Chapter 36

The Nervous System

What You'll Learn

- You will relate the structure of a nerve cell to the transmission of a nerve signal.
- You will identify the senses and their signal pathways.
- You will compare and contrast various types of drugs and their effects on the nervous system.

Why It's Important

Your nervous system helps you perceive and react to the world around you. It controls vital involuntary processes such as respiration and digestion. By understanding how drugs affect the function of the nervous system, you will discover their role in treating medical disorders, and the danger they pose if misused.

Understanding the Photo

These people feel the tingle of fear and excitement when they realize the height of the ride. Messages from the brain allow them to scream or smile as well as hold on tightly. It is the nervous system that interprets these messages and coordinates the responses of the body.

Biology Online

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Section
36.1

The Nervous System

SECTION PREVIEW

Objectives

Analyze how nerve impulses travel within the nervous system.

Interpret the functions of the major parts of the nervous system.

Compare voluntary responses and involuntary responses.

Review Vocabulary

stimulus: anything in an organism's internal or external environment that causes the organism to react (p. 9)

New Vocabulary

neuron
dendrite
axon
synapse
neurotransmitter
central nervous system
peripheral nervous system
cerebrum
cerebellum
medulla oblongata
somatic nervous system
reflex
autonomic nervous system
sympathetic nervous system
parasympathetic nervous system

Cellular Communication

Using an Analogy When you use the telephone you communicate with a person in another location. You may know that your message is transmitted as an electrical impulse across telephone wires. Similar electrical impulses travel through your body, allowing some parts to communicate with others.

Sequence *As you read through this section, record the sequence of changes that occurs in a neuron when it is excited by a stimulus.*

Like telephone wires between homes, nerve cells relay messages within the human body.

Neurons: Basic Units of the Nervous System

The basic unit of structure and function in the nervous system is the neuron, or nerve cell. **Neurons** (NYU ronz) conduct impulses throughout the nervous system. As shown in ***Figure 36.1***, a neuron is a long cell that consists of three regions: a cell body, dendrites, and an axon.

Dendrites (DEN drites) are branchlike extensions of the neuron that receive impulses and carry them toward the cell body. The **axon** is an extension of the neuron that carries impulses away from the cell body and toward other neurons, muscles, or glands.

Neurons fall into three categories: sensory neurons, motor neurons, and interneurons. Sensory neurons carry impulses from the body to the spinal cord and brain. Interneurons are found within the brain and spinal cord. They process incoming impulses and pass response impulses on to motor neurons. Motor neurons carry the response impulses away from the brain and spinal cord to a muscle or gland.

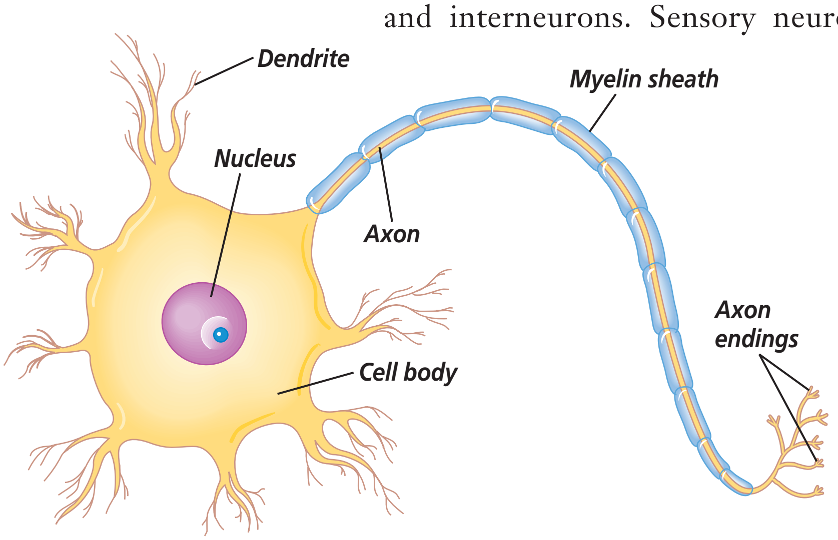


Figure 36.1
Dendrites and axons are extensions that branch out from the cell body of a neuron.

Figure 36.2
The nervous system sorts and interprets incoming information before directing a response.

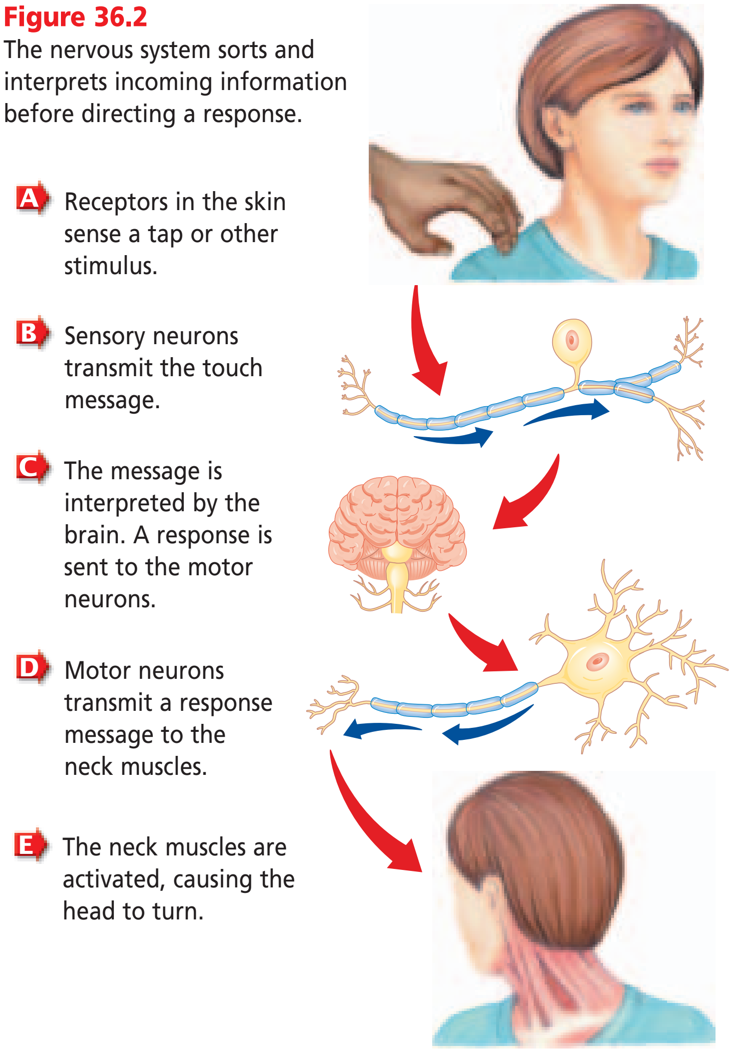
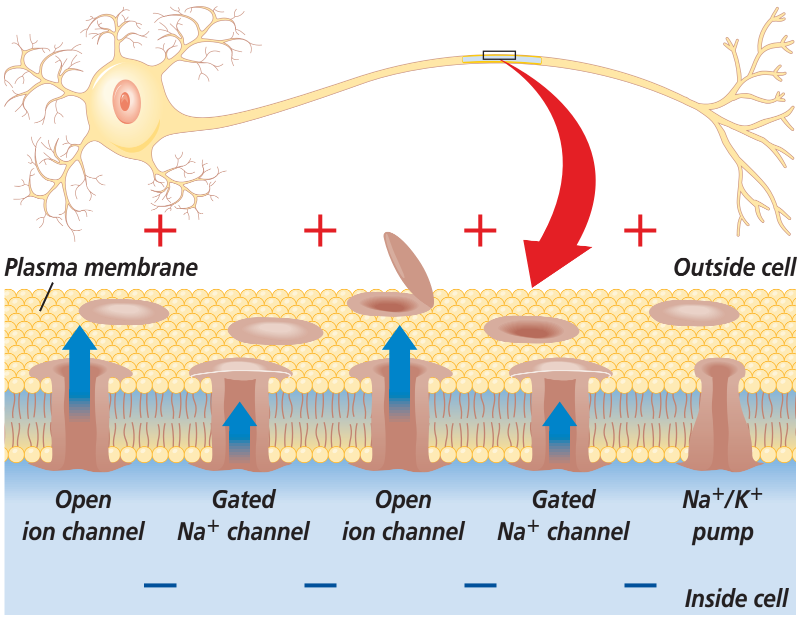


Figure 36.3
In a neuron at rest, the sodium/potassium pump (Na^+/K^+) and the presence of many negatively charged ions within a cell keeps the inside of a cell more negatively charged than the outside.



Relaying an impulse

Suppose you're in a crowded, noisy store and you feel a tap on your shoulder. Turning your head, you see the smiling face of a good friend. How did the shoulder tap get your attention? The touch stimulated sensory receptors located in the skin of your shoulder to produce an impulse. The sensory impulse was carried to the spinal cord and then up to your brain. From your brain, an impulse was sent out to your motor neurons, which then transmitted the impulse to muscles in your neck. Your neck muscles then turned your head. ***Figure 36.2*** shows how a stimulus, such as a tap on the shoulder, is transmitted through your nervous system.

A neuron at rest

First, let's look at a resting neuron—one that is not transmitting an impulse. You have learned that the plasma membrane controls the concentration of ions in a cell. Because the plasma membrane of a neuron is more permeable to potassium ions (K^+) than it is to sodium ions (Na^+), more potassium ions exist inside of the cell membrane than outside it. Similarly, more sodium ions exist outside the cell membrane than inside of it.

The neuron membrane also contains an active transport system, called the sodium/potassium (Na^+/K^+) pump, which uses ATP to pump three sodium ions out of the cell for every two potassium ions it pumps in. As you can see in ***Figure 36.3***, the action of the pump increases the concentration of positive charges on the outside of the membrane. In addition, the presence of many negatively charged proteins and organic phosphates means that the inside of the membrane is more negatively charged than the outside. Under these conditions, which exist when the cell is at rest, the plasma membrane is said to be polarized. A polarized membrane has the potential to transmit an impulse.

How an impulse is transmitted

When a stimulus excites a neuron, gated sodium channels in the membrane open up and sodium ions rush into the cell. As the positive sodium ions build up inside the membrane, the inside of the cell becomes more positively charged than the outside. This change in charge, called depolarization, moves like a wave down the length of the axon, as seen in ***Figure 36.4.*** As the wave passes, gated channels and the Na^+/K^+ pump act to return the neuron to its resting state, with the inside of the cell negatively charged and the outside positively charged.

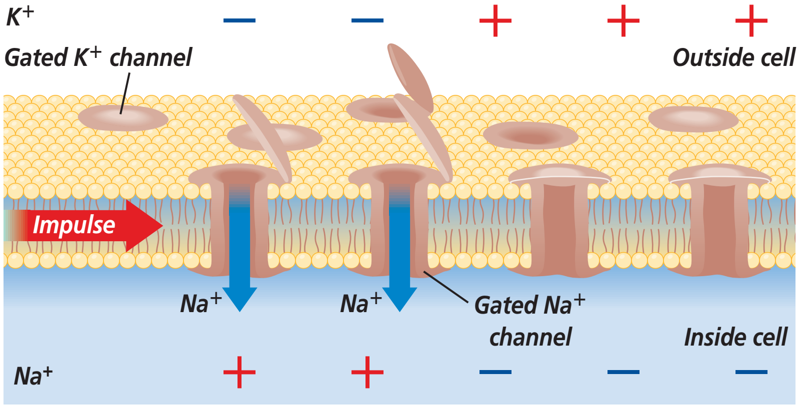
An impulse can move down the complete length of an axon only when stimulation of the neuron is strong enough. If the threshold level—the level at which depolarization occurs—is not reached, the impulse quickly dies out.

Reading Check **Describe** the threshold level.

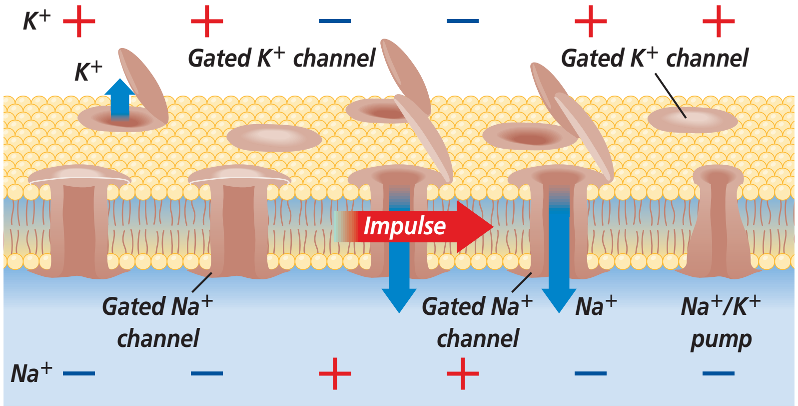
White matter and gray matter

Most axons are surrounded by a white covering of cells called the myelin sheath, shown previously in ***Figure 36.1.*** Like the plastic coating on an electric wire, the myelin sheath insulates the axon, hindering the movement of ions across its plasma membrane. The ions move quickly down the axon until they reach a gap in the sheath. Here, the ions pass through the plasma membrane of the nerve cell and depolarization occurs. As a result, the impulse jumps from gap to gap, greatly increasing the speed at which it travels.

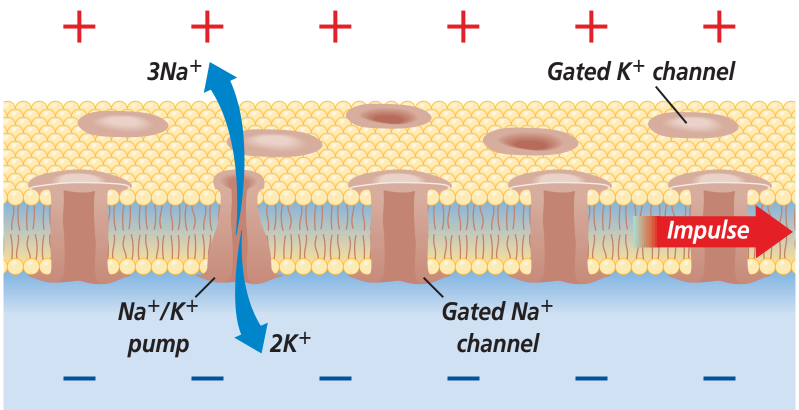
Figure 36.4
A wave of depolarization moves down the axon of a neuron.



A Gated sodium channels open, allowing sodium ions to enter and make the inside of the cell positively charged and the outside negatively charged.



B As the impulse passes, gated sodium channels close, stopping the influx of sodium ions. Gated potassium channels open, letting potassium ions out of the cell. This action repolarizes the cell.



C As gated potassium channels close, the Na^+/K^+ pump restores the ion distribution.

Physical Science Connection

Nerve impulses and parallel circuits Parallel circuits contain branched paths in which electric current can flow. Connections among neurons also can form branched paths. However, in a parallel circuit, the amount of charge that flows into and out of a junction must be equal. Neurons are different in that the strength of the impulse that moves through an excited neuron does not depend on the number of connections to other neurons.

The myelin sheath gives axons a white appearance. In the brain and spinal cord, masses of myelinated axons make up what is called "white matter." The absence of myelin in masses of neurons accounts for the grayish color of "gray matter" in the brain.

Connections between neurons

Although neurons lie end to end—axons to dendrites—they don't actually touch. A tiny space lies between one neuron's axon and another neuron's dendrites. This junction between neurons is called a **synapse.** Impulses traveling to and from the brain must move across the synaptic space that separates the axon and dendrites. How do they make this leap?

As an impulse reaches the end of an axon, calcium channels open, allowing calcium to enter the end of the axon. As shown in ***Figure 36.5,*** the calcium causes vesicles in the axon to fuse with the plasma membrane, releasing their chemicals into the synaptic space by exocytosis. These chemicals, called **neurotransmitters,** diffuse across the space to the dendrites of the next neuron. As the neurotransmitters reach the dendrites, they signal receptor sites to open the ion channels. These open channels change the polarity in the neuron, initiating a new impulse. Enzymes in the synapse typically break down the neurotransmitters shortly after transmission, preventing the continual firing of impulses.

Reading Check **Explain** what prevents the continual firing of impulses at the synapse.

The Central Nervous System

When you make a call to a friend, your call travels through wires to a control center where it is switched over to wires that connect with your friend's telephone. In the same manner, an impulse traveling through neurons in your body usually reaches the control center of the nervous system—your brain—before being rerouted. The brain and the spinal cord together make up the **central nervous system,** which coordinates all your body's activities.

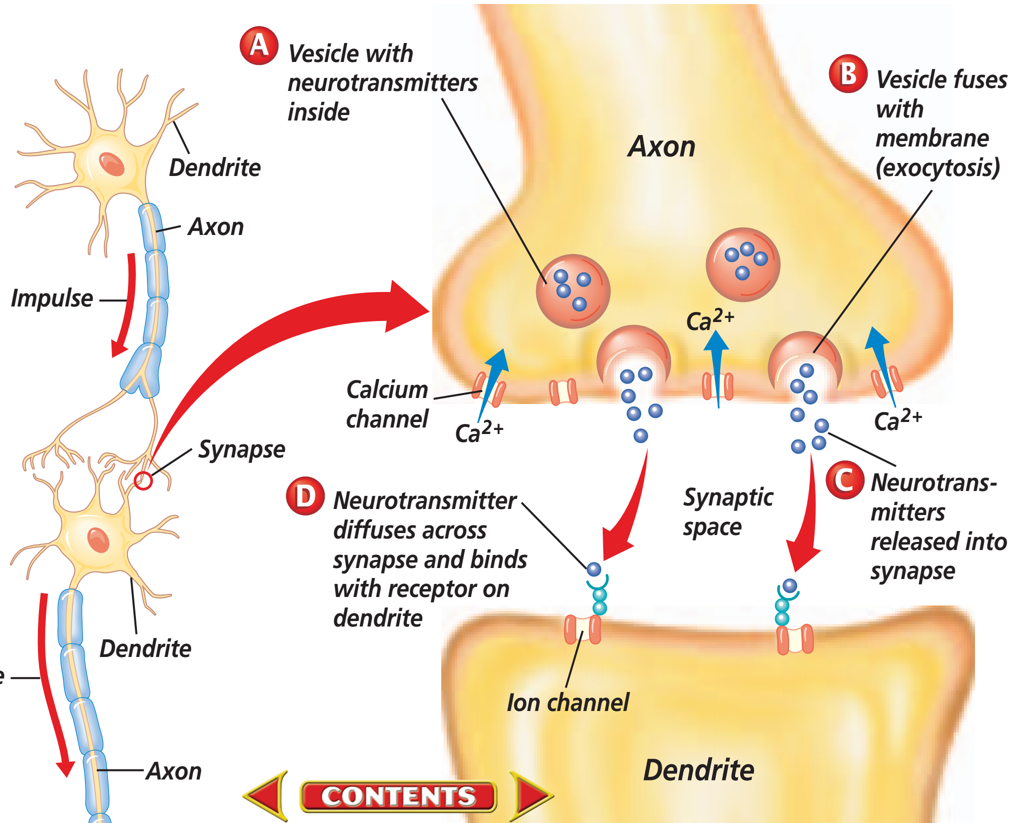
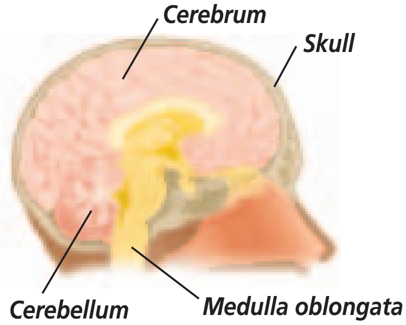


Figure 36.5
As an impulse reaches the end of an axon, calcium channels open and calcium enters the end of the axon. **Explain** ***How do nerve impulses move across a synapse?***

Two systems work together

Another division of your nervous system, called the **peripheral** (puh RIH frul) **nervous system,** is made up of all the nerves that carry messages to and from the central nervous system. It is similar to the telephone wires that run between a phone system's control center and the phones in individual homes. Together, the central nervous system (CNS) and the peripheral nervous system (PNS), shown in ***Figure 36.6,*** respond to stimuli from the external environment.



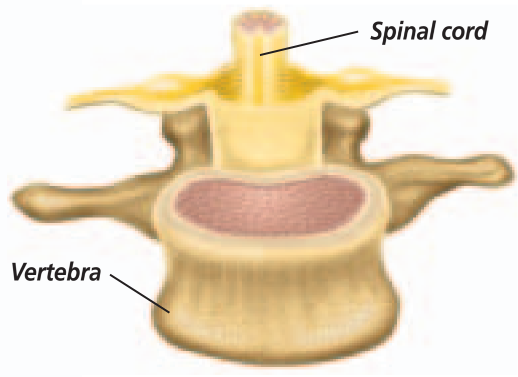


Figure 36.6
The human nervous system is made up of the CNS, in pink, and the PNS, in yellow. The brain and spinal cord are protected by the skull and the vertebrae, respectively.

Anatomy of the brain

The brain is the control center of the entire nervous system. For descriptive purposes, it is useful to divide the brain into three main sections: the cerebrum, the cerebellum, and the brain stem.

The **cerebrum** (suh REE brum) is divided into two halves, called hemispheres, that are connected by bundles of nerves. Your conscious activities, intelligence, memory, language, skeletal muscle movements, and senses are all controlled by the cerebrum. The outer surface of the cerebrum, called the cerebral cortex, is made up of gray matter. The cerebral cortex contains countless folds and grooves that increase its total surface area. This increase in surface area played an important role in the evolution of human intelligence as greater surface area allowed more and more complex thought processes.

The **cerebellum** (ser uh BE lum), located at the back of your brain, controls your balance, posture, and coordination. If the cerebellum is injured, your movements become jerky.

The brain stem is made up of the medulla oblongata, the pons, and the midbrain. The **medulla oblongata** (muh DU luh • ah blon GAH tuh) is the part of the brain that controls involuntary activities such as breathing and heart rate. The pons and midbrain act as pathways connecting various parts of the brain with each other. Read more about how the brain evolved on pages 1090–1091 in the *Focus On*. For the latest on technological advances in brain imaging, check out the *Biotechnology* section at the end of the chapter.

The Peripheral Nervous System

Remember that the peripheral nervous system carries impulses between the body and the central nervous system. For example, when a stimulus is picked up by receptors in your skin, it initiates an impulse in the sensory neurons. The impulse is carried to the CNS. There, the impulse transfers to motor neurons that carry the impulse to a muscle.

The peripheral nervous system can be separated into two divisions—the somatic nervous system and the autonomic nervous system.

The somatic nervous system

The **somatic nervous system** is made up of 12 pairs of cranial nerves from the brain, 31 pairs of spinal nerves from the spinal cord, and all of their branches. These nerves are actually bundles of neuron axons bound together by connective tissue. The cell bodies of the neurons are found in clusters along the spinal column. Most nerves contain both sensory and motor axons.

The nerves of the somatic system relay information mainly between your skin, the CNS, and skeletal muscles. This pathway is voluntary, meaning that you can decide whether or not to move body parts under the control of this system. Try the *MiniLab* on this page to find out how distractions can affect the time it takes you to respond to a stimulus.

Reflexes in the somatic system

Sometimes a stimulus results in an automatic, unconscious response within the somatic system. When you touch something hot, you automatically jerk your hand away. Such an action is a **reflex,** an automatic response to a stimulus. Rather than proceeding to the cerebrum or cerebellum for interpretation, a reflex impulse travels to the spinal column or brain stem where it causes an impulse to be sent directly back to a muscle. The brain becomes aware of the reflex only after it occurs. ***Figure 36.7*** on the next page shows the shortened route of a reflex impulse.

MiniLab 36.1

Experiment

Distractions and Reaction Time Have you ever tried to read while someone is talking to you? What effect does such a distracting stimulus have on your reaction time?

Matt Meadows

Procedure

1. Work with a partner. Sit facing your partner as he or she stands.
2. Have your partner hold the top of a meterstick above your hand. Hold your thumb and index finger about 2.5 cm away from either side of the lower end of the meterstick without touching it.
3. Tell your partner to drop the meterstick straight down between your fingers.
4. Catch the meterstick between your thumb and finger as soon as it begins to fall. Measure how far it falls before you catch it. Practice several times.
5. Run ten trials, recording the number of centimeters the meterstick drops each time. Average the results.
6. Repeat the experiment, this time counting backwards from 100 by fives (100, 95, 90, . . .) as you wait for your partner to release the meterstick.

Analysis

1. **Analyze** Did your reaction time improve with practice?
2. **Evaluate** How was your reaction time affected by the distraction (counting backwards)?
3. **Infer** What other factors, besides distractions, would increase reaction time?

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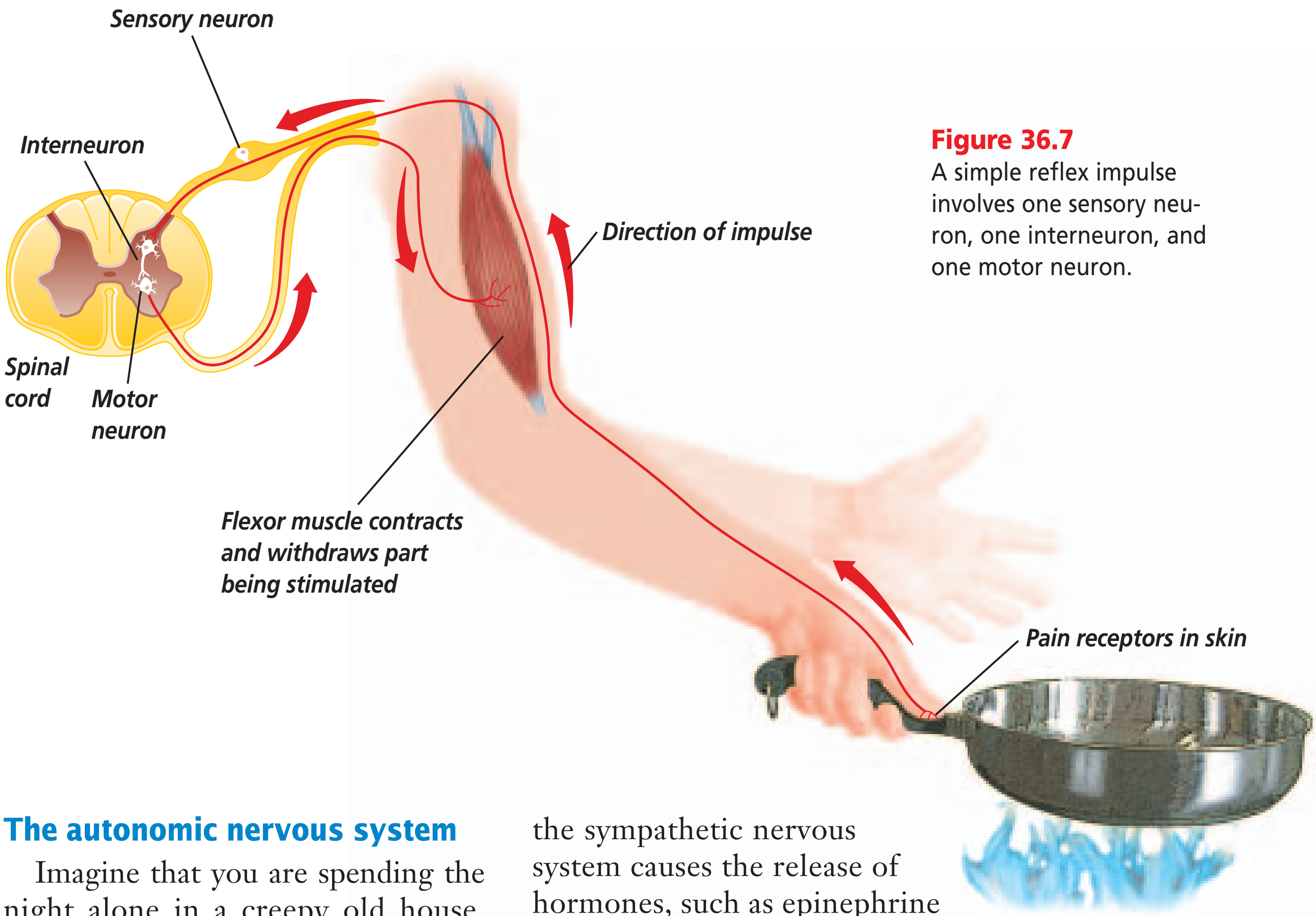


Figure 36.7
A simple reflex impulse involves one sensory neuron, one interneuron, and one motor neuron.

The autonomic nervous system

Imagine that you are spending the night alone in a creepy old house. Suddenly, a creak comes from the attic and you think you hear footsteps. Your heart begins to pound. Your breathing becomes rapid. Your thoughts race wildly as you try to figure out what to do—stay and confront the unknown, or run out of the house!

Your internal reactions to this scary situation are being controlled by your autonomic nervous system. The **autonomic nervous system** carries impulses from the CNS to internal organs. These impulses produce responses that are involuntary, or not under conscious control.

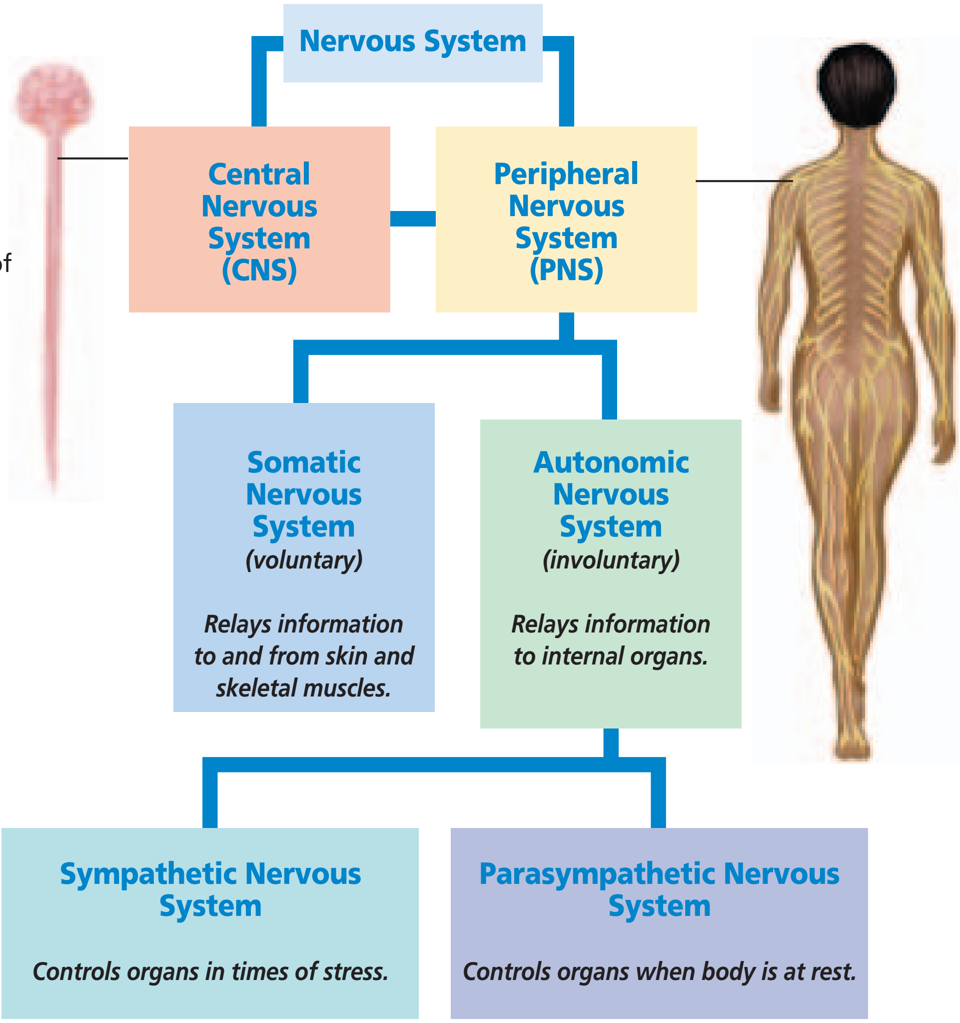
There are two divisions of the autonomic nervous system—the **sympathetic nervous system** and the parasympathetic nervous system. The sympathetic nervous system controls many internal functions during times of stress. When something frightens you, such as the rattlesnake shown in ***Figure 36.8***, the sympathetic nervous system causes the release of hormones, such as epinephrine and norepinephrine, that results in the fight-or-flight response.

The **parasympathetic nervous system** on the other hand, controls many of the body's internal functions when it is at rest. It is in control when you are relaxing after a picnic or reading quietly in your room. Both the sympathetic and parasympathetic systems send signals to the same internal organs. The resulting activity of the organ depends on the intensities of the opposing signals.

Figure 36.8
A fight-or-flight response to a rattlesnake will increase heart and breathing rates.

R. Andrew Odum/Peter Arnold, Inc.

Figure 36.9
Understanding the organization of your nervous system can be made easier by studying the different divisions of the nervous system.



The different divisions and subsystems of your nervous system are summarized in ***Figure 36.9.*** Each division plays a key role in communication and control within your body.

Note that the sympathetic and parasympathetic systems are part of the autonomic nervous system. The autonomic and somatic systems are part of the PNS. The peripheral nervous system carries information to and from the CNS. Together, these two systems respond to stimuli from the external and internal environment.

Section Assessment

Understanding Main Ideas

1. Summarize how nerve impulses travel within the nervous system.
2. Interpret and compare the functions of the central and peripheral nervous systems.
3. Interpret the functions of the three major parts of the brain.
4. Compare and contrast voluntary responses and involuntary responses.

Thinking Critically

5. Why is it nearly impossible to stop a reflex from taking place?

Skill Review

6. **Get the Big Picture** Compare the interrelationships between the nervous system and other body systems in response to an external stimulus. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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CONTENTS

Section 36.2

The Senses

SECTION PREVIEW

Objectives

Define the role of the senses in the human nervous system.

Recognize how senses detect chemical, light, and mechanical stimulation.

Identify ways in which the senses work together to gather information.

Review Vocabulary

dermis: inner, thicker portion of the skin that contains nerves and nerve endings (p. 895)

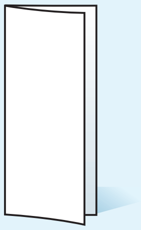
New Vocabulary

taste bud
retina
rod
cone
cochlea
semicircular canals

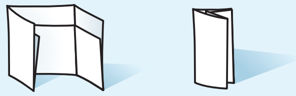
FOLDABLES Study Organizer

The Senses Make the following Foldable to help you organize information about the senses.

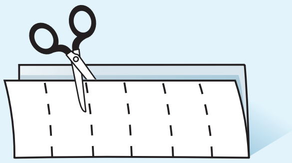
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the back edge about 5cm longer than the front edge.



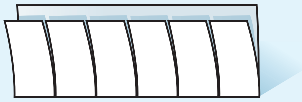
STEP 2 **Turn** lengthwise and **fold** into thirds, then **fold again** in half to make sixths.



STEP 3 **Unfold and cut** only the top layer along the five folds to make six tabs.



STEP 4 **Label** each tab as follows: *Smell, Taste, Sight, Hearing, Balance* and *Touch*. Label the top edge as *Senses*.



Read for Main Ideas As you read Chapter 36, record under the appropriate tab each process by which your body responds to stimuli.

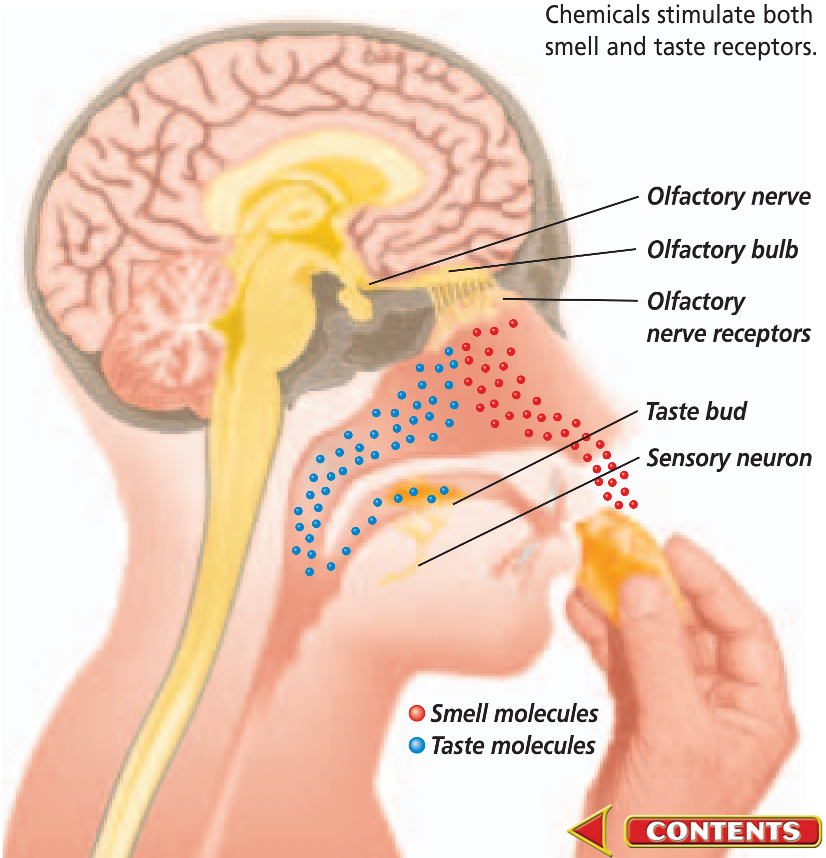


Figure 36.10
Chemicals stimulate both smell and taste receptors.

Sensing Chemicals

How are you able to smell and taste an orange? Chemical molecules of the orange contact receptors in your nose and mouth as you sniff and eat the fruit. The receptors for smell are hairlike nerve endings located in the upper portion of your nose, as shown in ***Figure 36.10.*** Chemicals acting on these nerve endings initiate impulses in the olfactory nerve, which is connected to your brain. In the brain, this signal is interpreted as a particular odor.

The senses of taste and smell are closely linked. Think about what your sense of taste is like when your nose is stuffed up and you can smell little, if anything. Because much of what you taste depends on your sense of smell, your sense of taste may also be dulled.

Physical Science Connection

Levers The bones of the inner ear amplify the input force applied on them by the eardrum. The malleus and incus together act as a lever, and apply the output force to the stapes. Here, the mechanical advantage, which is the output force divided by the input force, is about 1.3. How much larger is the output force than the input force?

You taste something when chemicals dissolved in saliva contact sensory receptors on your tongue called **taste buds.** Tastes that you experience can be divided into four basic categories: sour, salty, bitter, and sweet. As seen with the sequence of electrochemical changes a neuron undergoes as it is depolarized, each of the different tastes produces a similar change in the cells of taste buds. As these cells are depolarized, signals from your taste buds are sent to the cerebrum. There, the signal is interpreted and you notice a particular taste. A young adult has approximately 10 000 taste buds. As a person ages, his or her sense of smell becomes less sharp and taste buds may decrease in number or become less sensitive. This can result in a decreased sense of taste.

Sensing Light

How are you able to see? Your sense of sight depends on receptors in your eyes that respond to light energy. The **retina,** found at the back of the eye, is a thin layer of tissue made up of light receptors and sensory neurons. Light enters the eye through the pupil and is focused by the lens onto the back of the eye, where it strikes the retina. Follow the pathway of light to the retina in ***Figure 36.11.***

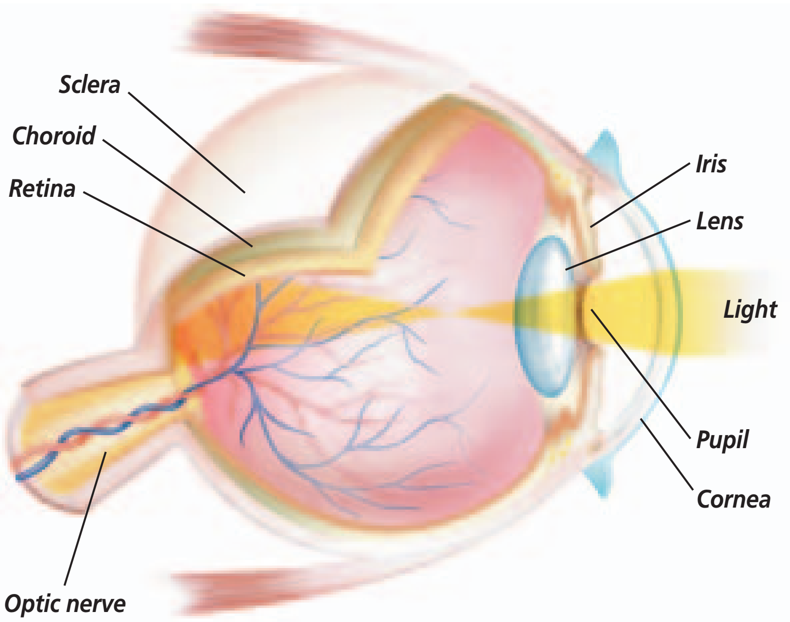


Figure 36.11
A cross section through the human eye shows the path light takes as it enters through the pupil.

The retina contains two types of light receptor cells—rods and cones. **Rods** are receptor cells adapted for vision in dim light. They help you detect shape and movement. **Cones** are receptor cells adapted for sharp vision in bright light. They also help you detect color.

At the back of the eye, retinal tissue comes together to form the optic nerve, which leads to the brain, where images are interpreted. Can you see as well with one eye as with two? To find out more about how the brain forms a visual image, look at ***Figure 36.12.***

Reading Check **Compare and contrast** rods and cones.

Sensing Mechanical Stimulation

How are you able to hear the leaves rustle and feel the grass as you relax in the park? These senses, hearing and touch, depend on receptors that respond to mechanical stimulation.

Your sense of hearing

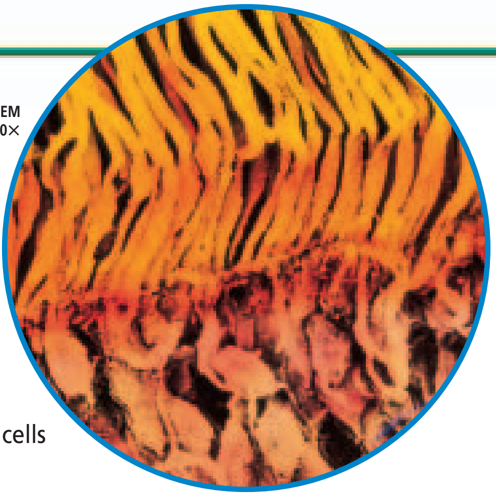
Every sound causes the air around it to vibrate. These vibrations travel outward from the source in waves, called sound waves. Sound waves enter your outer ear and travel down to the end of the ear canal, where they strike a membrane called the eardrum and cause it to vibrate. The vibrations then pass to three small bones in the middle ear—the malleus, the incus, and the stapes. As the stapes vibrates, it causes the membrane of the oval window, a structure between the middle and inner ear, to move back and forth.

INSIDE STORY

The Eye

Figure 36.12
The light energy that reaches your retina is converted into nerve impulses, which are interpreted by your brain, allowing you to see the world around you. **Critical Thinking** ***How would a person's vision be affected if his or her rod cells didn't function?***

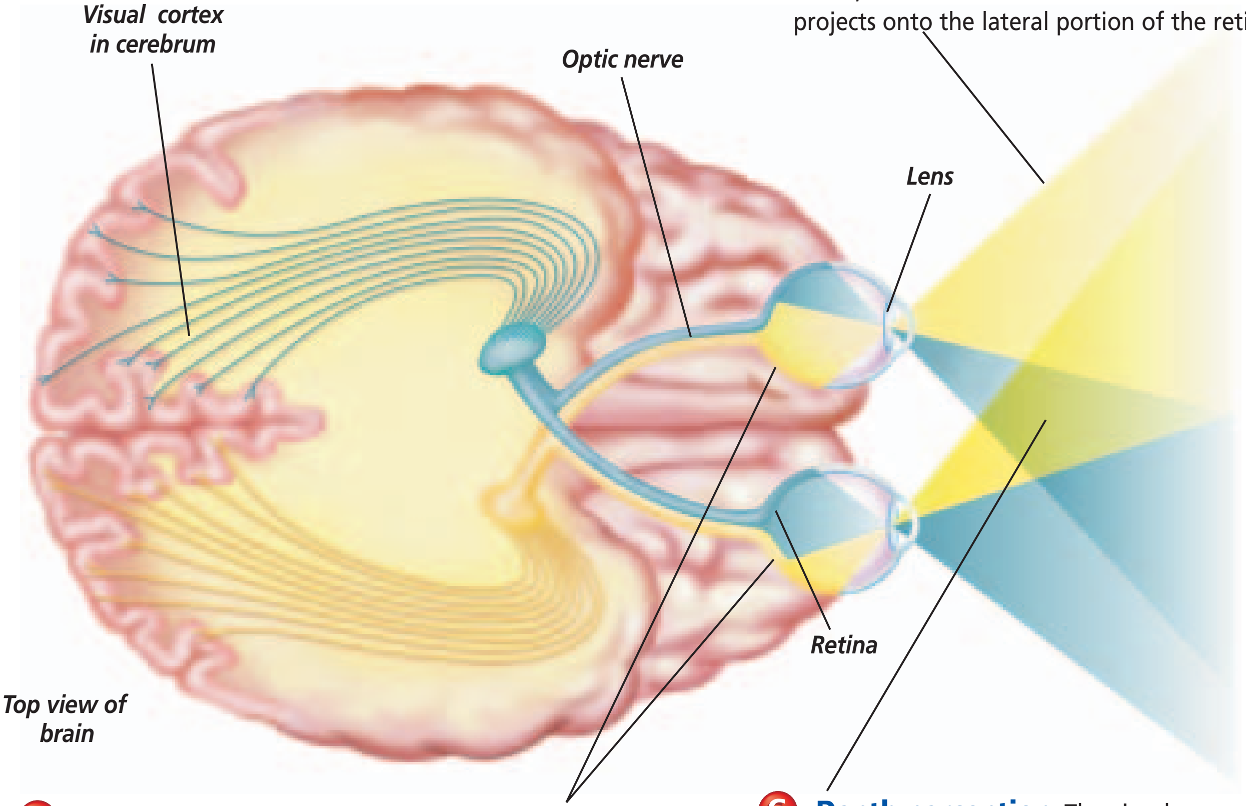
Color-enhanced SEM
Magnification: 500×



Rod and cone cells

A **Rod and cone cells** Rod cells in the retina are excited by low levels of light. These cells convert light signals into nerve impulses and relay them to the brain. Your brain interprets the information as a black and white picture. Your cone cells respond to bright light. They provide the brain with information about color.

B **Visual field** Close one eye. Everything you can see with one eye open is the visual field of that eye. The visual field of each eye can be divided into two parts: a lateral, or outer portion, and a medial, or inner portion. As shown, the lateral half of the visual field projects onto the medial portion of the retina, and the medial half of the visual field projects onto the lateral portion of the retina.



C **Depth perception** The visual fields of the eyes partially overlap, each eye seeing about two-thirds of the total field. This overlap allows your brain to judge the depth of your visual field.

D **Brain image projections** The right half of the retina in each eye is connected to the right side of the visual cortex in the cerebrum. The left half of the retina is similarly connected to the left side of the visual cortex. Thus images entering the eye from the right half of each visual field project to the left half of the brain, and vice versa.

Problem-Solving Lab 36.1

Interpret and Analyze

When are loud sounds dangerous to our hearing? Observations may be described as either qualitative or quantitative. A qualitative observation about a woman's height might be that she is tall. A quantitative observation about the same person might be that she is 1.92 m tall.

Solve the Problem

"Hearing loss afflicts approximately 28 million people in the United States. Approximately 10 million of these impairments may be partially attributable to damage from exposure to loud sounds. Sounds that are sufficiently loud to damage sensitive inner ear structures can produce hearing loss that is not reversible. Very loud sounds of short duration, such as an explosion or gunfire, can produce immediate, severe, and permanent loss of hearing. Longer exposure to less intense but still hazardous sounds encountered in the workplace or during leisure activities, exacts a gradual toll on hearing sensitivity, initially without the victim's awareness. Live or recorded high-volume music, lawn-care equipment, and airplanes are examples of potentially hazardous noise."

—"Noise and Hearing Loss," NIH Consensus Statement, January 22–24, 1990

Thinking Critically

1. **Analyze** Choose and record two sentences or phrases from the passage above that provide examples of quantitative observations. Explain your selections.
2. **Analyze** Choose and record two sentences or phrases that provide examples of qualitative observations. Explain your selections.
3. **Infer** Choose and record one sentence or phrase that provides an example of an inference. Explain your selection.
4. **Think Critically** Suggest ways to minimize the type of noise exposure discussed in the last sentence.

From here, the vibrations continue to travel deeper into the ear. The movement from the oval window causes fluid in the **cochlea,** a snail-shaped structure in the inner ear, to move. Inside the circular walls of the cochlea are structures that are lined with hair cells. The fluid in the cochlea moves like a wave against the hair cells causing them to bend.

The movement of the hairs produces electrical impulses, which travel along the auditory nerve to the sides of the cerebrum, where they are interpreted as sound. Trace the pathway of sound waves in ***Figure 36.13.*** Hearing loss can occur if the auditory nerve or the hair cells in the cochlea are damaged. To find out what impact loud sounds have on your hearing, do the *Problem-Solving Lab* on this page.

Your sense of balance

The inner ear also converts information about the position of your head into nerve impulses which travel to your brain, informing it about your body's equilibrium.

Maintaining balance is the function of your **semicircular canals.** Like the cochlea, the semicircular canals are also filled with a thick fluid and lined with

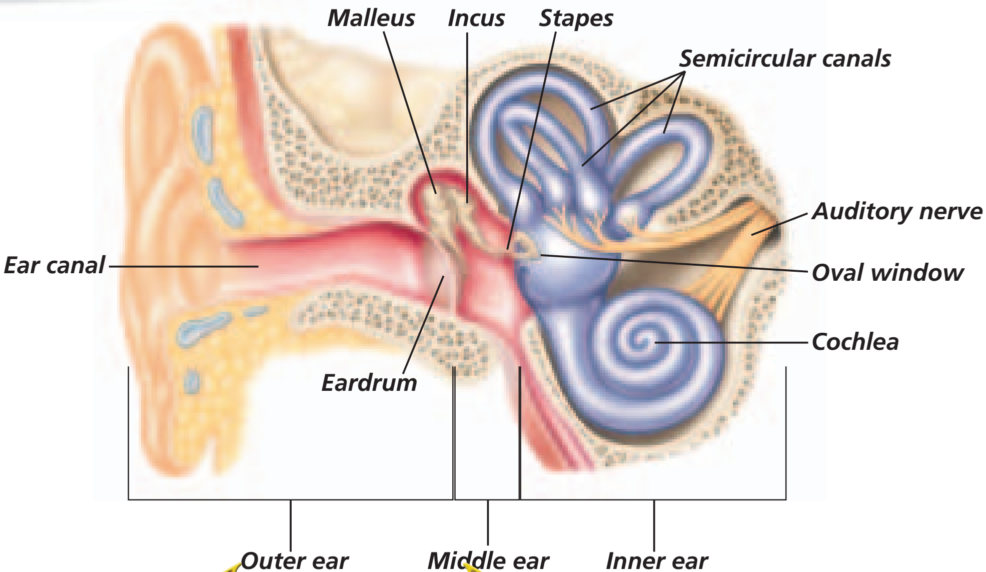


Figure 36.13
The internal structure of the human ear is divided into three areas: the outer ear, middle ear, and inner ear. Follow the pathway sound waves take as they move through your ear.

hair cells. When you tilt your head, the fluid moves, causing the hairs to bend. This movement stimulates the hair cells to produce impulses. Neurons from the semicircular canals carry the impulses to the brain, which sends an impulse to stimulate your neck muscles and readjust the position of your head.

Reading Check **Explain** the function of the semicircular canals.

Your sense of touch

Like the ear, your skin also responds to mechanical stimulation with receptors that convert the stimulus into a nerve impulse. Receptors in the dermis of the skin respond to changes in temperature, pressure, and pain. It is with the help of these receptors, shown in ***Figure 36.14,*** that your body is able to respond to its external environment.

Although some receptors are found all over your body, those responsible for responding to particular stimuli are usually concentrated within certain areas of your body. For example, receptors that respond to light pressure are numerous in the dermis of your fingertips, eyelids, lips, the tip of your tongue, and the palms of your hands. When these receptors are stimulated, you perceive sensations of light touch.

Receptors that respond to heavier pressure are found inside your joints, in muscle tissue, and in certain organs. They are also abundant on the skin of your palms and fingers and on the soles of your feet. When these receptors are stimulated, you perceive heavy pressure.

Free nerve endings extend into the lower layers of the epidermis. Free nerve endings act as receptors for itch, tickle, hot and cold, and pain sensations. Heat receptors are found deep in the dermis, while cold receptors are found closer to the surface of your skin. Pain receptors can be found in all tissues of the body except those in the brain.

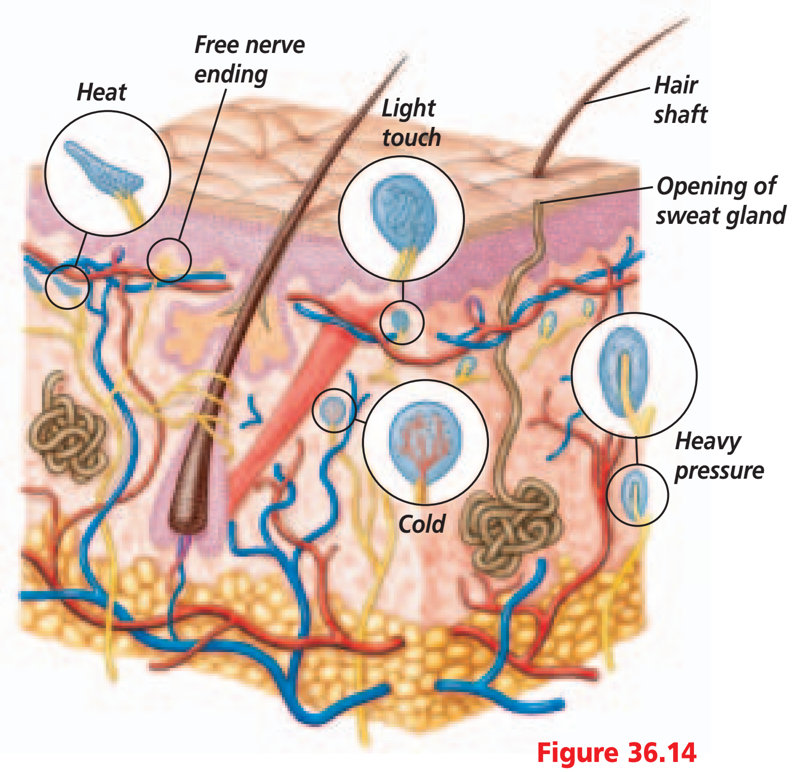


Figure 36.14
Many kinds of receptors are located throughout the skin. **Describe** ***What types of sensations are perceived when the different receptors are stimulated?***

Section Assessment

Understanding Main Ideas

1. Summarize the different types of messages the senses receive.
2. When you have a cold, why is it difficult to taste food?
3. Explain how your eyes detect light and images.
4. List the different types of receptors that are found in the skin.

Thinking Critically

5. Why might an ear infection lead to problems with balance?

Skill Review

6. **Sequence** List the sequence of structures through which sound waves pass to reach the auditory nerve. For more help, refer to *Sequence* in the **Skill Handbook.**

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Section

36.3

The Effects of Drugs

SECTION PREVIEW

Objectives

Recognize the medicinal uses of drugs.

Identify the different classes of drugs.

Interpret the effects of drug misuse and abuse on the body.

Review Vocabulary

receptors: specific binding sites found on the surface of or within a cell (p. 930)

New Vocabulary

drug
narcotic
stimulant
depressant
addiction
tolerance
withdrawal
hallucinogen

Drugs and the Nervous System

Finding Main Ideas On a piece of paper, construct an outline about the effects of drugs on the nervous system. Use the red and blue titles in the section as a guideline. As you read the paragraphs that follow the titles, add important information and vocabulary words to your outline.

Example:

I. Drugs act on the body

  A. Drugs affect body functions

II. Medicinal uses of drugs

  A. Relieving Pain

    1. Narcotics

Use your outline to help you answer questions in the Section Assessment on page 963. For more help, refer to *Outline* in the **Skill Handbook.**

Tobacco leaves, used to make cigarettes, contain the addictive drug nicotine.

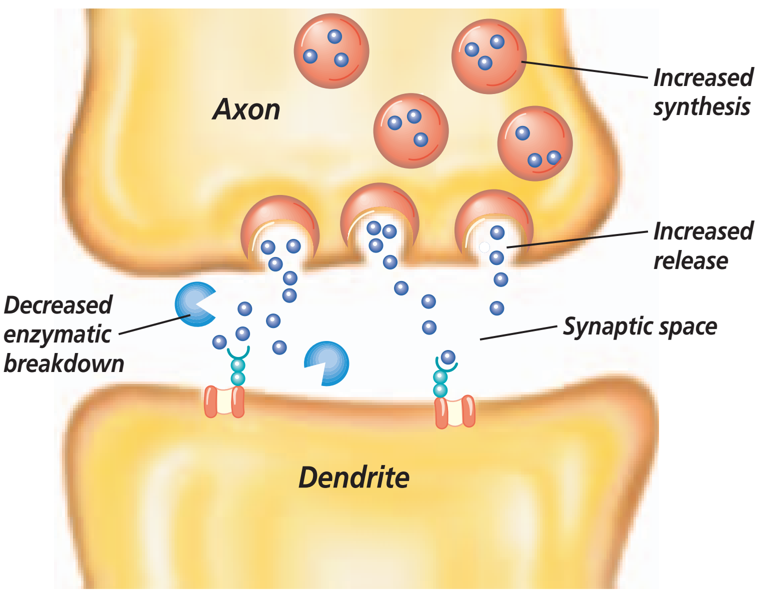


Figure 36.15
Drugs can increase neurotransmitter levels in the synapse by stimulating their synthesis, increasing their release, or by slowing their breakdown by enzymes.

Drugs Act on the Body

You probably hear the word *drug* used often, maybe even every day. A **drug** is a chemical that affects the body's functions. Most drugs interact with receptor sites on cells, probably the same ones used by neurotransmitters of the nervous system or hormones of the endocrine system. Some drugs increase the rate at which neurotransmitters are synthesized and released, or slow the rate at which they are broken down, as illustrated in ***Figure 36.15.*** Other drugs interfere with a neurotransmitter's ability to interact with its receptor. Explore how these different drugs work on neurotransmitters by doing the *Problem-Solving Lab* on the next page.

Adam Jones/Photo Researchers

CONTENTS

Medicinal Uses of Drugs

A medicine is a drug that, when taken into the body, helps prevent, cure, or relieve a medical problem. Some of the many kinds of medicines used to relieve medical conditions are discussed below.

Relieving pain

Headache, muscle ache, cramps—all are common pain sensations. You just studied how pain receptors in your body send signals to your brain. Medicines that relieve pain manipulate either the receptors that initiate the impulses or the central nervous system that receives them.

Pain relievers that do not cause a loss of consciousness are called analgesics. Some analgesics, like aspirin, work by inhibiting receptors at the site of pain from producing nerve impulses. Analgesics that work on the central nervous system are called **narcotics.** Many narcotics are made from the opium poppy flower, shown in ***Figure 36.16.*** Opiates, as they are called, can be useful in controlled medical therapy because these drugs are able to relieve severe pain from illness or injury.

Reading Check **Describe** how medicines that relieve pain work.

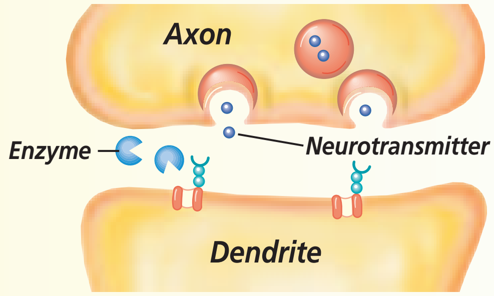
Problem-Solving Lab 36.2

Formulate Models

How do different drugs affect the levels of neurotransmitters in synapses? Drugs can act on neurotransmitters in a number of different ways. For example, they may block the release of the neurotransmitter from the axon of a neuron. They may also prevent the breakdown of the neurotransmitter by blocking the enzyme responsible for this action.

Solve the Problem

Examine the diagram shown here, which illustrates how neurotransmitters work.



Thinking Critically

1. **Formulate Models** Draw models for two different drugs:
   a. Illustrate a drug that could block the enzyme from breaking down the neurotransmitter.
   b. Illustrate a drug that could block the release of the neurotransmitter from the axon.
2. **Evaluate** Evaluate your models according to their adequacy in representing the effects a drug can have on the transmission of an impulse across a synapse.
3. **Predict** Predict the effects of each drug on the body.

Figure 36.16
Sticky sap from the fruit of an opium poppy is used to make drugs called opiates.

Robert Lyons/Visuals Unlimited

BIOTECHNOLOGY CAREERS

Pharmacist

Would you like to help people control or recover from illness by dispensing the latest medications developed through biotechnology? Then consider a career as a pharmacist.

Skills for the Job

Pharmacists read prescriptions written by doctors and other health professionals and carefully prepare containers with the correct medicine. (Few pharmacists still mix the medicine themselves; that is done by the drug manufacturer.) Pharmacists must know how drugs interact and guide people in avoiding harmful combinations. Besides drugstores, pharmacists work in hospitals and nursing homes, and for drug companies and government agencies. To become a pharmacist, you must complete a five-year bachelor's degree in pharmacy and pass a state examination.

For more careers in related fields, visit bdol.glencoe.com/careers

Word Origin

cardiovascular from the Greek word *kardia,* meaning "the heart," and the Latin word *vasculum,* meaning "small vessel"; Cardiovascular drugs treat problems associated with blood vessels of the heart.

Treating circulatory problems

Many drugs have been developed to treat heart and circulatory problems such as high blood pressure. These medicines are called cardiovascular drugs. In addition to treating high blood pressure, cardiovascular drugs may be used to normalize an irregular heartbeat, increase the heart's pumping capacity, or enlarge small blood vessels. Discover how various types of drugs can affect heart rate by doing the *BioLab* at the end of this chapter.

Treating nervous disorders

Several kinds of medicines are used to help relieve symptoms of nervous system problems. Among these medicines are stimulants and depressants.

Drugs that increase the activity of the central and sympathetic nervous systems are called **stimulants.** Amphetamines (am FE tuh meenz) are synthetic stimulants that increase the output of CNS neurotransmitters. Amphetamines are seldom prescribed because they can lead to dependence. However, because they increase wakefulness and alertness, amphetamines are sometimes used to treat patients with sleep disorders.

Drugs that lower, or depress, the activity of the nervous system are called **depressants,** or sedatives. The primary medicinal uses of depressants are to encourage calmness and produce sleep. For some people, the symptoms of anxiety are so extreme that they interfere with the person's ability to function effectively. By slowing down the activities of the CNS, a depressant can temporarily relieve some of this anxiety.

The Misuse and Abuse of Drugs

The misuse or abuse of drugs can cause serious health problems—even death. Drug misuse occurs when a medicine is taken for an unintended use. For example, giving your prescription medicine to someone else, not following the prescribed dosage by taking too much or too little, and mixing medicines, are all instances of drug misuse. You must pay careful attention to the specific instructions given on the label of a drug you are taking. The *MiniLab* on the next page shows you how to analyze such a label.

Drug abuse is the inappropriate self-administration of a drug for nonmedical purposes. Drug abuse may involve use of an illegal drug, such as cocaine; use of an illegally obtained medicine, such as someone else's prescribed drugs; or excessive use of a legal drug, such as alcohol or nicotine. Drugs abused in this way can have powerful effects on the nervous system and other systems of the body, as described in ***Figure 36.17.***

Addiction to drugs

When a person believes he or she needs a drug in order to feel good or function normally, that person is psychologically dependent on the drug. When a person's body develops a chemical need for the drug in order to function normally, the person is physiologically dependent. Psychological and physiological dependence are both forms of **addiction.**

Tolerance and withdrawal

When a drug user experiences tolerance to or withdrawal from a frequently used drug, that person is addicted to the drug. **Tolerance** occurs when a person needs larger or more frequent doses of a drug to achieve the same effect. The dosage increases are necessary because the body becomes less responsive to the drug. **Withdrawal** occurs when the person stops taking the drug and actually becomes ill.

Figure 36.17
The use of anabolic steroids without careful guidance from a physician is illegal. Some dangerous side effects of steroid abuse include cardiovascular disease, kidney damage, and cancer.

MiniLab 36.2

Analyze Information

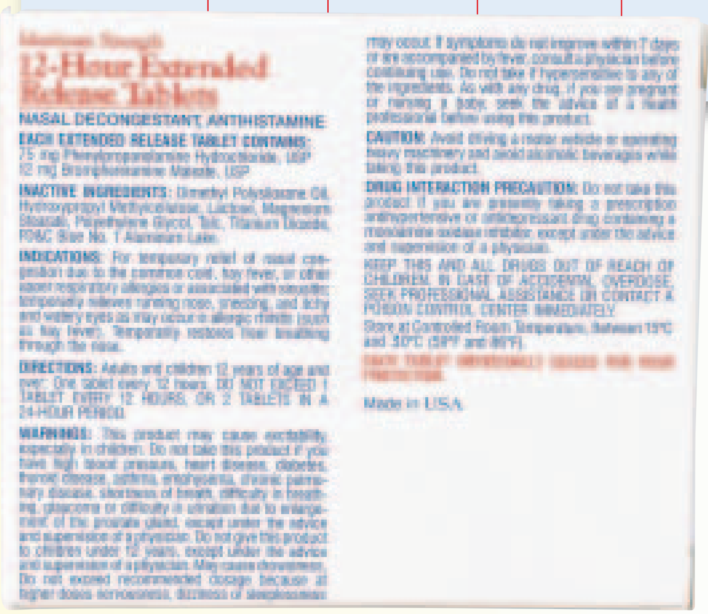
Interpret a Drug Label One common misuse of drugs is not following the instructions that accompany them. Over-the-counter medicines can be harmful—even fatal—if they are not used as directed. The Food and Drug Administration requires that certain information about a drug be provided on its label to help the consumer use the medicine properly and safely.

Procedure

1. The photograph below shows a label from an over-the-counter drug. Read it carefully.
2. Make a data table like the one shown. Then fill in the table using information on the label.

Information from a Drug Label

People with these conditions should avoid this drug	Possible Side Effects	This drug should not be taken with these medicines	Symptoms This Drug Will Relieve	Correct Dosage



Analysis

1. **Evaluate** Evaluate the promotional claims on this product's label. What symptoms will this product relieve? What side effects can result from using this product? Is this product appropriate for everyone to use?
2. **Infer** Why should a person never take more than the recommended dosage?

Figure 36.18
Babies born addicted to crack cocaine are usually low in birth weight, continually irritable, and may shake constantly.

Classes of Commonly Abused Drugs

Each class of drug produces its own special effect on the body, and its own particular symptoms of withdrawal. ***Table 36.1*** summarizes the health effects of some commonly abused drugs.

Stimulants: Cocaine, amphetamines, caffeine, and nicotine

You already know that stimulants increase the activity of the central nervous system and the sympathetic nervous system. Increased CNS stimulation can result in mild elevation of alertness, increased nervousness, anxiety, or even convulsions.

Cocaine stimulates the CNS by working on the part of the inner brain that governs emotions and basic drives, such as hunger and thirst. When these needs are met under normal circumstances, neurotransmitters—such as dopamine—are released to reward centers and the person experiences pleasure. Cocaine artificially increases levels of these neurotransmitters in the brain. As a result, false messages are sent to reward centers indicating that a basic drive has been satisfied. The user quickly feels a euphoric high called a rush. This sense of intense pleasure and satisfaction cannot be maintained, however, and soon the effects of the drug change. Physical hyperactivity follows. Often, anxiety and depression set in.

Cocaine also disrupts the body's circulatory system by interfering with the sympathetic nervous system. Although initially causing a slowing of the heart rate, it soon produces a great increase in heart rate and a narrowing of blood vessels, known as vasoconstriction. The result is high blood pressure. Heavy use of this drug compromises the immune system and often leads to heart abnormalities. Cocaine may affect more than just the individual who uses it. As ***Figure 36.18*** shows, babies of addicted mothers are sometimes born already dependent on this drug.

Amphetamines are stimulants that increase levels of CNS neurotransmitters. Like cocaine, amphetamines also cause vasoconstriction, a racing heart, and increased blood pressure. Other adverse side effects of amphetamine abuse include irregular heartbeat, chest pain, paranoia, hallucinations, and convulsions.

Not all stimulants are illegal. As shown in ***Figure 36.19***, one stimulant in particular is as close as the nearest coffee maker or candy machine. Caffeine—a substance found in coffee, some carbonated soft drinks, cocoa,

Figure 36.19
Caffeine can trigger a condition called tachycardia, when the heart beats more than 100 times per minute.

CONTENTS

Table 36.1 Commonly Abused Drugs

Category • Substance	Commercial or Street Name	Potential Health Hazards
Cannabinoid • Marijuana	• Grass, joints, pot, reefer, weed	Respiratory problems, impaired learning
Stimulants • Cocaine • Methylphenidate • Nicotine • Methamphetamine • MDMA	• Blow, coke, crack, rock • Ritalin, Skippy, vitamin R • Chew, cigarettes, cigars • Ice, speed, glass • Ecstasy, Eve	Increased heart rate and blood pressure, irregular heart beat, heart failure, and weight loss
Depressants • Benzodiazepines • Barbiturates	• Librium, Valium, Xanax, downers, sleeping pills • Barbs, red birds, yellows	Respiratory depression and arrest, lowered blood pressure, poor concentration
Hallucinogens • LSD	• Cubes, microdot	Chronic mental disorders, nausea, flashbacks
Opioids • Heroin	• H, junk, skag, smack	Respiratory depression and arrest, collapsed veins
Other • Inhalants • Anabolic steroids • Ketamine	• Paint thinners, gasoline, butane, nitrates, laughing gas • Juice • Special K, vitamin K	Headache, nausea, vomiting, unconsciousness, sudden death Liver and kidney cancer, acne, high blood pressure Respiratory depression and arrest, nausea, vomiting

and tea—is a CNS stimulant. Its effects include increased alertness and some mood elevation. Caffeine also causes an increase in heart rate and urine production, which can lead to dehydration.

Nicotine, a substance found in tobacco, is also a stimulant. By increasing the release of the hormone epinephrine, nicotine increases heart rate, blood pressure, breathing rate, and stomach acid secretion. Although nicotine is the addictive substance in tobacco, there are many other harmful chemicals found in tobacco products. Smoking cigarettes leads to an increased risk of lung cancer and cardiovascular disease. Use of chewing tobacco is associated with oral and throat cancers.

Depressants: Alcohol and barbiturates

As you already know, depressants slow down the activities of the CNS. All CNS depressants relieve anxiety, but most produce noticeable sedation.

One of the most widely abused drugs in the world today is alcohol. Easily produced from various grains and fruits, this depressant is distributed throughout a person's body via the bloodstream. Like other drugs, alcohol affects cellular communication by influencing the release of or interacting with receptors for several important neurotransmitters in the brain. Alcohol also appears to block the movement of sodium and calcium ions across the cell membrane, a process that is important in the transmission of impulses and the release of neurotransmitters.

Tolerance to the effects of alcohol develops as a result of heavy alcohol consumption. Addiction to alcohol—alcoholism—can cause the destruction of nerve cells and brain damage. A number of organ diseases are directly attributable to chronic alcohol use. For example, cirrhosis, a hardening of the tissues of the liver, is a common affliction of alcoholics.

Barbiturates (bar BIH chuh ruts) are sedatives and anti-anxiety drugs. When barbiturates are used in excess, the user's respiratory and circulatory systems become depressed. Chronic use results in addiction.

Narcotics: Opiates

Most narcotics are opiates, derived from the opium poppy. They act directly on the brain. The most abused narcotic in the United States is heroin. It depresses the CNS, slows breathing, and lowers heart rate. Tolerance develops quickly, and withdrawal from heroin is painful.

Hallucinogens: Natural and synthetic

Natural hallucinogens have been known and used for thousands of years, but the abuse of hallucinogenic drugs did not become widespread in the United States until the 1960s, when new synthetic versions became widely available.

Hallucinogens (huh LEW sun uh junz) stimulate the CNS—altering moods, thoughts, and sensory perceptions. The user sees, hears, feels, tastes, or smells things that are not actually there. This disorientation can impair the user's judgment and place him or her in a potentially dangerous situation. Hallucinogens also increase heart rate, blood pressure, respiratory rate, and body temperature, and sometimes cause sweating, salivation, nausea, and vomiting. After large enough doses, convulsions of the body may even occur.

Unlike the hallucinogens shown in ***Figure 36.20***, LSD—or acid—is a synthetic drug. The mechanism by which LSD produces hallucinations is still debated, but it may involve the blocking of a CNS neurotransmitter.

Reading Check **Describe** the effects of hallucinogens on the body.

Figure 36.20
Some hallucinogens are found in nature.

A Mushrooms of the genus *Psilocybe* contain the CNS hallucinogen psilocybin. These mushrooms are considered sacred by certain Native American tribes, who use them in traditional religious rites.

B Ergot, a mold disease of cereal grains, contains a hallucinogen chemically related to LSD.

(l)Matt Meadows/Peter Arnold, Inc., (r)Holt Studios International/Photo Researchers
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Anabolic steroids

Anabolic steroids are synthetic drugs that are similar to the hormone testosterone. Like testosterone, anabolic steroids stimulate muscles to increase in size. Physicians use anabolic steroids in the treatment of hormone imbalances or diseases that result in a loss of muscle mass. Abuse of anabolic steroids is associated with infertility in men, high cholesterol, and extreme mood swings.

Breaking the Habit

Once a person has become addicted to a drug, breaking the habit can be very difficult. Recall that an addiction can involve both physiological and psychological dependencies. Besides the desire to break the addiction, studies have shown that people usually need both medical and psychological therapy—such as counseling—to be successful in their treatment. Support groups such as Alcoholics Anonymous allow addicts to share their experiences in an effort to maintain sobriety. Often, people going through the same recovery are able to offer the best support.

Nicotine replacement therapy

Nicotine replacement therapy is one example of a relatively successful drug treatment approach. People who are trying to break their addiction to tobacco often go through stressful withdrawals when they stop smoking cigarettes. To ease the intensity of the withdrawal symptoms, patients wear adhesive patches that slowly release small amounts of nicotine into their bloodstream, as shown in ***Figure 36.21.*** Alternatively, pieces of nicotine-containing gum are chewed periodically to temporarily relieve cravings.

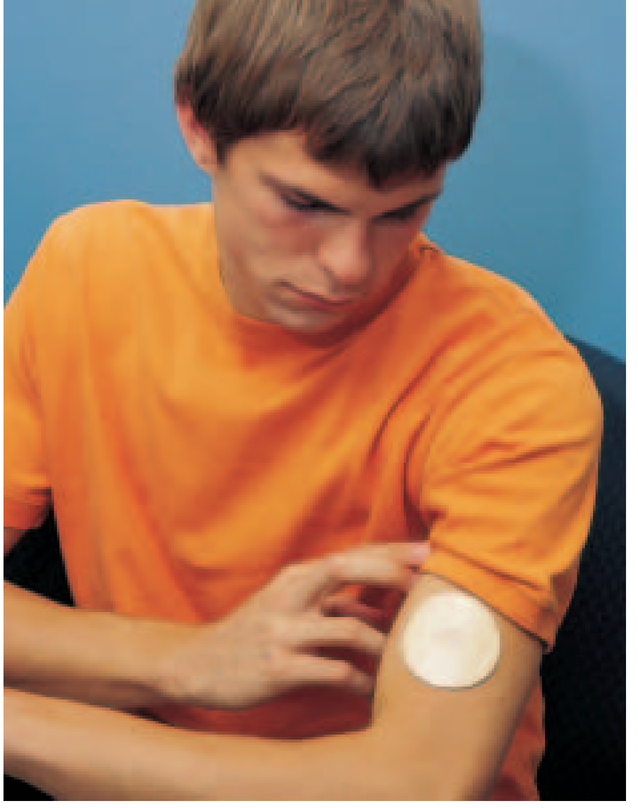

Figure 36.21
To help break an addiction to tobacco, this patient is wearing a patch on his arm that releases small amounts of nicotine directly into his bloodstream.

Section Assessment

Understanding Main Ideas

1. How can drugs affect levels of neurotransmitters between neurons?
2. In what ways can drugs be used to treat a cardiovascular problem?
3. Identify the different classes of drugs. Give an example of each class.
4. How does nicotine affect the body?

Thinking Critically

5. Form a hypothesis as to how a person develops tolerance to a drug.

Skill Review

6. **Compare and Contrast** Distinguish between stimulants and depressants, comparing their effects on the body. For more help, refer to *Compare and Contrast* in the **Skill Handbook.**

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DESIGN YOUR OWN BioLab

What drugs affect the heart rate of *Daphnia?*

Before You Begin

Depending on their chemical composition, drugs affect different parts of your body. Stimulants and depressants are drugs that affect the central nervous system and the autonomic nervous system. Stimulants increase the activity of the sympathetic nervous system and cause an increase in your breathing rate and in your heart rate. Depressants decrease the activity of the sympathetic nervous system, reducing your breathing and heart rates. In this lab, you will investigate the effects that different drugs have on an organism's heart rate.

PREPARATION

Problem

What legally available drugs are stimulants to the heart? What legal drugs are depressants? Because these drugs are legally available, are they less dangerous?

Hypotheses

Based on what you learned in this chapter, which of the drugs listed under Possible Materials do you think are stimulants? Which are depressants? How will they affect the heart rate in *Daphnia?* Make a hypothesis concerning how each of the drugs listed will affect heart rate.

Objectives

In this BioLab, you will:

- **Measure** the resting heart rate in *Daphnia.*
- **Compare** the resting heart rate with the heart rate when a drug is applied.

Possible Materials

aged tap water
Daphnia culture
dilute solutions of coffee, tea, cola, ethyl alcohol, tobacco, and cough medicine (containing dextromethorphan)
dropper
microscope
microscope slide

Safety Precautions

CAUTION: ***Do not drink any of the solutions used in this lab. Always wear goggles in the lab. Use caution when working with a microscope, microscope slides, and glassware.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

Matt Meadows

Plan the Experiment

1. Design an experiment to measure the effect on heart rate of four of the drug-containing substances in the Possible Materials list.
2. Design and construct a data table for recording your data.

Check the Plan

1. Be sure to consider what you will use as a control.
2. Plan to add two drops of a drug-containing substance directly to the slide.
3. When you are finished testing one drug, you will need to flush the used *Daphnia* with the solution into a beaker of aged tap water provided by your teacher. Plan to use a new *Daphnia* for each substance tested.
4. ***Make sure your teacher has approved your experimental plan before you proceed further.***
5. Begin your experiment by using a dropper to place a single *Daphnia* on a slide. Observe the animal on low power and find its heart. **CAUTION:** ***Wash your hands with soap and water immediately after making observations.***
6. **Cleanup and Disposal** Collect the used *Daphnia* in a beaker of aged tap water and give them to your teacher. Make wise choices about the disposal or recycling of other materials.

Daphnia

Color-enhanced SEM
Magnification: 1200×

Analyze and Conclude

1. **Infer** Examine your results and infer which drugs are stimulants. Which are depressants?
2. **Check Your Hypotheses** Compare your predicted results with the experimental data. Explain whether or not your data support your hypotheses regarding the drugs' effects.
3. **Draw Conclusions** How do the drugs affect the heart rate of this animal?
4. **Error Analysis** Compare your data to that of other groups. How can you account for differences in results with other lab groups? How would you alter your experiment if you did it again?

Apply Your Skill

Use Variables, Constants, and Controls Many other over-the-counter drugs are available. You may wish to test their effect on the heart rate of *Daphnia.*

Web Links To find out more about drug effects, visit bdol.glencoe.com/drug_effects

BIO TECHNOLOGY

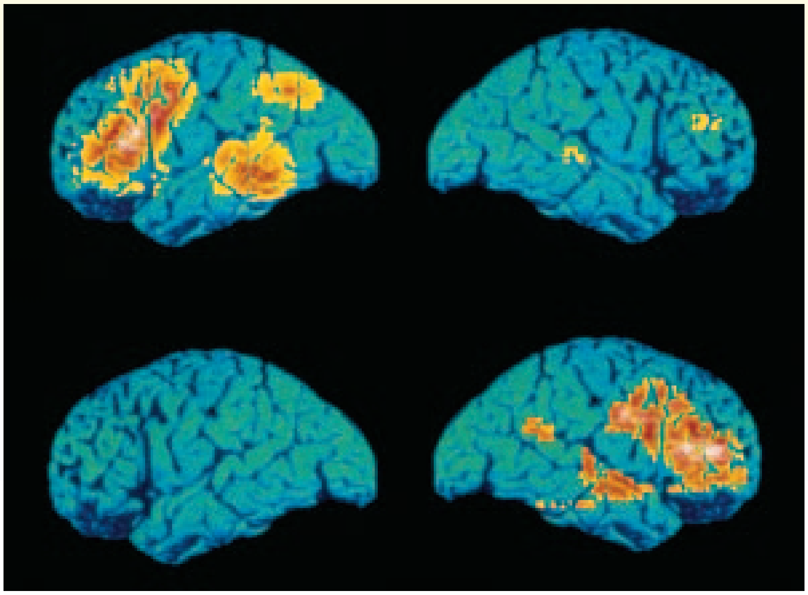
Scanning the Mind

Advancements in medical technology have led to instruments—such as X-ray and magnetic resonance imaging (MRI) machines—that can examine the human body in a noninvasive way. In addition to X rays and MRIs, another technology has been added to the medical toolbox—positron emission tomography (PET). This instrument is unique in that it allows a physician to view internal body tissues while they carry out their normal daily functions.

PET scanners are excellent tools for studying the human brain. By monitoring either the blood flow to an area or the amount of glucose being metabolized there, doctors are able to pinpoint active sections of the brain.

Here's how it works: The patient is injected with a compound containing radioactive isotopes. These isotopes emit detectable radiation and can be tracked by the sensitive PET scanner. Computers create a picture of brain activity by converting the energy emitted from the radioisotopes into a colorful map. The image indicates the location of an activity, such as glucose utilization, and its relative intensity in various regions.

Valuable research PET scanners are important in brain research, including the detection and diagnosis of brain tumors, the evaluation of damage due to stroke, and the mapping of brain functions. PET scans can also be used to see how learning takes place in the brain. The images on this page show activity in the left and right brains of two people. Each person was given a list of nouns and asked to visualize them. The unpracticed brain (top) had no previous experience with this exercise and thus was forced to engage in a high level of brain activity to perform the task. The practiced brain (bottom), by comparison, was able to picture the words with much less brain activity. Biologists can discover functions of different parts of the brain and their roles in learning.



PET scans

PET scans are also proving useful in the study of drug and alcohol addiction. Addicts can be given the addictive drug and then asked questions about their physical and emotional status while the scanner records metabolic activity in the brain. Researchers hope that information gained about how the brain works from the study of drug addiction will provide help in diagnosing and treating other illnesses such as manic-depressive psychosis and schizophrenia.

Applying Biotechnology

Evaluate Evaluate the impact of research done on the brain through PET scans. What effect has this had on scientific thought and society? What new information about the brain has been discovered through studies using a PET scan? How will this affect future diagnosis and treatment of brain diseases or disorders?

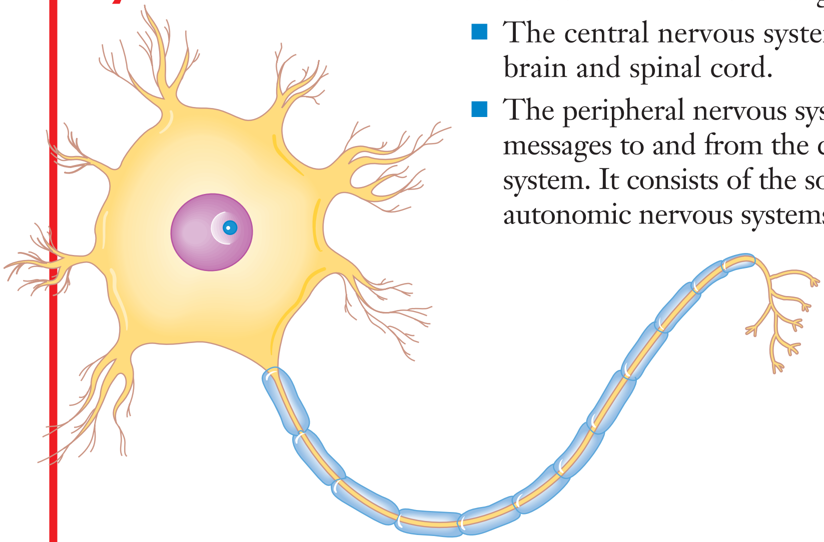
To find out more about PET scans, visit **bdol.glencoe.com/biotechnology**

Chapter 36 Assessment

Study Guide

Section 36.1

The Nervous System



Key Concepts

- The neuron is the basic structural unit of the nervous system. Impulses move along a neuron in a wave of changing charges.
- The central nervous system consists of the brain and spinal cord.
- The peripheral nervous system relays messages to and from the central nervous system. It consists of the somatic and autonomic nervous systems.

Vocabulary

autonomic nervous system (p. 949)
axon (p. 943)
central nervous system (p. 946)
cerebellum (p. 947)
cerebrum (p. 947)
dendrite (p. 943)
medulla oblongata (p. 947)
neuron (p. 943)
neurotransmitter (p. 946)
parasympathetic nervous system (p. 949)
peripheral nervous system (p. 947)
reflex (p. 948)
somatic nervous system (p. 948)
sympathetic nervous system (p. 949)
synapse (p. 946)

Section 36.2

The Senses

Key Concepts

- The senses of taste and smell are responses to chemical stimulation.
- The sense of sight is a response to light stimulation.
- The senses of hearing, balance, and touch are responses to mechanical stimulation.

Vocabulary

cochlea (p. 954)
cones (p. 952)
retina (p. 952)
rods (p. 952)
semicircular canals (p. 954)
taste bud (p. 952)

Section 36.3

The Effects of Drugs

Key Concepts

- Drugs act on the body's nervous system.
- Some medicinal uses of drugs include relieving pain and treating cardiovascular problems and nervous disorders.
- The misuse of drugs involves taking a medicine for an unintended use. Drug abuse involves using a drug for a non-medical purpose.

Vocabulary

addiction (p. 959)
depressant (p. 958)
drug (p. 956)
hallucinogen (p. 962)
narcotic (p. 957)
stimulant (p. 958)
tolerance (p. 959)
withdrawal (p. 959)

FOLDABLES Study Organizer

To help you review the senses, use the Organizational Study Fold on page 951.

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Matt Meadows

Chapter 36 Assessment

Vocabulary Review

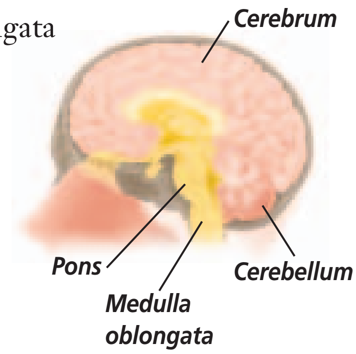
Review the Chapter 36 vocabulary words listed in the Study Guide on page 967. For each set of vocabulary words, choose the one that does not belong. Explain why it does not belong.

1. axon—cochlea—dendrite
2. rods—cones—reflex
3. retina—depressant—stimulant
4. synapse—taste bud—neurotransmitter
5. tolerance—addiction—cerebrum
6. neuron—drug—hallucinogen

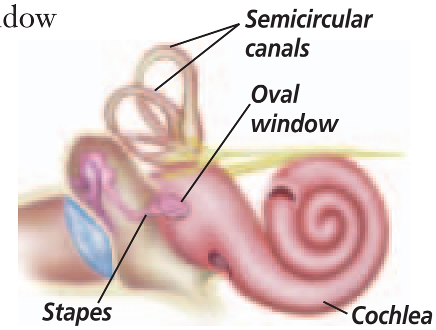
Understanding Key Concepts

7. Which of the following is NOT a type of neuron?
   A. interneuron
   B. sensory neuron
   C. motor neuron
   D. stimulus neuron

8. Which portion of the brain controls balance, posture, and coordination?
   A. pons
   B. medulla oblongata
   C. cerebellum
   D. cerebrum

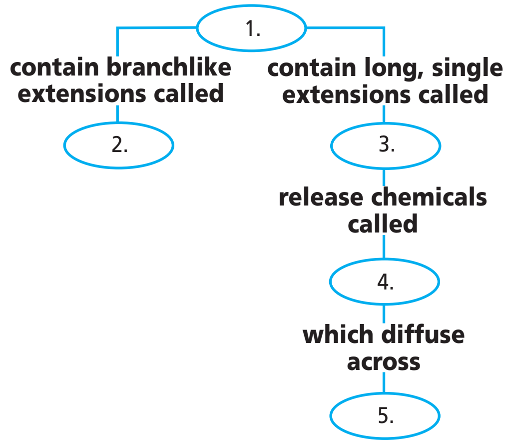


9. Which part of the ear is involved in maintaining balance?
   A. semicircular canals
   B. oval window
   C. stapes
   D. cochlea



10. Which type of neuron carries impulses toward the brain?
    A. sensory
    B. motor
    C. association
    D. none of the above

11. Complete the concept map by using the following vocabulary terms: neurons, neurotransmitters, axons, dendrites, synapses.



Constructed Response

12. **Open Ended** Compare and contrast the somatic nervous system and the autonomic nervous system.
13. **Open Ended** Identify how the nervous system responds to external stimuli.
14. **Open Ended** The drug ephedrine is a sympathetic nervous system mimic drug. What could be the effects of this drug on the body?

Thinking Critically

15. **REAL WORLD BIOCHALLENGE** Visit **bdol.glencoe.com** to answer the following questions. What is a spinal cord injury? What treatments are available? What research is currently being done to help people overcome the effects of a spinal cord injury?
16. **Infer** Local anesthetics block the opening of sodium channels in nerve cells. Explain how this would affect the transmission of pain impulses.

Chapter 36 Assessment

17. Recognize Cause and Effect During a rough ferry crossing, the horizon seems to be moving up and down as you hold on to the railing. You begin to feel seasick. Explain what is happening in your body that might be causing you to feel this sensation.

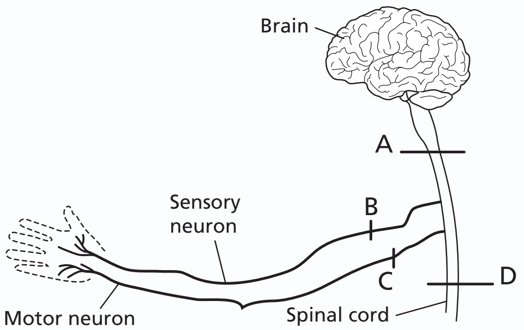
18. Hypothesize Patients with multiple sclerosis lose the ability to control their movement. This is due to a continual loss of myelin sheaths on motor neurons. Form a hypothesis as to how this would cause these patients to lose control of their ability to move.

Standardized Test Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the diagram to answer questions 19–21.

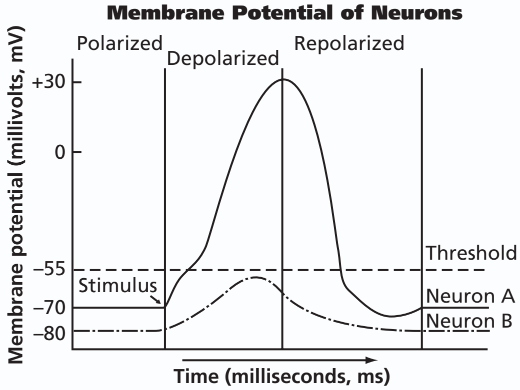


19. The diagram above shows four possible blockages of nerve impulses at A, B, C, and D by an anesthetic. If the patient can move her hand but can't feel it, where is the blockage?
A. A
B. B
C. C
D. D

20. If the patient can feel a pinprick but cannot move her hand, where is the blockage?
A. A
B. B
C. C
D. D

21. If the patient cannot feel a pinprick or move her hand, where is the blockage?
A. A
B. B
C. C
D. D

Study the graph and answer questions 22–25.



22. What is the membrane potential of Neuron A when it is polarized?
A. −80 mV
B. −70 mV
C. −55 mV
D. +30 mV

23. What is the membrane potential of Neuron B when it is polarized?
A. −80 mV
B. −70 mV
C. −55 mV
D. +30 mV

24. What is the highest membrane potential reached by Neuron A while it is depolarized?
A. −80 mV
B. −70 mV
C. −55 mV
D. +30 mV

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

25. Open Ended Neuron B is hyperpolarized, that is, it is more difficult for the threshold to be reached. Explain how this condition would affect the transmission of nerve impulses in this neuron. Form a hypothesis about how the neuron became hyperpolarized.

26. Open Ended Exposure to loud noises, such as a jet engine, damages the hair cells in the cochlea. Explain why extended exposure to loud noise results in hearing loss.