normal, brain cells adapt by increasing the number of receptors for them, also shown in **FIGURE 29.16**. By producing more receptors, cells increase the amount of neurotransmitter that bind to the cell. This causes the cell to generate more action potentials, just as if the normal amount of neurotransmitter were in the synapse.

FIGURE 29.16 Neurons Adapt

When the amount of neurotransmitter becomes abnormal, the adjacent neuron adapts.



Analyze What causes sensitization and desensitization?

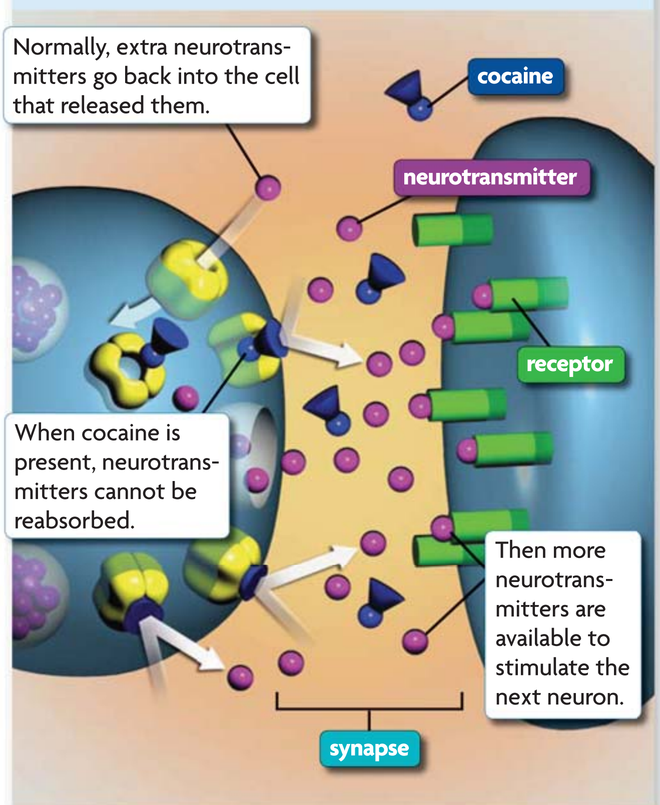
How Drugs Work

In order for drugs to have an effect on your behavior, they must change the number of action potentials your neurons generate.

Some drugs make a person feel happy, energetic, and alert. **Stimulants** are drugs that increase the number of action potentials that neurons generate by increasing the amounts of neurotransmitter in the synapses. Methamphetamine, for example, causes neurons to produce and release more neurotransmitters, especially serotonin and dopamine. However, there are other ways that stimulants can increase the amount of neurotransmitter.

FIGURE 29.17 How Cocaine Works

Cocaine keeps neurotransmitters in the synapse.



Analyze How does cocaine act as a stimulant?

Some drugs have almost the same chemistry as neurotransmitters, and they bind directly to the receptors on neuron membranes. Other drugs slow the removal of neurotransmitters from the synapses. These drugs can bind to enzymes that break down the neurotransmitters and make them unable to work. Drugs such as cocaine, however, bind to transport proteins on the axon terminal, as shown in **FIGURE 29.17**. Normally, these proteins would allow neurotransmitters to flow back into the cell that released them. If a drug is blocking the protein, the neurotransmitter remains in the synapse and an action potential is more likely to occur.

Depressants are drugs that make a person feel relaxed and tired. The person may react slowly or seem out of touch with the world around them. Depressants reduce the ability of neurons to generate impulses. Some depressants block neuron receptors so that neurotransmitters cannot produce an impulse. Other depressants, such as methaqualone, can make a person feel relaxed or sleepy by increasing in the synapses the amount of GABA, which prevents neurons from generating impulses.

Analyze How do stimulants and depressants affect a neuron's ability to generate impulses?

29.5 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. How are CT and MRI scans different from PET scans?
2. Why is it important that neurotransmitters are balanced in the brain?
3. How do **sensitization** and **desensitization** differ?

CRITICAL THINKING

4. **Synthesize** Draw before and after pictures to explain why a person whose neurons were sensitized by drug use experiences opposite symptoms when they quit.
5. **Analyze** How does desensitization relate to drug **tolerance**?

Connecting CONCEPTS

6. **Feedback Loops** What kind of feedback loops are sensitization and desensitization? Explain. (**Hint:** What causes these processes to begin and end?)

DATA ANALYSIS ClassZone.com

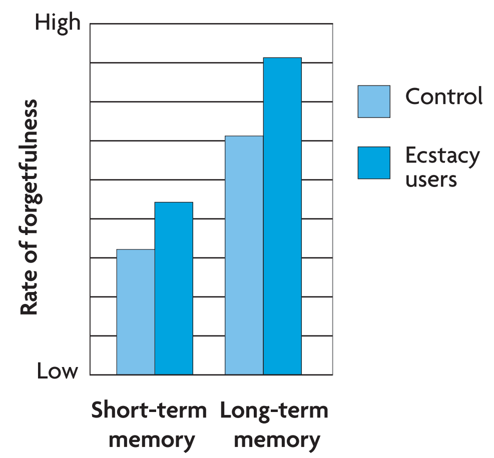
Relationships Between Variables

When scientists analyze their data, they must remember that just because two variables are related, it does not mean that one caused the other to change. A **causation** occurs when a change in one variable was caused by the other. Sometimes the cause of change in a variable may be the result of a third, unknown variable. A **correlation** occurs when scientists find that two variables are closely related, but the change in one variable did not definitely cause the change in the other. When a strong correlation exists between two variables, scientists will conduct other experiments to discover exactly how the variables are related.

EXAMPLE

Scientists studied the memory of people who regularly used the illegal drug ecstasy. They found that ecstasy users were more forgetful than people who didn't use ecstasy. Therefore, ecstasy use and memory loss are correlated. However, scientists do not know that ecstasy *causes* forgetfulness. It could be that people who are forgetful use ecstasy.

GRAPH 1. ECSTASY AND MEMORY



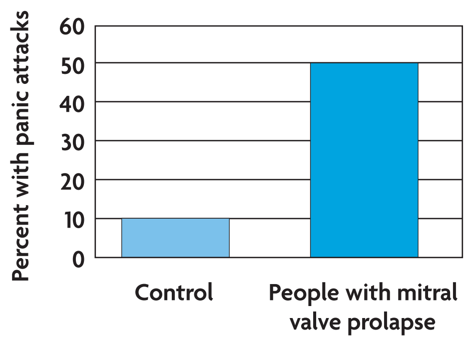
Source: T. M. Heffernan, et al., *Human Psychopharmacol Clinical Experiments* 2001:16.

DETERMINE CORRELATION OR CAUSATION

A panic attack is characterized by a sudden increase in pulse and anxiety. The graph on the right shows hypothetical data for the incidence of panic attacks in the general population and in a population of people who have a disorder called mitral valve prolapse, in which a heart valve does not work properly.

1. **Analyze** Does a correlation or a causation exist between mitral valve prolapse and panic attacks? How do you know?
2. **Evaluate** Can you conclude that mitral valve prolapse causes panic attacks? Why or why not?

GRAPH 2. MITRAL VALVE PROLAPSE AND PANIC ATTACKS



29.6 The Endocrine System and Hormones

KEY CONCEPT The endocrine system produces hormones that affect growth, development, and homeostasis.

MAIN IDEAS

- Hormones influence a cell's activities by entering the cell or binding to its membrane.
- Endocrine glands secrete hormones that act throughout the body.
- The hypothalamus interacts with the nervous and endocrine systems.
- Hormonal imbalances can cause serious illness.

VOCABULARY

hormone, p. 896
gland, p. 896
hypothalamus, p. 898
pituitary gland, p. 898
releasing hormones, p. 900

REVIEW AT CLASSZONE.COM

Connect If you hear a loud BANG, your brain tells your body that you could be in danger. You might need to run away or defend yourself. Your brain alerts your endocrine system to send out chemicals that will speed up your heart rate, increase blood flow to your muscles, and get you ready for action.

MAIN IDEA

Hormones influence a cell's activities by entering the cell or binding to its membrane.

The endocrine system makes chemical signals that help the body grow, develop, and maintain homeostasis. Some of these chemicals control processes such as cell division, cell death, and sexual development. Others help you maintain homeostasis by affecting body temperature, alertness, or salt levels.

The chemical signals made by the endocrine system are called **hormones.** Hormones are made in organs called **glands,** which are found in many different areas of the body. Glands release hormones into the bloodstream, as shown in **FIGURE 29.18.** As a hormone moves through the body, it comes into contact with many different cells. But it will interact only with a cell that has specific membrane receptors. If the hormone touches a cell that does not have a matching receptor, nothing happens. If it touches a cell that has the correct receptors, it binds to the cell and prompts the cell to make certain proteins or enzymes. Cells that have receptors for a hormone are called the target cells of that hormone.

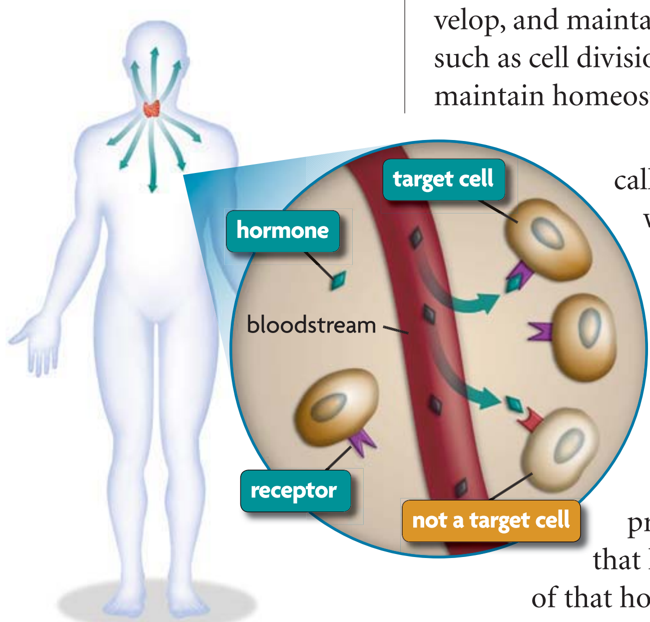


FIGURE 29.18 Glands release hormones into the bloodstream, but hormones will only affect cells that have receptors for those hormones.

All hormones belong to one of two categories: steroid hormones and nonsteroid hormones. All steroid hormones are made of cholesterol, a type of lipid. On the other hand, there are three types of nonsteroid hormones that are made up of one or more amino acids.

As **FIGURE 29.19** shows, steroid hormones and nonsteroid hormones influence cells' activities in different ways. A steroid hormone can enter its target cells by diffusing through the cell membrane. Once inside, the steroid hormone attaches to a receptor protein, which transports the protein into the nucleus. After it is inside, the steroid hormone binds to the cell's DNA. This binding causes the cell to produce the proteins that are coded by that portion of DNA.

Nonsteroid hormones do not enter their target cells. These hormones bind to protein receptors on a cell's membrane and cause chemical reactions to take place inside the cell. When nonsteroid hormones bind to receptors, the receptors change chemically. This change activates molecules inside the cell. These molecules, called second messengers, react with still other molecules inside the cell. The products of these reactions might initiate other chemical reactions in the cell or activate a gene in the nucleus.

Apply **Why do hormones only affect some cells?**

Connecting CONCEPTS

Cell Membrane Recall from **Chapter 3** that cell membranes are made of a phospholipid bilayer. Only some molecules, such as steroid hormones, can diffuse through it.

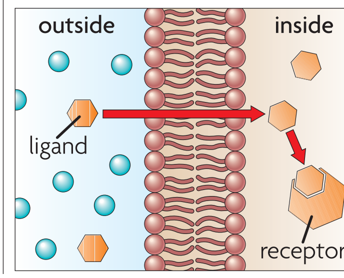
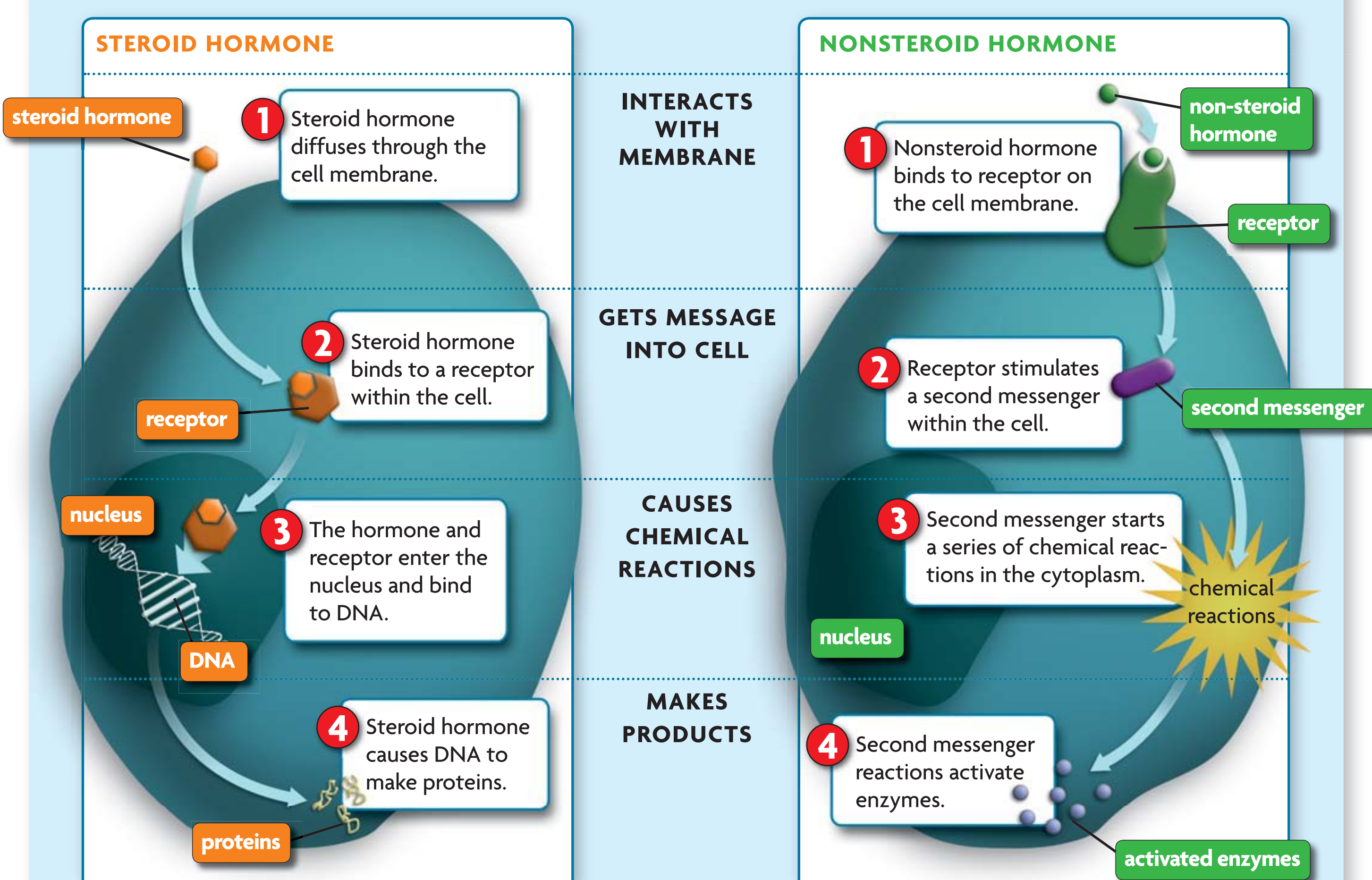


FIGURE 29.19 Hormone Action

Steroid hormones enter the cell, but nonsteroid hormones do not.



Contrast **How do the ways in which steroid and nonsteroid hormones affect a cell differ?**

MAIN IDEA

Endocrine glands secrete hormones that act throughout the body.

Unlike the nervous system, the endocrine system does not have its own connected network of tissues. However, its chemical messages can still travel where they need to go. Hormones travel in the bloodstream to all areas of the body to find target cells.

The endocrine system has many glands. Each gland makes hormones that have target cells in many areas of the body. Some of these glands make hormones that prompt other endocrine glands to make and release their hormones. Other glands affect different body systems. Their hormones prompt cells to divide or to take up nutrients. Other hormones keep the body's blood pressure within a set limit. Some of the major glands, along with a few of the hormones that they make, are described below and in **FIGURE 29.20**.

1. The **hypothalamus** is a small area of the middle of the brain, as you might recall from Section 29.4. It makes hormones that stimulate the pituitary gland to release hormones. It also stimulates the production of hormones that control growth, reproduction, and body temperature. You will read more about the hypothalamus later in this section.
2. The **pituitary gland** is also in the middle of the brain. It makes and releases hormones that control cell growth as well as osmoregulatory hormones that regulate the concentration of water in the blood. Some pituitary hormones stimulate the adrenals, thyroid, and gonads. The pituitary also acts as a gateway through which hypothalamus hormones pass before they enter the bloodstream.
3. The **thyroid gland** wraps around the windpipe on three sides. Its hormones regulate metabolism, growth, and development.
4. The **thymus** is in the chest. It makes hormones that cause white blood cells to mature. It also stimulates white blood cells to fight off infection.
5. The **adrenal glands** are above the kidneys. The adrenals secrete hormones that control the "fight or flight" response when stimulated by the parasympathetic nervous system. Adrenal hormones increase breathing rate, blood pressure, and alertness.
6. The **pancreas** lies between the stomach and intestines. It makes digestive enzymes as well as hormones that regulate how much glucose the body stores and uses.
7. The **gonads**—ovaries in women and testes in men—make steroid hormones that influence sexual development and functions. Gonads of men and women make the same hormones. However, men and women make them in different amounts, which gives men and women different sexual characteristics.

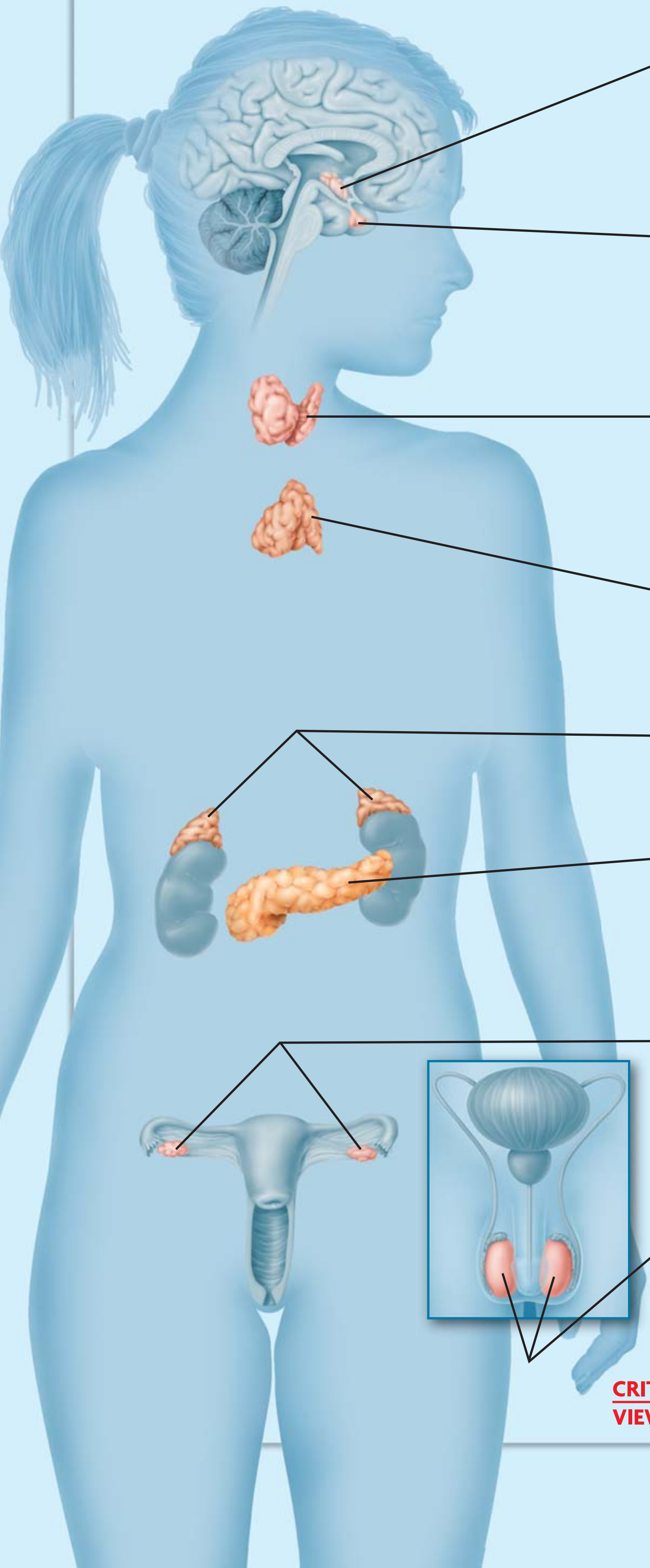
Summarize **What body processes do each of the main endocrine glands influence?**

Connecting CONCEPTS

Reproduction You can read more about how chemical signals in the body affect growth, development, and reproduction in **Chapter 34**.

FIGURE 29.20 Glands and Some of the Major Hormones

Endocrine glands are found throughout the body, and they influence whole-body processes. Some of the hormones they make are listed here.



1 HYPOTHALAMUS
- **Growth hormone-releasing hormone (GHRH)** causes the pituitary to release growth hormone.
- **Gonadotropin-releasing hormone (GnRH)** causes gonads to release hormones that control the reproductive system.

2 PITUITARY
- **Growth hormone (GH)** stimulates cell division, protein synthesis, and bone growth in multiple tissues.
- **Antidiuretic hormone (ADH)** causes the blood to absorb water from the kidneys.

3 THYROID
- **Thyroxin (T4)** and **Triiodothyronine (T3)** increase metabolism, digestion, and a person's energy levels.
- **Calcitonin** causes the body to remove calcium from the blood and increase bone formation.

4 THYMUS
- **Thymosin** causes white blood cells to reproduce and mature.

5 ADRENAL GLANDS
- **Epinephrine** causes the heart to increase its strength and number of contractions, circulating blood more quickly.

6 PANCREAS
- **Insulin** removes sugar from the bloodstream and increases sugar metabolism.
- **Glucagon** increases sugar production and adds sugar to the bloodstream.

7 FEMALE GONADS: OVARIES
- **Estrogen** causes sexual maturation, including egg production, and influences female characteristics, such as fat distribution and widening of the hips.
- **Progesterone** causes menstruation.

7 MALE GONADS: TESTES
- **Testosterone** causes sexual maturation, including sperm production, and male characteristics, such as facial hair and a deep voice.

CRITICAL VIEWING **Why is the bloodstream a good means for transporting hormones such as growth hormone and calcitonin?**

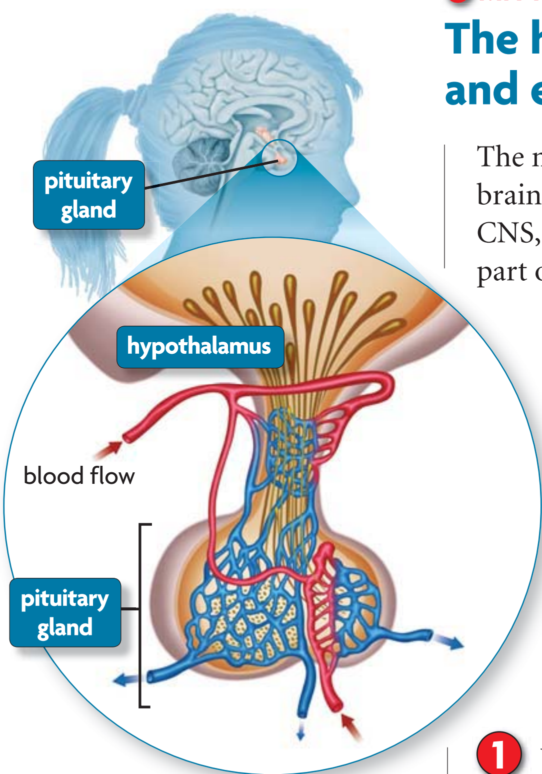


FIGURE 29.21 The hypothalamus stimulates the pituitary to secrete hormones into the bloodstream.

MAIN IDEA

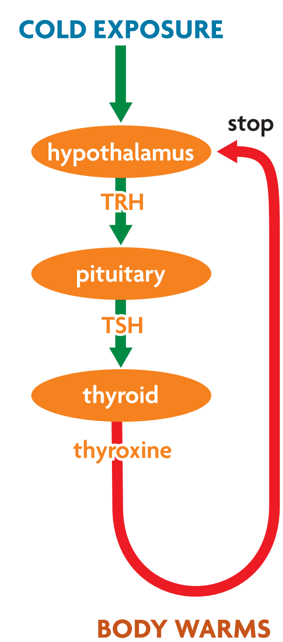
The hypothalamus interacts with the nervous and endocrine systems.

The nervous and endocrine systems connect to each other at the base of the brain, where the hypothalamus acts as a part of both systems. As part of the CNS, it receives, sorts, and interprets information from sensory organs. As part of the endocrine system, the hypothalamus produces releasing hormones that affect tissues and other endocrine glands. **Releasing hormones** are hormones that stimulate other glands to release their hormones.

Many of the hypothalamus's releasing hormones affect the pituitary gland. These glands can quickly pass hormones back and forth to each other. A series of short blood vessels connects the two, as you can see in **FIGURE 29.21.** These two glands work together to regulate various body processes. When the nervous system stimulates the hypothalamus, it releases hormones, which travel to the pituitary.

Together, the hypothalamus and pituitary regulate many processes. The diagram below shows how releasing hormones help glands to "talk with" one another to maintain body temperature.

1. When the body becomes cold, thermoreceptors in the nervous system send a signal that stimulates the hypothalamus.
2. The hypothalamus responds to this stimulus by secreting a releasing hormone called TRH (TSH-releasing hormone).
3. TRH travels through a short blood vessel and stimulates the pituitary to release TSH (thyroid-stimulating hormone).
4. TSH travels through the bloodstream to the neck, where it stimulates the thyroid to release thyroxine, a hormone that increases cells' activity.
5. As cells become more active, the body's temperature increases. Thermoreceptors signal the hypothalamus to stop releasing TRH. In the absence of TRH, the other glands are no longer stimulated. One by one, they stop releasing their hormones, and the cycle is turned off.



Notice that releasing hormones, such as TRH and TSH, act as a type of feedback on the glands they target. In Chapter 28, you learned that a feedback is something that stimulates a change. As long as releasing hormones are present, each target gland will continue to make more and more hormones. However, when the body reaches its ideal temperature, the hypothalamus stops releasing TRH. Then the pituitary and the thyroid stop releasing their hormones too.

Analyze How does the hypothalamus connect the nervous and endocrine systems?

MAIN IDEA

Hormonal imbalances can cause severe illness.

Because hormones play an important role in maintaining homeostasis, too much or too little of a hormone will affect the entire body. In Chapter 28, you learned that diabetes occurs when the pancreas does not make the right amounts of insulin and glucagon, hormones that regulate sugar concentration in the blood. When other glands do not function properly, a person may get other diseases. For example, if the thyroid does not make enough hormones, a person will develop hypothyroidism. In children, this condition slows growth and mental development. In adults, hypothyroidism causes weakness, sensitivity to cold, weight gain, and depression. Hyperthyroidism, or the condition of having too many thyroid hormones, produces opposite symptoms.

The wrong amount of adrenal hormones also affects the entire body. Cortisol is an adrenal hormone that helps the body break down and use sugars and control blood flow and pressure. If the adrenal glands produce too much cortisol, the body cannot metabolize sugars properly, and a person can develop Cushing's syndrome. This syndrome causes obesity, high blood pressure, diabetes, and muscle weakness. It occurs when the pituitary, which releases hormones that stimulate the adrenal glands, is not working the way it should. Steroids, a pituitary tumor, or some prescription drugs can make the pituitary overactive and indirectly cause Cushing's syndrome.

On the other hand, in Addison's disease the adrenal glands do not make enough cortisol. Usually, Addison's disease occurs because the immune system attacks the adrenal glands. The disease causes loss of appetite, weight loss, and low blood pressure. Although hormonal imbalances can cause serious illnesses and may even be fatal, many hormonal imbalances can be treated with surgery or medicine.

Infer Why might a problem with a person's pituitary gland lead to problems in other body systems?

NSTA SCILINKS
scilinks.org
To learn more about the endrocrine system, visit scilinks.org.
Keycode: MLB029

29.6 ASSESSMENT

ONLINE QUIZ
ClassZone.com

REVIEWING MAIN IDEAS

1. What determines whether a particular **hormone** will act on a target cell?
2. What two main hormones does the **pituitary gland** produce?
3. How do **releasing hormones** of the **hypothalamus** connect the nervous and endocrine systems?
4. Why do hormonal imbalances affect the entire body?

CRITICAL THINKING

5. **Predict** How might your body be affected if a certain **gland** made too much releasing hormone that stimulates the thyroid? What if it made too little releasing hormone?
6. **Apply** What two body systems does the endocrine system rely on to generate and transport signals?

Connecting CONCEPTS

7. **Cell Biology** Steroid hormones are made of cholesterol, which is a type of lipid. Using what you know about cell membranes, why do you think steroids can diffuse into a cell, while nonsteroid hormones cannot?

Use these inquiry-based labs and online activities to deepen your understanding of nervous and endocrine systems.

DESIGN YOUR OWN INVESTIGATION

Reaction Time

In this lab you will test reaction time during the completion of simple sorting tasks. You will first find a baseline, or "normal" level, of time needed to complete the tasks. Then you will repeat the tasks when distracting stimuli are also present.

MATERIALS
deck of cards

SKILLS Collecting Data, Analyzing Data, Graphing Data

PROBLEM How does a distraction affect task completion?

PROCEDURE

1. Measure and record the amount of time it takes to finish each of the following tasks. The deck of cards should be shuffled before the beginning of each task.
   - **a.** Separate a deck of cards into two even piles.
   - **b.** Sort a deck of cards into two piles, with one pile for each card color.
   - **c.** Separate a deck of cards into four even piles.
   - **d.** Sort a deck of cards into four piles, with one pile for each suit of cards.
2. Design your own experiment to test how a distraction will change the amount of time needed to complete a task. Distractions could include listening to music or a video in the background, tapping a ruler on the desktop, talking to the person, or having the person say the alphabet aloud while completing the task.
3. Determine what the independent variable is in your experiment. Form a hypothesis about how manipulating your independent variable may affect reaction time. Create a data table in which to record your data. One possible data table is shown below.

TABLE 1. TIME TAKEN TO COMPLETE TASK

Task	Baseline Time (sec)	Time with Distractor (sec)
Two even piles		
Two piles (by color)		
Four even piles		
Four piles (by suit)		

4. Have your teacher approve your procedure. Conduct your experiment.

ANALYZE AND CONCLUDE

1. **Analyze** Draw a graph to present your data.
2. **Analyze** What are the trends in your data regarding the completion of tasks without a distraction? What effect did the distraction have on reaction time?
3. **Experimental Design** What are some possible sources of unavoidable experimental data in your design?

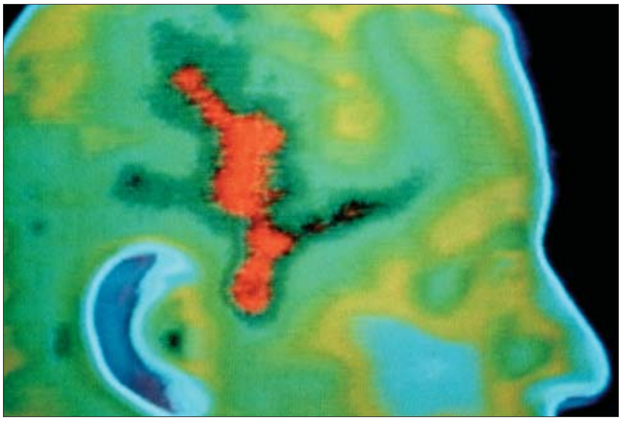
INVESTIGATION

Brain-Based Disorders

Scientists do not always know what causes many brain-based diseases or disorders because the scientific study of the brain is relatively new. Sometimes doctors find that drug treatments are effective, but they do not understand exactly how or why these treatments work.

SKILL Researching

PROBLEM Choose one of the following disorders or diseases to research: Autism, Tourette syndrome, obsessive-compulsive disorder, or migraine headaches.



This PET scan shows a person who is experiencing a migraine headache.

RESEARCH

1. What are the symptoms of this disorder?
2. What do scientists believe causes this disorder?
3. How is the disorder treated?
4. What are the trends in diagnosis of the disorder over the past 10 to 15 years?
5. What could explain the trends?
6. What new discoveries and discussions have been in the news over the past year that indicate how scientists' understanding of this disorder is changing?

Online BIOLOGY
CLASSZONE.COM

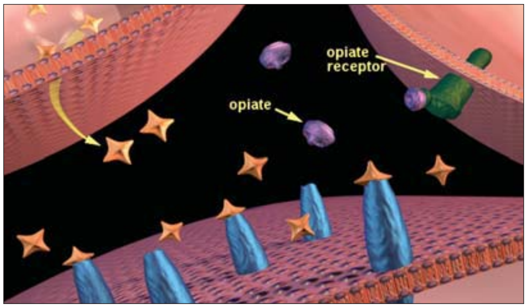
ANIMATED BIOLOGY

Diagnose a Hormone Disorder

Can you diagnose and correct a hormone imbalance? Review three patient histories and compare each to a set of hormone disorders. Diagnose the patients' disorders to get them, and their hormones, back on track.

WEBQUEST

A drug addiction is not just life-altering—it alters the brain as well. In this WebQuest, you will learn about the biology of addiction. Find out how different drugs affect neurons and neurotransmitters, creating dependency.



DATA ANALYSIS ONLINE

Cortisol is powerful hormone. Its many actions include metabolizing fats and proteins and managing stress. Graph cortisol levels in the body throughout the day and hypothesize why the body needs high amounts of cortisol at a specific time.

CHAPTER 29

Interactive Review @ CLASSZONE.COM

KEY CONCEPTS | Vocabulary Games | Concept Maps | Animated Biology | Online Quiz

29.1 How Organ Systems Communicate

The nervous system and the endocrine system provide the means by which organ systems communicate. The body's nervous system and endocrine system generate, interpret, and deliver messages that help to maintain homeostasis. The two systems have different rates of communication because they send their signals by different methods.

29.2 Neurons

The nervous system is composed of highly specialized cells. Neurons are specialized cells of the nervous system that have long extensions for transmitting signals over long distances. These cells produce, receive, and transmit impulses called action potentials.

29.3 The Senses

The senses detect the internal and external environments. The senses gather information about the body's internal and external environments. The senses use five types of receptors and many specialized cells, including rod, cone, and hair cells, that detect physical and chemical stimuli.

29.4 Central and Peripheral Nervous Systems

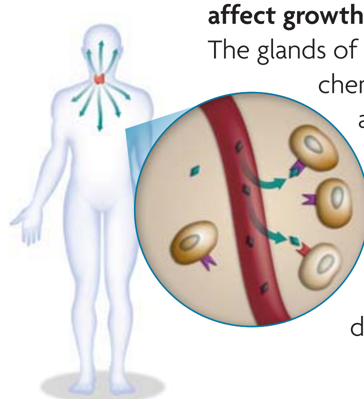
The central nervous system interprets information, and the peripheral nervous system gathers and transmits information. The CNS and PNS work together. In the CNS, the cerebrum controls conscious thought and interprets sensory signals from throughout the body. The PNS delivers messages from the body toward and away from the CNS.

29.5 Brain Function and Chemistry

Scientists study the function and chemistry of the brain. Imaging techniques allow scientists to look at the brain without having to have a patient undergo surgery. This technology can show chemical and physical changes in brains that have severe illnesses. Both prescription drugs and illegal drugs alter brain chemistry and neuron structure.

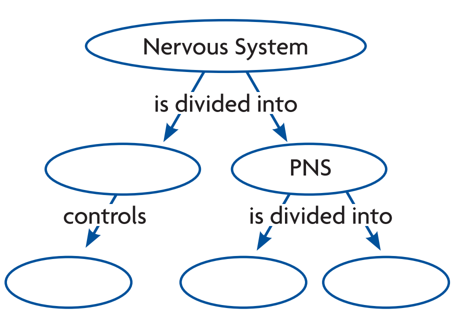
29.6 Endocrine System and Hormones

The endocrine system produces hormones that affect growth, development, and homeostasis. The glands of the endocrine system produce chemical signals called hormones that act throughout the body. The hypothalamus is a gland that interacts with the nervous and endocrine systems. Hormone imbalances can cause severe illnesses, such as hypothyroidism, diabetes, and Addison's disease.



Synthesize Your Notes

Concept Map Summarize your notes about the nervous system by drawing a concept map.



Three-Column Chart Make a chart to organize the information you learned about the senses.

Sense	Receptor Type	Receptor Name
sight	photoreceptor	

Chapter Assessment

Chapter Vocabulary

29.1 nervous system, p. 874
endocrine system, p. 874
stimulus, p. 874
central nervous system (CNS), p. 875
peripheral nervous system (PNS), p. 875

29.2 neuron, p .876
dendrite, p. 876
axon, p. 876
resting potential, p. 877
sodium-potassium pump, p. 877
action potential, p. 878
synapse, p. 879
terminal, p. 879
neurotransmitter, p. 879

29.3 rod cell, p. 881
cone cell, p. 881
hair cell, p. 882

29.4 cerebrum, p. 886
cerebral cortex, p. 887
cerebellum, p. 888
brain stem, p. 888
reflex arc, p. 889
somatic nervous system, p. 889
autonomic nervous system, p. 890
sympathetic nervous system, p. 890
parasympathetic nervous system, p. 890

29.5 addiction, p. 893
desensitization, p. 893
tolerance, p. 893
sensitization, p. 893
stimulant, p. 894
depressant, p. 894

29.6 hormone, p. 896
gland, p. 896
hypothalamus, p. 898
pituitary gland, p. 898
releasing hormones, p. 900

Reviewing Vocabulary

Compare and Contrast

Describe one similarity and one difference between the two terms in each of the following pairs.

1. somatic nervous system, autonomic nervous system
2. rod cell, cone cell
3. sensitization, desensitization

Greek and Latin Word Origins

4. *Dendrite* comes from the Greek word *dendron,* which means "tree." Explain how the root word relates to the meaning of *dendrite.*
5. *Addiction* comes from the Latin word *addicere,* which means "deliver, yield, devote." How does this meaning relate to addiction?
6. *Endocrine* comes from the Greek word *krinein,* which means "to distinguish, separate." Explain how the root word relates to the meaning of *endocrine.*

Keep It Short

For each vocabulary term below, write a short, precise phrase that describes its meaning. For example, a short phrase to describe *stimulus* could be "causes change."

7. action potential
8. reflex arc
9. hormone
10. axon

Reviewing MAIN IDEAS

11. Name two differences between the way in which the nervous and endocrine systems communicate.
12. How does the structure of a neuron make it effective in carrying out the functions of the nervous system?
13. Draw pictures to show how Na^+ ions, K^+ ions, and electrical charges are distributed across a neuron's membrane during resting and action potential.
14. What type of receptor do each of your five senses have?
15. If you have a question, you will raise your hand to ask it. How do your CNS and PNS work together to allow you to raise your hand?
16. What types of information do the occipital lobe and the temporal lobe process?
17. What are the differences between the sympathetic and the parasympathetic nervous systems?
18. How can a PET scan give clues about the activity of different neurotransmitters in the brain?
19. Why do hormones act only on some cells?
20. How do releasing hormones help glands to communicate with one another?
21. How are a target cell's activities changed if a gland produces too much of a particular hormone?

Critical Thinking

22. Apply You wake up at night and turn on the light next to your bed. The light seems very bright at first, but soon your eyes adjust. Describe how your senses and your brain interact to let your eyes adjust to the light level.

23. Infer Research on babies shows that a certain part of a neuron gets longer as the babies interact with more stimuli. Which part do you think it is? Why?

24. Analyze How does the inside of a neuron become positively charged during an action potential, even though both potassium (K^+) and sodium (Na^+) ions are positively charged?

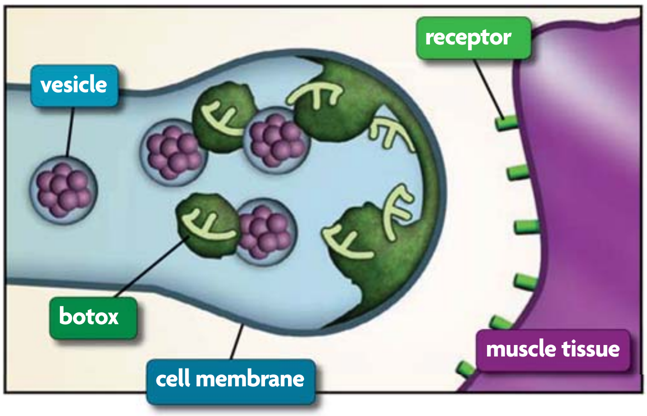
25. Predict An eye disease called macular degeneration damages the light-sensitive cells in the eye. How might this disease affect the ability of the eye to communicate with the brain?

26. Compare What are three similarities between neurotransmitters, used in the nervous system, and hormones, which are used in the endocrine system?

27. Apply The part of your brain that processes touch devotes more space to interpreting signals from your hands than from other parts of your body. Why might this be beneficial?

Interpreting Visuals

The toxin in the diagram is commonly known as Botox. It is a cosmetic treatment used on the muscles under skin to reduce wrinkles. Use the diagram below to answer the next two questions.

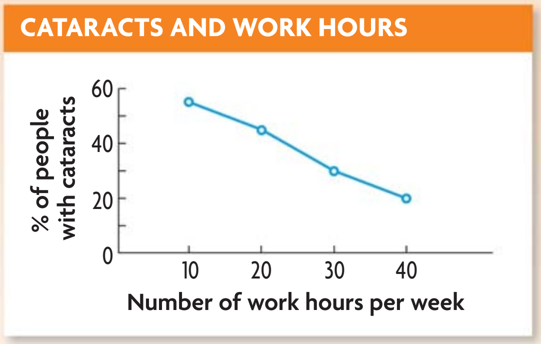


28. Apply What structures of the nervous system are being shown in the diagram?

29. Analyze Botox affects the normal functioning of nerve cells. According to the diagram, what part of the normal process is Botox affecting?

Analyzing Data

Cataracts can impair a person's vision, making objects appear fuzzy. Cataracts occur when the lens in a person's eye becomes cloudy, or less transparent. This happens when the proteins that make up the lens clump. Use the graph below to answer the next three questions.



30. Analyze Does a correlation exist between incidents of cataracts and work hours? Explain.

31. Evaluate Can you conclude for sure that the number of hours worked causes cataracts? Explain your reasoning.

32. Infer If a correlation exists between cataracts and work hours, what might explain it?

Connecting CONCEPTS

33. Write a Script Imagine you have a friend who wanted to try drugs, and you wanted to tell your friend about the effects that drugs have on the nervous system. Write a conversation that you could have about addiction and the negative effects of drug use.

34. Connect The image on page 873 shows some of a person's internal organs. Write a paragraph that discusses which division of the nervous system is shown in this picture. Also, discuss how the cells of this body system allow you to rapidly pull your hand off of a hot pan before your hand is burned.

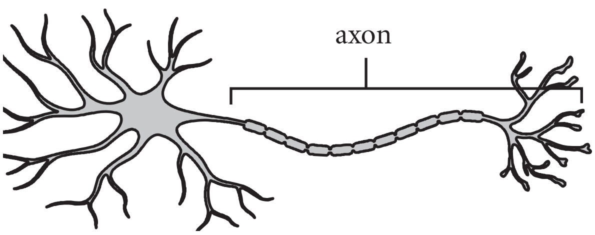
REVIEW AT CLASSZONE.COM

Test Practice
For more test practice, go to ClassZone.com.

1. A scientist investigates the toxic effects of a chemical on the brain. Which of the following experimental design elements would *most* likely lead to inconsistent results?

A using the same method to measure toxicity
B having a sample size that is very large
C keeping the chemical at a constant temperature
D running the tests in different locations

2.



What is the main function of the axon, which is illustrated here?

A receives signals from neighboring cells
B regulates nutrient intake within the body
C increases the cell's surface area
D transmits messages to neighboring cells

3. The hypothalamus releases antidiuretic hormone, which causes the kidneys to release less water from the body. Under which condition might the hypothalamus produce more antidiuretic hormone?

A having high levels of antidiuretic hormone
B having excess water in the body
C drinking a bottle of juice
D sweating due to exercise

THINK THROUGH THE QUESTION
Think carefully about each answer choice. Under which condition would the body respond by conserving water?

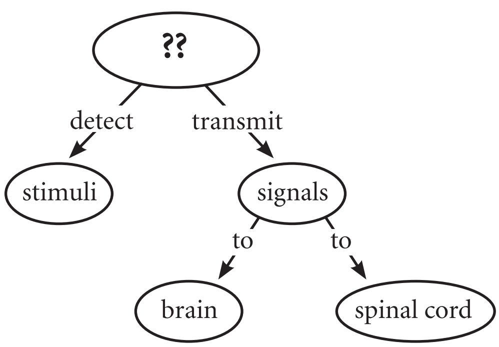
4. Anabolic steroids are drugs that mimic specific hormones in the body. As athletes abuse anabolic steroids in hopes of becoming stronger, their bodies produce less natural hormone. This effect can be best described as a(n)

A form of negative feedback.
B reflex arc.
C conditioned response.
D osmoregulatory response.

5. In what form does a nerve impulse travel from one neuron to another?

A electrical signal
B chemical signal
C magnetic signal
D ionic signal

6.



Which of the following best completes this concept map?

A motor neurons
B interneurons
C electric neurons
D sensory neurons