### Section Objectives

#### Section 36.1 2 sessions, 1 block

1. **Analyze** how nerve impulses travel within the nervous system.
2. **Interpret** the functions of the major parts of the nervous system.
3. **Compare** voluntary responses and involuntary responses.

#### Section 36.2 1 session

4. **Define** the role of the senses in the human nervous system.
5. **Recognize** how senses detect chemical, light, and mechanical stimulation.
6. **Identify** ways in which the senses work together to gather information.

#### Section 36.3 2 sessions, 1/2 block

7. **Recognize** the medicinal uses of drugs.
8. **Identify** the different classes of drugs.
9. **Interpret** the effects of drug misuse and abuse on the body.

### National Science Standards

UCP.1, UCP.2, UCP.5; A.1, A.2; C.6; F.1, F.5

### State/Local Standards

Biology/Life Sciences 9b, 9c, 9d, 9e

### Advanced Lab and Demo Planning

- **Student Labs:**
  - MiniLab 36.1, p. 948: meterstick
  - Additional Lab, p. 948: paper clips, metric ruler

- **Teacher Demonstrations:**
  - Quick Demo, p. 945: cable
  - Quick Demo, p. 949: rubber hammer

- **Student Lab:**
  - Problem-Solving Lab 36.1, p. 954

- **Teacher Demonstration:**
  - Quick Demo, p. 952: cassette tape of various everyday sounds

- **Student Labs:**
  - Problem-Solving Lab 36.2, p. 957
  - MiniLab 36.2, p. 959
  - Design Your Own BioLab, p. 964: See materials below.

- **School Demonstration:**
  - Quick Demo, p. 961: nonprescription drugs (aspirin, cough syrup, antacids)

- **Student Lab:**
  - Design Your Own BioLab, p. 964: aged tap water; *Daphnia* culture; dilute solutions of coffee, cola, ethyl alcohol, tobacco, cold medicine; dropper; microscope; microscope slide

### Level 1 activities should be appropriate for students with learning difficulties.

### Level 2 activities should be within the ability range of all students.

### Level 3 activities are designed for above-average students.

### ELL activities should be within the ability range of English Language Learners.

### COOP LEARN

Cooperative Learning activities are designed for small group work.

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**End of Chapter Assessment**

**Student Edition**

Study Guide, p. 967

Content Assessment, pp. 968–969
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Indicates materials created specifically for California.
Short on Time?
The BioDigest at the end of this unit can be used as a(n):

• preview to introduce important unit concepts.
• overview if time does not permit teaching the entire chapter.
• review of key unit concepts.

Understanding the Photo
Even though it appears the nervous system is working very hard during a time like a roller coaster ride and doing very little during sleep, the nervous system is always working to receive stimuli from the surroundings, interpret the stimuli, and react.

What You’ll Learn

I You will relate the structure of a nerve cell to the transmission of a nerve signal.
I You will identify the senses and their signal pathways.
I 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.

Demo
Create a loud noise by slamming a book on your desk. Use the students’ reactions to begin a discussion of how the nervous system reacts to environmental stimuli. Ask the students what stimuli their brains were receiving and reacting to when you slammed the book. What stimuli did your brain receive while slamming the book that the students did not receive (such as feeling the book)? In what ways did the students’ bodies react? What systems were involved besides the nervous system?
**The 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.

**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.

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** RESOURCE MANAGER**

**Unit 10 Fast File Resources**
- MiniLab Worksheet, p. 81
- Reinforcement and Study Guide in English, pp. 89–90
- Reinforcement and Study Guide in Spanish, pp. 93–94
- Critical Thinking/Problem Solving, p. 98
- Transparency Worksheets, pp. 99, 103–106

**Reading Essentials for Biology, Section 36.1**
- Probeware Labs, pp. 29–32
- Section Focus Transparency 87
- Basic Concepts Transparency 66, 67

**California Content Standards**

Pages 942–943:
- Biology/Life Sciences 9d, 9e
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.

**Visual Learning**

**Figure 36.2** Spend a few minutes reviewing the sequence of events involved in the nervous system’s response to a stimulus. Ask students what path the nervous system would take to turn the head in response to a sound such as a honking car horn. The path would be the same except for the initial receptors, which would be located in the ear rather than in the skin.

**Visual Learning**

**Figure 36.3** What effect does the Na⁺/K⁺ pump have on the charge of the normal resting neuron? It maintains a positive charge on the outside of the membrane and a negative charge within the membrane of a resting neuron.

**Biology Journal**

**Nerve Analogy** Have students write a paragraph that explains how a nerve is similar to a wire going from a controlling switch (stimulus) to a lightbulb.

**Challenge Activity**

**Dissection** Have students who need an additional challenge prepare a labeled dissection of a sheep brain. They should prepare whole brains and half brains, labeling areas discussed in this chapter.

---

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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.

---

**Using Models**

**Nerves: Kinesthetic** Ask students to obtain a small cable of wires, such as that used in the Quick Demo above. Have them mount the cable on a sheet of paper and draw a nerve beside it. Ask the students to write a paragraph that compares and contrasts the nerve and the cable. Similarities include the following: Both carry messages, connect two things, contain a bundle of “wires,” and have a covering. Differences include the following: The nerve is alive, made of cells, and can repair itself to a degree.

---

**Reinforcement**

**Visual-Spatial** Have students draw neurons similar to Figures 36.3 and 36.4, label the parts, and use arrows to show the pathway of the nerve impulse.

**Analogy** To demonstrate what a nerve is like, show students the end of a cable, such as a telephone cable. Compare each wire to an axon and the individual wire wrappings to myelin sheaths. Explain that the whole cable represents a nerve.

---

**Enrichment**

**Activity** Have students research how the diameter of a nerve fiber affects the speed with which it transmits an impulse. What other factors can affect the speed of transmission? The larger the diameter of the fiber, the more quickly an impulse can be transmitted. Other factors that affect the speed of transmission include whether or not the fiber is myelinated and temperature.
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.

For the continual firing of impulses at the synapse, enzymes in the synapse break down the neurotransmitters shortly after transmission.

Caption Question Answer

Figure 36.5 At the end of the axon, vesicles of neurotransmitters are released, which diffuse across the synapse and bind with receptors on the end of the dendrite of the next neuron, stimulating an action potential in that neuron.

Physical Science Connection

Have students compare and contrast parallel and series circuits. In a parallel circuit, at least two pathways exist for electric current to flow through. In a series circuit, electric current follows a single path, so disruption of the path at any point causes the flow of current to stop.

Enrichment

Linguistic Have interested students read “Wide Hats and Narrow Minds” (from Stephen Jay Gould’s The Panda’s Thumb), which looks at the topic of brain size versus intelligence.

Challenge Activity

Toxins Various snake and spider venoms as well as puffer fish toxin are used to study ion channels. Have students who need an additional challenge research how these chemicals are used to study ion channels.
Two systems work together

Another division of your nervous system, called the peripheral (puh RII 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.

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.

Enrichment

Linguistic The Chinese have used acupuncture as a complete system of medicine for thousands of years. The procedure involves inserting long, thin needles into specific areas of the patient’s body. The needles are either rotated or electrical impulses are then sent down the length of the needles. Acupuncture is used to relieve pain, cure cancer, and everything in between. It is also currently being used in China as a form of anesthesia for patients undergoing surgery.

Have students research and report on ancient methods of acupuncture. How did the methods used then differ from those used today? The needles used to be turned to achieve the desired effect. Now electrical impulses are used instead. L3

Portfolio

Neuroscience Research Have students research and prepare a multimedia presentation for the class on one of the following topics: sleep, split-brain experiments, Alzheimer’s disease, or amnesia. L2

Biology Journal

Neurology Have students who are interested in topics about the brain read An Anthropologist on Mars by Dr. Oliver Sacks. Students can write a summary of one of the stories in their journal. L3

Learning Disabled Ask students to list activities their bodies do without conscious thought. To get them started, have them consider what their bodies do while they are asleep. L1

Exploring Nursing Have students interested in nursing contact a local hospital and arrange to shadow a nurse for an afternoon to find out more about what these professionals do. L2
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.

The nerves of the somatic system are part of the peripheral nervous system that relays information between your CNS and skeletal muscles. A response by the somatic nervous system to a stimulus usually 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.

Additional Lab

Skin Sensitivity

Cheat Sheet

Students determine the distance between sensory neurons.

Materials

paper clips in "U" shapes, metric ruler

Procedure

1. Working with a partner, plan ten areas of the skin to test for the distance between sensory neurons.
2. Have your partner close his or her eyes. With the paper clip ends close together, test your partner by gently touching his or her skin with the opened paper clip.
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 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 rattle-snake will increase heart and breathing rates.

Concept Development

Have students name some of the reflexes an infant has from birth. List these reflexes on the chalkboard. Answers may include the rooting reflex: when the baby’s cheek is touched, the baby will turn his or her head in that direction and open his or her mouth; the sucking reflex: when the roof of the baby’s mouth is touched, he or she will begin to suck; the startle reflex: a baby will extend his or her arms and legs then quickly pull them back toward the body in response to a loud noise; the grasp reflex: the baby will close his or her fingers and toes in a grasp in response to the palm of the hand or sole of the foot being touched. Ask students how these behaviors are different from conscious behaviors such as walking and talking. Reflexes are not learned behaviors.

Quick Demo

Reflexes Demonstrate the knee-jerk reflex using a rubber hammer. Point out that students did not choose to move their legs—they did so automatically.

Analysis

1. Which areas of the skin did you find most sensitive? Least sensitive?
2. Explain why two stimuli are felt as two points when the ends of the paper clip are moved farther apart. The two signals are detected by different sensory neurons.
3. Continually spread the two ends of the paper clip farther apart until your partner can feel two points rather than one.
4. Determine the distance between sensory neurons by measuring the distance between the two ends of the paper clip. Record the data.

Responses will vary depending upon the areas tested. Regions of the back and inner arms will be less sensitive than areas of the palms and fingers.

Assessment

Portfolio Have students include a summary of the lab, the data table, and answers to Analysis questions in their portfolios. Have them also write a paragraph explaining possible advantages of some areas of the skin being more sensitive than others. Use the Performance Task Assessment List for Lab Report in PASC, p. 119.
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.

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

Thinking Critically

1. Nerve impulses travel down neurons and at the synapse, neurotransmitters are released. The neurotransmitters diffuse across the synapse and stimulate the next neuron impulse.
2. The CNS coordinates all the body’s activities. The PNS carries impulses from the body to the CNS and carries impulses from the CNS to muscles and glands.
3. The cerebrum controls conscious activities, intelligence, memory, language, movement, and the senses. The cerebellum controls balance, posture, and coordination. The medulla oblongata mainly controls involuntary activities.
4. Voluntary responses are under the conscious control of the individual, whereas involuntary responses are not.
5. A reflex is an involuntary action that is not consciously controlled by the brain.
6. The nervous system controls and can modify the actions of all other systems of the body.
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.
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 retina, where it strikes the retina. Follow the pathway of light to the retina in Figure 36.11.

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.

**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.

### Model the Senses: Kinesthetic

Have student groups select and make a model of one of the senses. The model may demonstrate the anatomy or the function of the sense. Have students explain and demonstrate their models to the class.
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?

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.

Visual cortex in cerebrum

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.

Top view of brain

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.

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.

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Critical Thinking
Because rod cells function in low levels of light, the person would be virtually blind in dimly lit areas.

Display
Visual-Spatial Obtain display models of the ear, eye, skin, or nose. Have students examine the models as they read about each sense. L1 ELL

Project
Comparing Eyes to Cameras Have students write an essay comparing the eye to a camera. They should include references to the lens, the aperture, the body, and the shutter of the camera. Students should include a copy of the essay in their journals. L3

California Content Standards
Pages 952-953: Biology/Life Sciences 9b, 9d
Purpose
Students gain practice in determining whether statements are observations or inferences.

Process Skills
acquire information, define operationally, observe and infer, recognize cause and effect, think critically

Teaching Strategies
Refer students to the “Observe and Infer” section in the Skill Handbook at the back of this text. The entire report can also be accessed on the Internet.

Thinking Critically
1. Student choices must include a specific number. A definition of the word quantitative should also be included in their answer.
2. Student choices should not include a specific number. A definition of the word qualitative should also be included.
3. Students may cite sentences that include “may be” or “can.” A definition of the word inference should also be included in their answer.
4. Student answers may include the wearing of protective hearing devices and reducing volume or exposure time.

Modified Assessment
Portfolio Explain the meaning of the term decibel and give students a listing of noise-causing agents and their decibel ratings. Have students prepare a poster based on the listing. Have them place the posters in their portfolios. Use the Performance Task Assessment List for Poster in PASC, p. 145.

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.

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.

Hearing Impaired/Visually Impaired
Students who are hearing or visually impaired may be sensitive during discussions of the senses. Be prepared to answer questions about the causes and possible treatments of hearing or visual impairment.
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.

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?
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.

Caption Question Answer

Figure 36.14 Each type of skin receptor (temperature, pain, or pressure) sends a signal to the brain that is perceived according to the type of receptor.
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.

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.
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.

Describe how medicines that relieve pain work.

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.

Thinking Critically

1. Student models will vary.
2. Make sure that each one produces the effect described.
3. (a) Message will be transmitted for a longer period of time than normal; (b) Message will not be delivered to dendrite.

Assessment

Knowledge Have students make and interpret a diagram of neurotransmitter blockage. Use the Performance Task Assessment List for Scientific Drawing in PASC, p. 127.

Inclusion Strategies

English Language Learners Have students with limited English proficiency make a poster that summarizes the effects on different body systems of one drug that is misused or abused. Have students combine their posters to create a bulletin board display.

2 Teach

Purpose

Students design drugs that will interfere with the action of neurotransmitters.

Process Skills

apply concepts, formulate models, hypothesize, interpret scientific illustrations, predict, recognize cause and effect, think critically

Teaching Strategies

- Review the nature of the synapse and how neurotransmitters work normally.
- Encourage students to consider the shapes of the neurotransmitter molecules, enzymes, and binding sites when designing their blockers.
- Allow students to work in small groups.

Thinking Critically

1. Student models will vary.
2. Make sure that each one produces the effect described.
3. (a) Message will be transmitted for a longer period of time than normal; (b) Message will not be delivered to dendrite.

Assessment

Knowledge Have students make and interpret a diagram of neurotransmitter blockage. Use the Performance Task Assessment List for Scientific Drawing in PASC, p. 127.

Inclusion Strategies

English Language Learners Have students with limited English proficiency make a poster that summarizes the effects on different body systems of one drug that is misused or abused. Have students combine their posters to create a bulletin board display.

Figure 36.16

Sticky sap from the fruit of an opium poppy is used to make drugs called opiates.
**Career Path**

Courses in higher education: chemistry, biology, and other advanced science and mathematics courses

**College:** for most states, a five-year bachelor's degree in pharmacy plus an internship; for some states, a six-year doctoral program

**Career Issue**

Ask students what a pharmacist may do if he or she does not agree with information that a doctor has given a patient. Remind the class that the training pharmacists receive about the function of the human body is not as thorough as the training doctors receive.

**For More Information**

For more information about becoming a pharmacist, students can contact the American Pharmaceutical Association at the following address:

American Pharmaceutical Association
2215 Constitution Avenue, NW
Washington, DC 20037

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**Word Origin**

Have students look up the meanings of *pericardium* and *endocardium* and explain why these terms and their roots fit anatomical sections of the heart.

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**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 non-medical 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

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**Word Origin**

From the Greek word *kardia,* meaning “the heart,” and the Latin word *vasculum,* meaning “small vessel”; Cardiovascular 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 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.

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**Withdrawal**

Have students research the symptoms of withdrawal from the different classes of drugs presented in this section. What treatments are available for people experiencing withdrawal symptoms? Have students present the results of their research to the class. **L2**
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.

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**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**

<table>
<thead>
<tr>
<th>People with these conditions should avoid this drug</th>
<th>Possible Side Effects</th>
<th>This drug should not be taken with these medicines</th>
<th>Symptoms this drug will relieve</th>
<th>Correct Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NURSING HOME, HOSPITAL, CHILDREN UNDER 12 YEARS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(use as directed)</td>
<td></td>
<td>Retained fluid, palpitations</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Symptoms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Correct Dosage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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?

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**Cultural Diversity**

**Solomon Carter Fuller** Students may obtain a more thorough understanding of brain function by learning about common neuropathologies, such as Alzheimer’s disease. During your discussions, emphasize the work of African American psychiatrist and researcher, Solomon Carter Fuller (1872–1953).

He was best known for expanding our medical knowledge in the fields of neuropathology and psychiatry. His research on degenerative diseases of the brain—including Alzheimer’s disease—was considered pioneering work.
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,
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.

### Table 36.1 Commonly Abused Drugs

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

**Bioethics**

Part of the procedure in getting a drug approved by the Food and Drug Administration (FDA) involves human drug tests. The deaths of participants in National Institute of Health (NIH) drug trials has raised questions as to the safety of these tests. Even though participants sign a consent form, desperately ill patients may be willing to place themselves in inordinately dangerous situations in hopes of helping to find a cure. As a result, researchers question whether these patients can be truly “informed” about the risks involved.

Ask students to research what consenting to drug testing by the FDA involves. Have students present their findings in a written report. Organize and moderate a classroom debate concerning the ethical issues involved in human drug testing.

### Quick Demo

**Over-The-Counter Comparison** Bring various nonprescription drugs (such as aspirin, cough syrup, antacids, and so on) to hold up for the class. Compare such things as price, type of drug, type of packaging, and purpose of the drug.

**Challenge Activity** Ask students who need an additional challenge to write a presentation on the effects of alcohol at various blood alcohol levels. Have them research how alcohol enters cells and what effects alcohol has on the brain and liver.
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 juhn 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.

Describe the effects of hallucinogens on the body.

Hallucinogens (huh LEW sun uh juhn junz) stimulate the CNS—altering moods, thoughts, and sensory perceptions. They also increase heart rate, blood pressure, respiratory rate, body temperature, and sometimes cause sweating, salivation, nausea, and vomiting.

Concept Development

Intrapersonal Have students find out how computers are allowing pharmacologists to design new drugs. L3

Biology Journal

Evaluate Advertising Ask students to cut out cigarette ads from magazines. Post the ads on a bulletin board so all students can view them. In groups, have students discuss who the ads are likely to influence (the targeted audience). Ask students to select one ad and discuss its effectiveness. L2

Challenge Activity

Steroids Have students who need an additional challenge research more information on the effects of anabolic steroids on the body. Students can make a multimedia presentation of their results to the class. L3
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 directly into his bloodstream. 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.

3 Assess

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.
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.
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.

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.

Teaching Strategies

- Age tap water by leaving it in a beaker overnight.
- Set up a distribution station for all the solutions being tested.

Daphnia that are placed in the aged tap water after being tested with a drug can be reused again later.

Possible Procedures

Students should measure the resting heart rate of each Daphnia before adding several drops of one of the solutions and measuring the heart rate again.
**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. 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.

**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?

**Data and Observations**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Heart rate/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>No drug</td>
<td>240</td>
</tr>
<tr>
<td>Coffee</td>
<td>270</td>
</tr>
<tr>
<td>Cola</td>
<td>270</td>
</tr>
<tr>
<td>Tea</td>
<td>280</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>215</td>
</tr>
<tr>
<td>Tobacco</td>
<td>300</td>
</tr>
<tr>
<td>Cough medicine</td>
<td>Heart rate varies with brand</td>
</tr>
</tbody>
</table>

**Cleanup and Disposal**

The dilute solutions of the coffee, tea, cola, ethyl alcohol, tobacco, and cough medicine can be poured down the drain with lots of running water.

**Web Links**

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

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1. **Stimulants** are coffee, tea, cola, and tobacco. Cough medicine may also be listed. **Depressants** are ethyl alcohol and cough medicine if it contains dextromethorphen hydrobromide.
2. Some students' hypotheses will be confirmed by their data; others' will be rejected.
3. Stimulants speed up the animal's heart rate. Depressants slow the heart rate.
4. **Error Analysis** Answers will vary. Differences may be due to how much water was on the slide when they added the drug-containing substance. Different Daphnia may be more or less sensitive to the drug.

**Assessment**

**Performance** Have students each prepare a laboratory report that includes the experimental plan, the data table, and the answers to Analyze and Conclude, to be placed in their journals. Use the Performance Task Assessment List for Lab Report in PASC, p. 119. [L2]

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**Apply Your Skill**

**Use Variables, Constants, and Controls** Have students compare the effects of four over-the-counter cough medicines on the heart rate of Daphnia. They should carefully make equal dilutions of each medicine after determining the concentration of the active drug in each (listed on the package). [L2]
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 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 ca.bdol.glencoe.com/biotechnology

**Going Further**

Students can find out how PET scans are used to distinguish between the two types of breast tumors: those that have estrogen receptors and those that do not have estrogen receptors.
Section 36.1
The Nervous System

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 36.2
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
- 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 36.3
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)
- hallucinogen (p. 962)
- narcotic (p. 957)
- stimulant (p. 958)
- tolerance (p. 959)
- withdrawal (p. 959)
**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.

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?

15. **REAL WORLD BIOCHALLENGE**
    Visit ca.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.

**Thinking Critically**

15. **REAL WORLD BIOCHALLENGE**
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**Rubric**

Evaluating Open-Ended Questions

Open-ended assessment questions are graded by using a multilevel rubric that guides you in assessing a student’s knowledge of a particular concept. The following rubric is a sample scoring device.
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.

Record your answers for Questions 12–14 on a separate sheet of paper.

Constructed Response/Grid In

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.