

UNIT
3

The Workings of Mind and Body

Contents

- Chapter 6** **Body and Behavior**
- Chapter 7** **Altered States of
Consciousness**
- Chapter 8** **Sensation and
Perception**

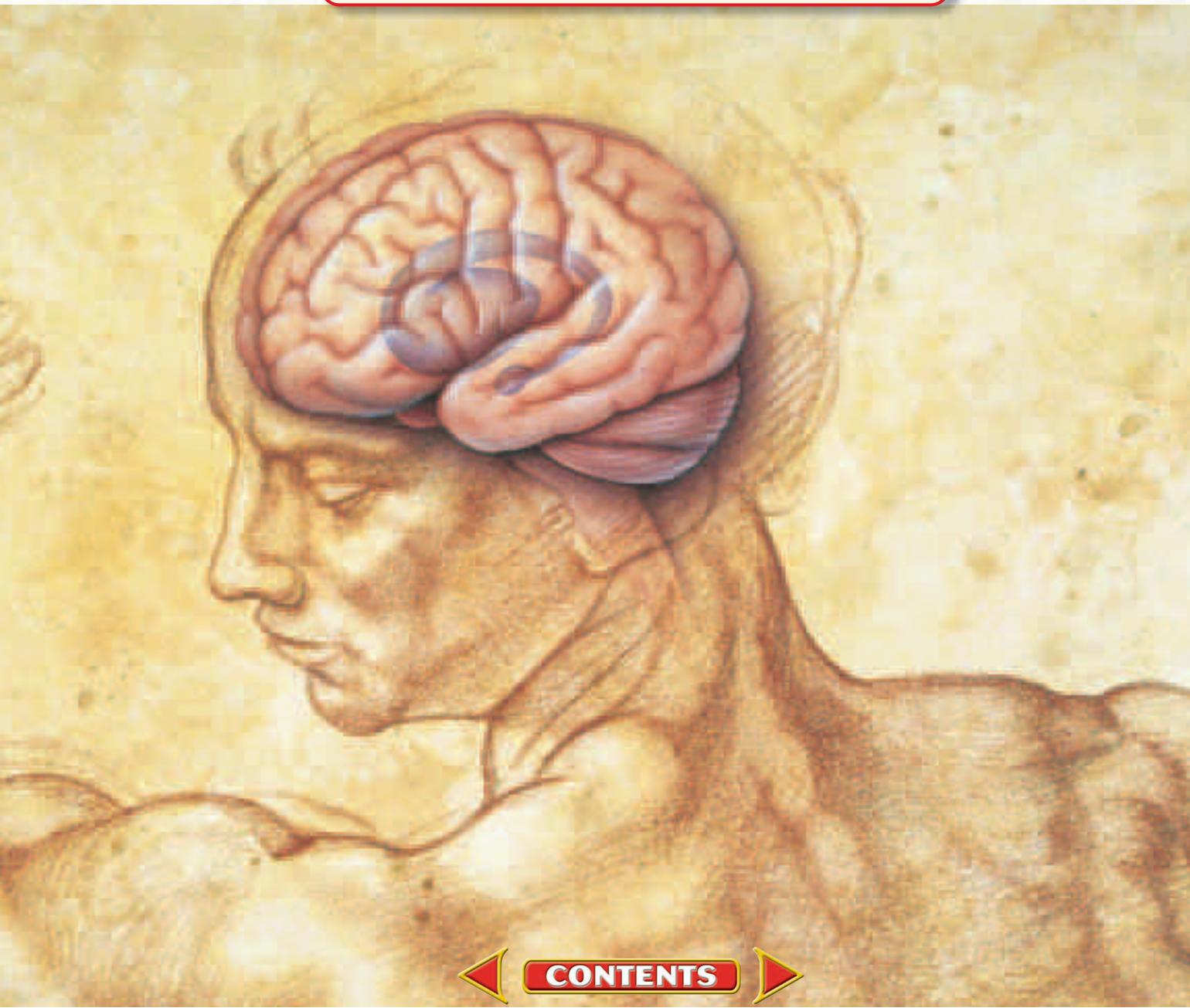


Sketch of the human
brain and body ▶

◀ **CONTENTS** ▶

Why It's Important

P sychology is the study of what the nervous system does. The nervous system produced by your genes interacts with the environment to produce your behaviors. Your thoughts, emotions, memories, intelligence, and creativity are based on biological processes that take place within and between cells.



◀ **CONTENTS** ▶

CHAPTER
6

Body and Behavior

PSYCHOLOGY JOURNAL

Ask yourself why it is important for psychologists to study the brain and nervous system. Write your answer to this question in your journal and justify your response. ■

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Chapter Overview

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The Nervous System: The Basic Structure

Reader's Guide

■ Main Idea

Learning about the nervous system helps us know how messages that are sent to the brain cause behavior.

■ Vocabulary

- central nervous system (CNS)
- spinal cord
- peripheral nervous system (PNS)
- neurons
- synapse
- neurotransmitters
- somatic nervous system (SNS)
- autonomic nervous system (ANS)

■ Objectives

- Identify the parts of the nervous system.
- Describe the functions of the nervous system.

EXPLORING PSYCHOLOGY

Have You Experienced the Runner's High?

It's almost like running is this great friend we both share . . . Anyway, that's what I'd like to talk to you about . . . running as a friend, a companion, a lover even . . . in other words, the relationship of running. "WHAT!?" many of you will be saying, "I thought that I was going to learn how to improve my 10k time." Go read *Runner's World* for that. You see, I don't view running as what I DO or who I AM, but as this thing, this force, that changes me over time. . . .

—from "Running and Me: A Love Story" by Joan Nesbit, 1999

Why does the writer above love running so much? One of the reasons may be that people who do a lot of running for exercise, especially long-distance running, often talk of an effect called a "runner's high." The longer they run, the more tired they get, of course; but at some point, the runners will "push through the wall" and "get their second wind." Why does this happen? Endorphins, which are neurotransmitters, produce the euphoria of a runner's high. As the body deals with a very physically stressful situation—running—the runner's body reacts to stress. So, in effect, running really does change you. In this section, you will learn how your nervous system can produce a runner's high.

HOW THE NERVOUS SYSTEM WORKS

The nervous system is never at rest. There is always a job for it to do. Even when you are sleeping the nervous system is busy regulating your body functions. The nervous system controls your emotions, movements, thinking, and behavior.

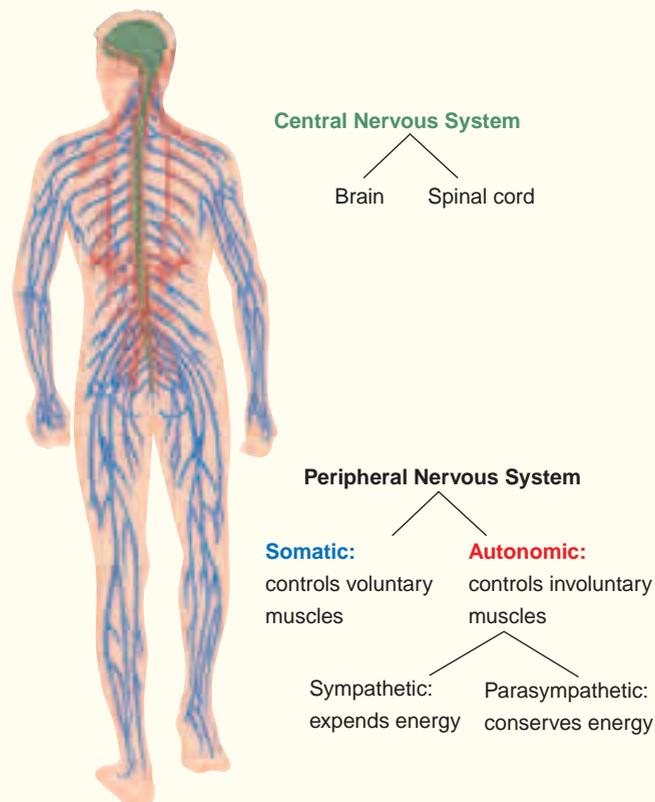
Structurally, the nervous system is divided into two parts—the **central nervous system [CNS]** (the brain and the **spinal cord**) and the **peripheral nervous system [PNS]** (the smaller branches of nerves that reach the other parts of the body) (see Figure 6.1). The nerves of the peripheral system conduct information from the bodily organs to the central nervous system and take information back to the organs. These nerves branch out from the spinal column and are about as thick as a pencil. Those in the extremities, such as the fingertips, are invisibly small. All parts of the nervous system are protected in some way: the brain by the skull and several layers of sheathing, the spinal cord by the vertebrae, and the peripheral nerves by layers of sheathing. The bony protection of the spinal cord is vital. An injury to the spinal cord could prevent the transmittal of messages between the brain and the muscles, and could result in paralysis.

central nervous system (CNS): the brain and spinal cord

spinal cord: nerves that run up and down the length of the back and transmit most messages between the body and brain

peripheral nervous system (PNS): nerves branching out from the spinal cord

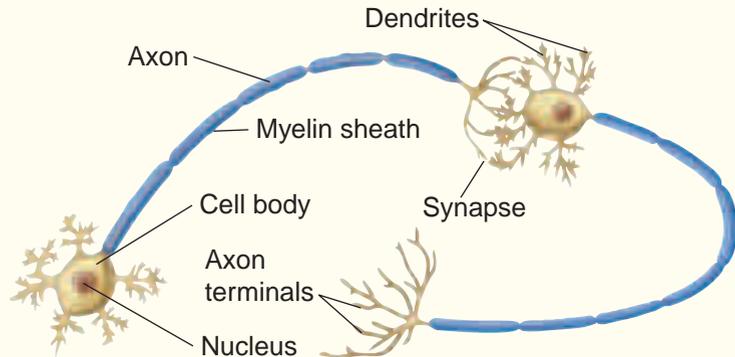
Figure 6.1 The Nervous System



The nervous system is divided into two parts: the central nervous system (CNS) and the peripheral nervous system (PNS). **What are the two main parts of the central nervous system?**



Photomicrograph of neuron



The human body contains billions of neurons. The neuron receives messages from other neurons on its dendrites. The messages are then transmitted down the axon and sent out through the axon terminals. The myelin sheath is wrapped around the axon to protect it. **What is the function of the dendrites?**

Neurons

Messages to and from the brain travel along the nerves, which are strings of long, thin cells called **neurons** (see Figure 6.2). Chemical-electrical signals travel down the neurons much as flame travels along a firecracker fuse. The main difference is that the neuron can fire (burn) over and over again, hundreds of times a minute.

Transmission between neurons, or nerve cells, occurs whenever the cells are stimulated past a minimum point and emit a signal. The neuron is said to fire in accord with the all-or-none principle, which states that when a neuron fires, it does so at full strength. If a neuron is not stimulated past the minimum, or threshold, level, it does not fire at all.

Basic Parts of a Neuron Neurons have three basic parts: the cell body, dendrites, and the axon (see Figure 6.2). The cell body contains the nucleus and produces the energy needed to fuel neuron activity. The *dendrites* are short, thin fibers that stick out from the cell body. Dendrites receive impulses, or messages, from other neurons and send them to the cell body. The *axon* is a long fiber that carries the impulses away from the cell body toward the dendrites of the next neuron. Axons can be very short or several feet in length.

A white, fatty substance called the *myelin sheath* insulates and protects the axon for some neurons. In cases of multiple sclerosis, the myelin sheath is destroyed, and as a result, the behavior of the person is erratic and uncoordinated. The myelin sheath also speeds the transmission of impulses. Small fibers, called *axon terminals*, branch out at the end of the axon. Axon terminals are positioned opposite the dendrite of another neuron.

The Neuron Connection If you look closely at Figure 6.2, you can see that there is a space between the axon terminals of one neuron and the dendrites of another neuron. This space between neurons is called the **synapse**. The synapse is a junction or connection between the neurons (see Figure 6.3). A neuron transmits its impulses or message to another neuron across the

neurons: the long, thin cells of nerve tissue along which messages travel to and from the brain

 **Reading Check**
What are the three basic parts of a neuron?

synapse: the gap that exists between individual nerve cells

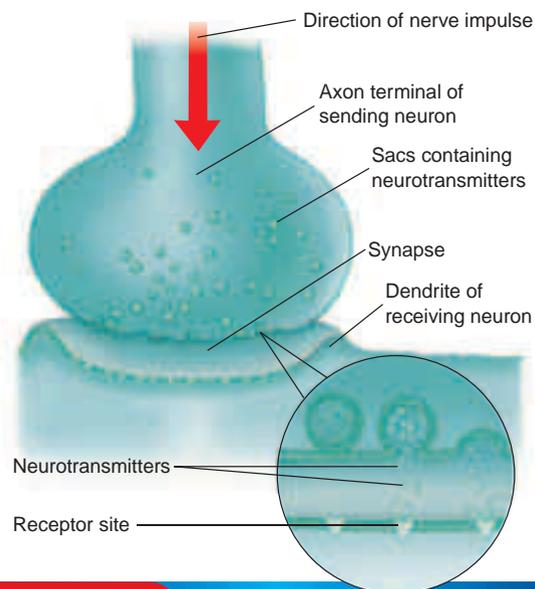


Figure 6.3 The Synapse

Neurons do not touch one another. Instead, a neuron sends its messages across a gap called a synapse by releasing neurotransmitters. These neurotransmitters are received by the dendrite of another neuron. **How are neurons involved in sending a message to the brain to raise your arm to answer a question?**

neurotransmitters: the chemicals released by neurons, which determine the rate at which other neurons fire

somatic nervous system (SNS): the part of the peripheral nervous system that controls voluntary movement of skeletal muscles

autonomic nervous system (ANS): the part of the peripheral nervous system that controls internal biological functions

sensory neurons, relay messages from the sense organs (including eye, ear, nose, and skin) to the brain. The *effluent* neurons, or motor neurons, send signals from the brain to the glands and muscles. The *interneurons* carry impulses between neurons in the body.

Voluntary and Involuntary Activities

Some of the actions that your body makes in response to impulses from the nerves are voluntary acts, such as lifting your hand to turn a page (which actually involves many impulses to many muscles). Others are involuntary acts, such as changes in the heartbeat, in the blood pressure, or in the size of the pupils. The term **somatic nervous system (SNS)** refers to the part of the peripheral nervous system that controls voluntary activities. The term **autonomic nervous system (ANS)** refers to the part of the nervous system that controls involuntary activities, or those that ordinarily occur automatically, such as heartbeat, stomach activity, and so on.

The autonomic nervous system has two parts: the sympathetic and parasympathetic nervous systems. The sympathetic nervous system prepares the body for dealing with emergencies or strenuous activity. It

synapse by releasing chemicals called **neurotransmitters**. These neurotransmitters open chemical locks or excite the receptors. The neurotransmitters can excite the next neuron or stop it from transmitting (inhibition). The neurotransmitters are like the valves in a water system that allow flow in only one direction. There are many different neurotransmitters; for example, *norepinephrine* is involved with memory and learning, and *endorphin* inhibits pain. The oversupply or undersupply of certain neurotransmitters has been linked to certain diseases. For instance, an undersupply of *acetylcholine*, a neurotransmitter involved in movement and memory, is associated with paralysis and Alzheimer's disease. An oversupply of *dopamine*, involved in learning, emotional arousal, and movement, is linked to schizophrenia, while an undersupply is linked to Parkinson's disease. An undersupply of norepinephrine and *serotonin* may result in depression.

Neuron Activity The intensity of activity in each neuron depends on how many other neurons are acting on it. Each individual neuron is either ON or OFF, depending on whether most of the neurons acting on it are exciting it or inhibiting it. The actual destination of nerve impulses produced by an excited neuron, as they travel from one neuron to another, is limited by what tract in the nervous system they are on. Ascending tracts carry sensory impulses to the brain, and descending tracts carry motor impulses from the brain. There are different types of neurons. The *afferent* neurons, or

speeds up the heart to hasten the supply of oxygen and nutrients to body tissues. It constricts some arteries and relaxes others so that blood flows to the muscles, where it is most needed in emergencies and strenuous activity (such as running, thereby sometimes producing a runner's high). It increases the blood pressure and suspends some activities, such as digestion. In contrast, the parasympathetic nervous system works to conserve energy and to enhance the body's ability to recover from strenuous activity. It reduces the heart rate and blood pressure and helps bring the body back to its normal resting state.

All of this takes place automatically. Receptors are constantly receiving messages (hunger messages, the need to swallow or cough) that alert the autonomic nervous system to carry out routine activities. Imagine how difficult it would be if you had no autonomic nervous system and had to think about it every time your body needed to digest a sandwich or perspire.

Figure 6.4 Voluntary and Involuntary Activities

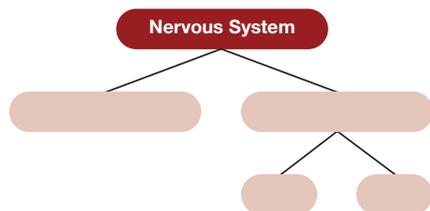
Climbing stairs is a voluntary activity. When the pupils of your eyes get smaller after they are exposed to brighter light, this is an involuntary activity. **What other involuntary activities take place in your body?**



SECTION I

Assessment

- 1. Review the Vocabulary** List and describe the parts of the neuron.
- 2. Visualize the Main Idea** In a diagram similar to the one below, list the divisions of the nervous system.
- 3. Recall Information** What is the difference between afferent and efferent neurons? What are interneurons?
- 4. Think Critically** Marty runs in marathons. Explain the functions of Marty's sympathetic and parasympathetic nervous systems during and after the race.



- 5. Application Activity** Put your pen or pencil down and then pick it up again. Identify and describe the parts of the nervous system that caused those movements to happen.

Reader's Guide

■ Main Idea

There are many parts in the human brain that work together to coordinate movement and stimulate thinking and emotions, resulting in behavior.

■ Vocabulary

- hindbrain
- midbrain
- forebrain
- lobes
- electroencephalograph (EEG)
- computerized axial tomography (CAT)
- positron emission tomography (PET)
- magnetic resonance imaging (MRI)

■ Objectives

- Identify the structure and functions of the human brain.
- Discuss the different ways psychologists study the brain.

EXPLORING PSYCHOLOGY

Origins of Thoughts

Early Greeks were not impressed with the brain. They suggested that the brain's main function was to cool the blood. They were much more impressed by the heart. They proposed that the heart was the source of feelings and thoughts. Hippocrates, however, observed the effect of head injuries on people's thoughts and actions and noted, "[F]rom the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear. . . . Eyes, ears, tongue, hands and feet act in accordance with the discernment [judgment] of the brain."

—adapted from *Psychology* by Peter Gray, 1999

Greek physician Hippocrates was right. In the 24 centuries since his observations, many attempts have been made to explain how the mass of soggy gray tissue known as the human brain could create the theory of relativity, the Sistine Chapel ceiling, and the energy crisis. The mind, however, remains a mystery to itself.

THE THREE BRAINS

The brain is composed of three parts: the hindbrain, midbrain, and forebrain (see Figure 6.5). The **hindbrain**, located at the rear base of the skull, is involved in the most basic processes of life. The hindbrain

hindbrain: a part of the brain located at the rear base of the skull that is involved in the basic processes of life

includes the *cerebellum*, *medulla*, and the *pons*. The cerebellum, located behind the spinal cord, helps control posture, balance, and voluntary movements. The medulla controls breathing, heart rate, and a variety of reflexes, while the pons functions as a bridge between the spinal cord and the brain. The pons is also involved in producing chemicals the body needs for sleep.

The **midbrain** is a small part of the brain above the pons that integrates sensory information and relays it upward. The medulla and pons extend upward into the midbrain. The medulla, pons, and midbrain compose most of

the brain stem, and the reticular activating system (RAS) spans across all these structures. The RAS serves to alert the rest of the brain to incoming signals and is involved in the sleep/wake cycle.

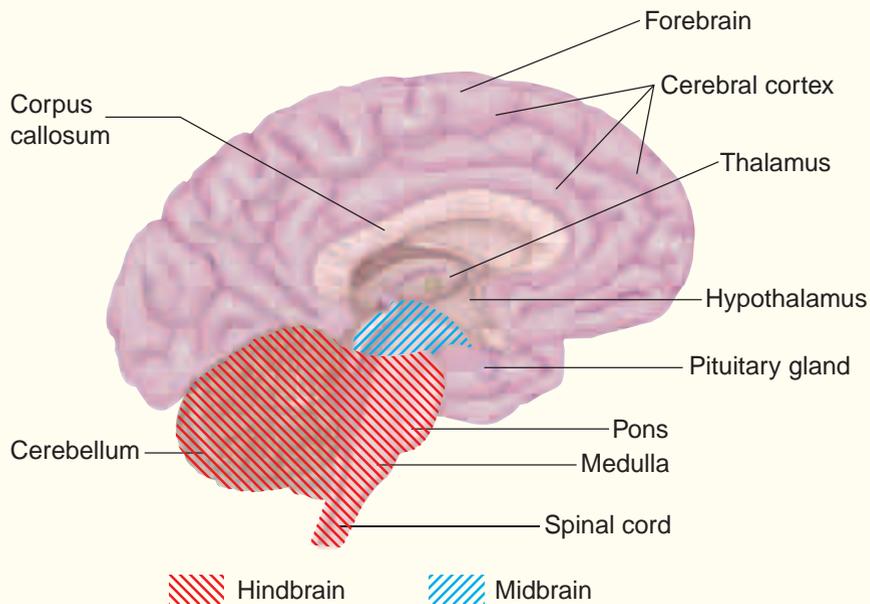
The **forebrain**, covering the brain's central core, includes the *thalamus*, which integrates sensory input. The thalamus is a relay station for all the information that travels to and from the cortex. All sensory information with the exception of smell enters the thalamus. All information from the eyes, ears, and skin enters the thalamus and then is sent to the appropriate areas in the cortex. Just below the thalamus is the *hypothalamus*. It controls functions such as hunger, thirst, and sexual behavior. It also controls the body's reactions to changes in temperature, so when we are warm, we begin to sweat, and when we are cold, we shiver.

The higher thinking processes—those that make us unique—are housed in the forebrain. The outer layer of the forebrain consists of the *cerebral cortex*. The inner layer is the *cerebrum*. The cerebral cortex and cerebrum surround the hindbrain and brain stem like the way a mushroom surrounds its stem. The cerebral cortex gives you the ability to learn and store complex and abstract information, and to project your thinking into the future. Your cerebral cortex allows you to see, read, and understand this sentence. The cortex, or bark, of the cerebrum is the site of your conscious thinking processes, yet it is less than one-fourth inch thick.

The *limbic system*, found in the core of the forebrain, is composed of a number of different structures in the brain that regulate our emotions and motivations. The limbic system includes the hypothalamus, amygdala, thalamus, and hippocampus. The amygdala controls violent

Figure 6.5

The Parts of the Brain



The brain is the largest, most complex part of the nervous system.

What are the functions of the cerebellum?

midbrain: a small part of the brain above the pons that integrates sensory information and relays it upward

forebrain: a part of the brain that covers the brain's central core

emotions such as rage and fear. The hippocampus is important in the formation of memories. If the hippocampus is damaged, it would be difficult to form new memories. Covering all these parts is the cerebrum.

Reading Check
What are the three parts of the human brain?

lobes: the different regions into which the cerebral cortex is divided

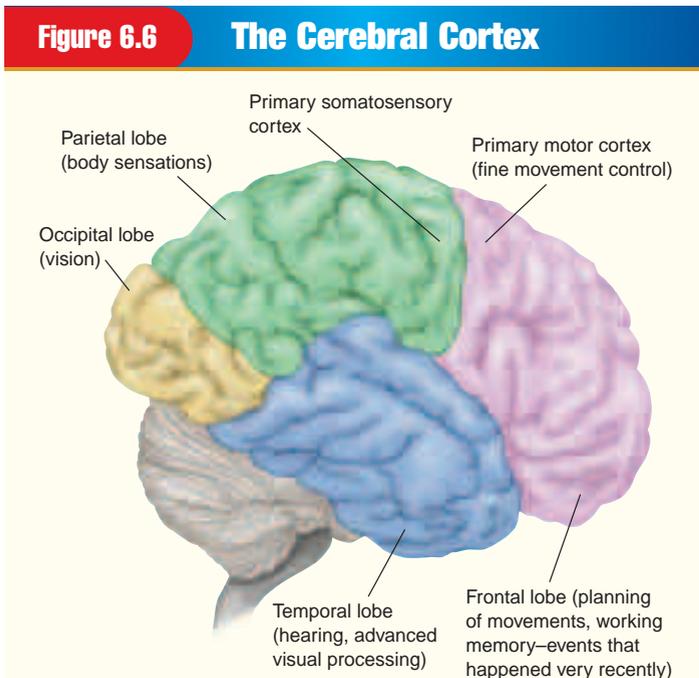
The Lobes of the Brain

The cerebrum is really two hemispheres, or two sides. The cerebral hemisphere is connected by a band of fibers called the *corpus callosum*. Each cerebral hemisphere has deep grooves, some of which mark regions, or **lobes** (see Figure 6.6). The occipital lobe is where the visual signals are processed. Damage to this area can cause visual problems. The parietal lobe is concerned with information from the senses from all over the body. The temporal lobe is concerned with hearing, memory, emotion, and speaking. The frontal lobe is concerned with organization, planning, and creative thinking.

Some areas of the cortex receive information from the skin senses and from muscles. The number of touch sensors in a body part determines its sensitivity, and, along with the complexity of the part's movement, governs the amount of brain tissue associated with the part. The touch and movement of the hands, for example, involve more brain area than the more limited calves. The somatosensory cortex receives information from the touch sensors. The motor cortex sends information to control body movement. The motor cortex is also divided according to need. The more sophisticated the movements (such as those used in speaking), the bigger the brain area involved in their control.

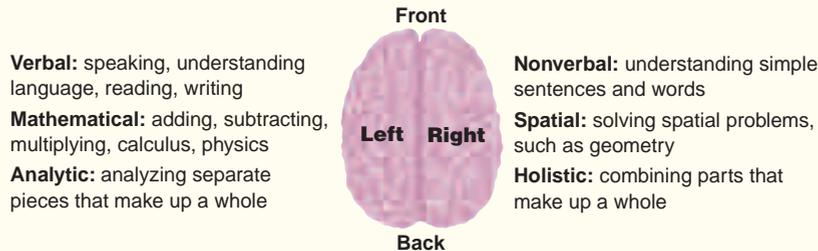
The association areas mediate between the other areas and do most of the synthesizing of information. For example, association areas turn sensory input into meaningful information. Different neurons are activated when we see different shapes and figures. The association areas receive this input and then arrange the information so that we perceive something meaningful, like our friend's face.

Left and Right Hemispheres There is much concern that information about properties of the left and right hemispheres is misinterpreted. Popular books have oversimplified the properties of the two hemispheres. In reality, the left and right sides complement and help each other, so be aware of this as we list the properties of each hemisphere. The two hemispheres in the cortex are roughly mirror images of each other. (Each of the four lobes is present in both hemispheres.) The corpus callosum carries messages back and forth



The functions of the cerebral cortex are not fully understood. Indicated here are some areas of behavioral importance. **What is the function of the motor cortex?**

The idea of whether we are “right-brained” or “left-brained” has been exaggerated. We constantly use both hemispheres of the brain, since each hemisphere is specialized for processing certain kinds of information. *In what areas does the right hemisphere specialize?*



between the two hemispheres to jointly control human functions. Each hemisphere is connected to one-half of the body in a crisscrossed fashion. The left hemisphere controls the movements of the right side of the body. For most people, the left side of the brain is where speech is located. The left side also is specialized for mathematical ability, calculation, and logic.

The right hemisphere controls the left side of the body. (Thus a stroke that causes damage to the right hemisphere will result in numbness or paralysis on the left side of the body.) The right hemisphere is more adept at visual and spatial relations. Putting together a puzzle requires spatial ability. Perceptual tasks seem to be processed primarily by the right hemisphere. The right side is better at recognizing patterns. Thus, music and art are better understood by the right hemisphere. Creativity and intuition are also found in the right hemisphere (see Figure 6.7) (Levy, 1985).

Split-Brain Operations In a normal brain, the two hemispheres communicate through the corpus callosum. Whatever occurs on one side is communicated to the other side. Some people have grand mal seizures, the most severe kind of seizure. Separating the brain hemispheres lessens the number and severity of the seizures (Kalat, 2001). As a result, the person has a split brain. The person has two brains that operate independently of each other. Since the corpus callosum is severed, there no longer is any communication between the hemispheres.

Many psychologists became interested in differences between the cerebral hemispheres when split-brain operations were tried on epileptics like Harriet Lees. For most of her life Lees’s seizures were mild and could be controlled with drugs. However, at age 25 they began to get worse, and by 30 Lees was having as many as a dozen violent seizures a day. An epileptic seizure involves massive uncontrolled electrical activity that begins in either hemisphere and spreads to the other. To enable Lees to live a normal life, she and the doctors decided to sever the corpus callosum so that seizures could not spread.

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Profiles In Psychology

Roger Wolcott Sperry

1913–1994

“In other words, each hemisphere [of the brain] seems to have its own separate and private sensations; its own perceptions; its own concepts; and its own impulses to act. . . .

Following surgery, each hemisphere also has thereafter its own separate chain of memories that are rendered inaccessible to the recall processes of the other.”

Roger Sperry first became well-known in the specialized area of developmental neurobiology. He devised experiments that helped establish the means by which nerve cells become wired in particular ways in the central nervous system.

Sperry is probably best known for his pioneering split-brain research. In the 1950s and 1960s, Sperry devised a number of experiments to test the functions of each hemisphere of the brain. He argued that two separate hemispheres of consciousness could exist under one skull. Sperry pioneered the behavioral investigation of split-brain animals and humans. His experiments and techniques laid the groundwork for constructing a map of mental functions. In 1981 he became corecipient of the Nobel Prize for Physiology and Medicine for his investigation of brain functions.

Not only did the operation reduce the severity of seizures, but it also resulted in fewer seizures (Kalat, 2001). Psychologists were even more interested in the potential side effects of this operation. Despite the fact that patients who had this operation now had two functionally separate brains, they seemed remarkably normal. Researchers went on to develop a number of techniques to try to detect subtle effects of the split-brain operation.

If a man whose brain has been split holds a ball in his right hand, he would be able to say it is a ball. Place the ball in his left hand and he would not be able to say what it is. Information from the left hand is sent to the right hemisphere of the brain. Since the corpus callosum is severed, information cannot cross to the speech center in the left hemisphere.

Another experiment with split-brain patients involves tactile stimulation, or touch. In this experiment, objects are held in a designated hand but are blocked from the split-

brain patient’s view. Researchers project a word describing an object on a screen to either the right or left visual field. The patient’s task is to find the object corresponding to the word they are shown. When words are presented for the right hemisphere to see, patients cannot say the word, but they can identify the object with their left hand touching it behind the screen.

To explore emotional reactions in split-brained individuals, researchers designed a test to incorporate emotional stimuli with objects in view. In one of these experiments, a picture of a nude person was flashed to either hemisphere. When researchers flashed the picture to the left hemisphere, the patient laughed and described what she saw. When

the same was done to the right hemisphere, the patient said nothing, but her face became flush and she began to grin.

Research on split-brain patients has presented evidence that each hemisphere of the brain is unique with specialized functions and skills. Individuals who have had split-brain operations remained practically unchanged in intelligence, personality, and emotions.

HOW PSYCHOLOGISTS STUDY THE BRAIN

Mapping the brain's fissures and inner recesses has supplied scientists with fascinating information about the role of the brain in behavior. Psychologists who do this kind of research are called physiological psychologists, or psychobiologists. Among the methods they use to explore the brain are recording, stimulating, lesioning, and imaging.

Recording

Electrodes are wires that can be inserted into the brain to record electrical activity in the brain. By inserting electrodes in the brain, it is possible to detect the minute electrical changes that occur when neurons fire. The wires are connected to electronic equipment that amplifies the tiny voltages produced by the firing neurons. Even single neurons can be monitored.

The electrical activity of whole areas of the brain can be recorded with an **electroencephalograph (EEG)**. Wires from the EEG machine are attached to the scalp so that millions upon millions of neurons can be monitored at the same time (see Figure 6.8). Psychologists have observed that the overall electrical activity of the brain rises and falls rhythmically and that the pattern of the rhythm depends on whether a person is awake, drowsy, or asleep (as illustrated in Chapter 7). These rhythms, or brain waves, occur because the neurons in the brain tend to increase or decrease their amount of activity in unison.

Stimulation

Electrodes may be used to set off the firing of neurons as well as to record it. Brain surgeon Wilder Penfield stimulated the brains of his patients during surgery to determine what functions the various parts of the brain perform. In this way he could localize the malfunctioning part for which surgery was required, for example, for epilepsy. When Penfield applied a tiny electric current to points on the temporal lobe of the brain,



Quick Lab

Can you determine whether the left or right hemisphere of the brain is dominant?

The left hemisphere controls the movements of the right side of the body. This side of the brain is adept at language-related skills, mathematical ability, and logic. The right hemisphere controls the movements of the left side of the body. It is also the side that is more adept for creativity, intuition, and creative expressions such as art and music. Can you tell which side is dominant in people you know?

Procedure

1. Think about two of your friends or family members.
2. Compare them in terms of the areas that they seem to be most adept at—mathematics, logical thinking, musical ability, art, or speech.
3. Record your observations in a two-column chart.

Analysis

1. Based on your observations, which hemisphere seems to be dominant in each individual?



See the **Skills Handbook**, page 622, for an explanation of designing an experiment.

electroencephalograph (EEG): a machine used to record the electrical activity of large portions of the brain

Scientists use an electroencephalograph (EEG) machine to measure brain waves.

What have psychologists observed about the electrical activity of the brain?



he could trigger whole memory sequences. During surgery, one woman heard a familiar song so clearly that she thought a record was being played in the operating room (Penfield & Rasmussen, 1950).

Stimulation techniques have aroused great medical interest. They have been used with terminal cancer patients to relieve them of intolerable pain without using drugs. A current delivered through electrodes implanted in certain areas of the brain may provide a sudden temporary relief (Delgado, 1969). Furthermore, some psychiatrists have experimented with similar methods to control violent emotional behavior in otherwise uncontrollable patients.

Lesions

Scientists sometimes create lesions by cutting or destroying part of an animal's brain. If the animal behaves differently after the operation, they assume that the destroyed brain area is involved with that type of behavior. For example, in one classic lesion study, two researchers removed a certain area of the temporal lobe from rhesus monkeys. Normally, these animals are fearful, aggressive, and vicious, but after the operation, they became less fearful and at the same time less violent (Klüver & Bucy, 1937). The implication was that this area of the brain controlled aggression. The relations revealed by this type of research are far more subtle and complex than people first believed.

Accidents

Psychologists can learn from the tragedies when some people suffer accidents. These accidents may involve the brain. Psychologists try to draw a connection between the damaged parts of the brain and a person's behavior. One such case involved an unusual accident in 1848. Phineas Gage was a respected railroad foreman who demonstrated restraint, good judgment, and the ability to work well with other men. His crew of men was about to explode some dynamite to clear a path for the railroad rails. As Gage filled a narrow hole with dynamite and tamped it down, it suddenly exploded. The tamping iron had caused a spark that ignited the dynamite. The tamping iron, which weighed over 13 pounds and was over 3 feet in length, shot into the air! It entered Gage's head right below the left eye, and it exited through the top of the skull.

Gage survived the accident, but his personality changed greatly. He became short-tempered, was difficult to be around, and often said inappropriate things. Gage lived for several years after the accident. In 1994 psychologists (Damasio & Damasio) examined Gage's skull using the newest methods available. They reported that the tamping iron had caused damage to parts of the frontal cortex. They found that damage to the frontal lobes prevents censoring of thoughts and ideas.

Another unusual case took place in the nineteenth century. Dr. Paul Broca had a young patient who could only respond with hand gestures and the word “tan.” Broca theorized that a part of the brain on the left side was destroyed, limiting the young man’s communication processes. Many years later, researchers examined the young man’s brain using modern methods. They discovered that Dr. Broca’s theory was correct. The left side of the cortex, which is involved with the production of speech, was damaged. This area of the cortex is now known as Broca’s area.

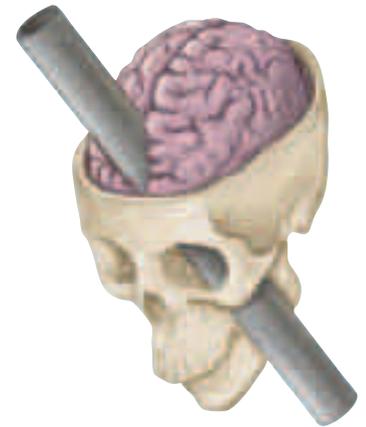
Images

Dr. Paul Broca uncovered the connection between the brain and speech. Researchers proved Dr. Broca’s theory using PET scans. Today psychologists and medical researchers are using this and other sophisticated techniques, including CAT scans and MRI scans.

In the 1970s, **computerized axial tomography (CAT)** scans were used to pinpoint injuries and other problems in brain deterioration. During a CAT scan, a moving ring passes X-ray beams around and through a subject’s head. Radiation is absorbed in different amounts depending on the density of the brain tissue. Computers measure the amount of radiation absorbed and transform this information into a three-dimensional view of the brain.

The **positron emission tomography (PET)** scan can capture a picture of the brain as different parts are being used. It involves injecting a slightly radioactive solution into the blood and then measuring the amount of radiation absorbed by blood cells. Active neurons absorb more radioactive solution than nonactive ones (see Figure 6.9). Researchers use the PET scan to see which areas are being activated while performing a task (Raichle, 1994). PET scans show activity in different areas of the brain when a person is thinking, speaking, and looking at objects. The scan changes when one is talking and when one is looking at a piece of art. These pictures change as the activity changes.

Another device, **magnetic resonance imaging**, or **MRI**, enables researchers to study both activity and brain structures (see Figure 6.10). It



Phineas Gage’s skull

computerized axial tomography (CAT): an imaging technique used to study the brain to pinpoint injuries and brain deterioration

positron emission tomography (PET): an imaging technique used to see which brain areas are being activated while performing tasks

magnetic resonance imaging (MRI): an imaging technique used to study brain structure and activity

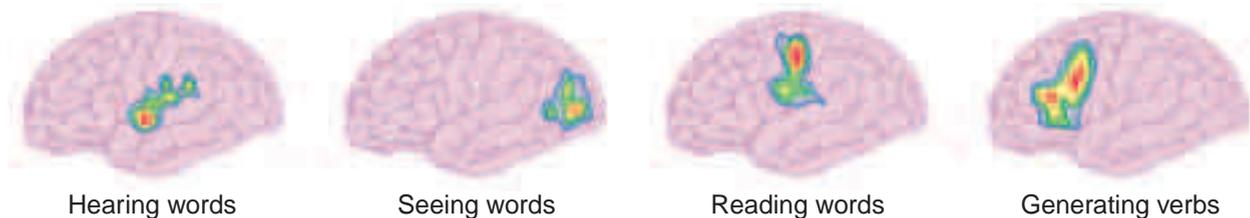


Figure 6.9 Brain Activity on a PET Scan

A computer transforms the different levels of absorption by neurons of radioactive solution into colors. Red and yellow indicate maximum activity of neurons, while blue and green indicate minimal activity.

Why would psychologists use a PET scan?

Magnetic resonance imaging (MRI) studies the activities of the brain. *Why does an MRI of the brain give a more thorough picture than a CAT or PET scan would give?*



combines the features of both CAT and PET scans. It involves passing nonharmful radio frequencies through the brain. A computer measures how these signals interact with brain cells and translates these signals into a detailed image of the brain. Researchers use MRIs to study the structure of the brain as well as to identify tumors or types of brain damage.

Researchers use a new technique of imaging, functional magnetic resonance imaging (fMRI), to directly observe both the functions of different structures of the brain and which structures participate in specific functions. The fMRI provides high resolution reports of neural activity based on signals that are determined by blood oxygen level. The fMRI actually detects an increase in blood flow to the active structure of the brain. So, unlike the MRI, the

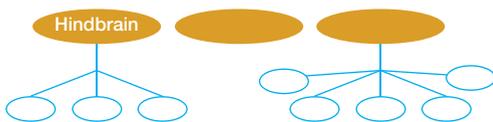
fMRI does not require passing radio frequencies through the brain. With this new method of imaging, researchers have confirmed their hypotheses concerning the functions of areas such as the visual cortex, the motor cortex, and Broca's area of speech and language-related activities.

SECTION 2

Assessment

- Review the Vocabulary** List and describe the main functions of the lobes of the human brain.
- Visualize the Main Idea** In a diagram similar to the one below, list the parts of the brain.
- Recall Information** What are the functions of the thalamus and hypothalamus?
- Think Critically** If a person suffers a traumatic head injury and then begins behaving differently, can we assume that brain damage is the reason for the personality change? Why or why not?

Parts of the Human Brain



- Application Activity** A woman severely injured the right hemisphere of her brain. Create a scenario in which you describe two body functions that might be affected by the woman's injury.

Case Studies

One Person . . . Two Brains?

Period of Study: 1967

Introduction: Victoria had experienced intense epileptic seizures since she was six years old. Doctors placed Victoria on medication that prevented seizures for a period of time. However, after many years, the seizures returned with greater intensity. Weary and disgusted from living her life with the uncontrollable and agonizing seizures, Victoria decided it was time to seek a new treatment.

Doctors suggested and Victoria opted for a split-brain operation—an innovative procedure that has proved successful in treating patients with seizures. This operation involved opening the patient's skull and separating the two brain hemispheres by cutting the corpus callosum. Split-brain operations disrupt the major pathway between the brain hemispheres but leave each hemisphere functioning almost completely independently. The procedure prevents the spread of seizures from one hemisphere to the other. This reduces the chance of having a seizure or shortens the seizure if one does occur.

Upon completion of Victoria's split-brain operation, the time came to test her various brain functions that now involved nonconnected, independent hemispheres.

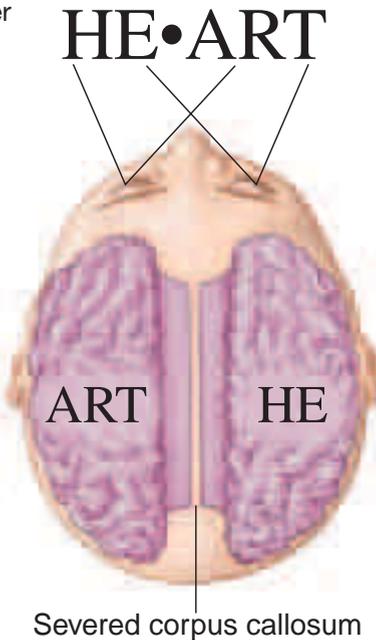
Hypothesis: Researchers wanted to explore the degree to which the two halves of the brain could communicate and function on their own after the operation.

Method: Researchers asked Victoria to stare at a black dot between the letters HE and ART. The information from each side of the black dot will be interpreted by the opposite hemisphere in Victoria's split brain. Victoria's right hemisphere will see HE and her left will only see ART (see diagram).

When Victoria was asked what she had seen, she reported to have seen the word ART. The word ART was projected to her left hemisphere, which contains the ability for speech. She did indeed see the word HE; however, the right hemisphere could not make Victoria say what she had seen. With her left hand, though, Victoria could point to a picture of a man, or HE. This indicated that her right hemisphere could understand the meaning of HE.

Results: Four months after Victoria's split-brain operation, she was alert and could easily remember and speak of past and present events in her life. Her reading, writing, and reasoning abilities were all intact. She could easily carry out everyday functions such as dressing, eating, and walking.

Although the effects of her operation became apparent under special testing, they were not apparent in everyday life. Victoria, now free of her once-feared seizures, could live her life seizure-free, split-brained but unchanged.



Analyzing the Case Study

1. Why did Victoria choose to have a split-brain operation? What did the operation involve?
2. What questions did researchers set out to answer after Victoria's operation?
3. **Critical Thinking** What problems do you think Victoria might encounter in everyday life?

Reader's Guide

■ Main Idea

The endocrine system controls and excites growth and affects emotions and behavior in people.

■ Vocabulary

- endocrine system
- hormones
- pituitary gland

■ Objectives

- Describe the endocrine system.
- Identify hormones and their function in the endocrine system.

EXPLORING PSYCHOLOGY

Running With the Bulls

And then the gun goes off. I run up the cobblestone street. People are jogging at a moderate pace. There's no tremendous push for speed. . . . The second gun goes off—now people pick up the pace: the bulls have been released. . . . There's a sudden burst of speed, energy, panic, of bodies, and the bulls are in the ring. I high tail it to the perimeter, having heard too many tales of bulls going mad in the ring. . . . I caught up with Von and Don. I was just about to ask Don a question when I saw a bull charging Von. He stood frozen for a second, and at the last second jumped sideways in a crescent shape, as the bull missed him and tried to put his shoulder into Von. We ran up to him and he was five shades of white. . . .

—from “I Run With the Bulls” by Mike Silva, 1995

Every year in Pamplona, Spain, many people experience what some consider the ultimate “adrenaline rush.” Fighting bulls and steers run through the town every morning of a nine-day fiesta. Hundreds of revelers literally run with the bulls. The bull-racing ritual is inhumane (more than 50 bulls are killed each day), and participants risk death if they should get gored by a bull. Why do people do it?

Many do it for the “rush.” The rush comes from a hormone secreted by the endocrine system called adrenaline or epinephrine. The adrenal hormone declares an emergency situation to the body, requiring the body to become very active.

THE ENDOCRINE GLANDS

The nervous system is one of two communication systems for sending information to and from the brain. The second is the **endocrine system**. The endocrine system sends chemical messages, called hormones. The **hormones** are produced in the endocrine glands and are distributed by the blood and other body fluids. (The names and locations of these glands are shown in **Figure 6.11**.) Hormones circulate throughout the bloodstream but are properly received only at a specific site: the particular organ of the body that they influence. The endocrine glands are also called ductless glands because they release hormones directly into the bloodstream. In contrast, the duct glands release their contents through small holes, or ducts, onto the surface of the body or into the digestive system. Examples of duct glands are sweat glands, tear glands, and salivary glands.

Hormones have various effects on your behavior. They affect the growth of bodily structures such as muscles and bones, so they affect what you can do physically. Hormones affect your metabolic processes; that is, they can affect how much energy you have to perform actions. Some hormonal effects take place before you are born. Essentially all the physical differences between boys and girls are caused by a hormone called testosterone. Certain other hormones are secreted during stressful situations to prepare the body for action. Hormones also act in the brain to directly influence your moods and drives.

Pituitary Gland

Directed by the hypothalamus, the **pituitary gland** acts as the master gland. The pituitary gland, located near the midbrain and the hypothalamus, secretes a large number of hormones, many of which control the output of hormones by other endocrine glands. The hypothalamus monitors the amount of hormones in the blood and sends out messages to correct imbalances.

What do these hormone messages tell the body to do? They carry messages to organs involved in regulating and storing nutrients so that despite changes in conditions outside the body, cell metabolism can continue on an even course. They also control growth and reproduction, including ovulation and lactation (milk production) in females.

Thyroid Gland

The *thyroid gland* produces the hormone thyroxine. Thyroxine stimulates certain chemical reactions that are important for all tissues of the body. Too little thyroxine makes people feel lazy and lethargic—a



Do You Do This?

Human ethology is the study of human behavior as it naturally occurs. Basketball fans know that Michael Jordan stuck out his tongue when he attempted a difficult shot. Similarly, it has been found that expert billiard players stick out their tongues more often when making hard shots than when attempting relatively easy shots. According to ethologists, a tongue display acts as a nonverbal sign that interaction is not desired. For humans, the tongue displays seem to indicate that the person does not want to be interrupted because of the need to concentrate in a difficult situation.

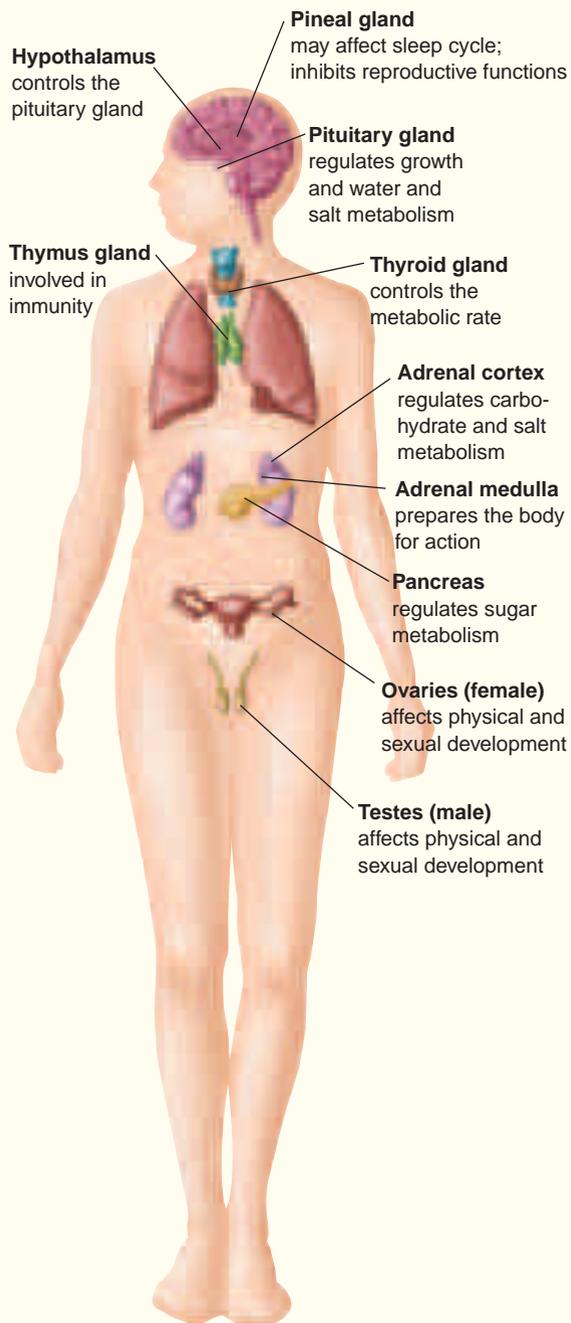
endocrine system: a chemical communication system, using hormones, by which messages are sent through the bloodstream

hormones: chemical substances that carry messages through the body in blood

pituitary gland: the center of control of the endocrine system that secretes a large number of hormones

 **Reading Check**
What is the function of the pituitary gland? The thyroid gland?

Figure 6.11 The Endocrine System



The endocrine system, which consists of ductless glands and the hormones they produce, works closely with the nervous system in regulating body functions. **What is the function of the adrenal glands?**

condition known as hypothyroidism. Too much thyroxine may cause people to lose weight and sleep and to be overactive—a condition known as hyperthyroidism.

Adrenal Glands

The *adrenal glands* become active when a person is angry or frightened. They release epinephrine and norepinephrine (also called adrenaline and noradrenaline) into the bloodstream. These secretions cause the heartbeat and breathing to increase. They can heighten emotions, such as fear and anxiety. These secretions and other changes help a person generate the extra energy he or she needs to handle a difficult situation.

The adrenal glands also secrete cortical steroids. Cortical steroids help muscles develop and cause the liver to release stored sugar when the body requires extra energy for emergencies.

Sex Glands

There are two types of sex glands—*testes* in males and *ovaries* in females. Testes produce sperm and the male sex hormone *testosterone*. Low levels of testosterone are also found in females. Ovaries produce eggs and the female hormones *estrogen* and *progesterone*, although low levels of these hormones are also found in males.

Testosterone is important in the physical development of males, especially in the prenatal period and in adolescence. In the prenatal period, testosterone helps decide the sex of a fetus. In adolescence, testosterone is important for the growth of muscle and bone along with the growth of male sex characteristics.

Estrogen and progesterone are important in the development of female sex characteristics. These hormones also regulate the reproductive cycle of females. The levels of estrogen and progesterone vary throughout the menstrual cycle. These variances can cause premenstrual syndrome (PMS) in some women. PMS includes symptoms such as fatigue, irritability, and depression.

HORMONES VS. NEUROTRANSMITTERS

Both hormones and neurotransmitters work to affect the nervous system. In fact, the same chemical (such as norepinephrine) can be used as both a hormone and a neurotransmitter. So what is the difference between a hormone and a neurotransmitter?

When a chemical is used as a neurotransmitter, it is released right beside the cell that it is to excite or inhibit. When a chemical is used as a hormone, it is released into the blood, which diffuses it throughout the body. For example, norepinephrine is a hormone when it is secreted into the blood by the adrenal glands. Norepinephrine is a neurotransmitter, though, when it is released by the sympathetic motor neurons of the peripheral nervous system.

Hormones and neurotransmitters appear to have a common evolutionary origin (Snyder, 1985). As multicellular organisms evolved, the system of communication among cells coordinated their actions so that all the cells of the organism could act as a unit. As organisms grew more complex, this coemunication system began to split into two more specialized communication systems. One, the nervous system, developed to send rapid and specific messages, while the other, involving the circulatory system, developed to send slow and widespread communication. In this second system, the chemical messengers evolved into hormones. Whereas neural messages can be measured in thousandths of a second, hormonal messages may take minutes to reach their destination and weeks or months to have their total effect.

Figure 6.12 An Adrenaline Rush

In the event of a life-threatening or highly stressful situation, the adrenal glands produce adrenaline to give people the necessary energy to cope. *How does adrenaline affect emotions in people?*



SECTION 3

Assessment

- Review the Vocabulary** What are three ways that the endocrine system affects behavior?
- Visualize the Main Idea** In a chart similar to the one at right, identify the hormones produced by the glands and the functions of those hormones.
- Recall Information** How does the endocrine system differ from the nervous system?

Glands of the Endocrine System	
Gland	Hormone(s) released

- Think Critically** Explain what psychologists might learn about behavior by studying sex hormones.

5. Application Activity

Describe a medical situation in which a psychologist would examine the thyroid gland. Describe the situation from the perspective of a patient.

Reader's Guide

■ Main Idea

Heredity is the transmission of characteristics from parents to children. Environment is the world around you. Heredity and environment affect your body and behavior.

■ Vocabulary

- heredity
- identical twins
- genes
- fraternal twins

■ Objectives

- Give examples of the effects of heredity and environment on behavior.
- Summarize research on the effects of heredity and environment on behavior.

EXPLORING PSYCHOLOGY

Nature or Nurture?

Two monozygotic [derived from the same egg] twin girls were separated at birth and placed in homes far apart. About four years later, researchers interviewed the adoptive parents of each girl. The parents of Shauna said, “She is a terrible eater—won’t cooperate, stubborn, strong-willed. I can’t get her to eat *anything* unless I put cinnamon on it.” The parents of Ellen said, “Ellen is a lovely child—cooperative and outgoing.” The researcher probed, asking, “How are her eating habits?” The response was: “Fantastic—she eats anything I put before her, as long as I put cinnamon on it!”

—from *Nature’s Thumbprint: The New Genetics of Personality* by P.B. Neubauer and A. Neubauer, 1990

How much do genetic factors contribute to our behavior? How much do environmental factors? These questions have haunted psychologists for years. Some psychologists believe that genetics is like a flower, and the environment is like rain, soil, or fertilizer. Genes establish what you could be, and the environment defines the final product.

HEREDITY AND ENVIRONMENT

People often argue about whether human behavior is instinctive (due to heredity) or learned (due to environment). **Heredity** is the genetic transmission of characteristics from parents to their offspring. Do people learn to be good athletes, or are they born that way? Do people learn to

heredity: the genetic transmission of characteristics from parents to their offspring

do well in school, or are they born good at it? The reason for the intensity of the argument may be that many people assume that something learned can probably be changed, whereas something inborn will be difficult or impossible to change. The issue is not that simple, however. Inherited factors and environmental conditions always act together in complicated ways. Asking whether heredity or environment is responsible for something turns out to be like asking, “What makes a cake rise, baking powder or heat?” Obviously, an interaction of the two is responsible.

A Question of Nature vs. Nurture

The argument over the nature-nurture question has been going on for centuries. Nature refers to the characteristics that a person inherits—his or her biological makeup. Nurture refers to environmental factors, such as family, culture, education, and individual experiences. Sir Francis Galton became one of the first to preach the importance of nature in the modern era. In 1869 he published *Hereditary Genius*, a book in which he analyzed the families of over 1,000 eminent politicians, religious leaders, artists, and scholars. He found that success ran in families and concluded that heredity was the cause.

Many psychologists, however, have emphasized the importance of the environment. The tone was set by John Watson, the founder of behaviorism, who wrote in 1930: “Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I’ll guarantee to take any one at random and train him to become any type of specialist I might select—a doctor, lawyer, artist, merchant-chief, and, yes, even beggarman and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors” (Watson, 1930).

Genes and Behavior Genes are the basic units of heredity. They are reproduced and passed along from parent to child. All the effects that genes have on behavior occur through their role in building and modifying the physical structures of the body. Those structures must interact with their environment to produce behavior. For example, if your parents are musicians, you may have inherited a gene that influences your musical ability by contributing to brain development that analyzes sounds well.

Twin Studies

One way to find out whether a trait is inherited is to study twins. **Identical twins** develop from a single fertilized egg (thus, they are called monozygotic) and share the same **genes**. Genes are the basic building blocks of heredity (see Figure 6.13).

 **Reading Check**
What is heredity and how does it affect your behavior?

identical twins: twins who come from one fertilized egg; twins having the same heredity

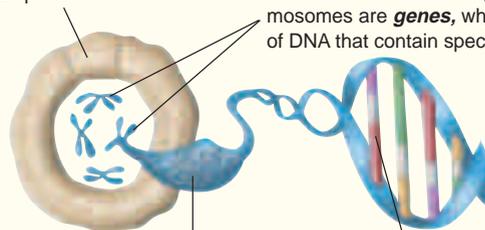
genes: the basic building blocks of heredity

Figure 6.13 DNA and Genes

The molecules of DNA make up chromosomes that contain the codes for our biological makeup. **What are genes?**

The **cell body** contains 23 pairs of chromosomes.

Each **chromosome** is made of a long strand of DNA. On each pair of chromosomes are **genes**, which are pieces of DNA that contain specific instructions.



A strand of **DNA** is stretched out to show that it looks like a twisted ladder with “chemical” rungs.

“Chemical rungs” carry instructions (genes) for development of millions of parts for your brain and body.

Source: Plotnik, 1999.

Figure 6.14

Identical Twins

Because identical twins share the same genes and most often the same environment, studying them is one way to find out whether a trait is inherited or learned. **What do psychologists mean by the “nature-nurture question”?**



Fraternal twins develop from two fertilized eggs (thus, dizygotic), and their genes are not more similar than those of brothers or sisters.

Twins growing up in the same house share the same general environment, but identical twins also share the same genes. So, if identical twins who grow up together prove to be more alike on a specific trait than fraternal twins do, it probably means that genes are important for that trait.

Psychologists at the University of Minnesota have been studying identical twins who were separated at birth and reared in different environments (Holden, 1980). One of the researchers, Thomas

Bouchard, reports that despite very different social, cultural, and economic backgrounds, the twins shared many common behaviors. For example, in one set of twins (both named Jim), both had done well in math and poorly in spelling while in school, both worked as deputy sheriffs, vacationed in Florida, gave identical names to their children and pets, bit their fingernails, had identical smoking and drinking patterns, and liked mechanical drawing and carpentry. These similarities and others suggest that heredity may contribute to behaviors that we normally associate with experience.

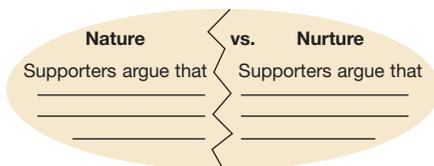
Many researchers now believe that many of the differences among people can be explained by considering heredity as well as experience. Contrary to popular belief, the influence of genes on behavior does not mean that nothing can be done to change the behavior. Although it is true that it is difficult and may be undesirable to change the genetic code that may direct behavior, it is possible to alter the environment in which the genes operate.

fraternal twins: twins who come from two different eggs fertilized by two different sperm

SECTION 4

Assessment

- Review the Vocabulary** Explain the difference between fraternal twins and identical twins.
- Visualize the Main Idea** In a diagram like the one below, explain how proponents of each view argue the nature-nurture debate.
- Recall Information** What role do the genes play in influencing someone’s behavior?
- Think Critically** Sue and Tracy are identical twins. Sue is good at drawing. Tracy is a starter on the basketball team. Explain what may cause differences in these twins.



- Application Activity** Describe a characteristic that you have. Explain whether you think this characteristic is hereditary or environmental.

Some psychologists (psychobiologists) study how our behavior and psychological processes are connected to our biological processes. Our bodies and minds work together to create who we are.

Section 1 The Nervous System: The Basic Structure

Main Idea: Learning about the nervous system helps us know how messages that are sent to the brain cause behavior.

- The nervous system is divided into two parts: the central nervous system and the peripheral nervous system.
- Messages to and from the brain travel along the nerves.
- Nerve cells called neurons have three basic parts: the cell body, dendrites, and the axon.
- The somatic nervous system controls the body's voluntary activities, and the autonomic nervous system controls the body's involuntary activities.

Section 2 Studying the Brain

Main Idea: There are many parts in the human brain that work together to coordinate movement and stimulate thinking and emotions, resulting in behavior.

- The brain is made of three parts: the hindbrain, the midbrain, and the forebrain.
- The cortex of the brain is divided into the left and the right hemispheres; the left hemisphere controls the movements of the right side of the body, and the right hemisphere controls the movements of the left side of the body.
- Psychologists use recording, stimulation, lesions, and imaging to study the brain.

Section 3 The Endocrine System

Main Idea: The endocrine system controls and excites growth and affects emotions and behavior in people.

- The endocrine system, in addition to the nervous system, is a communication system for sending information to and from the brain.
- The endocrine system sends chemical messages, called hormones.

Section 4 Heredity and Environment

Main Idea: Heredity is the transmission of characteristics from parents to children. Environment is the world around you. Heredity and environment affect your body and behavior.

- Heredity is the genetic transmission of characteristics from parents to their offspring.
- Genes are the basic units of heredity; they are reproduced and passed along from parents to child.
- All the effects that genes have on behavior occur through their role in building and modifying the physical structures of the body.

Chapter Vocabulary

central nervous system (CNS) (p. 156)
 spinal cord (p. 156)
 peripheral nervous system (PNS) (p. 156)
 neurons (p. 157)
 synapse (p. 157)
 neurotransmitters (p. 158)
 somatic nervous system (SNS) (p. 158)
 autonomic nervous system (ANS) (p. 158)
 hindbrain (p. 160)
 midbrain (p. 161)
 forebrain (p. 161)
 lobes (p. 162)
 electroencephalograph (EEG) (p. 165)
 computerized axial tomography (CAT) (p. 167)
 positron emission tomography (PET) (p. 167)
 magnetic resonance imaging (MRI) (p. 167)
 endocrine system (p. 171)
 hormones (p. 171)
 pituitary gland (p. 171)
 heredity (p. 174)
 identical twins (p. 175)
 genes (p. 175)
 fraternal twins (p. 176)

CLICK HERE

PSYCHOLOGY
Online



Self-Check Quiz

Visit the *Understanding Psychology* Web site at psychology.glencoe.com and click on **Chapter 6—Self-Check Quizzes** to prepare for the Chapter Test.

Reviewing Vocabulary

Choose the letter of the correct term or concept below to complete the sentence.

- | | |
|------------------------------------|---------------------------|
| a. neurotransmitters | f. hindbrain |
| b. somatic nervous system | g. pituitary gland |
| c. autonomic nervous system | h. synapse |
| d. hormones | i. identical twins |
| e. midbrain | j. fraternal twins |
- The part of the nervous system that controls voluntary activities is the _____.
 - _____ develop from two fertilized eggs, and their genes are not more similar than those of brothers or sisters.
 - The space between neurons is called the _____.
 - The _____ is the part of the brain that integrates sensory information.
 - As a neuron transmits its message to another neuron across the synapse, it releases chemicals called _____.
 - _____ develop from a single fertilized egg and share the same genes.
 - Located at the rear base of the skull, the _____ is involved in the basic processes of life.
 - The _____ acts as the master gland of the body, controlling the output of hormones by other endocrine glands.
 - _____ are produced by endocrine glands and are distributed by the blood and other body fluids.
 - The part of the nervous system that controls involuntary activities is the _____.

Recalling Facts

- Explain how messages travel to and from the brain through the nervous system.
- Using a chart similar to the one below, describe the main function of each of the four lobes of the cerebral cortex.

Lobe	Main Function
Occipital	
Parietal	
Temporal	
Frontal	

- Describe four methods used to study the brain.
- How are the messages of the endocrine system transmitted throughout the body?
- One way to find out whether a trait is inherited is to compare the behavior of identical and fraternal twins. Explain how this works.

Critical Thinking

- Analyzing Concepts** How would people's lives be different if the nervous system were not made of the somatic and the autonomic nervous systems? What if people had only a somatic nervous system?
- Synthesizing Information** Suppose a person suffers a stroke that causes damage to the frontal lobes. What aspects of the person's behavior would you expect to see change?
- Making Inferences** Provide an example of how the physiological reaction created by adrenaline is helpful in emergency situations.
- Applying Concepts** Do you think it is important for parents who wish to adopt a child to find out about the genetic makeup of the child? Why do you think so?
- Evaluating Information** Which aspects of your personality, your way of acting, and your appearance seem obviously the result of heredity? Which seem to be more related to your environmental upbringing? Which characteristics are definitely the result of an interaction between heredity and environment?

Psychology Projects

1. The Nervous System: The Basic Structure

Working with two or three classmates, prepare a video that can be used to teach younger children how the brain and the nervous system work. You might consider making the video humorous to more easily gain the attention of younger children. Arrange to have children in lower grades view the video. Evaluate its effectiveness.

2. Studying the Brain Contact a hospital to find out more about the uses of CAT scans, PET scans, and MRIs. Find out under what circumstances each of the techniques would be used. Present your findings in a written report.

3. The Endocrine System Find out about problems that occur as a result of malfunctioning of parts of the endocrine system. Find out how such problems are treated and present your findings in an oral report.



Technology Activity

Scientists have recently gained greater insight into brain and neuron development in infants and young children. Search the Internet for information about this topic and about the implications the information has for parents and other caregivers. Summarize your findings in a brief report.



Psychology Journal

Much of what we know about the brain and its functioning has come from studies and experiments performed on animals. In your journal write an editorial explaining the reasons for your support of or opposition to using animals for psychological research. Be sure to include information on the American Psychological Association's stand on this issue.

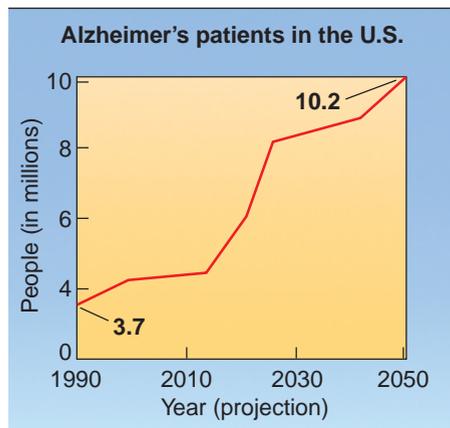
Building Skills

Interpreting a Graph Researchers have found that the brains of patients with Alzheimer's disease have a large number of destroyed neurons in the part of the brain that is crucial for making memories permanent. These patients have also exhibited a loss of the neurotransmitter acetylcholine, resulting in memory difficulties. Review the graph and then answer the questions that follow.

1. According to the graph, how many people in the United States suffer from Alzheimer's disease?
2. How would you describe the projected number of cases of Alzheimer's by the year 2050?
3. What impact might the researchers' findings and the information in the graph have on the direction researchers might take to find a cure for the disease?



Practice and assess key social studies skills with **Glencoe Skillbuilder Interactive Workbook CD-ROM, Level 2.**



See the **Skills Handbook**, page 628, for an explanation of interpreting graphs.

TIME REPORTS

LOTS OF ACTION IN THE MEMORY GAME

New experiments are prompting scientists to rethink their old ideas about how memories form—and why the process sometimes falters

By **GEORGE JOHNSON**

SCIENTISTS HAVE LONG BELIEVED that constructing memories is like playing with neurological Tinkertoys. Exposed to a barrage of sensations from the outside world, we snap together brain cells to form new patterns of electrical connections

that stand for images, smells, touches and sounds.

The most unshakable part of this belief is that the neurons used to build these memory circuits are a depletable resource, like petroleum or gold. We are each bequeathed a finite number of cellular building blocks, and the supply gets smaller each year. That is certainly

how it feels as memories blur with middle age and it gets harder and harder to learn new things. But like so many absolutes, this time-honored notion may have to be forgotten—or at least radically revised.

In the past year, a series of puzzling experiments has forced scientists to rethink this and other cherished assumptions about how memory works, reminding them how much they have to learn about one of the last great mysteries—how the brain keeps a record of our individual passage through life, allowing us to carry the past inside our head.

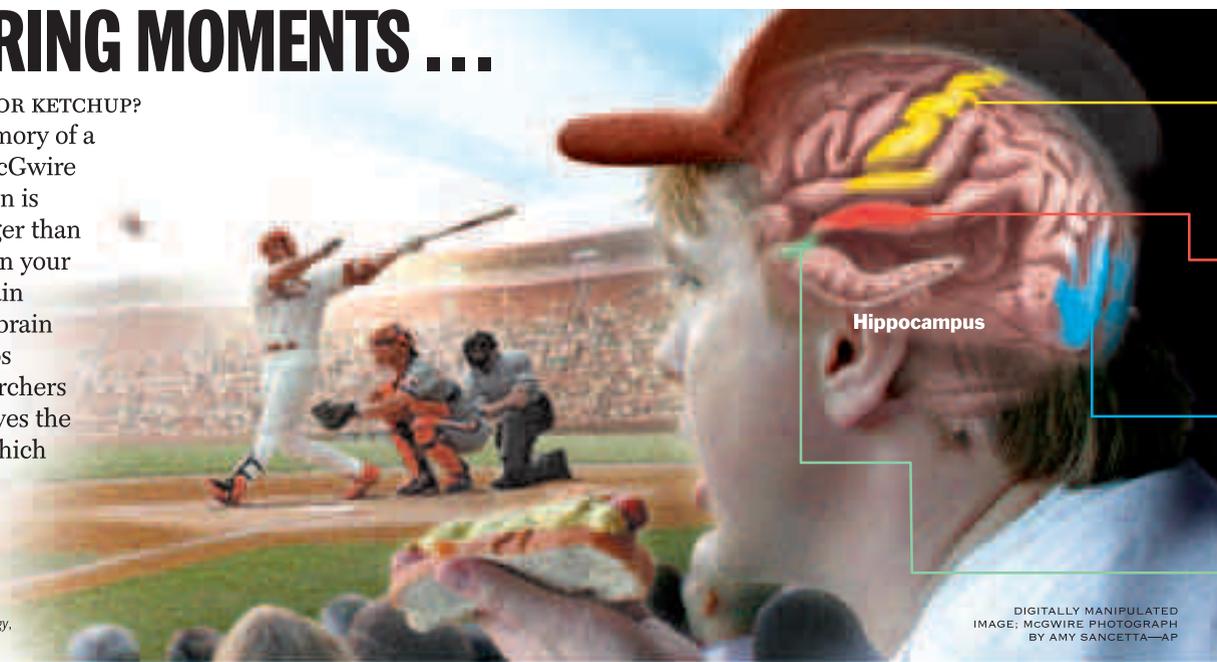
“The number of things we know now that we didn’t know 10 years ago is not very large,” laments Charles Stevens, a memory researcher at the Salk Institute in La Jolla, California. “In fact, in some ways we know less.”

This much seems clear: the traces of memory—or engrams, as neuroscientists call them—are first forged deep inside the brain in an area called the hippocampus (after the Latin word for seahorse because of its arching shape). Acting as a kind of neurological scratch pad, the hippocampus stores the engrams temporarily until they are transferred somehow (perhaps during sleep) to permanent storage sites

CAPTURING MOMENTS ...

MUSTARD OR KETCHUP?
The memory of a Mark McGwire home run is likely to last longer than what you piled on your hot dog. Uncertain exactly how the brain creates and keeps memories, researchers do know it involves the hippocampus, which ultimately feeds memories to the cerebral cortex.

TIME Graphic by Lon Tweeten and Joe Zeff
Sources: *Understanding Psychology*, Robert S. Feldman; Dr. Charles Stevens, The Salk Institute



DIGITALLY MANIPULATED
IMAGE; MCGWIRE PHOTOGRAPH
BY AMY SANCETTA—AP

throughout the cerebral cortex. This area, located behind the forehead, is often described as the center of intelligence and perception. Here, as in the hippocampus, the information is thought to reside in the form of neurological scribbles, clusters of connected cells.

It has been considered almost gospel that these patterns are constructed from the supply of neurons that have been in place since birth. New memories, the story goes, don't require new neurons—just new ways of stringing the old ones together. Retrieving a memory is a matter of activating one of these circuits, coaxing the original stimulus back to life.

The picture appears eminently sensible. The billions of neurons in a single brain can be arranged in countless combinations, providing more than enough clusters to record even the richest life. If adult brains were cranking out new neurons as easily as skin and bone grow new cells, it would serve only to scramble memory's delicate filigree.

Studies with adult monkeys in the mid-1960s seemed to support the belief that the supply of neurons is fixed at birth. Hence the surprise when Elizabeth Gould and Charles Gross of Princeton University reported last year that the monkeys they studied seemed

to be minting thousands of new neurons a day in the hippocampus of their brain. Even more jarring, Gould and Gross found evidence that a steady stream of the fresh cells may be continually migrating to the cerebral cortex.

No one is quite sure what to make of these findings. There had already been hints that spawning of brain cells, a process called neurogenesis, occurs in animals with more primitive nervous systems. For years, Fernando Nottebohm of Rockefeller University has been showing that canaries create a new batch of neurons every time they learn a song, then slough them off when it's time to change tunes.

But it was widely assumed that in mammals and especially primates (including the subset *Homo sapiens*), this wholesale manufacture of new brain parts had long ago been phased out by evolution. With a greater need to store memories for the long haul, these creatures would need to ensure that

the engrams weren't disrupted by interloping new cells.

Not everyone found this argument convincing. (Surely birds had important things to remember too.) When neurogenesis was found to occur in people, the rationalizations began to take the tone of special pleading: there was no evidence that the new brain cells had anything to do with memory or that they did anything at all.

That may yet turn out to be the case with the neurons found by the Princeton lab. The mechanism Gould and her colleagues uncovered in macaque monkeys could be nothing more than a useless evolutionary leftover, a kind of neurological appendix. But if, as many suspect, the new neurons turn out to be actively involved with inscribing memories, the old paradigm is in for at least a minor tune-up—and maybe a complete overhaul. ■

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ANALYZING THE ARTICLE

1. What assumptions did the Gould/Gross study challenge?
2. **CRITICAL THINKING** Recall an early-childhood event that made a strong impression on you. What do you remember seeing, hearing, tasting, smelling and touching?

Touch

The sun's heat activates sensory nerves, sending data to the cortex's **somato-sensory area** for processing

Sound

The ear detects the roar of the crowd and relays it to the **primary auditory cortex** in the temporal lobe

Sight

The eye encodes the image of McGwire as nerve impulses and sends them to the **primary visual cortex**

Taste and Smell

Receptors in the nose pick up the flavor of the mustard and relay it to the **olfactory cortex**

... TO LAST A LIFETIME



Immediate memory

LESS THAN ONE MINUTE

Consisting of a brief flash of raw stimuli corresponding to the senses, it creates an image containing almost an exact replica of each stimulus. Unless transferred to short-term memory, however, the mental snapshot is quickly lost



Short-term memory

A FEW HOURS TO A WEEK

All the sensory information is then sent to the hippocampus where it is coordinated and organized. Over the next day, some parts of the snapshot begin to blur, while the more important details are moved to permanent storage



Long-term memory

PERMANENT

Some theorize that organization and repetition of the information cause it to be transferred and held in storage sites throughout the cerebral cortex. What is finally remembered is only a fraction of the original picture