35–3 Divisions of the Nervous System

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

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

CA a

Guide for Reading

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

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

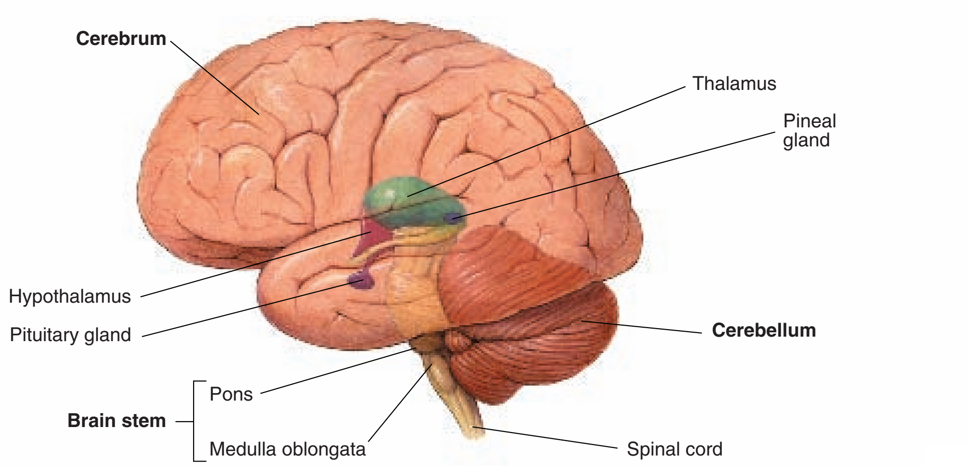
Reading Strategy: Asking Questions Before you read, rewrite the headings in the section as *how, why,* or *what* questions about the nervous system. As you read, write down the answers to your questions.

a BI 9.b

The Central Nervous System

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

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



SECTION RESOURCES

Print:
- ***Laboratory Manual A,*** Chapter 35 Lab
- ***Laboratory Manual B,*** Chapter 35 Lab
- ***Teaching Resources,*** Lesson Plan 35–3, Adapted Section Summary 35–3, Adapted Worksheets 35–3, Section Summary 35–3, Worksheets 35–3, Section Review 35–3
- ***Reading and Study Workbook A,*** Section 35–3
- ***Adapted Reading and Study Workbook B,*** Section 35–3
- ***Issues and Decision Making,*** Issues and Decisions 44

Technology:
- ***iText,*** Section 35–3
- ***Transparencies Plus,*** Section 35–3

Section 35–3

1 FOCUS

Objectives

35.3.1 ***Identify*** the functions of the central nervous system.

35.3.2 ***Describe*** the functions of the two divisions of the peripheral nervous system.

Guide for Reading

Vocabulary Preview

Point out that all of the Vocabulary terms refer to structures within the brain except for two terms. Ask: **Which two terms do not refer to structures in the brain?** (*Reflex and reflex arc*) Challenge students to predict what these two terms might mean, and then have them check to see if they were correct as they read the section.

Reading Strategy

Possible questions students might write include: What are the parts of the central nervous system? *(The brain and the spinal cord)* What is the role of the brain? *(It is the main switching unit of the central nervous system.)* What is the function of the spinal cord? *(It is the main communications link between the brain and the rest of the body.)* What structures make up the peripheral nervous system? *(All the nerves and associated cells that are not part of the brain and the spinal cord)*

2 INSTRUCT

The Central Nervous System

Use Visuals

Figure 35–9 Point out the location of the cerebrum and cerebellum. Explain that the brain stem is the region in front of the cerebellum that contains the pons and medulla oblongata. Ask: **Which part of the human brain is the largest part?** *(Cerebrum)* **Where in the brain are structures with endocrine function located?** *(Above the brain stem)* L1 L2

35–3 (continued)

The Brain

Build Science Skills

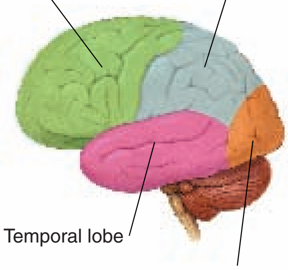
Calculating Help students appreciate how the folds in the brain greatly increase its surface area. First, have students measure the sides of a small box, such as a cereal box or shoe box, and use the measurements to calculate its surface area. Next, have students stuff the box with folded sheets of newspaper until the box is full. Then, have students count the number of sheets of newspaper and find their total area (by multiplying the number of sheets by the area of one sheet). Students should add this number to the surface area of the box. Ask: **How much was the surface area increased by the folded sheets?** *(Exact answers will vary. Students will find that the surface area was increased greatly by the addition of the folded sheets.)* L2 L3

Use Community Resources

Invite a diagnostic imaging technician to visit the class and explain how brain injuries, tumors, and other abnormalities of the brain are diagnosed. Ask the visitor to describe MRIs and CT scans and what they reveal about the brain. If possible, have the visitor bring sample images or scans to share with students. Urge students to take notes during the talk and later use the notes to write a summary of what they learned. L2

Go Online NSTA SCILINKS

Download a worksheet on the human brain for students to complete, and find additional teacher support from NSTA SciLinks.



▲ **Figure 35–10** This view of the cerebrum shows the four different lobes of the brain. Different functions of the body are controlled by different lobes of the brain. **Drawing Conclusions** ***The frontal lobe controls voluntary muscle movements. What might happen if this part of the brain became injured?***

Go Online NSTA SCILINKS

For: Links on the human brain
Visit: www.SciLinks.org
Web Code: cbn-0353

The Brain

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

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

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

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

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

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

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

UNIVERSAL ACCESS

Inclusion/Special Needs

Use a hands-on experience to help students understand the functions of the somatic and autonomic nervous systems. First, have students raise one hand over their heads. Tell them that this behavior is voluntary and controlled by the somatic nervous system. Then, have them feel their pulse to detect their heartbeat. Explain that the beating of their heart is involuntary and controlled by the autonomic nervous system. L1

Less Proficient Readers

The organization of the peripheral nervous system may be confusing to less proficient readers. Have them create a concept map to show how it is subdivided, including the sensory and motor divisions, somatic and autonomic nervous systems, and sympathetic and parasympathetic nervous systems. After they have completed their concept maps, call on students to name the function of each subdivision. L1 L2

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

The Spinal Cord

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

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

CHECKPOINT *What is a reflex?*

The Peripheral Nervous System

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

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

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

Quick Lab

How do you respond to an external stimulus?

Materials sheet of scrap paper

Procedure

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

Analyze and Conclude

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

BIO INSIGHTS — HISTORY OF SCIENCE

Broca's area

In the middle of the nineteenth century, Paul Broca, a French neurologist, discovered that a small region just above the sylvian fissure of the left frontal lobe of the cerebral cortex controls the ability to speak words correctly (rather than sounds). This area is now called Broca's area. Broca made his discovery by studying people with brain damage who had lost the ability to speak. He also studied split-brain patients—people whose hemispheres were no longer physically connected due to brain damage. Broca's discovery of this speech area was important for two reasons. It provided some of the first evidence that the left and right hemispheres of the brain have separate functions, and it was one of the first indicators that particular brain functions are localized in specific regions of the brain.

The Spinal Cord

Quick Lab

Objective Students will be able to describe a common reflex and explain its function.

Skills Focus Observing, Inferring

Materials Sheet of scrap paper

Time 10 minutes

Safety Make sure students put on their safety goggles before the paper ball is thrown at them.

Expected Outcome Students who have the ball thrown at them should automatically blink.

Analyze and Conclude

1. The partner blinked when the paper ball was thrown at him or her.

2. The reaction happened involuntarily. Therefore, it is an automatic response, or reflex.

3. After several repetitions, the partner may not blink because he or she expects the stimulus and is able to control the response.

4. The function of the blink reflex is to help protect the eyes from injury.

Demonstration

With the help of a student volunteer, demonstrate the knee-jerk reflex. Ask students to observe how quickly the reflex occurs. Explain that this is because it is processed directly in the spinal cord and not in the brain.

L1 L2

The Peripheral Nervous System

Build Science Skills

Applying Concepts Challenge students to explain how a person with a healthy peripheral nervous system could lack nervous control of the leg muscles due to a spinal cord injury.

L2

Answers to . . .

CHECKPOINT *A quick, automatic response to a stimulus that is processed in the spinal cord*

Figure 35–10 *There might be less control over voluntary muscle movements, such as walking and writing.*

35–3 (continued)

Quick Lab

Objective Students will be able to conclude that a stronger stimulus does not produce a stronger nerve impulse.

Skills Focus **Drawing Conclusions, Evaluating, Applying Concepts**

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

Time 20 minutes

Safety Show students how to hold the traps open safely with one hand while using the other hand to insert a string through the bait platform.

Strategy If students are working with a partner or in groups, make sure each student has a chance to set off the trap in step 3 in order to appreciate the all-or-nothing nature of the "reflex" response.

Expected Outcome Students should find that only a tug greater than a certain threshold triggers the mousetraps.

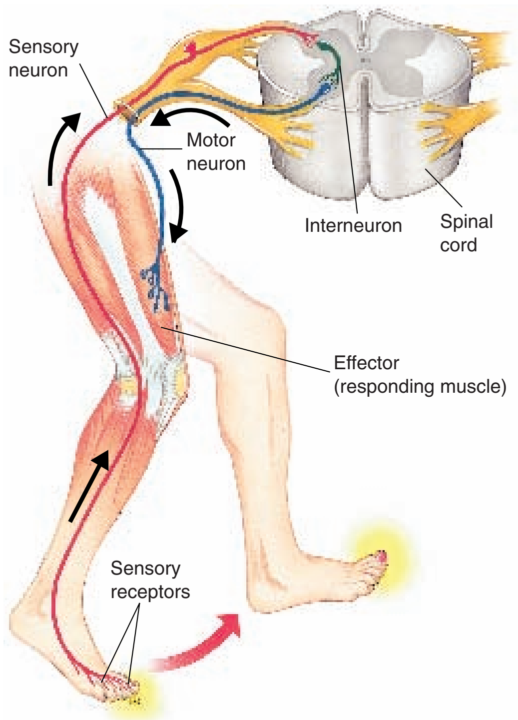
Analyze and Conclude

1. A sufficiently strong tug is required. This level of force can be compared with the threshold level of stimulus required to activate a neuron.

2. A stronger stimulus does not produce a stronger impulse because the response of a neuron is an all-or-nothing response.

3. Answers will vary. Students may say the procedure is not an adequate model because it is slower than an actual reflex arc or because it uses mechanical instead of electrical impulses.

4. Students should say that they handled the scissors carefully and did not let the mousetrap snap on their fingers.



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

If you accidentally step on a tack with your bare foot, your leg may recoil before you are aware of the pain. This rapid response (a reflex) is possible because receptors in your skin stimulate sensory neurons, which carry the impulse to your spinal cord. Even before the information is relayed to your brain, a group of neurons in your spinal cord automatically activates the appropriate motor neurons. These motor neurons cause the muscles in your leg to contract, pulling your foot away from the tack.

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

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

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

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

TEACHER TO TEACHER

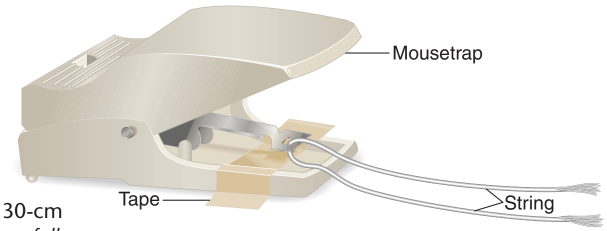
In order to test reaction time, I divide the class into pairs of students. One student should rest his or her elbow on a table and extend his or her arm over the side of the table. The second student should hold a meter stick in the air and release it unexpectedly. The first student should try to catch the meter stick between the thumb and index finger. Use the equation: Δ time = (Δ distance)/(9.8 m/s^2). After each person has calculated his or her reaction time, have students record their times in a chart on the chalkboard to see who has the best reaction time in the class. Using the meter stick and a physics equation allows the students to see the relationship between physics and biology.

—Charlotte Parnell
Biology Teacher
Lakeside High School
Hot Springs, AR

Quick Lab

How do reflexes occur?

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



Procedure

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

Analyze and Conclude

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

35–3 Section Assessment

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

Focus on the BIG Idea

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

35–3 Section Assessment

1. To relay messages and to process and analyze information
2. The sensory division transmits impulses from sense organs to the central nervous system. The motor division transmits impulses from the central nervous system to muscles.
3. It is protected by the skull and vertebrae, the meninges, and the cerebrospinal fluid.
4. It recognizes and analyzes hunger, thirst, fatigue, anger, and body temperature. It also controls the coordination of the nervous and endocrine systems.
5. Both, because it involves sensory and motor neurons of the peripheral system and is processed in the spinal cord
6. Less developed, because birds have less ability to think and learn than humans do

Build Science Skills

Observing Demonstrate the pupillary reflex, which is the automatic widening or narrowing of the pupil of the eye when the amount of light falling on it changes. Ask several volunteers to cover their eyes with a blindfold and keep their eyes closed. After a few minutes, have the volunteers uncover and open their eyes while the other students observe what happens to the size of the volunteers' pupils. Ask: **How did the size of their pupils change?** *(They were wide at first and gradually narrowed.)* **How long did the change take?** *(Several seconds)* L1 L2

3 ASSESS

Evaluate Understanding

Ask students to make a concept map of the divisions and subdivisions of the nervous system.

Reteach

Have each student create a crossword puzzle using the Vocabulary terms. Then, have students exchange and solve the puzzles.

Focus on the BIG Idea

Reflex arcs are most likely to be involved with innate behaviors, which are functional the first time they are performed. The brain plays a major role in learned behaviors, which depend on data collected through experience being processed and analyzed.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 35–3.