

Control and Coordination

chapter preview

sections

1 The Nervous System

Lab Improving Reaction Time

2 The Senses

Lab Skin Sensitivity



Virtual Lab *How does human hearing compare with that of other organisms?*

Could you stop the puck?


One second, the puck is across the ice rink. In the next second the goalie is trying to stop a goal. A goalie needs to be able to respond quickly, without even thinking about it. In this chapter, you will learn how your body senses and responds to stimuli in the world around you.

Science Journal Which senses do you think are at work when you respond to a glass crashing on a tile floor?

Start-Up Activities



How quick are your responses?

If the weather is cool, you might put on a jacket. If you see friends, you might call out to them. You also might pick up a crying baby. Every second of the day you react to different sights, sounds, and smells in your environment. You control some of these reactions, but others take place in your body without thought. Some reactions protect you from harm. 

1. Wearing safety goggles, sit on a chair 1 m away from a partner.
2. Ask your partner to toss a wadded-up piece of paper at your face without warning you.
3. Switch positions and repeat the activity.
4. **Think Critically** Describe in your Science Journal how you reacted to the ball of paper being thrown at you. Explain how your anticipation of being hit altered your body's response.



Preview this chapter's content and activities at bookd.msscience.com

FOLDABLES™ Study Organizer

Senses Your body is constantly responding to stimuli around you. Make the following Foldable to help you understand your five senses.

- STEP 1** **Collect** three sheets of paper and layer them about 1.25 cm apart vertically. Keep the edges level.



- STEP 2** **Fold** up the bottom edges of the paper to form six equal tabs.



- STEP 3** **Crease** the fold, and then staple along the fold. **Label** the tabs *Five Senses, Vision, Hearing, Smell, Taste, and Touch*.



Read and Write As you read the chapter, write what you learn about each of your senses under the appropriate tab.

The Nervous System

as you read

What You'll Learn

- **Describe** the basic structure of a neuron and how an impulse moves across a synapse.
- **Compare** the central and peripheral nervous systems.
- **Explain** how drugs affect the body.

Why It's Important

Your body is able to react to your environment because of your nervous system.

Review Vocabulary

response: a reaction to a specific stimulus

New Vocabulary

- homeostasis
- neuron
- dendrite
- axon
- synapse
- central nervous system
- peripheral nervous system
- cerebrum
- cerebellum
- brain stem
- reflex

How the Nervous System Works

After doing the dishes and finishing your homework, you settle down in your favorite chair and pick up that mystery novel you've been trying to finish. Only three pages to go . . . Who did it? Why did she do it? Crash! You scream. What made that unearthly noise? You turn around to find that your dog's wagging tail has just swept the lamp off the table. Suddenly, you're aware that your heart is racing and your hands are shaking. After a few minutes though, your breathing returns to normal and your heartbeat is back to its regular rate. What's going on?

Responding to Stimuli The scene described above is an example of how your body responds to changes in its environment. Any internal or external change that brings about a response is called a stimulus (STIHM yuh lus). Each day, you're bombarded by thousands of stimuli, as shown in **Figure 1**. Noise, light, the smell of food, and the temperature of the air are all stimuli from outside your body. Chemical substances such as hormones are examples of stimuli from inside your body. Your body adjusts to changing stimuli with the help of your nervous system.



Figure 1 Stimuli are everywhere and all the time, even when you're with your friends.

List the types of stimuli present at this party.

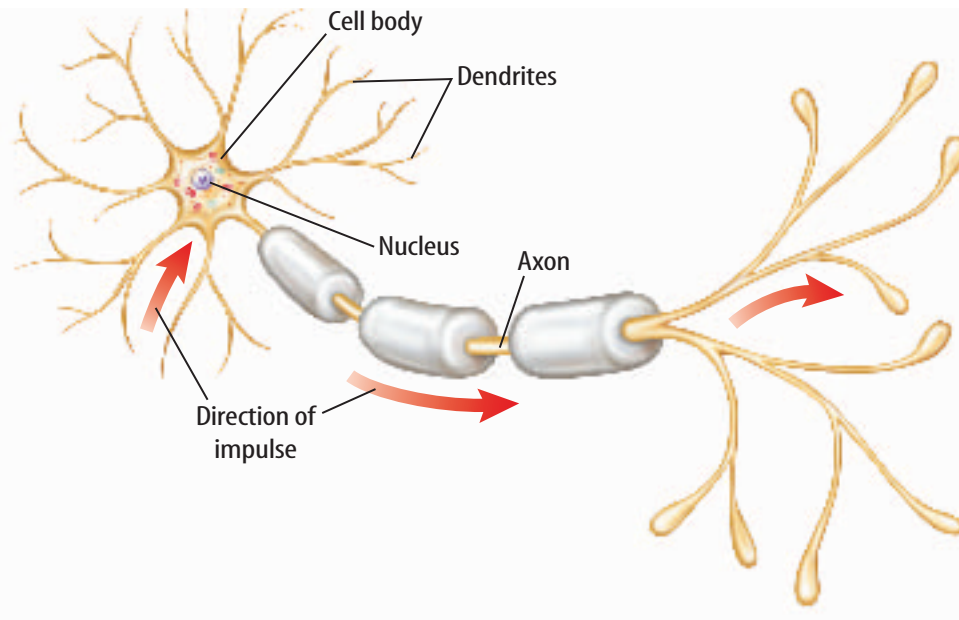


Figure 2 A neuron is made up of a cell body, dendrites, and axons. **Explain** how the branching of the dendrites allows for more impulses to be picked up by the neuron.

Homeostasis It's amazing how your body handles all these stimuli. Control systems maintain steady internal conditions. The regulation of steady, life-maintaining conditions inside an organism, despite changes in its environment, is called **homeostasis**. Examples of homeostasis are the regulation of your breathing, heartbeat, and digestion. Your nervous system is one of several control systems used by your body to maintain homeostasis.

Nerve Cells

The basic functioning units of the nervous system are nerve cells, or **neurons** (NOOR ahnz). As shown in **Figure 2**, a neuron is made up of a cell body and branches called dendrites and axons. Any message carried by a neuron is called an impulse. **Dendrites** receive impulses from other neurons and send them to the cell body. **Axons** (AK sahns) carry impulses away from the cell body. Notice the branching at the end of the axon. This allows the impulses to move to many other muscles, neurons, or glands.

Types of Nerve Cells Your body has sensory receptors that produce electrical impulses and respond to stimuli, such as changes in temperature, sound, pressure, and taste. Three types of neurons—sensory neurons, motor neurons, and interneurons—transport impulses. Sensory neurons receive information and send impulses to the brain or spinal cord, where interneurons relay these impulses to motor neurons. Motor neurons then conduct impulses from the brain or spinal cord to muscles or glands throughout your body.



Multiple Sclerosis In 1868, Jean Martin Charcot, a neurology professor in Paris, was the first to scientifically describe, document, and name the disease multiple sclerosis. It was named because of the many scars found widely dispersed throughout the central nervous system. Research to find out the symptoms of multiple sclerosis.



Figure 3

Millions of nerve impulses are moving throughout your body as you read this page. In response to stimuli, many impulses follow a specific pathway—from sensory neuron to interneuron to motor neuron—to bring about a response. Like a relay team, these three types of neurons work together. The illustration on this page shows how the sound of a breaking window might startle you and cause you to drop a glass of water.



SENSORY NEURONS When you hear a loud noise, receptors in your ears—the specialized endings of sensory neurons—are stimulated. These sensory neurons produce nerve impulses that travel to your brain.

INTERNEURONS Interneurons in your brain receive the impulses from sensory neurons and pass them along to motor neurons.

MOTOR NEURONS Impulses travel down the axons of motor neurons to muscles—in this case, your biceps—which contract to jerk your arms in response to the loud noise.

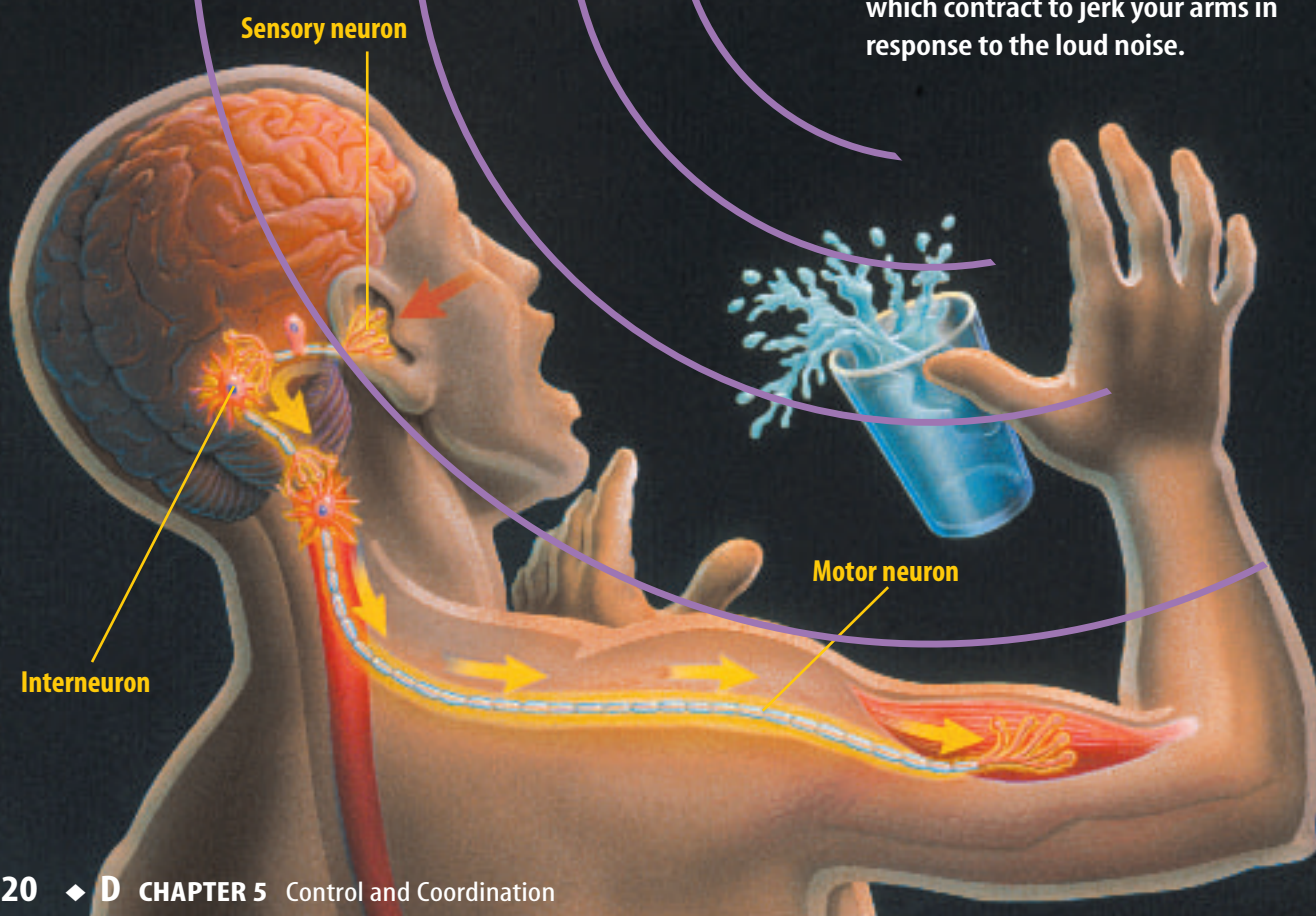
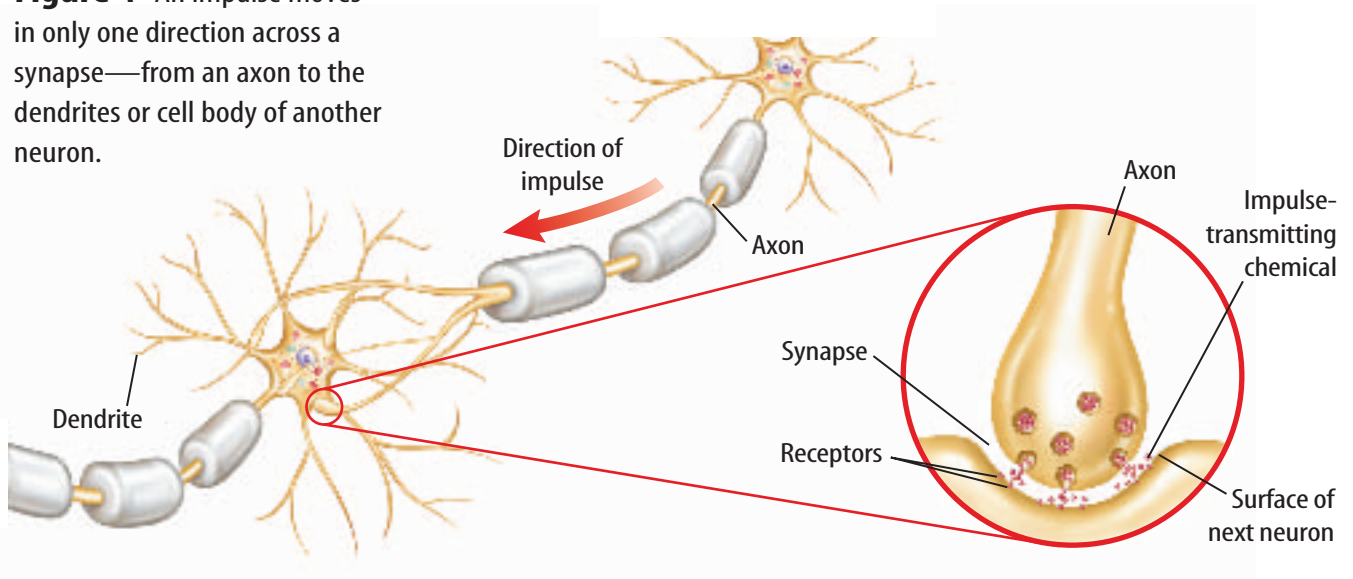


Figure 4 An impulse moves in only one direction across a synapse—from an axon to the dendrites or cell body of another neuron.



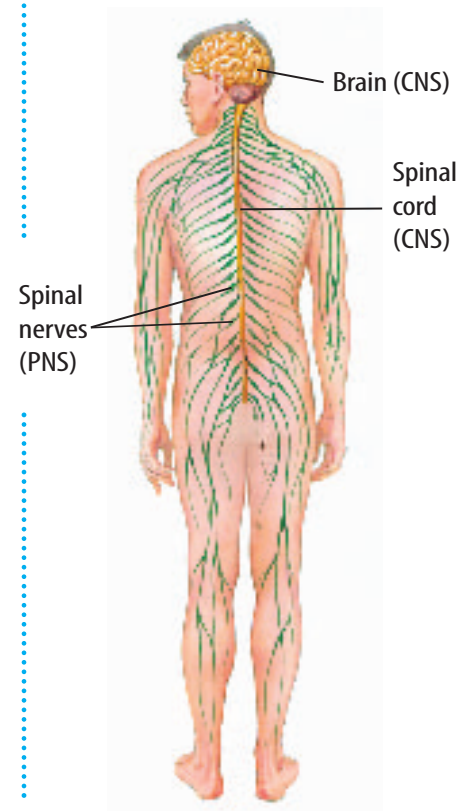
Synapses In a relay race, the first runner sprints down the track with a baton in his or her hand. As the runner rounds the track, he or she hands the baton off to the next runner. The two runners never physically touch each other. The transfer of the baton signals the second runner to continue the race.

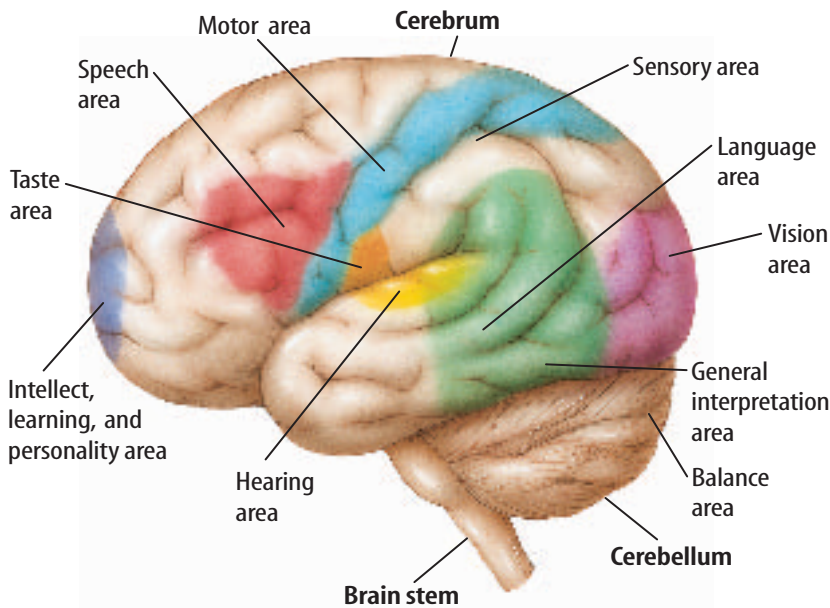
As shown in **Figure 3**, your nervous system works in a similar way. Like the runners in a relay race, neurons don't touch each other. How does an impulse move from one neuron to another? To move from one neuron to the next, an impulse crosses a small space called a **synapse** (SIH naps). In **Figure 4**, note that when an impulse reaches the end of an axon, the axon releases a chemical. This chemical flows across the synapse and stimulates the impulse in the dendrite of the next neuron. Your neurons are adapted in such a way that impulses move in only one direction. An impulse moves from neuron to neuron just like a baton moves from runner to runner in a relay race. The baton represents the chemical at the synapse.

The Central Nervous System

Figure 5 shows the organs of the central nervous system (CNS) and the peripheral (puh RIH fuh rul) nervous system (PNS). The **central nervous system** is made up of the brain and spinal cord. The **peripheral nervous system** is made up of all the nerves outside the CNS. These nerves include those in your head, called cranial nerves, and the nerves that come from your spinal cord, called spinal nerves. The peripheral nervous system connects the brain and spinal cord to other body parts. Sensory neurons send impulses to the brain or spinal cord.

Figure 5 The brain and spinal cord (yellow) form the central nervous system (CNS). All other nerves (green) are part of the peripheral nervous system (PNS).





The Brain The brain coordinates all of your body activities. If someone tickles your feet, why does your whole body seem to react? The brain is made up of approximately 100 billion neurons, which is nearly ten percent of all the neurons in the human body. Surrounding and protecting the brain are a bony skull, three membranes, and a layer of fluid. As shown in **Figure 6**, the brain is divided into three major parts—the brain stem, the cerebellum (ser uh BE lum), and the cerebrum (suh REE brum).

Figure 6 Different areas of the brain control specific body activities.

Describe the three major parts of the brain, and their functions.

Cerebrum Thinking takes place in the **cerebrum**, which is the largest part of the brain. This also is where impulses from the senses are interpreted, memory is stored, and movements are controlled. The outer layer of the cerebrum, called the cortex, is marked by many ridges and grooves. These structures increase the surface area of the cortex, allowing more complex thoughts to be processed. **Figure 6** shows some of the motor and sensory tasks that the cortex controls.

Reading Check

What major activity takes place within the cerebrum?

Cerebellum Stimuli from the eyes and ears and from muscles and tendons, which are the tissues that connect muscles to bones, are interpreted in the **cerebellum**. With this information, the cerebellum is able to coordinate voluntary muscle movements, maintain muscle tone, and help maintain balance. A complex activity, such as riding a bike, requires a lot of coordination and control of your muscles. The cerebellum coordinates your muscle movements so that you can maintain your balance.

Brain Stem At the base of the brain is the **brain stem**. It extends from the cerebrum and connects the brain to the spinal cord. The brain stem is made up of the midbrain, the pons, and the medulla (muh DUH luh). The midbrain and pons act as pathways connecting various parts of the brain with each other. The medulla controls involuntary actions such as heartbeat, breathing, and blood pressure. The medulla also is involved in such actions as coughing, sneezing, swallowing, and vomiting.



Impulses Acetylcholine (uh see tul KOH leen) is a chemical produced by neurons, which carries an impulse across a synapse to the next neuron. After the impulse is started, the acetylcholine breaks down rapidly. In your Science Journal, hypothesize why the breakdown of acetylcholine is important.

The Spinal Cord Your spinal cord, illustrated in **Figure 7**, is an extension of the brain stem. It is made up of bundles of neurons that carry impulses from all parts of the body to the brain and from the brain to all parts of your body. The adult spinal cord is about the width of an adult thumb and is about 43 cm long.

The Peripheral Nervous System

Your brain and spinal cord are connected to the rest of your body by the peripheral nervous system. The PNS is made up of 12 pairs of nerves from your brain called cranial nerves and 31 pairs from your spinal cord called spinal nerves. Spinal nerves are made up of bundles of sensory and motor neurons bound together by connective tissue. For this reason, a single spinal nerve can have impulses going to and from the brain at the same time. Some nerves contain only sensory neurons, and some contain only motor neurons, but most nerves contain both types of neurons.

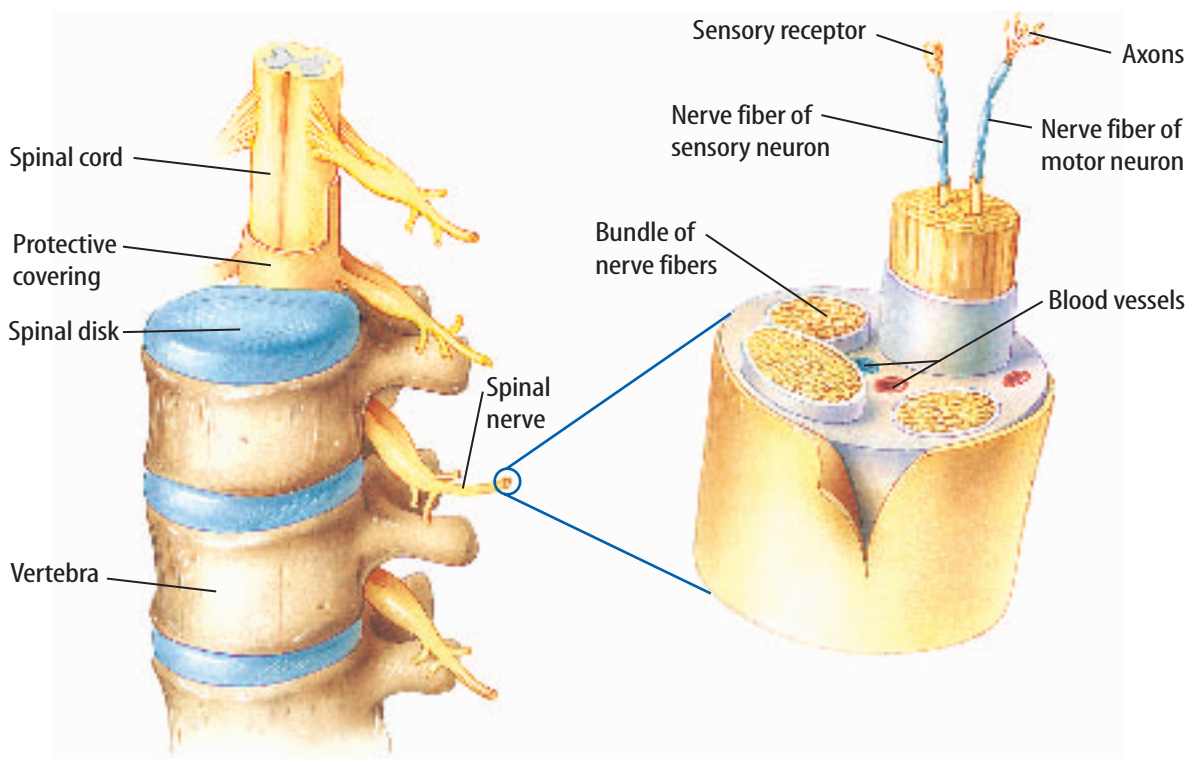
Somatic and Autonomic Systems The peripheral nervous system has two major divisions. The somatic system controls voluntary actions. It is made up of the cranial and spinal nerves that go from the central nervous system to your skeletal muscles. The autonomic system controls involuntary actions—those not under conscious control—such as your heart rate, breathing, digestion, and glandular functions. These two divisions, along with the central nervous system, make up your body's nervous system.

Topic: Nervous System

Visit bookd.msscience.com for Web links to information about the nervous system.

Activity In your Science Journal, make a brochure outlining recent medical advances.

Figure 7 A column of vertebrae, or bones, protects the spinal cord. The spinal cord is made up of bundles of neurons that carry impulses to and from all parts of the body, similar to a telephone cable.



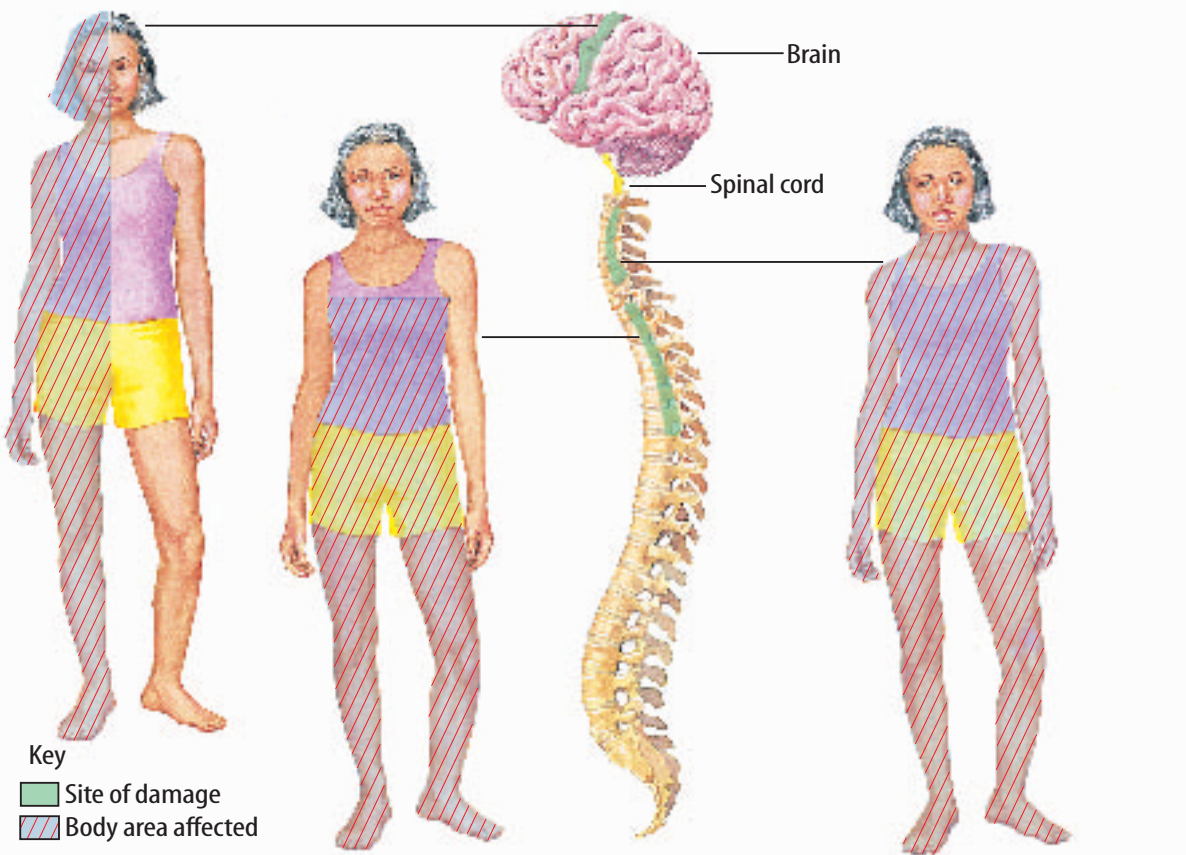
Safety and the Nervous System

Every mental process and physical action of the body is associated with the structures of the central and peripheral nervous systems. Therefore, any injury to the brain or the spinal cord can be serious. A severe blow to the head can bruise the brain and cause temporary or permanent loss of mental and physical abilities. For example, the back of the brain controls vision. An injury in this region could result in the loss of vision.

Although the spinal cord is surrounded by the vertebrae of your spine, spinal cord injuries do occur. They can be just as dangerous as a brain injury. Injury to the spine can bring about damage to nerve pathways and result in paralysis (puh RA luh suhs), which is the loss of muscle movement. As shown in **Figure 8**, a neck injury that damages certain nerves could prevent a person from breathing. Major causes of head and spinal injuries include automobile, motorcycle, and bicycle accidents, as well as sports injuries. Just like wearing safety belts in automobiles, it is important to wear the appropriate safety gear while playing sports and riding on bicycles and skateboards.

Figure 8 Head and spinal cord damage can result in paralysis, depending on where the injury occurs.

Explain why it is important to wear safety equipment and safety belts.



Damage to one side of the brain can result in the paralysis of the opposite side of the body.

Damage to the middle or lower spinal cord can result in the legs and possibly part of the torso being paralyzed.

Damage to the spinal cord in the lower neck area can cause the body to be paralyzed from the neck down.

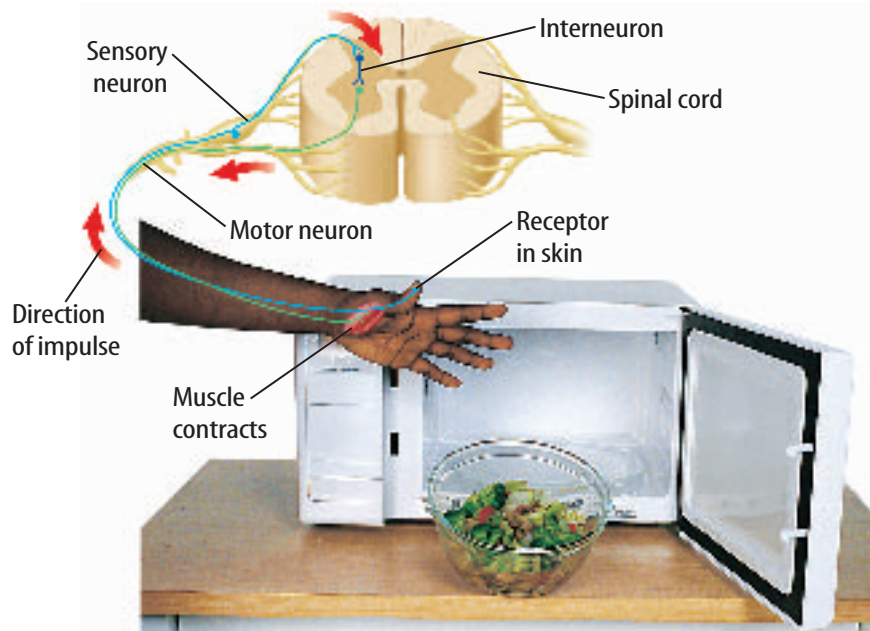


Figure 9 Your response in a reflex is controlled in your spinal cord, not your brain.

Reflexes You experience a reflex if you accidentally touch something sharp, something extremely hot or cold, or when you cough or vomit. A **reflex** is an involuntary, automatic response to a stimulus. You can't control reflexes because they occur before you know what has happened. A reflex involves a simple nerve pathway called a reflex arc, as illustrated in **Figure 9**.

Imagine that while walking on a sandy beach, a pain suddenly shoots through your foot as you step on the sharp edge of a broken shell. Sensory receptors in your foot respond to this sharp object, and an impulse is sent to the spinal cord. As you just learned, the impulse passes to an interneuron in the spinal cord that immediately relays the impulse to motor neurons. Motor neurons transmit the impulse to muscles in your leg. Instantly, without thinking, you lift up your leg in response to the sharp-edged shell. This is a withdrawal reflex.

A reflex allows the body to respond without having to think about what action to take. Reflex responses are controlled in your spinal cord, not in your brain. Your brain acts after the reflex to help you figure out what to do to make the pain stop.

Reading Check *Why are reflexes important?*

Do you remember reading at the beginning of this chapter about being frightened after a lamp was broken? What would have happened if your breathing and heart rate didn't calm down within a few minutes? Your body systems can't be kept in a state of continual excitement. The organs of your nervous system control and coordinate body responses. This helps maintain homeostasis within your body.



Topic: Reflexes and Paralysis

Visit bookd.msscience.com for Web links to information about reflexes and paralysis.

Activity Make a small poster that illustrates what you learn.



Figure 10 Caffeine, a substance found in colas, coffee, chocolate, and some teas, can cause excitability and sleeplessness.

Drugs and the Nervous System

Many drugs, such as alcohol and caffeine, directly affect your nervous system. When swallowed, alcohol passes directly through the walls of the stomach and small intestine into the circulatory system. After it is inside the circulatory system, it can travel throughout your body. Upon reaching neurons, alcohol moves through their cell membranes and disrupts their normal cell functions. As a result, this drug slows the activities of the central nervous system and is classified as a depressant. Muscle control, judgment, reasoning, memory, and concentration also are impaired. Heavy alcohol use destroys brain and liver cells.

A stimulant is a drug that speeds up the activity of the central nervous system. Caffeine is a stimulant found in coffee, tea, cocoa, and many soft drinks, as shown in **Figure 10**. Too much caffeine can increase heart rate and aggravates restlessness, tremors, and insomnia in some people. It also can stimulate the kidneys to produce more urine.

Think again about a scare from a loud noise. The organs of your nervous system control and coordinate responses to maintain homeostasis within your body. This task might be more difficult when your body must cope with the effects of drugs.

section 1 review

Summary

How the Nervous System Works

- The nervous system responds to stimuli to maintain homeostasis.
- To move from one neuron to another, an impulse crosses a synapse.

The Central Nervous System

- The brain controls all body activities.
- Spinal neurons carry impulses from all parts of the body to the brain.

The Peripheral Nervous System

- The somatic system controls voluntary actions and the autonomic system controls involuntary actions.

Safety and the Nervous System

- The spinal cord controls reflex responses.

Drugs and the Nervous System

- Many drugs affect your nervous system.

Self Check

1. **Draw and label** the parts of a neuron.
2. **Compare and contrast** the central and peripheral nervous systems.
3. **Explain** why you have trouble falling asleep after drinking several cups of hot cocoa.
4. **Explain** the advantage of having reflexes controlled by the spinal cord.
5. **Think Critically** Explain why many medications caution the consumer not to operate heavy machinery.

Applying Skills

6. **Concept Map** Prepare an events-chain concept map of the different kinds of neurons that pass an impulse from a stimulus to a response.
7. **Use a Word Processor** Create a flowchart showing the reflex pathway of a nerve impulse when you step on a sharp object. Label the body parts involved in each step.

LAB

IMPROVING REACTION TIME

Your reflexes allow you to react quickly without thinking. Sometimes you can improve how quickly you react. Complete this lab to see if you can decrease your reaction time.

Real-World Question

How can reaction time be improved?

Goals

- **Observe** reflexes.
- **Identify** stimuli and responses.

Materials

metric ruler

Procedure

1. Make a data table in your Science Journal to record where the ruler is caught during this lab. Possible column heads are *Trial*, *Right Hand*, and *Left Hand*.
2. Have a partner hold the ruler as shown.
3. Hold the thumb and index finger of your right hand apart at the bottom of the ruler. Do not touch the ruler.
4. Your partner must let go of the ruler without warning you.
5. Catch the ruler between your thumb and finger by quickly bringing them together.

6. Repeat this lab several times and record in a data table where the ruler was caught.
7. Repeat this lab with your left hand.

Conclude and Apply

1. **Identify** the stimulus, response, and variable in this lab.
2. Use the table on the right to determine your reaction time.
3. **Calculate** the average reaction times for both your right and left hand.
4. **Compare** the response of your writing hand and your other hand for this lab.
5. Draw a conclusion about how practice relates to stimulus-response time.

Reaction Time	
Where Caught (cm)	Reaction Time(s)
5	0.10
10	0.14
15	0.17
20	0.20
25	0.23
30	0.25

Communicating Your Data

Compare your conclusions with those of other students in your class. For more help, refer to the **Science Skill Handbook**.



The Senses

as you read

What You'll Learn

- **List** the sensory receptors in each sense organ.
- **Explain** what type of stimulus each sense organ responds to and how.
- **Explain** why healthy senses are needed.

Why It's Important

Your senses make you aware of your environment, enable you to enjoy your world, and help keep you safe.

Review Vocabulary

sense organ: specialized organ that, when stimulated, initiates a process of sensory perception

New Vocabulary

- retina
- olfactory cell
- cochlea
- taste bud

The Body's Alert System

“Danger . . . danger . . . code-red alert! An unidentified vessel has entered the spaceship’s energy force field. All crew members are to be on alert!” Like spaceships in science fiction movies, your body has an alert system, too—your sense organs. You might see a bird, hear a dog bark, or smell popcorn. You can enjoy the taste of salt on a pretzel, the touch of a fuzzy peach, or feel heat from a warm, cozy fire. Light rays, sound waves, heat, chemicals, or pressure that comes into your personal territory will stimulate your sense organs. Sense organs are adapted for intercepting these different stimuli. They are then converted into impulses by the nervous system.

Vision

Think about the different kinds of objects you might look at every day. It’s amazing that with one glance you might see the words on this page, the color illustrations, and your classmate sitting next to you. The eye, shown in **Figure 11**, is the vision sense organ. Your eyes have unique adaptations that usually enable you to see shapes of objects, shadows, and color.

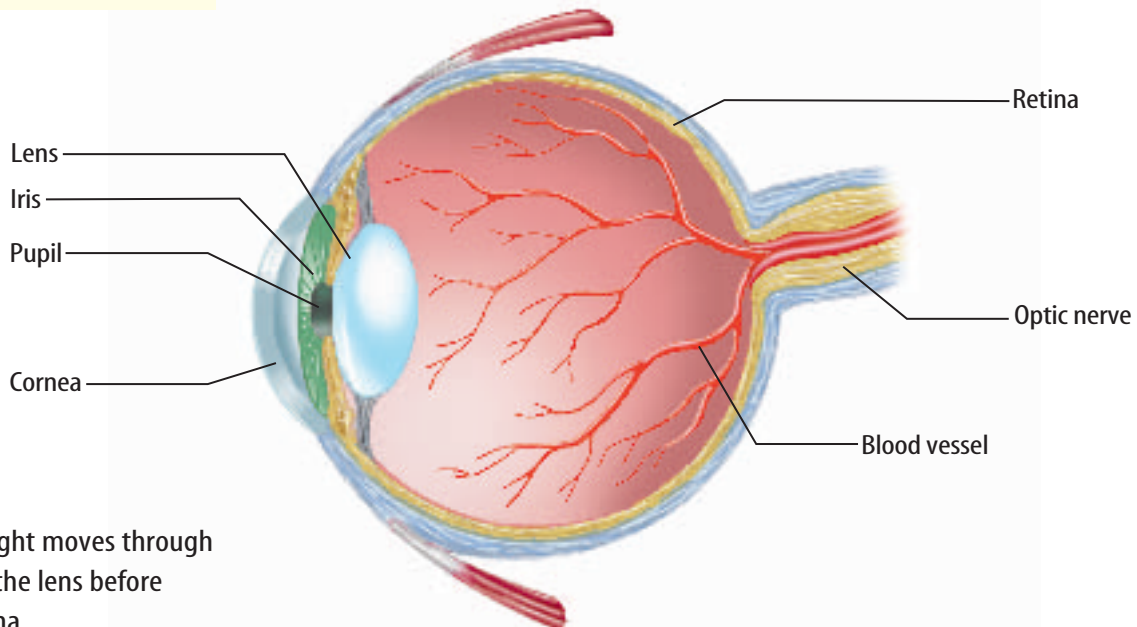


Figure 11 Light moves through the cornea and the lens before striking the retina.

How do you see? Light travels in a straight line unless something causes it to refract or change direction. Your eyes are equipped with structures that refract light. Two of these structures are the cornea and the lens. As light enters the eye, it passes through the cornea—the transparent section at the front of the eye—and is refracted. Then light passes through a lens and is refracted again. The lens directs the light onto the retina (RET nuh). The **retina** is a tissue at the back of the eye that is sensitive to light energy. Two types of cells called rods and cones are found in the retina. Cones respond to bright light and color. Rods respond to dim light. They are used to help you detect shape and movement. Light energy stimulates impulses in these cells.

The impulses pass to the optic nerve. This nerve carries the impulses to the vision area of the cortex, located on your brain's cerebrum. The image transmitted from the retina to the brain is upside down and reversed. The brain interprets the image correctly, and you see what you are looking at. The brain also interprets the images received by both eyes. It blends them into one image that gives you a sense of distance. This allows you to tell how close or how far away something is.

 **Reading Check**

What difficulties would a person who had vision only in one eye encounter?

Lenses



Light is refracted when it passes through a lens. The way it refracts depends on the type of lens it passes through. A lens that is thicker in the middle and thinner on the edges is called a convex lens. As shown in **Figure 12**, the lens in your eye refracts light so that it passes through a point, called a focal point. Convex lenses can be used to magnify objects. The light passes through a convex lens and enters the eye in such a way that your brain interprets the image as enlarged.

A lens that is thicker at its edges than in its middle is called a concave lens. Follow the light rays in **Figure 12** as they pass through a concave lens. You'll see that this kind of lens causes the parallel light to spread out.

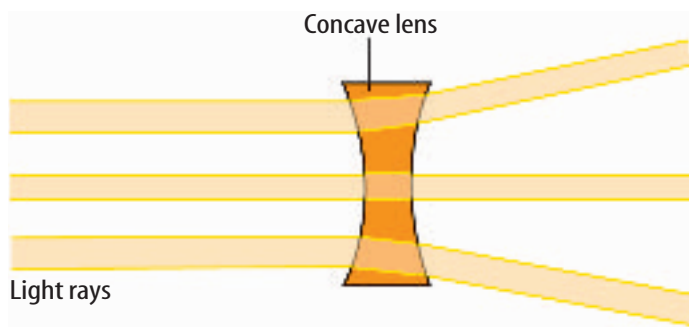
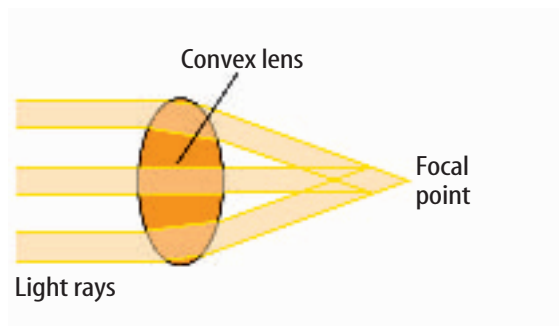
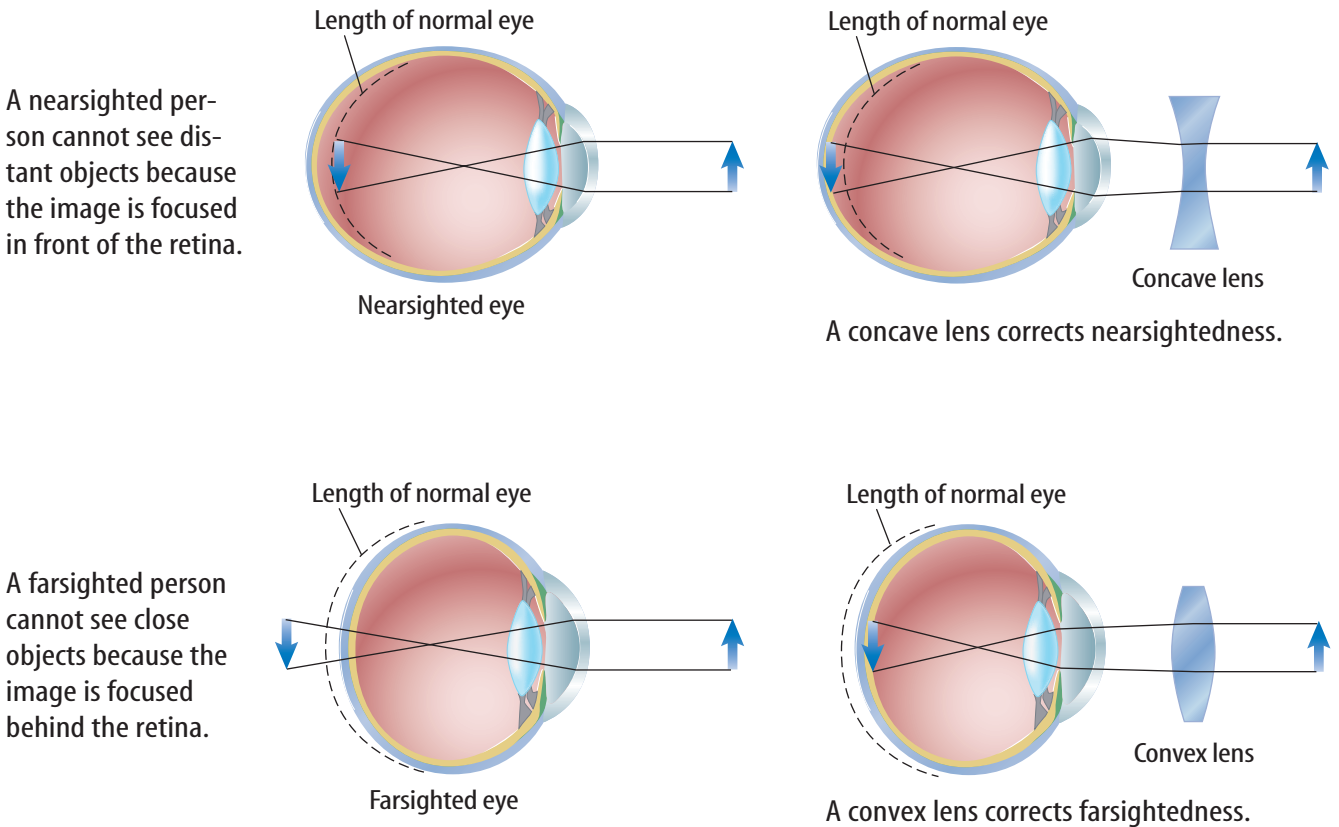


Figure 12 Light passing through a convex lens is refracted toward the center and passes through a focal point. Light that passes through a concave lens is refracted outward.

Name the type of lens found in a microscope.

Figure 13 Glasses and contact lenses sharpen your vision.



Correcting Vision Problems Do you wear contact lenses or eyeglasses to correct your vision? Are you nearsighted or farsighted? In an eye with normal vision, light rays are focused onto the retina by the coordinated actions of the eye muscles, the cornea, and the lens. The image formed on the retina is interpreted by the brain as being sharp and clear. However, if the eyeball is too long from front to back, as illustrated in **Figure 13**, light from objects is focused in front of the retina. This happens because the shape of the eyeball and lens cannot be changed enough by the eye muscles to focus a sharp image onto the retina. The image that reaches the retina is blurred. This condition is called nearsightedness—near objects are seen more clearly than distant objects. To correct nearsightedness, concave lenses are used to help focus images sharply on the retina.

Similarly, vision correction is needed when the eyeball is too short from front to back. In this case, light from objects is focused behind the retina despite the coordinated actions of the eye muscles, cornea, and lens. This condition is called farsightedness, also as illustrated in **Figure 13**, because distant objects are clearer than near objects. Convex lenses correct farsightedness.



Telescopes Refracting telescopes have two convex lenses for viewing objects in space. The larger lens collects light and forms an inverted, or upside-down, image of the object. The second lens magnifies the inverted image. In your Science Journal, hypothesize why telescopes used to view things on Earth have three lenses, not two.

Hearing

Whether it's the roar of a rocket launch, the cheers at a football game, or the distant song of a robin in a tree, sound waves are necessary for hearing sound. Sound energy is to hearing as light energy is to vision. When an object vibrates, sound waves are produced. These waves can travel through solids, liquids, and gases as illustrated in **Figure 14**. When the waves reach your ear, they usually stimulate nerve cells deep within your ear.

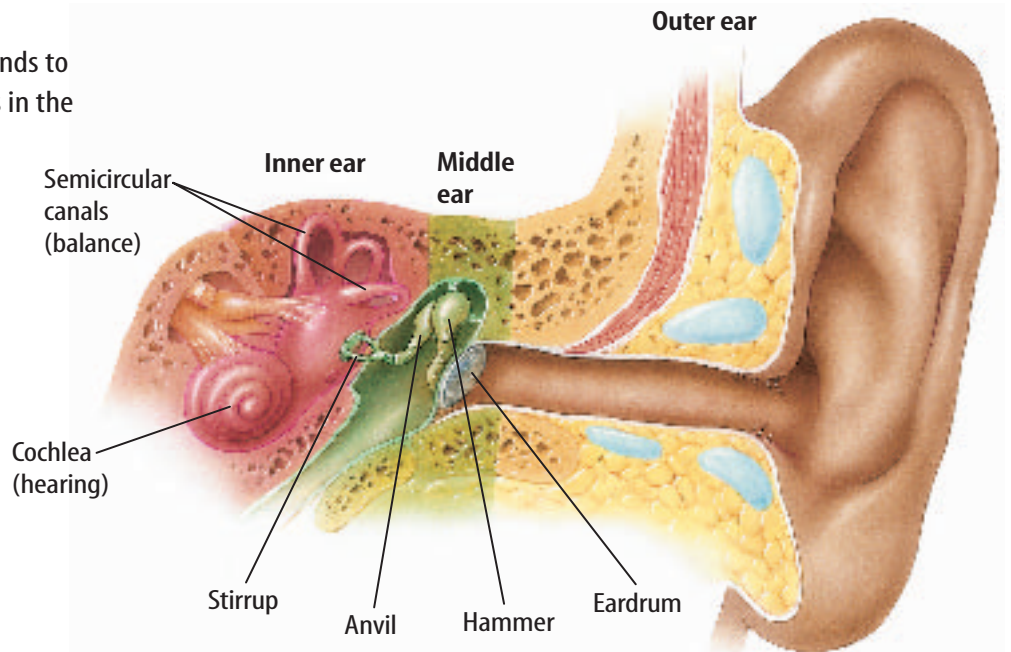
Impulses are sent to the brain. When the sound impulse reaches the hearing area of the cortex, it responds and you hear a sound.



Figure 14 Objects produce sound waves that can be heard by your ears.

The Outer Ear and Middle Ear **Figure 15** shows that your ear is divided into three sections—the outer ear, middle ear, and inner ear. Your outer ear intercepts sound waves and funnels them down the ear canal to the middle ear. The sound waves cause the eardrum to vibrate much like the membrane on a musical drum vibrates when you tap it. These vibrations then move through three tiny bones called the hammer, anvil, and stirrup. The stirrup bone rests against a second membrane on an opening to the inner ear.

Figure 15 Your ear responds to sound waves and to changes in the position of your head.



Mini LAB

Observing Balance Control

Procedure

1. Place **two narrow strips of paper** on the wall to form two parallel vertical lines 20–25 cm apart. Have a person stand between them for 3 min, without leaning on the wall.
2. Observe how well balance is maintained.
3. Have the person close his or her eyes, then stand within the lines for 3 min.

Analysis

1. When was balance more difficult to maintain? Why?
2. What other factors might cause a person to lose his or her sense of balance?



The Inner Ear The **cochlea** (KOH klee uh) is a fluid-filled structure shaped like a snail's shell. When the stirrup vibrates, fluids in the cochlea begin to vibrate. These vibrations bend hair cells in the cochlea, which causes electrical impulses to be sent to the brain by a nerve. High-pitched sounds make the endings move differently than lower sounds do. Depending on how the nerve endings are stimulated, you hear a different type of sound.

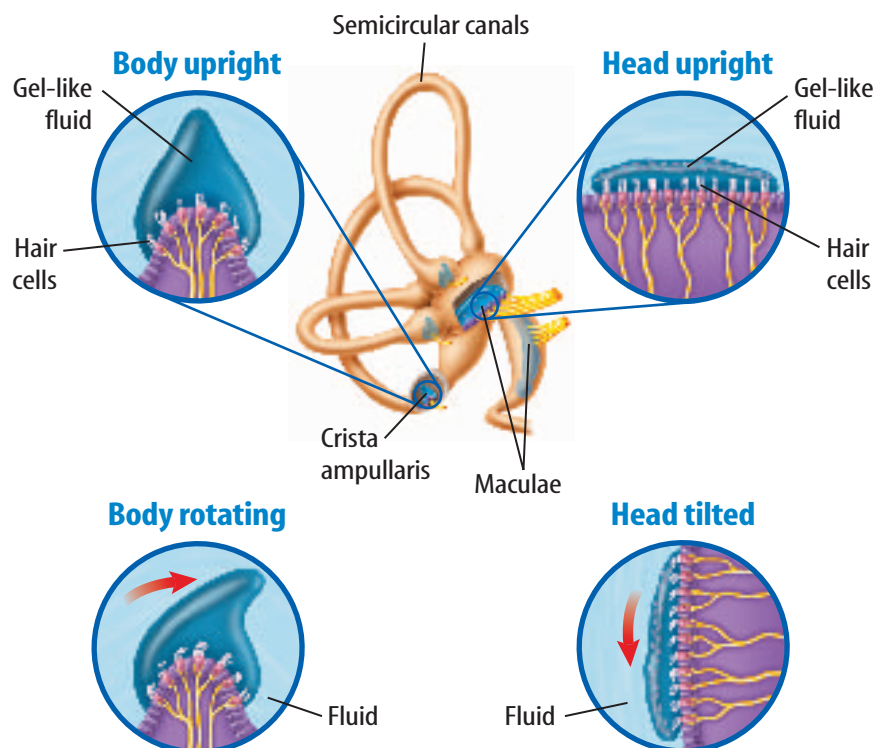
Balance Structures in your inner ear also control your body's balance. Structures called the cristae ampullaris (KRIHS tee • am pyew LEER ihs) and the maculae (MA kyah lee), illustrated in **Figure 16**, sense different types of body movement.

Both structures contain tiny hair cells. As your body moves, gel-like fluid surrounding the hair cells moves and stimulates the nerve cells at the base of the hair cells. This produces nerve impulses that are sent to the brain, which interprets the body movements. The brain, in turn, sends impulses to skeletal muscles, resulting in other body movements that maintain balance.

The cristae ampullaris react to rotating body movements. Fluid in the semicircular canals swirls when the body rotates. This causes the gel-like fluid around the hair cells to move and a stimulus is sent to the brain. In a similar way, when the head tips, the gel-like fluid surrounding the hair cells in the maculae is pulled down by gravity. The hair cells are then stimulated and the brain interprets that the head has tilted.

Figure 16 In your inner ear, the cristae ampullaris react to rotating movements of your body, and the maculae check the position of your head with respect to the ground.

Explain why spinning around makes you dizzy.



Smell

Some sharks can sense as few as ten drops of tuna liquid in an average-sized swimming pool. Even though your ability to detect odors is not as good as a shark's, your sense of smell is still important. Smell can determine which foods you eat. Strong memories or feelings also can be responses to something you smell.

You smell food because it gives off molecules into the air. These molecules stimulate sensitive nerve cells, called **olfactory** (ohl FAK tree) **cells**, in your nasal passages. Olfactory cells are kept moist by mucus. When molecules in the air dissolve in this moisture, the cells become stimulated. If enough molecules are present, an impulse starts in these cells, then travels to the brain where the stimulus is interpreted. If the stimulus is recognized from a previous experience, you can identify the odor. If you don't recognize a particular odor, it is remembered and may be identified the next time you encounter it.



Topic: Sense of Smell

Visit bookd.msscience.com for Web links to information about the sense of smell in humans compared to that of other mammals.

Activity In your Science Journal, summarize your research.

Applying Math Solve a One-Step Equation

SPEED OF SOUND You see the flash of fireworks and then four seconds later, you hear the boom because light waves travel faster than sound waves. Light travels so fast that you see it almost instantaneously. Sound, on the other hand, travels at 340 m/s. How far away are you from the source of the fireworks?

Solution

- 1** *This is what you know:*
 - time: $t = 4$ s; speed of sound: $v = 340$ m/s
- 2** *This is what you need to find out:*

How far are you away from the fireworks?
- 3** *This is the procedure you need to use:*
 - Use the equation: $d = vt$
 - Substitute known values and solve:
 $d = (340 \text{ m/s})(4 \text{ s})$
 $d = 1360 \text{ m}$
- 4** *Check your answer:*

Divide your answer by time. You should get speed.

Practice Problems

1. A hiker standing at one end of a lake hears his echo 2.5 s after he shouts. It was reflected by a cliff at the end of the lake. How long is the lake?
2. If you see a flash of lightning during a thunderstorm and it takes 5 s to hear the thunder, how far away is the lightning?



For more practice, visit
[bookd.msscience.com/
math_practice](http://bookd.msscience.com/math_practice)

Comparing Sense of Smell

Procedure

1. To test your classmates' abilities to recognize different odors, blindfold them one at a time, then pass near their noses small **samples of different foods, colognes, or household products.**
WARNING: Do not eat or drink anything in the lab. Do not use any products that give off noxious fumes.
2. Ask each student to identify the different samples.
3. Record each student's response in a data table according to his or her gender.

Analysis

1. Compare the numbers of correctly identified odors for males and females.
2. What can you conclude about the differences between males and females in their abilities to recognize odors?

Figure 17 Taste buds are made up of a group of sensory cells with tiny taste hairs projecting from them. When food is taken into the mouth, it is dissolved in saliva. This mixture then stimulates receptor sites on the taste hairs, and an impulse is sent to the brain.

Taste

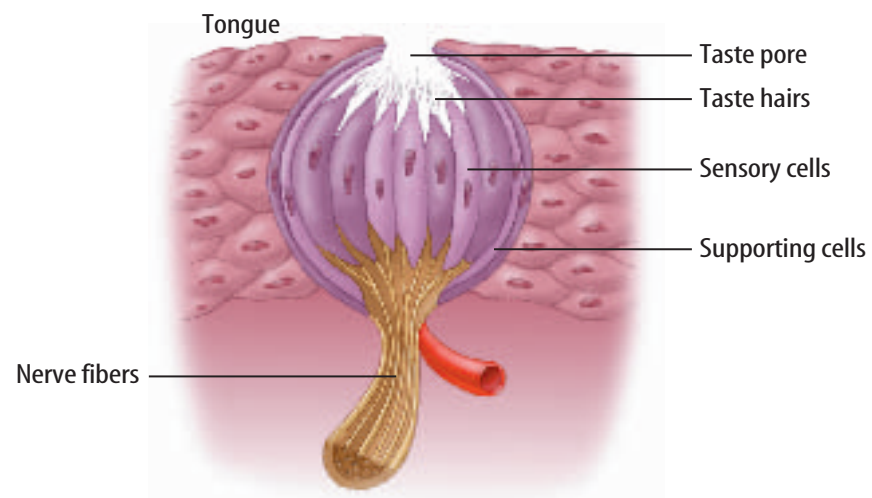
Sometimes you taste a new food with the tip of your tongue and find that it tastes sweet. Then when you chew it, you are surprised to find that it tastes bitter. **Taste buds** on your tongue, like the one in **Figure 17**, are the major sensory receptors for taste. About 10,000 taste buds are found all over your tongue, enabling you to tell one taste from another.

Tasting Food Taste buds respond to chemical stimuli. Most taste buds respond to several taste sensations. However, certain areas of the tongue are more receptive to one taste than another. The five taste sensations on the tongue are sweet, salty, sour, bitter, and the taste of MSG (monosodium glutamate). When you think of hot french fries, your mouth begins to water. This response is helpful because in order to taste something, it has to be dissolved in water. Saliva begins this process. This solution of saliva and food washes over the taste buds, and impulses are sent to your brain. The brain interprets the impulses, and you identify the tastes.

Reading Check

What needs to happen to food before you are able to taste it?

Smell and Taste Smell and taste are related. The sense of smell is needed to identify some foods such as chocolate. When saliva in your mouth mixes with the chocolate, odors travel up the nasal passage in the back of your throat. The olfactory cells are stimulated, and the taste and smell of chocolate are sensed. So when you have a stuffy nose and some foods seem tasteless, it may be because the food's molecules are blocked from contacting the olfactory cells in your nasal passages.



Other Sensory Receptors in the Body

As you are reading at school, you suddenly experience a bad pain in your lower right abdomen. The pain is not going away and you yell for help. Several hours later, you are resting in a hospital bed. The doctor has removed the source of your problem—your appendix. If not removed, a burst appendix can spread poison throughout your body.

Your internal organs have several kinds of sensory receptors. These receptors respond to touch, pressure, pain, and temperature. They pick up changes in touch, pressure, and temperature and transmit impulses to the brain or spinal cord. In turn, your body responds to this new information.

Sensory receptors also are located throughout your skin. As shown in **Figure 18**, your fingertips have many different types of receptors for touch. As a result, you can tell whether an object is rough or smooth, hot or cold, and hard or soft. Your lips are sensitive to heat and prevent you from drinking something so hot that it would burn you. Pressure-sensitive skin cells warn you of danger and enable you to move to avoid injury.

The body responds to protect itself from harm. All of your body's senses work together to maintain homeostasis. Your senses help you enjoy or avoid things around you. You constantly react to your environment because of information received by your senses.



Figure 18 Many of the sensations picked up by receptors in the skin are stimulated by mechanical energy. Pressure, motion, and touch are examples.

section 2 review

Summary

Vision

- Light causes impulses that pass to the optic nerve. Your brain interprets the image.

Lenses

- Convex lenses and concave lenses are used to correct vision.

Hearing

- Sound waves stimulate nerve cells in the inner ear.
- Structures in the inner ear sense body movements.

Smell

- Molecules in the air stimulate nasal nerve cells, which allow you to smell.

Taste

- Taste buds are sensory receptors.

Self Check

1. **List** the types of stimuli your ears respond to.
2. **Describe** the sensory receptors for the eyes and nose.
3. **Explain** why it is important to have sensory receptors for pain and pressure in your internal organs.
4. **Outline** the role of saliva in tasting.
5. **Think Critically** Unlike many other organs, the brain is insensitive to pain. What is the advantage of this?

Applying Skills

6. **Make and Use Tables** Organize the information on senses in a table that names the sense organs and which stimuli they respond to.
7. **Communicate** Write a paragraph in your Science Journal that describes what each of the following objects would feel like: ice cube, snake, silk blouse, sandpaper, jelly, and smooth rock.

Skin Sensitivity

Goals

- **Observe** the sensitivity to touch on specific areas of the body.
- **Design** an experiment that tests the effects of a variable, such as how close the contact points are, to determine which body areas can distinguish which stimuli are closest to one another.

Possible Materials

3-in × 5-in index card
toothpicks
tape
*glue
metric ruler
*Alternate materials

Safety Precautions



WARNING: Do not apply heavy pressure when touching the toothpicks to the skin of your classmates.

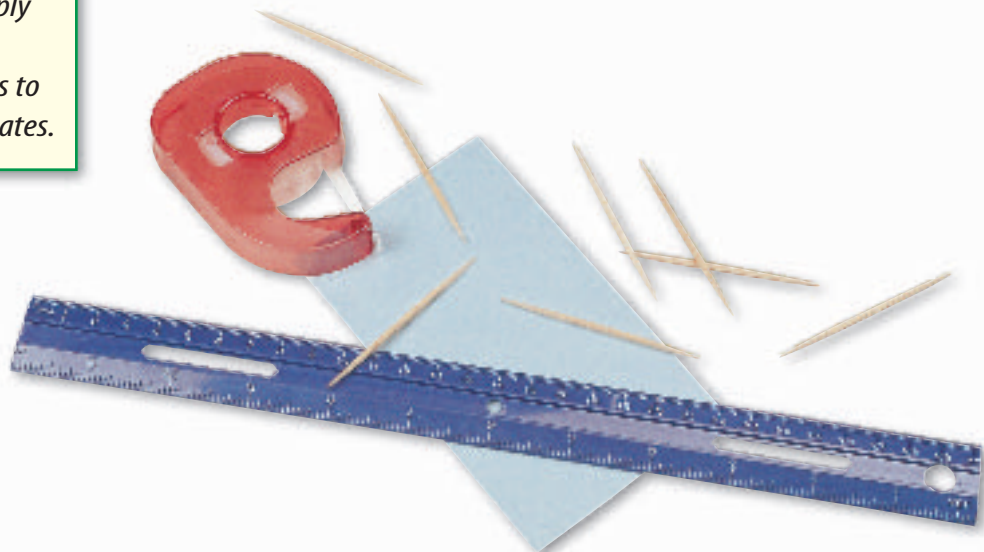
Real-World Question

Your body responds to touch, pressure, temperature, and other stimuli. Not all parts of your body are equally sensitive to stimuli. Some areas are more sensitive than others are. For example, your lips are sensitive to heat. This protects you from burning your mouth and tongue. Now think about touch. How sensitive is the skin on various parts of your body to touch? Which areas can distinguish the smallest amount of distance between stimuli? What areas of the body are most sensitive to touch?



Form a Hypothesis

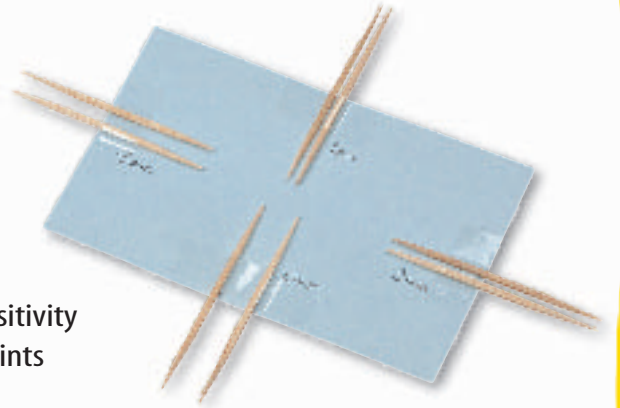
Based on your experiences, state a hypothesis about which of the following five areas of the body—fingertip, forearm, back of the neck, palm, and back of the hand—you believe to be most sensitive. Rank the areas from 5 (most sensitive) to 1 (least sensitive).



▶ Test Your Hypothesis

Make a Plan

1. As a group, agree upon and write the hypothesis statement.
2. As a group, list the steps you need to test your hypothesis. Describe exactly what you will do at each step. Consider the following as you list the steps. How will you know that sight is not a factor? How will you use the card shown on the right to determine sensitivity to touch? How will you determine that one or both points are sensed?
3. **Design** a data table in your Science Journal to record your observations.
4. Reread your entire experiment to make sure that all steps are in the correct order.
5. **Identify** constants, variables, and controls of the experiment.



Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Carry out the experiment as planned.
3. While the experiment is going on, write down any observations that you make and complete the data table in your Science Journal.

▶ Analyze Your Data

1. **Identify** which part of the body is least sensitive and which part is most sensitive.
2. **Identify** which part of the body tested can distinguish between the closest stimuli.
3. **Compare** your results with those of other groups.
4. Rank body parts tested from most to least sensitive. Did your results from this investigation support your hypothesis? Explain.

▶ Conclude and Apply

1. Based on the results of your investigation, what can you infer about the distribution of touch receptors on the skin?
2. What other parts of your body would you predict to be less sensitive? Explain your predictions.

Communicating Your Data

Write a report to share with your class about body parts of animals that are sensitive to touch. For more help, refer to the **Science Skill Handbook**.

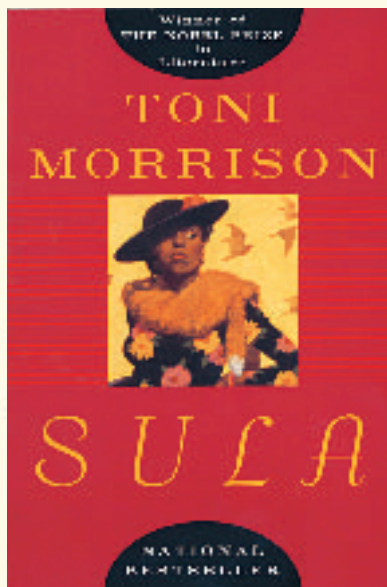
Sula

by Toni Morrison

In the following passage from Sula, a novel by Toni Morrison, the author describes Nel's response to the arrival of her old friend Sula.

Nel alone noticed the peculiar quality of the May that followed the leaving of the birds. It had a sheen, a glimmering as of green, rain-soaked Saturday nights (lit by the excitement of newly installed street lights); of lemon-yellow afternoons bright with iced drinks and splashes of daffodils. It showed in the damp faces of her children and the river-smoothness of their voices. Even her own body was not immune to the magic. She would sit on the floor to sew as she had done as a girl, fold her legs up under her or do a little dance that fitted some tune in her head. There were easy sun-washed days and purple dusks

Although it was she alone who saw this magic, she did not wonder at it. She knew it was all due to Sula's return to the Bottom.



Understanding Literature

Diction and Tone An author's choice of words, or diction, can help convey a certain tone in the writing. In the passage, Toni Morrison's word choices help the reader understand that the character Nel is enjoying the month of May. Find two more examples in which diction conveys a pleasant tone.

Respond to the Reading

1. Describe, in your own words, how Nel feels about the return of her friend Sula.
2. What parts of the passage help you determine Nel's feelings?
3. **Linking Science and Writing** Write a paragraph describing the month of January that clearly shows a person's dislike for the month.



In the passage, Nel has a physical reaction to her environment. She is moved to "do a little dance" in response to the sights and sounds of May. This action is an example of a voluntary response to stimuli from outside the body. Movement of the body is a coordinated effort of the skeletal, muscular, and nervous system. Nel can dance because motor neurons conduct impulses from the brain to her muscles.

Reviewing Main Ideas

Section 1 The Nervous System

1. Your body constantly is receiving a variety of stimuli from inside and outside the body. The nervous system responds to these stimuli to maintain homeostasis.
2. A neuron is the basic unit of structure and function of the nervous system.
3. A stimulus is detected by sensory neurons. Electrical impulses are carried to the interneurons and transmitted to the motor neurons. The result is the movement of a body part.
4. A response that is made automatically is a reflex.
5. The central nervous system contains the brain and spinal cord. The peripheral nervous system is made up of cranial and spinal nerves.

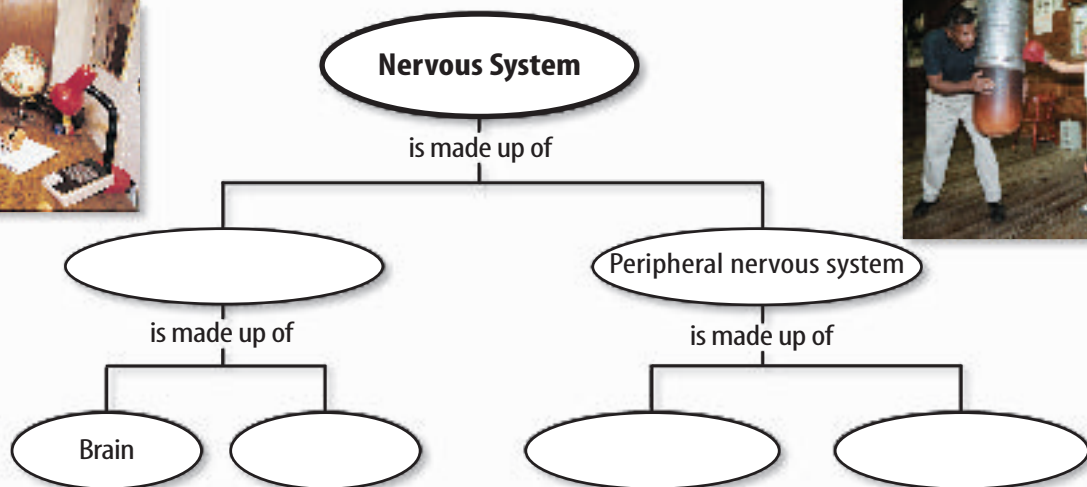
6. Many drugs, such as alcohol and caffeine, have a direct effect on your nervous system.

Section 2 The Senses

1. Your senses respond to stimuli. The eyes respond to light energy, and the ears respond to sound waves.
2. Olfactory cells of the nose and taste buds of the tongue are stimulated by chemicals.
3. Sensory receptors in your internal organs and skin respond to touch, pressure, pain, and temperature.
4. Your senses enable you to enjoy or avoid things around you. You are able to react to the changing conditions of your environment.

Visualizing Main Ideas

Copy and complete the following concept map about the nervous system.



Using Vocabulary

axon p.119	neuron p.119
brain stem p.122	olfactory cell p.133
central nervous system p.121	peripheral nervous system p.121
cerebellum p.122	reflex p.125
cerebrum p.122	retina p.129
cochlea p.132	synapse p.121
dendrite p.119	taste bud p.134
homeostasis p.119	

Explain the difference between the vocabulary words in each of the following sets.

- axon—dendrite
- central nervous system—peripheral nervous system
- cerebellum—cerebrum
- reflex—synapse
- brain stem—neuron
- olfactory cell—taste bud
- dendrite—synapse
- cerebrum—central nervous system
- retina—cochlea
- synapse—neuron

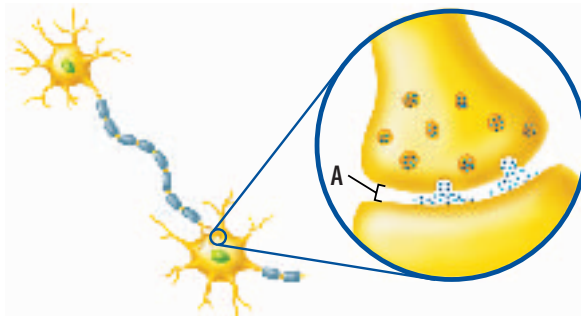
Checking Concepts

Choose the word or phrase that best answers the question.

- How do impulses cross synapses between neurons?
 - by osmosis
 - through interneurons
 - through a cell body
 - by a chemical
- Which of the following is in the inner ear?
 - anvil
 - hammer
 - eardrum
 - cochlea

- What are neurons called that detect stimuli in the skin and eyes?
 - interneurons
 - synapses
 - motor neurons
 - sensory neurons
- Which of the following does the skin not sense?
 - pain
 - pressure
 - temperature
 - taste
- What part of the brain controls voluntary muscles?
 - cerebellum
 - brain stem
 - cerebrum
 - pons
- What part of the brain has an outer layer called the cortex?
 - pons
 - brain stem
 - cerebrum
 - spinal cord
- What does the somatic system of the PNS control?
 - skeletal muscles
 - heart
 - glands
 - salivary glands
- What part of the eye is light finally focused on?
 - lens
 - retina
 - pupil
 - cornea
- What is the largest part of the brain?
 - cerebellum
 - brain stem
 - cerebrum
 - pons

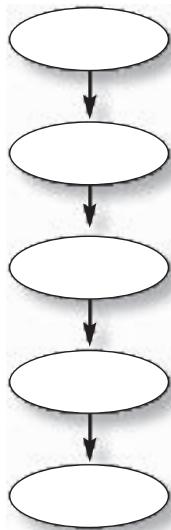
Use the illustration below to answer question 20.



- What is the name given to A?
 - axon
 - dendrite
 - synapse
 - nucleus

Thinking Critically

- 21. **Describe** why it is helpful to have impulses move only in one direction in a neuron.
- 22. **Describe** how smell and taste are related.
- 23. **Form a Hypothesis** If a fly were to land on your face and another one on your back, which might you feel first? How could you test your choice?
- 24. **Concept Map** Copy and complete this events-chain concept map to show the correct sequence of the structures through which light passes in the eye.



- 25. **Classify** Group the types of neurons as to their location and direction of impulse.
- 26. **Compare and contrast** the structures and functions of the cerebrum, cerebellum, and brain stem. Include in your discussion the following functions: balance, involuntary muscle movements, muscle tone, memory, voluntary muscles, thinking, and senses.
- 27. **Draw Conclusions** If an impulse traveled down one neuron but failed to move on to the next neuron, what might you conclude about the first neuron?

Performance Activities

- 28. **Illustrate** In an emergency room, the doctor notices that a patient has uncoordinated body movements and has difficulty maintaining his balance. Draw and label the part of the brain that may have been injured.

Applying Math

- 29. **Sound Waves** How deep is a cave if you shout into the cave and it takes 1.5 seconds to hear your echo? Remember that the speed of sound is 340 m/s.

Use the paragraph and table below to answer question 30.

A police officer brought the following table into a school to educate students about the dangers of drinking and driving.

Approximate Blood Alcohol Percentage for Men

Drinks	Body Weight in Kilograms							
	45.4	54.4	63.5	72.6	81.6	90.7	99.8	108.9
1	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
2	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03
3	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05
4	0.15	0.12	0.11	0.09	0.08	0.08	0.07	0.06
5	0.19	0.16	0.13	0.12	0.11	0.09	0.09	0.08

Subtract 0.01% for each 40 minutes of drinking. One drink is 40 mL of 80-proof liquor, 355 mL of beer, or 148 mL of table wine.

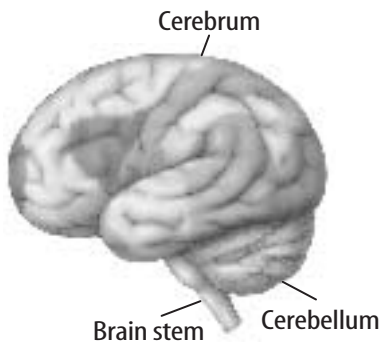
- 30. **Blood Alcohol** A 72-kg man has been tested for blood alcohol content. His blood alcohol percentage is 0.07. Based upon the information in the table above, about how much has he had to drink?
 - A) 628 mL of 80-proof liquor
 - B) 1,064 mL of beer
 - C) 295 mL of table wine
 - D) four drinks

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- An internal or external change that brings about a response is called a
 - reflex.
 - stimulus.
 - receptor.
 - heartbeat.

Use the illustration below to answer questions 2–4.



- Which part of the brain helps in maintaining balance?
 - cerebrum
 - cerebellum
 - brain stem
 - no brain region
- Which part of the brain controls involuntary actions?
 - cerebrum
 - cerebellum
 - brain stem
 - no brain region
- In which part of the brain is memory stored?
 - cerebrum
 - cerebellum
 - brain stem
 - no brain region
- Which of the following structures helps control the body's balance?
 - retina
 - eardrum
 - cochlea
 - cristae ampullaris

Test-Taking Tip

Focus On Your Test During the test, keep your eyes on your own paper. If you need to rest them, close them or look up at the ceiling.

Use the table below to answer questions 6 and 7.

Approximate Blood Alcohol Percentage for Men								
Drinks	Body Weight in Kilograms							
	45.4	54.4	63.5	72.6	81.6	90.7	99.8	108.9
1	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
2	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03
3	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05
4	0.15	0.12	0.11	0.09	0.08	0.08	0.07	0.06
5	0.19	0.16	0.13	0.12	0.11	0.09	0.09	0.08

Subtract 0.01% for each 40 minutes of drinking. One drink is 40 mL of 80-proof liquor, 355 mL of beer, or 148 mL of table wine.

- In Michigan, it is illegal for drivers under 21 years of age to drink alcohol. Underage drivers can be arrested for drinking and driving if their blood alcohol percentage is more than 0.02 percent. According to this information, how many drinks would it take a 72-kg man to exceed this limit?
 - three
 - two
 - one
 - zero
- In some states, the legal blood alcohol percentage limit for driving while under the influence of alcohol is 0.08 percent. According to this information, how many drinks would a 54-kg man have to consume to exceed this limit?
 - four
 - three
 - two
 - one
- What neurons conduct impulses from the brain to glands?
 - dendrites
 - interneurons
 - sensory neurons
 - motor neurons
- What carries impulses from the eye to the vision area of the brain?
 - visual cortex
 - optic nerve
 - sensory neurons
 - dendrites

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- 10.** Meningitis is an infection of the fluid that surrounds the spinal cord and the brain. Meningitis can be caused by bacteria or viruses. In bacterial meningitis, the amount of fluid in the brain and spinal cord may increase. What do you think might happen if the amount of fluid increases?

Use the table below to answer questions 11–13.

Number of Bicycle Deaths per Year		
Year	Male	Female
1996	654	107
1997	712	99
1998	658	99
1999	656	94
2000	605	76

Data from Insurance Institute for Highway Safety

- 11.** Head injuries are the most serious injuries that are found in people who died in bicycle accidents. Ninety percent of the deaths were in people who were not wearing bicycle helmets. Using the data in the table, approximately how many of the people (male and female) who died in bicycle accidents in 1998 were wearing bicycle helmets?
- 12.** In 2000, what percentage of the people who died were women?
- 13.** Which of the years from 1996 to 2000 had the greatest total number of bicycle deaths?
- 14.** Jeremy used a magnifying lens to study an earthworm. What kind of lens did he use? What part of this type of lens is the thickest?
- 15.** Explain why alcohol is classified as a depressant.

Part 3 Open Ended

Record your answers on a sheet of paper.

- 16.** Compare and contrast the somatic and autonomic systems.

Use the illustration below to answer question 17.



- 17.** Identify the structure in the illustration. Explain what might happen if chemical was not released here.
- 18.** Inez and Maria went to the ice cream parlor. They both ordered strawberry sundaes. Marie thought that the sundae was made with fresh strawberries, because it tasted so great. Inez thought that her sundae did not have much flavor. What could be the reason that Inez's sundae was tasteless? Explain why.

Use the illustration below to answer question 19.



- 19.** The person with this foot sore has diabetes. People with diabetes often lose sensation in their feet. Explain why a sore like the one in the photograph might develop if skin sensory receptors were not working properly.