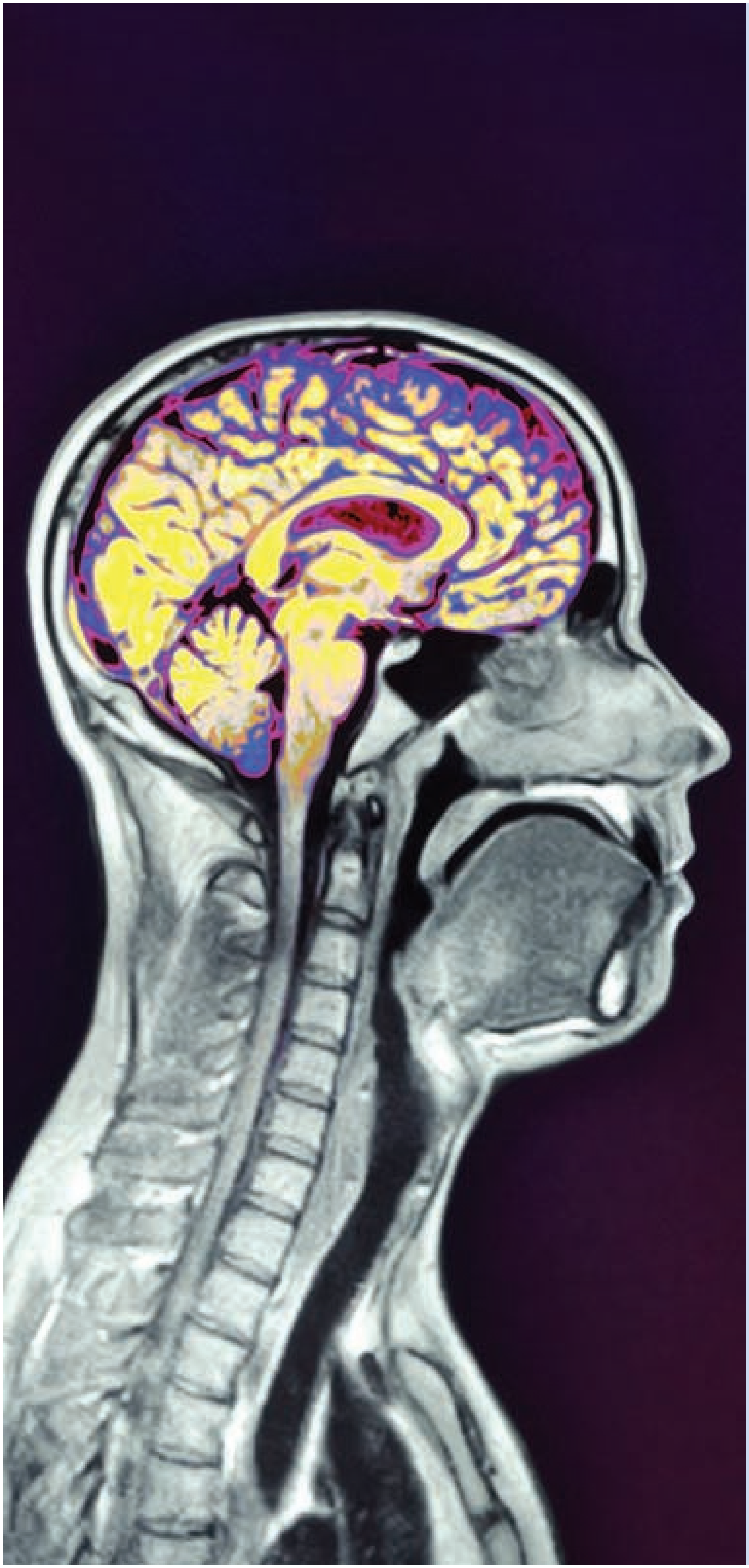


Chapter Outline

CHAPTER 3

Biological Foundations of Behavior

PROLOGUE

Psychological life depends on biological life for its very existence. This means that the way we behave is influenced to a great extent by the nature of the body. If humans did not have hands that grasp, we might never have learned to write, paint, or play racquetball. If we did not have eyes that could see color, we would see a world that existed only in shades of black and white.

The brain is the part of the body that is most intimately linked to psychological life. A simple experiment conducted by Canadian brain surgeon Wilder Penfield in the 1930s dramatically illustrates the key role played by the brain. Dr. Penfield was conducting surgery on the surface layer of the brain known as the cerebral cortex while the patient was awake during local anesthesia. When Penfield placed a small rod that carried a mild electric current against the brain, there were astonishing results. The patient began to recall in vivid detail an incident from years before. She was in her kitchen, listening to the voice of her little boy playing in the yard. In the background, she could hear the noises of the neighborhood, the cars passing in the street. Penfield was amazed to discover that stimulation of particular spots on the brain could produce experiences of sights and sounds. Another patient recalled a small-town baseball game that included a boy trying to crawl under a fence. Another woman recalled a melody each time a certain point on the cortex was stimulated. The lesson of Penfield's experiments is clear—the brain and our psychological lives are intimately connected.

This chapter is about topics that you would expect to find in a biology course, but it was written to help you understand psychology better. We will discuss only those aspects of human biology that are directly relevant to understanding behavior: the brain and nervous system, endocrine glands, and genetic mechanisms. Without these biological systems, psychological life could not exist.

When we look at ourselves in this way, we see that we are psychological beings living in biological "machines." Just as electronic machines are built from wires, transistors, and other components, the nervous system is built from specialized cells called neurons. Billions of neurons in your nervous system transmit messages to one another in complex ways that make the nervous system both the computer and communication network of the body. The biological control center of the nervous system is the brain. It has many parts that carry out different functions, but the many parts of the brain operate together in an integrated way.

The nervous system can be thought of as consisting of two large parts. One part consists of the brain and the bundle of nerves that run through the spinal column. Because it is located within the skull and spine, this part is called the central nervous system. The many nerves that lie outside of the skull and spine comprise the second part of the nervous system. Because it reaches the periphery of the body, this part is called the peripheral nervous system.

The brain communicates with the body through an intricate network of neurons that fan out to every part of the body. But the brain also uses the endocrine glands to communicate with the body. These glands secrete chemical messengers, called hormones, that travel to the body through the bloodstream. Hormones

KEY TERMS

regulate the functions of many parts of the body and influence our behavior and experience. Hormones are powerful tools of the brain, but they influence us in diffuse rather than precise ways.

The fact that the nature of the nervous and endocrine systems influences our psychological functioning means that heredity can influence our behavior by shaping our nervous and endocrine systems. Heredity operates through genes in the nucleus of the body's cells. These genes contain codes that allow heredity to influence the development of our bodies. We do not inherit specific behaviors in the same way that we inherit eye color, though. Instead, the genes influence the development of the brain, endocrine glands, and other body structures in ways that influence our behavior in very *broad* ways. For example, we do not inherit the ability to read, but it appears that heredity is one of the factors that influences how quickly a child learns to read. This is because heredity seems to be one of the factors that determines our intelligence. Similarly, it appears that heredity influences broad aspects of personality.

Nervous System: Biological Control Center

The nervous system is both a powerful computer and a complex communication network. But unlike any computer, the complex mass of nerve cells called the **brain** not only thinks and calculates but also feels and controls motivation. The brain is connected to a thick bundle of long nerves running through the spine, called the **spinal cord.** Individual nerves exit or enter the spinal cord and brain, linking every part of the body to the brain. Some of these nerves carry messages from the body to the brain to keep the brain informed about what is going on in the body. Other nerves carry messages from the brain to the body to regulate the body's functions and the person's behavior. Without the nervous system, the body would be no more than a mass of uncoordinated parts that could not act, reason, or experience emotions. In other words, without a nervous system, there would be no psychological life.

brain
The complex mass of neural cells and related cells encased in the skull.

spinal cord
The nerve fibers in the spinal column.

neuron
(nu´ron) An individual nerve cell.

cell body
The central part of the neuron that includes the nucleus.

Neurons: The Units of the Nervous System

Computers, telephone systems, and other electronic systems are made of individual wires, transistors, microchips, and other components that transmit and regulate electricity. These components are arranged in complex patterns to create functioning systems. The nervous system is similarly made up of components. The most important unit of the nervous system is the individual nerve cell, or **neuron.** We will begin our discussion of the nervous system with the neuron and then progress to a discussion of the larger parts of the nervous system. As we discuss the neuron in technical, biological terms, try not to forget its importance to consciousness and behavior.

In the early 1900s, Santiago Ramón y Cajal, the scientist who first discovered neurons, described them as "the mysterious butterflies of the soul, the beating of whose wings may someday—who knows?—clarify the secret of mental life." Since his time, much has been learned about these building blocks of the brain. Much remains to be learned about neurons, but some current research is so advanced that it sounds more like science fiction than reality. For example, Masuo Aizawa (1994) has used specially treated living nerve cells outside of the body to construct a simple "living computer" that processes information much like the nervous system does. In time, research like Aizawa's may lead to the ability to repair damaged nerves, like those of actor Christopher Reeve, who was paralyzed by a fall from a horse.

The knoblike tips of the axons transmit messages to the next nerve cell.

Parts of Neurons

Neurons range in length from less than a millimeter to more than a meter in length, yet all neurons are made up of essentially the same parts (see fig. 3.1). The **cell body** is the

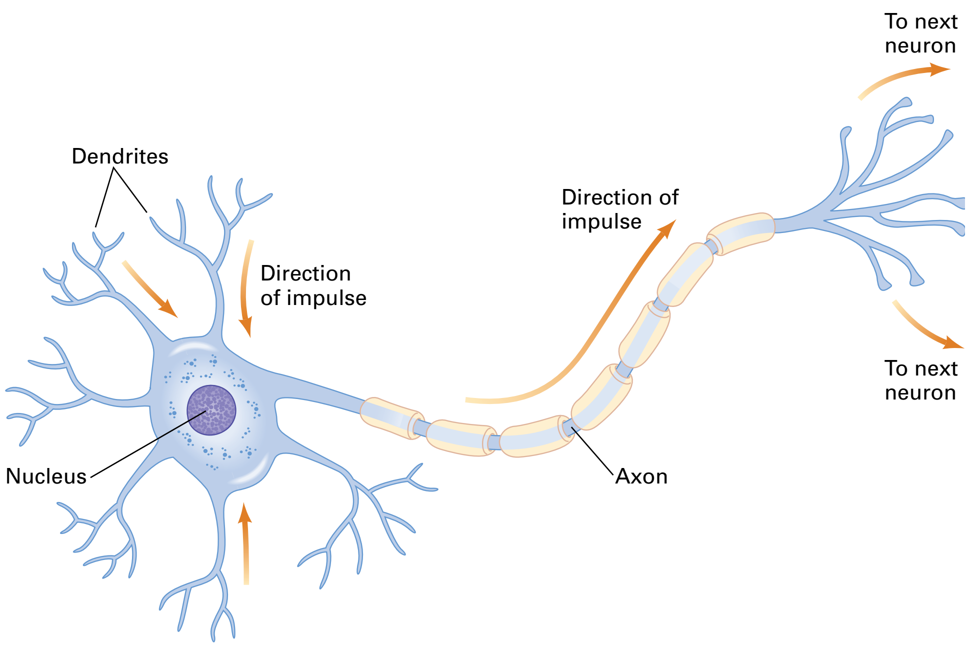


FIGURE 3.1
Neurons are typically composed of a cell body, which contains the nucleus of the cell, dendrites that typically receive impulses from other neurons, and an axon that passes the neural impulse on to the next neuron.

central part of the nerve cell. It contains the cell's control center, or *nucleus*, and other components of the cell necessary for the cell's preservation and nourishment. **Dendrites** are small branches that extend out from the cell body and receive messages from other neurons. Other parts of the neuron play a role in receiving messages from other neurons, but the dendrite is the specialized part of the neuron that plays the greatest role in receiving neural messages.

The **axons** are small branches at the other end of the neuron that perform a function opposite that of the dendrites. They carry messages away from the cell body and transmit these messages to the next neuron. (It's easy to remember the difference between the functions of the dendrites and axons by remembering that the axon "acts on" the next cell.) The message transmitted along the axon may be picked up by the dendrites of one or more other neurons. Neurons, then, have a cell body, dendrites, and an axon. The shape and size of these parts can vary greatly, depending on what function the neuron serves.

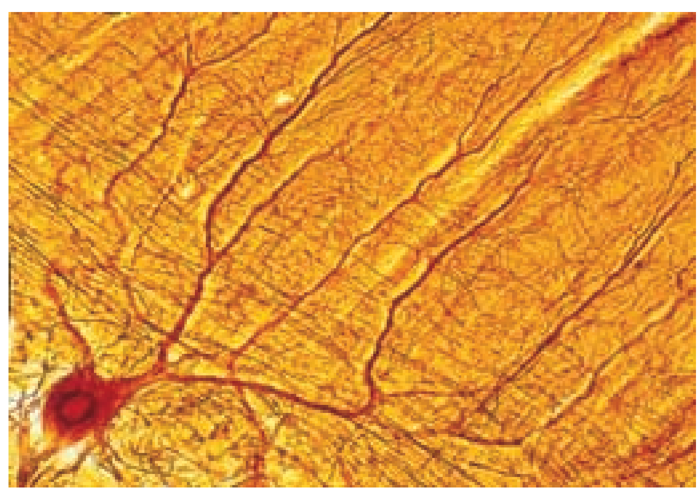
dendrites
(den´ drīts) Extensions of the cell body that usually serve as receiving areas for messages from other neurons.

axons
(ak´sonz) Neuron branches that transmit messages to other neurons.

nerve
A bundle of long neurons outside the brain and spinal cord.

Neurons are grouped in complex networks that make the largest computer seem like a child's toy. The nervous system is composed of 100 billion neurons (Kandel, Schwartz, & Jessel, 1995), about as many as the number of stars in our galaxy. Each neuron can receive messages from or transmit messages to 1,000 to 10,000 other neural cells. All told, your body contains trillions of neural connections, most of them in the brain. These numbers are not important in their own right, but they may help us understand the incredibly rich network of neural interconnections that makes us humans. Incidentally, be careful not to confuse the term *neuron* with the term **nerve;** they are not synonyms. A nerve is a bundle of many long neurons—sometimes thousands of them—outside the brain and spinal cord.

As described in the next two sections, neurons transmit messages in the nervous system in two steps: the transmission of the message from one end of the neuron to the other end (neural transmission) and transmission from one neuron to the next neuron (synaptic transmission).



A neuron in the human brain.

Neural Transmission

Neurons are the “wires” of the nervous system—messages are transmitted over the neuron much like your voice is transmitted over a telephone line. But neurons are living wires, with their own built-in supplies of electrical power—they are the “batteries” of the nervous system, too.

Neurons can take on the functions of wires and batteries because, like all living cells, they are wet. Neurons are sacs filled with one type of fluid on the inside and bathed in a different type of fluid on the outside. This is an important fact. Both types of fluid are thick “soups” of dissolved chemicals, including **ions,** which are particles that carry either a positive or negative electrical charge. More of the ions inside neurons are negatively rather than positively charged, making the overall charge of the cell a negative one. This negative charge attracts positively charged ions, just as the negative pole of a magnet attracts the positive pole of another magnet. Thus, the outside of the cell membrane becomes cloaked in positive ions, particularly sodium (Na+). In the resting state, there are 10 times as many positively charged sodium ions outside the membrane of the neuron than inside. This is the source of the neuron’s electrical energy—it is electrically positive on one side of the membrane and negative on the other.

ions
(i´ons) Electrically charged particles.

cell membrane
The covering of a neuron or another cell.

semipermeable
(sem´´ē-peŕ-mē-ah-b´l) A surface that allows some, but not all, particles to pass through.

polarized
(pō̆lar-īz´d) The resting state of a neuron, when more negative ions are inside and more positive ions are outside the cell membrane.

If you have trouble remembering which side of the membrane has most of the positive sodium ions, keep in mind that there is a lot of sodium in salty seawater. The fluid on the *outside* of neurons is almost identical to seawater in its chemical contents, including the high amounts of sodium. Why is this so? According to the theory of evolution, as animals evolved and moved from the oceans onto the land, they brought seawater with them *in their bodies*. This seawater-like liquid fills the space between the body’s cells. Therefore, it makes sense that the fluid bathing the neural cells is rich in sodium ions.

Many ions are able to move freely through the **cell membrane** of the neuron, but other ions cannot, including the sodium ions. For this reason, the membrane is said to be **semipermeable**—only some chemicals can permeate, or pass through, “holes” in the membrane. When the neuron is in its normal resting state, the membrane is semipermeable and does not let positive sodium ions into the cell. Therefore, a balance exists between the mostly negative ions on the inside and the mostly positive ions on the outside. In this condition, the neuron is said to be electrically **polarized** (see fig. 3.2).

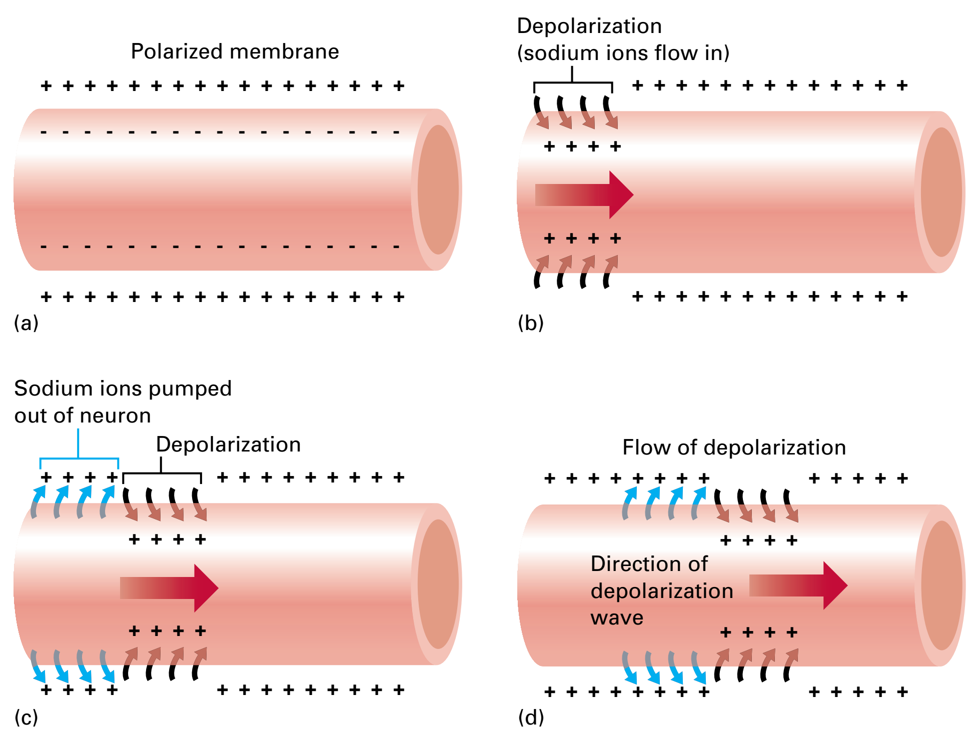


FIGURE 3.2
Short sections of an axon illustrating neural transmission (an action potential). (a) When an axon is in its resting state, there is a balance between the number of positively and negatively charged ions along the membrane. (b) When the axon is sufficiently stimulated, the membrane allows positively charged sodium ions to pass into the cell, depolarizing that spot on the membrane. (c) This depolarization disturbs the adjacent section of the membrane, allowing sodium ions to flow in again while sodium ions are being pumped back out of the first section. (d) This process continues as the swirling storm of depolarization continues to the end of the axon.

When the membrane is stimulated by an adjacent neuron, however, the semipermeability of the membrane is changed. Positively charged ions, including the important sodium ions, are then allowed to enter the neuron, making the inside less negative. This process is called **depolarization.**

Neural transmission operates according to the **all-or-none principle.** This means that a small amount of depolarization will not affect the neuron. A larger depolarization, however, will trigger a dramatic chain of events known as the **action potential.** It is the action potential that transmits the neural message. The depolarization must be strong enough to trigger an action potential, but the strength of the action potential does not depend on the strength of the depolarization. They are all the same once they get started. In a sense, then, our nervous systems are more like digital electronic systems (that transmit either 1s or 0s) than analog systems (that transmit signals of different strengths). If the depolarization is strong enough to fire the neuron, it is a "1." If not, no transmission occurs at all (it is a "0").

During an action potential, a small section of the axon adjacent to the cell body becomes more permeable to the positive sodium ions. The sodium ions rush in, producing a dramatic depolarization in that part of the axon. Very quickly, however, the membrane regains its semipermeability and "pumps" the positive sodium ions back out, reestablishing the neuron's polarization. This tiny electrical storm of sodium ions flowing in and out of the neuron—which lasts approximately one-thousandth of a second—does not stop there, however. It disturbs the adjacent section of the membrane of the axon, so that it depolarizes, which in turn disturbs the next section of the membrane, and so on. Thus, the action potential—the flowing storm of ions rushing in and out—travels the length of the axon. Local anesthetics, such as the Novocain that your dentist injects, stop pain by chemically interrupting this flowing process of depolarization in the axons of nerves that carry pain messages to the brain.

Many axons are encased in a white, fatty coating called the **myelin sheath.** This sheath, which is wrapped around the axon like the layers of a jelly roll, insulates the axon and greatly increases the speed at which the axon conducts neural impulses (see fig. 3.3).

The myelin sheath continues to grow in thickness into late adulthood. Interestingly, from early childhood to late adulthood, the average thickness of myelin is greater in females than males in some areas of the brain (Benes, 1998). This may indicate more efficient neural processing of some kinds of information by females. Sadly, the importance of the myelin sheath in neural transmission can be seen in victims of multiple sclerosis. This disease destroys the myelin sheath of many neurons, leaving them unable to

depolarization
The process during which positively charged ions flow into the axon, making it less negatively charged inside.

all-or-none principle
The law that states that once a neural action potential is produced, its magnitude is always the same.

action potential
A brief electrical signal that travels the length of the axon.

myelin sheath
(mī´ e-lin) The insulating fatty covering wrapped around the axon that speeds the transmission of neural messages.

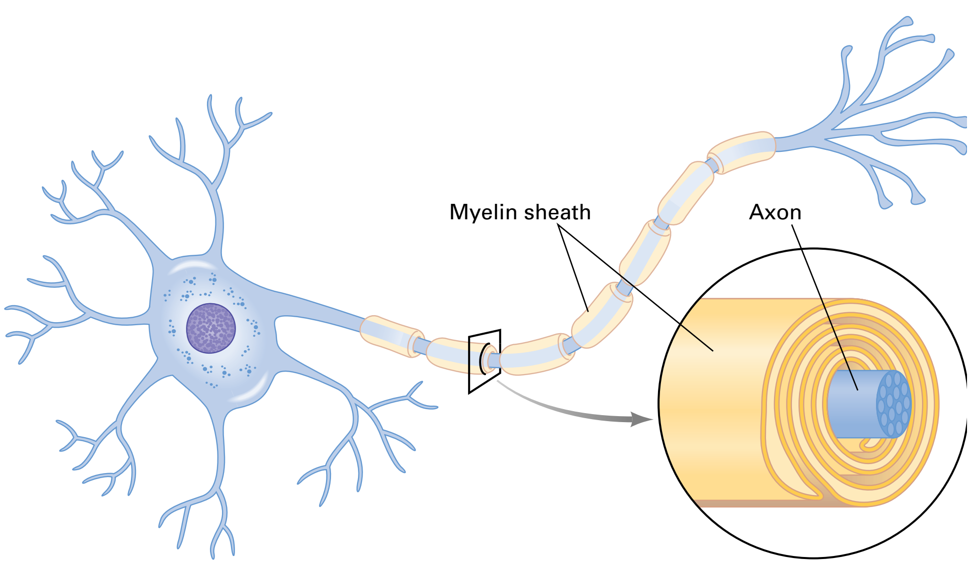


FIGURE 3.3
Many neurons are wrapped like a jelly roll in a white, fatty substance called myelin. The myelin sheath insulates the axon and speeds neural transmission.

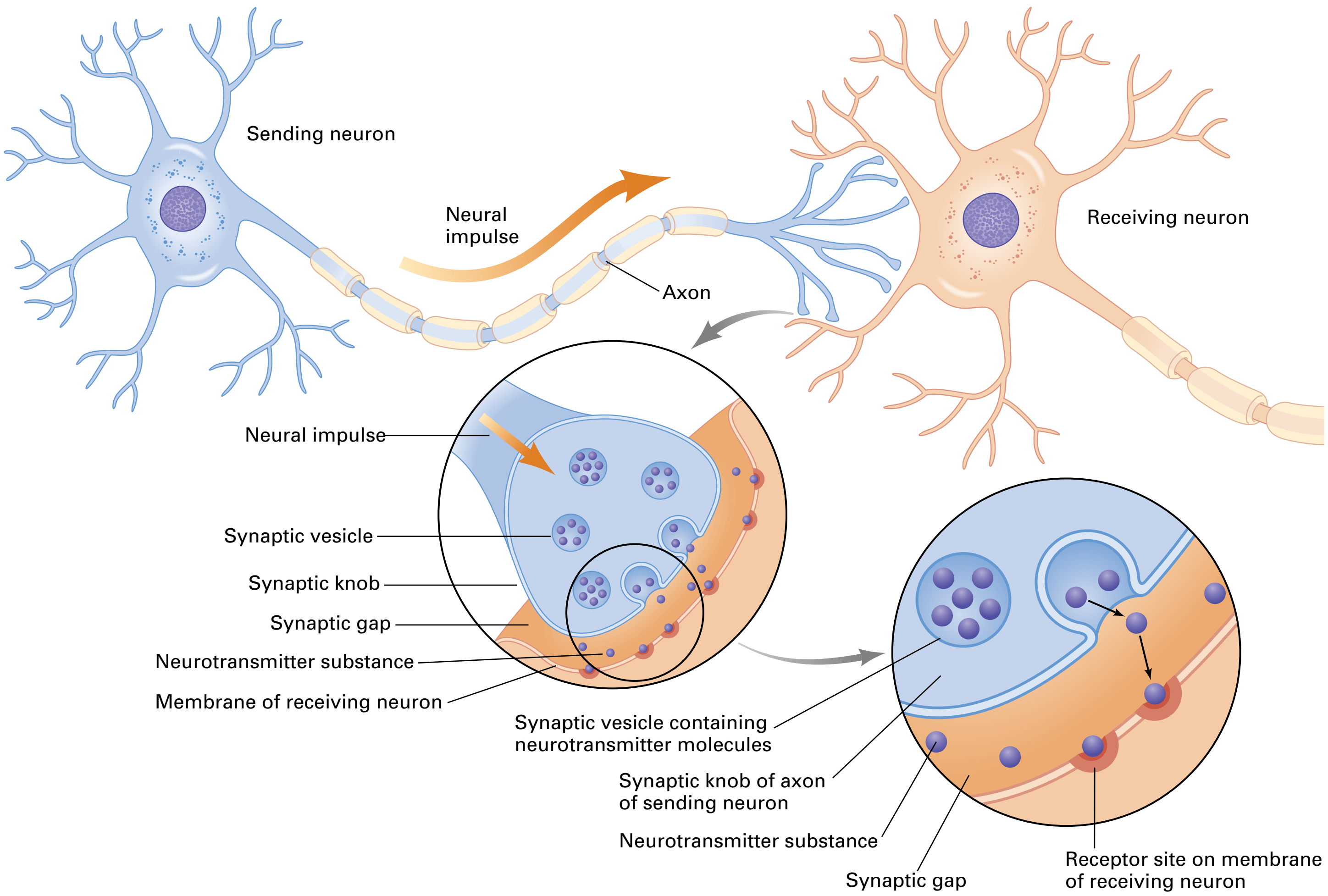


FIGURE 3.4
Neural messages are transmitted chemically from the axon of the sending neuron to the receiving neuron. The neurotransmitter substance contained in the synaptic vesicles is secreted across the synaptic gap. The neurotransmitter is able to stimulate the receiving neuron because its chemical "shape" matches that of receptor sites on the receiving neuron.

operate at normal efficiency. As a result, individuals with multiple sclerosis have severe difficulties controlling their muscles; experience fatigue, dizziness, and pain; and suffer serious vision problems (Morell & Norton, 1980).

Neurotransmitters and Synaptic Transmission

Neurons are linked together in complex chains, but they are not directly connected to each other. The junction between one neuron and another is called the **synapse.** The small space between two neurons is known as the **synaptic gap.** The electrical action potential cannot jump across this gap, however. Instead, the neural message is carried across the gap by chemical substances called **neurotransmitters.** The capacity of the brain to process information is multiplied many times by the fact that not all neurotransmitters are *excitatory.* Some axons transmit *inhibitory* substances across synapses, which makes it more difficult for the next neuron to fire. Thus, the brain is composed of a staggering network of "yes" and "no" circuits that process and create our experiences (Kandel & others, 1995).

Most neurotransmitters are stored in tiny packets called **synaptic vesicles** located in the knoblike ends of the axons—called **synaptic knobs.** When an action potential reaches the axon knob, it stimulates the vesicles to release the neurotransmitter into the

synapse
(sin-aps´) The space between the axon of one neuron and another neuron.

synaptic gap
The small space between two neurons at a synapse.

neurotransmitters
(nu´´rō-tranz´-mit-erz) Chemical substances, produced by axons, that transmit messages across the synapse.

synaptic vesicles
Tiny vessels containing stored quantities of the neurotransmitter substance held in the synaptic knobs of the axon.

synaptic knobs
(si-nap´tik) The knoblike tips of axons.

gap. The neurotransmitter floats across the gap and "fits" into **receptor sites** on the adjacent neuron's membrane like keys fitting into locks. This changes the polarity of the receiving neuron, which either causes an action potential that continues the neural message on its way (see fig. 3.4) or inhibits the receiving neuron from firing.

Many different neurotransmitter substances operate in different parts of the brain, carrying out different functions—probably as many as 50 different neurotransmitters (Kandel & others, 1995). Because of this fact, the process of synaptic transmission in a particular portion of the brain can be altered through the use of drugs that chemically alter the function of one of these neurotransmitters. Thus, emerging knowledge about neurotransmitters has made possible the use of psychiatric drugs to help control anxiety, depression, and other psychological problems. These drugs operate by increasing or decreasing the effectiveness of a specific neurotransmitter. Most drugs that have psychological effects influence neural transmission at the synapse. Some drugs have a chemical structure that is similar enough to a neurotransmitter to fit the receptor sites on the receiving neuron and cause an action potential. Other drugs are similar in chemical structure to a neurotransmitter, but they block the receptor site and reduce the likelihood of neural transmission. Still another class of drugs reduces the amount of neurotransmitter that is reabsorbed by the axon, keeping it active in the synapse longer and increasing the likelihood of neural transmission. The drug Prozac, which is widely used for depression, operates by reducing the reabsorption of a neurotransmitter. (See table 3.1.)

receptor sites
Sites on the neuron that receive the neurotransmitter substance.

acetylcholine
(a˝suh-teel´ koh˝leen) A neurotransmitter used by somatic neurons that contract the body's large muscles. Acetylcholine also plays a role in memory and is thought to help regulate dreaming.

dopamine
(do˝pah´meen) A neurotransmitter substance used by neurons in the brain that control large muscle movements and by neurons in pleasure and reward systems in the brain.

serotonin
(ser´uh-to˝nin) A neurotransmitter used by systems of neurons believed to regulate sleep, dreaming, appetite, anxiety, depression, and the inhibition of violence.

TABLE 3.1 Selected Neurotransmitters

The neurons of the brain and nervous system use a large number of different neurotransmitters to intricately manage its complex functions. Each year, new neurotransmitters are discovered and more is learned about their biological and psychological functions. A few of the many neurotransmitters are described here to provide examples of their diversity and to lay a foundation for more detailed discussions in later chapters (Cooper, Blum, & Roth, 1996).

Acetylcholine

Acetylcholine is used by the somatic neurons that contract the body's large muscles. Some poisonous snakes and spiders secrete venoms that disrupt the action of acetylcholine in the synapse, suffocating their prey by interfering with the muscular control of breathing. Similarly, some native peoples of South America put *curare* on the tips of blowgun darts to paralyze animals by blocking the action of acetylcholine. Acetylcholine also plays a role in regulating wakefulness in the brain, is one of the neurotransmitters believed to play a role in dreaming, and plays a role in memory.

Dopamine

One large group of neurons in the brain that uses **dopamine** as the neurotransmitter is involved in the control of large muscle movements. Persons with Parkinson's disease experience uncontrollable muscle tremors and other movement problems because of the depletion of dopamine in these neural circuits. A second group of dopamine neurons appears to play a central role in pleasure and reward systems in the brain and may be involved in the mental disorders of schizophrenia and attention-deficit hyperactivity disorder. This second group of neurons appears to be stimulated by cocaine and other drugs of abuse.

Serotonin

Serotonin plays an important role in a number of seemingly unrelated psychological processes. Serotonin is one of the brain neurotransmitters that is believed to regulate sleep cycles and dreaming, appetite, anxiety, depression, and the inhibition of violence. The widely discussed drug Prozac increases the action of serotonin by keeping it active in the synapse longer.

(continued on page 64)

norepinephrine
(nor´ep-i-nef´rin) A neurotransmitter believed to be involved in vigilance and attention and released by sympathetic autonomic neurons and the adrenal glands.

glutamate
(gloo-tuh-māt) The most widespread excitatory neurotransmitter in the brain.

neuropeptides
(nur-o-pep-tidz) A large group of neurotransmitters sometimes referred to as neuromodulators, as they appear to broadly influence the action of the other neurotransmitters.

Table 3.1 continued

Norepinephrine
Systems of neurons in the brain that use **norepinephrine** (also known as *noradrenaline*) as the neurotransmitter are believed to play a role in vigilance and attention to important events, such as the presence of rewards or dangers in the environment. It is also thought to be one of the neurotransmitters involved in anxiety and depression. Norepinephrine is also the neurotransmitter in many neurons of the sympathetic division of the autonomic nervous system and plays the role of a hormone when it is released by the adrenal glands.
Glutamate
Glutamate is the major excitatory neurotransmitter in the central nervous system, with virtually every neuron in the brain containing glutamate receptors. Glutamate is thought to play a key role in the regulation of cognition and emotion (and their serious dysfunction in schizophrenia) and is believed to play a key role in the development and shaping of the neural structure of the brain over the life span.
Neuropeptides
The **neuropeptides** are a broad class of neurotransmitters that differ considerably in chemical composition from other transmitters. They often are secreted by the same neurons that secrete other neurotransmitters. Neuropeptides are sometimes referred to as neuromodulators, because they influence the action of the other neurotransmitters released by their neuron in broad ways. For example, some neurons that release acetylcholine into their synapses also release one or more neuropeptides. When the neuropeptide is released, it can increase or decrease the normal effects of the acetylcholine. Neuropeptides have longer-lasting effects than other neurotransmitters, are released through parts of the neuron other than the axon in many instances, and diffusely affect other nearby neurons. As will be discussed later in this chapter, some neuropeptides are also secreted by some endocrine glands.

Review

The nervous system is a highly effective living computer and communication system built of neurons. These specialized cells transmit neural messages from their dendrites to their axons in a flowing swirl of electrically charged molecules produced by the changing semipermeability of their membranes. When the neural message reaches the tip of the axon, it is transmitted across the synaptic gap to the next neuron by a neurotransmitter substance. Many of the longer neurons are wrapped in an insulating layer called the myelin sheath, which increases the speed of transmission of neural messages.

Check Your Learning

To be sure that you have learned the key points from the preceding section, cover the list of correct answers and try to answer each question. If you give an incorrect answer to any question, return to the page given next to the correct answer to see why your answer was not correct. Remember that these questions cover only some of the important information in this section; it is important that you make up your own questions to check your learning of other facts and concepts.

1. The part of the neuron that most often receives messages from other neurons is called the

    a) axon.
    b) cell body.
    c) dendrite.
    d) myelin sheath.

2. The part of the neuron that transmits the neural message to the next neuron by releasing a neurotransmitter across the synaptic gap is called the

   a) axon. c) dendrite.
   b) cell body. d) myelin sheath.

3. During the process of conducting an action potential down the length of the neuron's membrane, the balance of positive ions on the outside of the neuron and negative ions on the inside is disturbed for a moment (called "depolarization") when the ________________ are allowed to rush into the neuron through the semipermeable membrane of the cell.

   a) sodium ions c) LSD
   b) neurotransmitters d) negative ions

4. The fatty covering of some long neurons that insulates them and allows them to carry messages more rapidly is called the ________________.

Thinking Critically about Psychology

1. The neurons in the nervous system are not directly connected to one another, and messages must be transmitted across the synaptic gap using neurotransmitters. How would we be different if the neurons were simply connected like wires?
2. Some drugs that affect the nervous system are thought of as useful medications, whereas others are illegal because they are thought to be harmful. Why do such drugs have the potential to harm or help?

Correct Answers: **1.** c (p. 59), **2.** a (p. 59), **3.** a (p. 60), **4.** myelin sheath (p. 61).

Divisions of the Nervous System

Our complex nervous systems have many different parts, or divisions. The major divisions of the nervous system are the central nervous system and the peripheral nervous system. The **central nervous system** consists of the brain and the spinal cord. The **peripheral nervous system** is composed of the nerves that branch from the brain and the spinal cord to all parts of the body (see fig. 3.5). Nerves of the peripheral nervous system transmit messages from the body to the central nervous system. They also transmit messages from the central nervous system to the muscles, glands, and organs that put the messages into action.

Messages can travel across the synapse in only one direction. So messages coming from the body into the central nervous system are carried by one set of neurons, the **afferent neurons.** Messages going out from the central nervous system to the organs and muscles are carried by another set, the **efferent neurons.**

The spinal cord's primary function is to relay messages between the brain and the body, but it also does some rudimentary processing of information on its own. A simple reflex, such as the reflexive withdrawal from a hot object, is a good example. The impulse caused by the hot object travels up an afferent nerve to the spinal cord. Here a neuron, called an **interneuron,** transmits the message to an efferent neuron that, in turn, stimulates the muscles of the limb to contract (see fig. 3.6). Any behavior more complicated than a simple reflex, however, usually requires processing within the mass of interneurons that makes up the brain.

central nervous system
The brain and the spinal cord.

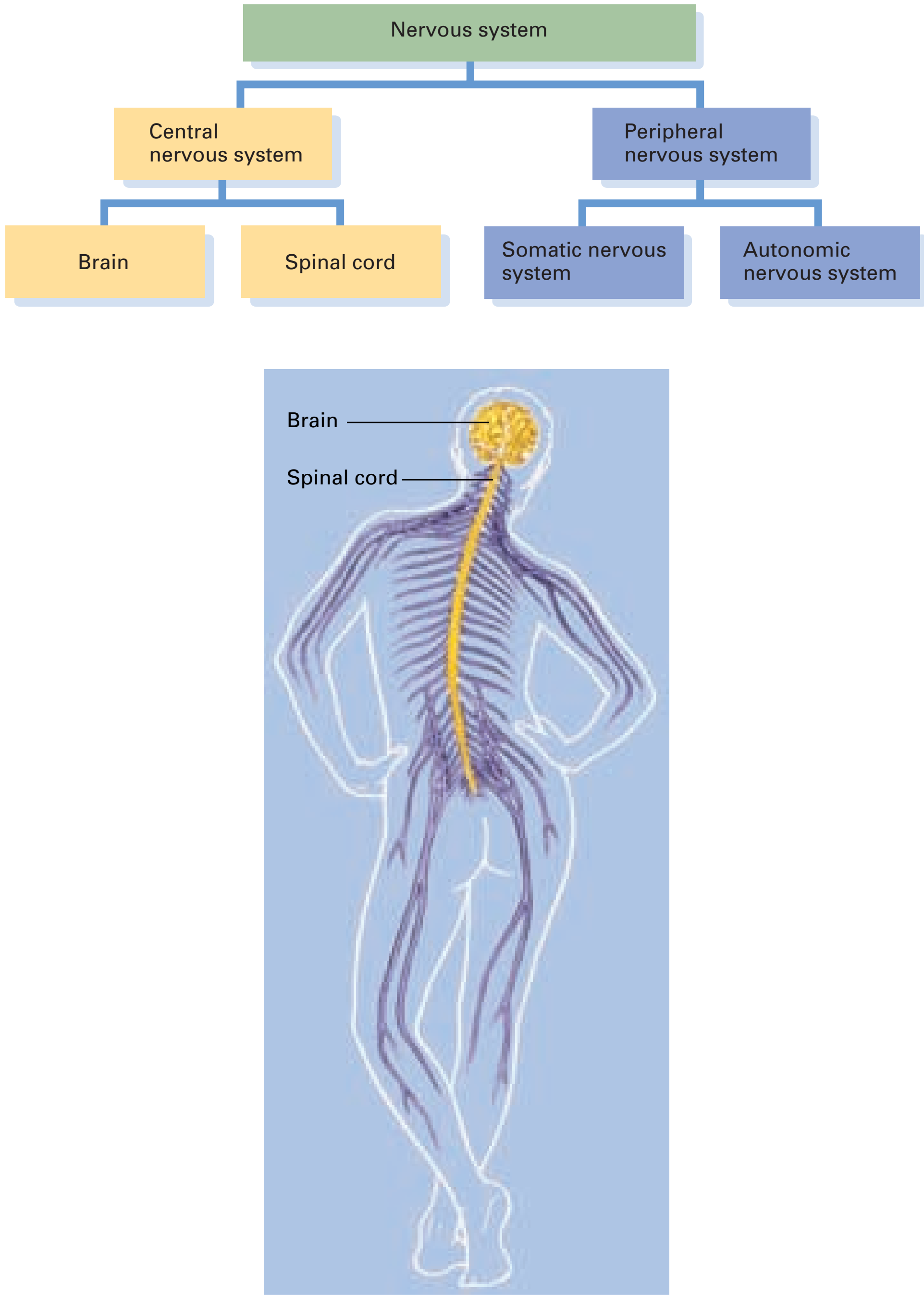
peripheral nervous system
(pĕ-rif´ er-al) The network of nerves that branches from the brain and spinal cord to all parts of the body.

afferent neurons
(af´er-ent) Neurons that transmit messages from sense organs to the central nervous system.

efferent neurons
(ef´er-ent) Neurons that transmit messages from the central nervous system to organs and muscles.

interneuron
Neurons in the central nervous system that connect other neurons.

FIGURE 3.5
Organization of the human nervous system.



somatic nervous system
(sō-mat′ik) The division of the peripheral nervous system that carries messages from the sense organs to the central nervous system and from the central nervous system to the skeletal muscles.

Divisions of the Peripheral Nervous System

The peripheral nervous system is further divided into the somatic and autonomic nervous systems. The **somatic nervous system** carries messages from the central nervous system to the skeletal muscles that control movements of the body. These include voluntary movements, as when I type the words on a manuscript page, and involuntary movements, as when my eyes maintain fixation on the screen of my word processor in spite of small but frequent changes in the position of my head as I type. The somatic nervous system also receives incoming messages from the sense organs, muscles, joints, and skin and transmits them to the central nervous system.

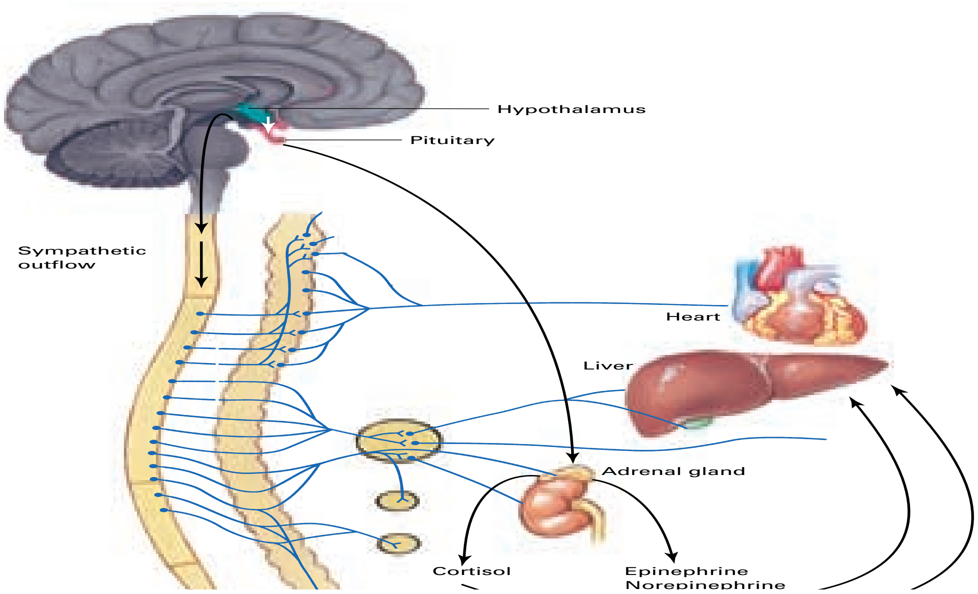


FIGURE 3.6
Some simple reflexes, such as the reflexive withdrawal of the hand from a hot object, are a result of a message's traveling along an afferent neuron from the hot spot on the hand to the spinal cord. In the spinal cord, the message travels across a short interneuron to an efferent neuron, which causes the muscles in the limb to contract.

The **autonomic nervous system** is composed of nerves that carry messages to the glands and visceral organs (heart, stomach, intestines, etc.). The autonomic nervous system only affects the skeletal muscles by influencing general muscle tension during stress. The autonomic nervous system plays a role in two primary functions:

1. ***Essential body functions.*** The autonomic nervous system automatically regulates many essential functions of the body. Heartbeat, breathing, digestion, sweating, and sexual arousal operate through the autonomic nervous system.
2. ***Emotion.*** The autonomic nervous system also plays a role in emotion. Have you ever wondered why you sometimes get a stomachache, diarrhea, a pounding heart, or a headache when you feel anxious? It's because the autonomic nervous system is activated during emotional states. When a person becomes very emotional, the autonomic system throws the internal organs out of balance in minor, but uncomfortable, ways. As we will see in chapter 13, prolonged emotional arousal can adversely affect the true health of the organs controlled by the autonomic nervous system.

autonomic nervous system (aw″to-nom′ik) The division of the peripheral nervous system that regulates the actions of internal body organs, such as heartbeat.

sympathetic nervous system (sim″pa-thet′ik) The division of the autonomic nervous system that prepares the body to respond to psychological or physical stress.

Divisions of the Autonomic Nervous System

The autonomic nervous system is composed of two integrated parts called the sympathetic and parasympathetic nervous systems. These two systems work together to adjust and balance the functioning of the body according to the circumstances that the individual faces.

As shown in figure 3.7, the **sympathetic nervous system** prepares the body to respond to psychological or physical stress. In many cases the sympathetic nervous system *activates* organs to improve our ability to respond to stress, but in other cases, it *inhibits* organs that are not needed at times of stress.

The sympathetic nervous system:

1. Opens (dilates) the pupils of the eyes to let in light
2. Decreases salivation as part of an overall inhibition of digestion
3. Speeds the beating of the heart
4. Dilates the passageways (bronchi) of the lungs to increase the flow of air

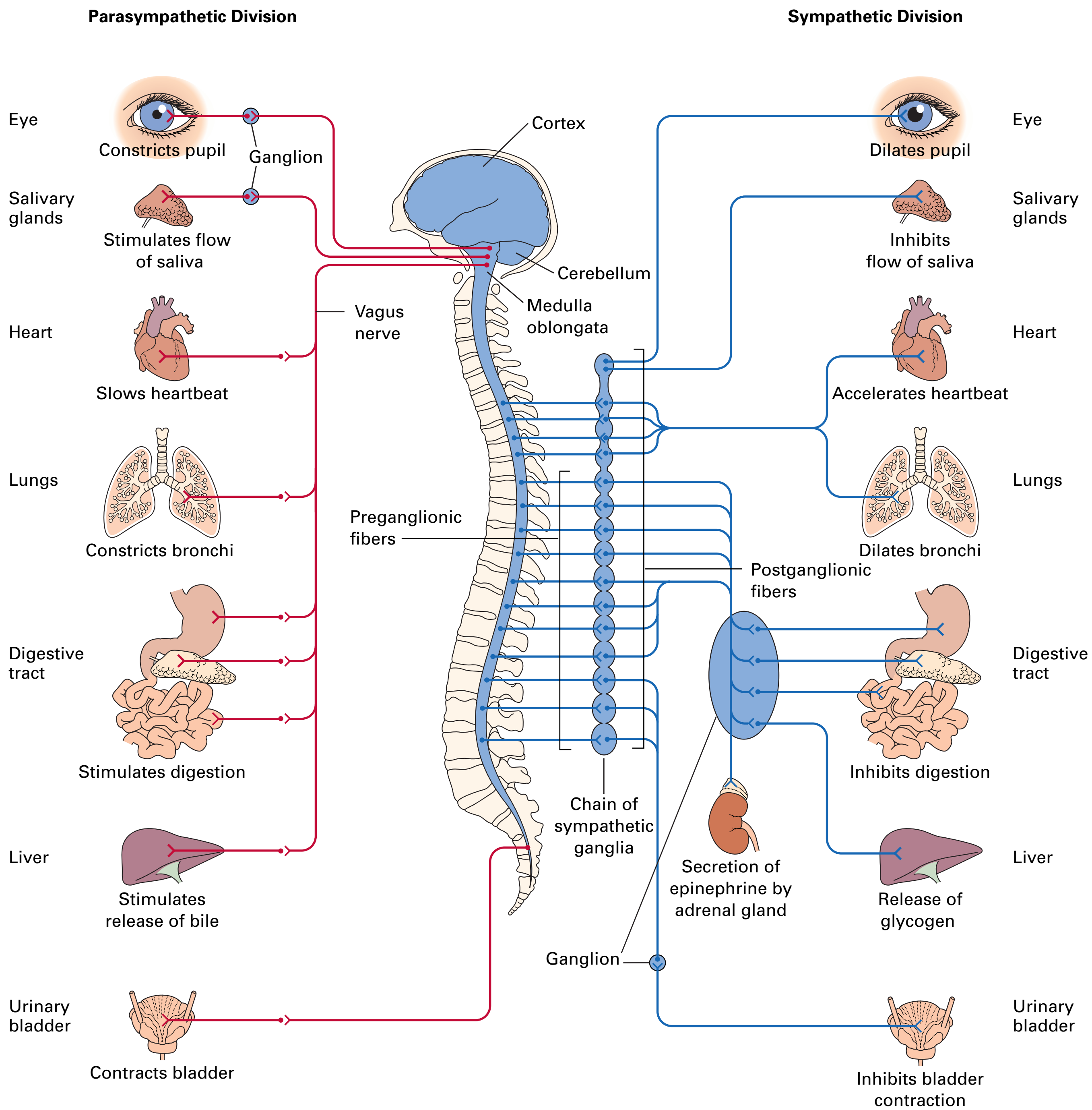


FIGURE 3.7
The sympathetic and parasympathetic divisions of the autonomic nervous system regulate many of the body's organs.

5. Inhibits the digestive tract (stomach, pancreas, intestines)
6. Releases sugar (glycogen) from the liver
7. Stimulates secretion of epinephrine from the adrenal glands
8. Inhibits contraction of the urinary bladder
9. Increases blood flow and muscle tension in the large muscles (not shown in figure 3.7)

The **parasympathetic nervous system** acts in tandem with the sympathetic nervous system to maintain balanced regulation of the internal organs and large body muscles. When stress levels are low, it stimulates maintenance activities and energy conservation. The parasympathetic nervous system:

1. Closes (constricts) the pupils of the eyes
2. Increases salivation to facilitate digestion
3. Slows the beating of the heart rate
4. Constricts the bronchi of the lungs
5. Activates the digestive tract
6. Releases bile from the liver to aid digestion of fats
7. Inhibits secretion of epinephrine from the adrenal glands
8. Contracts the urinary bladder
9. Reduces blood flow and muscle tension in the large muscles (not shown in fig. 3.7)

Why do many people experience a dry mouth and feel their heart pound when stressed—and have digestive problems under prolonged stress? The answers are in the list above. Here is an easy way to remember the difference between the functions of the sympathetic and parasympathetic nervous system. Use this simple mnemonic device: S is for sympathetic and stress, and P is for parasympathetic and peaceful.

The structure and functions of these two divisions of the autonomic nervous system can be seen more clearly by referring to figure 3.7. Essentially, all organs that are served by the sympathetic division are also served by the parasympathetic division. Note also that the clusters of cell bodies of neurons—called **ganglia**—are organized in different ways in the two divisions of the autonomic nervous system. The ganglia of the sympathetic division are all connected in a chain near the spinal column. This arrangement results in the sympathetic division's operating in a diffuse manner. That is, when the sympathetic division is aroused, it tends to stimulate all of the organs it serves to some extent—because all of its parts are chained together through the ganglia. The ganglia of the parasympathetic division, in contrast, are separate and located near the individual organs. This allows the parasympathetic division to operate more selectively, which is particularly fortunate in some instances. For example, the parasympathetic division stimulates the flow of saliva and the flow of urine. If the parasympathetic ganglia that control the salivary glands and the urinary system were not separate, we would wet our pants every time we salivated!

We do not consciously control the actions of the autonomic nervous system. It carries out its regulation of the heart, lungs, intestines, sweat glands, and so on in an automatic way that does not require our awareness or intentional control. It plays its role in emotion in an equally automatic way.

parasympathetic nervous system
(par″uh-sim″pa-thet′ik) The division of the autonomic nervous system that promotes bodily maintenance and energy conservation and storage under nonstressful conditions.

ganglia
(gang′glē-ah) Clusters of cell bodies of neurons outside of the central nervous system.

Review

The nervous system can be divided into a central nervous system, composed of the brain and spinal cord, and a peripheral nervous system, composed of nerves that carry messages to and from the body. The peripheral nervous system is further divided into the somatic and autonomic nervous systems. The somatic nervous system carries messages from the sense organs, muscles, and joints to the central nervous system and from the central nervous system to the skeletal muscles. The autonomic nervous system is responsible for the regulation of the internal organs in response to changing demands. The autonomic nervous system can be divided into two working parts: the sympathetic nervous system, which prepares the body for stress or exertion, and the parasympathetic nervous system, which promotes bodily maintenance and energy conservation and storage during peaceful times.

Check Your Learning

To be sure that you have learned the key points from the preceding section, cover the list of correct answers and try to answer each question. If you give an incorrect answer to any question, return to the page given next to the correct answer to see why your answer was not correct.

1. The nervous system can be divided into two major parts, the peripheral and the ________________ nervous system.

   a) autonomic c) somatic
   b) afferent d) central

2. The neurons in the somatic division of the peripheral nervous system that transmit messages from the sense organs to the central nervous system are called ________________ neurons.

   a) efferent c) sympathetic
   b) afferent d) parasympathetic

3. The division of the peripheral nervous system that adjusts the functioning of the body according to the circumstances that it faces is called the ____________ nervous system.

   a) autonomic c) automatic
   b) somatic d) central

4. During stress, the division of the autonomic nervous system that prepares the body for exertion or danger is called the ________________ division.

   a) visceral c) parasympathetic
   b) sympathetic d) central

Thinking Critically about Psychology

1. Why do you think our simple reflexes are "wired" into the nervous system (connections of afferent neurons, interneurons, and afferent neurons)?
2. What are the advantages and disadvantages to human beings of an autonomic nervous system that operates largely automatically (that we do not voluntarily control)?

Correct Answers: 1. **d** (p. 65), 2. **b** (p. 65), 3. **a** (p. 67), 4. **b** (p. 67).

Structures and Functions of the Brain

The brain is the fundamental basis for psychological life. We will begin our discussion of the brain with a brief description of the brain-imaging techniques that have revolutionized the study of the brain. We will then turn to the structures of the brain and their functions.

Images of the Brain at Work

Scientists have long studied the brain, but during the past 25 years, a number of exciting scientific tools have made the study of brain functions much easier. These techniques create images of the activities of the *living* brain by using computers to compile and interpret huge amounts of information from electrical activity, magnetic waves, and other forms of radiation. These computer-enhanced images of the brain are far more accurate and revealing than conventional X rays. In a very real sense, the advent of modern brain-

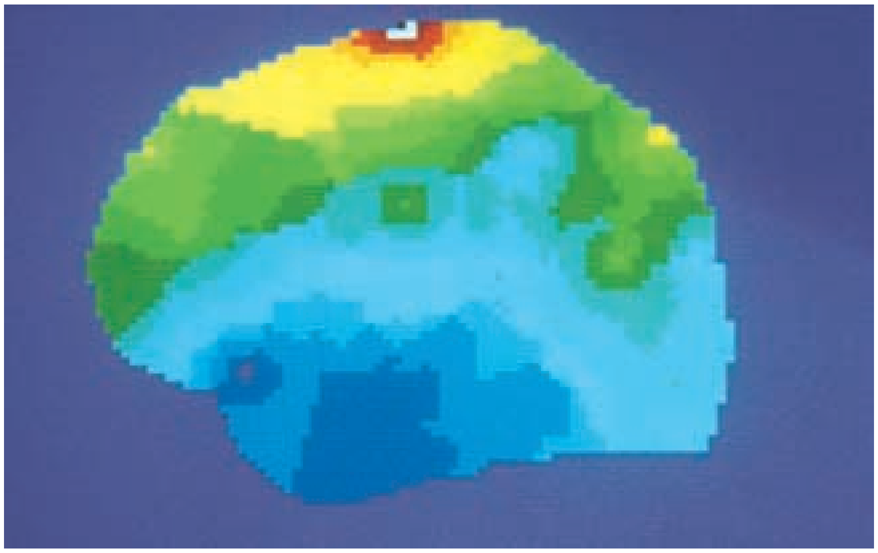


FIGURE 3.8
Image of the brain at work created by a computer from electrical recordings (EEG) of the activity of the brain. The image shows the activation of areas of the cerebral cortex of Dr. Monte Buchsbaum immediately after he administered a mild electric shock to his own arm.

imaging techniques is as important to the development of psychology and medicine's understanding of the brain as the invention of the telescope was to astronomy.

A traditional method of studying the brain's activity is the **electroencephalogram,** or **EEG.** Electrodes are placed on the surface of the person's scalp, and electrical activity from the brain is recorded. The EEG is commonly used to study the sleep cycle and to diagnose medical conditions, such as seizure disorder. One brain-imaging technique converts EEG recordings into computer-generated "maps" of brain activity. The head is covered with closely spaced electrodes to record brain activity. The computer converts these recordings into color images of the brain. The image in figure 3.8 shows the pattern of activity in the brain of psychiatric researcher Monte Buchsbaum moments after he administered a mild electrical shock to his own arm. The area of greatest neural activity (red and orange) is at the top of the brain. We will see later in this section that this is the area of the brain that receives skin sensations (Buchsbaum, 1983).

electroencephalogram (EEG) (e-lek´´trō-en-sef´ah-lo-gram) A recording of the electrical activity of the brain obtained through electrodes placed on the scalp.

positron emission tomography (PET) An imaging technique that reveals the functions of the brain.

A different kind of image is shown in figure 3.9. These images were created by computer interpretation of the activity of the brain obtained by **positron emission tomography,** or **PET** scanning. We see reduced activity in the outer portions of the brain beginning in image H and moving through image K as the powerful drug morphine (related to heroin) takes effect (London & others, 1990). In many similar experiments,

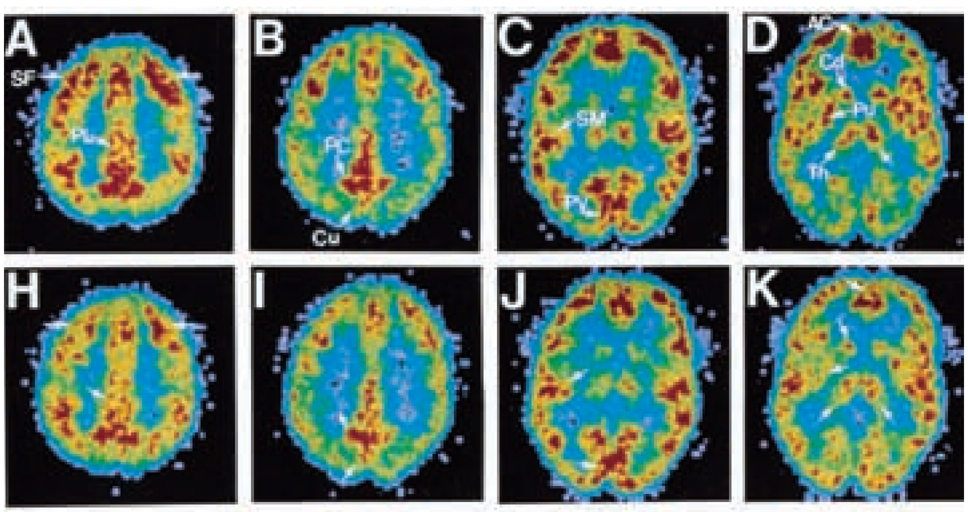


FIGURE 3.9
Color-coded PET scans showing rates of glucose use, a measure of brain activity, in a human volunteer who received placebo (A–D) and then morphine, a drug related to heroin (H–K). These images are displayed in sequence from upper to lower levels of the brain (left to right). The lower images (H–K) show a reduction in brain activity in key areas when the subject received the drug.

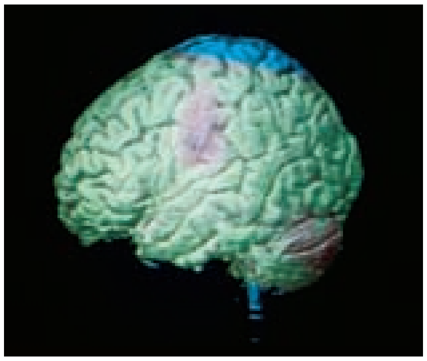


FIGURE 3.10
Three-dimensional image of the living brain based on computer-enhanced MRI.

the PET scan has given brain researchers extraordinary "photographs" of the living brain at work.

Perhaps the most amazing imaging technique is called **magnetic resonance imaging,** or **MRI.** This technique detects magnetic activity from the nuclei of atoms in living cells and creates visual images of the anatomy of the brain. Figure 3.10 shows an MRI of a living brain. Notice the amazingly accurate picture of the anatomy of the brain provided by MRI. More recently, a type of MRI has been developed that allows researchers not only to image the anatomy of the brain but also to measure the *activity* of specific parts of the brain. **Functional MRI** measures changes in the use of oxygen by neurons that reflect their levels of activity. This technique is safer than PET because it does not involve exposure to radiation.

Hindbrain and Midbrain: Housekeeping Chores and Reflexes

All mental functions require the integrated functioning of many parts of the brain; no function of the brain is carried out solely in one part. Still, the brain does have many specialized parts, each bearing primary responsibility for certain activities. The brain's many and complex structures can be classified in various ways. The most convenient classification divides the brain into three major parts: the hindbrain, the midbrain, and the forebrain. The major structures and functions of each part are described on the following pages. As we look at the brain, we will start at the bottom and work our way up.

The **hindbrain** is the lowest part of the brain, located at the rear base of the skull. Its primary responsibility is to perform routine "housekeeping" functions that keep the body working properly. The hindbrain has three principal parts: the medulla, the pons, and the cerebellum (see fig. 3.11). The **medulla** is a swelling just above the top of the spinal cord, where the cord enters the brain. It controls breathing and a variety of reflexes, including those that enable you to maintain an upright posture. The **pons** is concerned with balance, hearing, and some parasympathetic functions. It is located just above the medulla. The **cerebellum** consists of two rounded structures with a complex architecture located to the rear of the pons. It has long been known that the cerebellum plays a key role in the coordination of complex muscle movements, but it has become clear in recent years that it also plays an important role in types of learning and memory that involve coordinated sequences of information (Andreasen, 1999; Woodruff-Pak, 1999).

The **reticular formation** spans the medulla and pons. Neurons project from the reticular formation down the spinal cord and play a role in maintaining muscle tone and cardiac responsiveness to changing circumstances. More interesting to psychologists, rich networks of neurons arise in the reticular formation and end throughout the cerebral cortex. These networks play very important general roles in influencing wakefulness, arousal level, and attention. Although the reticular formation was originally thought of as a single neural system, it is now clear that it is composed of many neural systems that primarily use different neurotransmitters, including serotonin, norepinephrine, and acetycholine. These parts of the reticular formation influence somewhat different functions of the brain (Guillery & others, 1998; Mesulam, 1995).

The **midbrain** is a small area at the top of the hindbrain that serves primarily as a center for several postural reflexes, particularly those associated with the senses. For example, the automatic movement of the eyes to keep them fixed on an object as the head moves and the reflexive movement of the head to better orient the ears to a sound are both controlled in the midbrain.

Forebrain: Cognition, Motivation, Emotion, and Action

By far the most interesting part of the brain to psychologists is the **forebrain.** Structurally, the forebrain consists of two distinct areas. One area, which contains the thalamus, hypothalamus, and most of the limbic system, rests at the top of the hindbrain and midbrain (see fig. 3.12). The other area, made up primarily of the cerebral cortex, sits

magnetic resonance imaging (MRI)
An imaging technique using magnetic resonance to obtain detailed views of the brain structure and function.

functional MRI
A type of MRI that measures the activity of parts of the brain by measuring the use of oxygen by groups of neurons.

hindbrain
The lowest part of the brain, located at the base of the skull.

medulla
(mĕ-dul´ah) The swelling just above the spinal cord within the hindbrain responsible for controlling breathing and a variety of reflexes.

pons
(ponz) The part of the hindbrain that is involved in balance, hearing, and some parasympathetic functions.

cerebellum
(ser˝e-bel´um) Two rounded structures behind the pons involved in the coordination of muscle movements, learning, and memory.

reticular formation
(reh-tik´ū-lur´) Sets of neurons that project from the medulla and pons downward into the spinal cord to play a role in maintaining muscle tone and cardiac reflexes and upward throughout the cerebral cortex where they influence wakefulness, arousal level, and attention.

midbrain
The small area at the top of the hindbrain that serves primarily as a reflex center for orienting the eyes and ears.

forebrain
The parts of the brain, including the thalamus, hypothalamus, and cerebral cortex, that cover the hindbrain and midbrain and fill much of the skull.

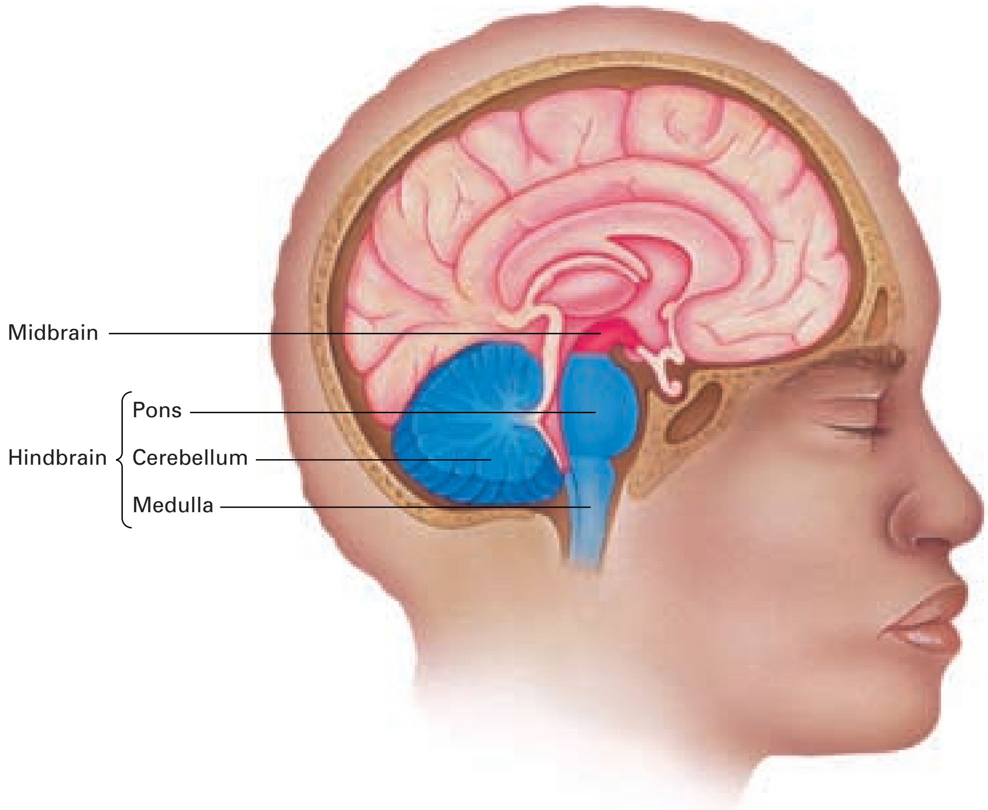


FIGURE 3.11
Important structures of the hindbrain and midbrain.

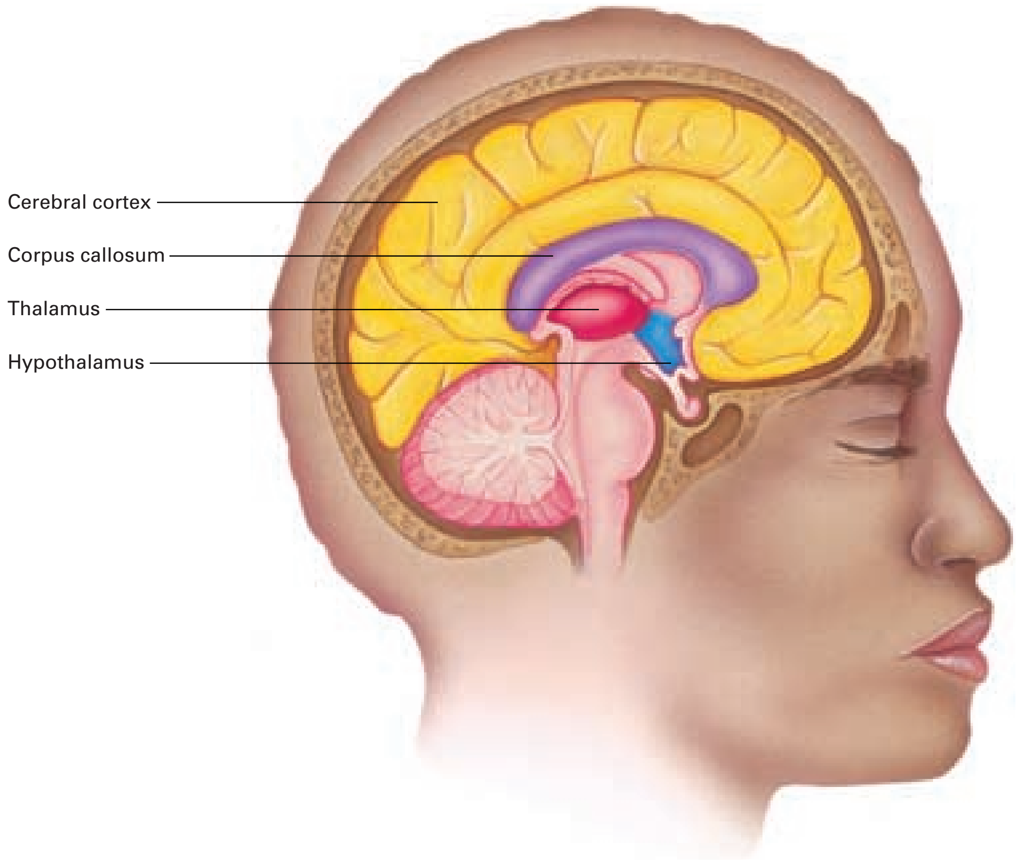


FIGURE 3.12
Key structures of the forebrain.

over the lower parts of the brain like the fat cap of an acorn covering its kernel. Not only are these two areas distinctly different in terms of structure, but they control very different functions as well.

Thalamus, Hypothalamus, and Limbic System

thalamus
(thal´-a-mus) The part of the forebrain that primarily routes sensory messages to appropriate parts of the brain.

hypothalamus
(hī˝po-thal´ah-mus) The small part of the forebrain involved with motives, emotions, and the functions of the autonomic nervous system.

limbic system
A complex brain system, composed of the amygdala, hippocampus, septal area, and cingulate cortex, that works with the hypothalamus in emotional arousal.

amygdala
(ah-mig´dah-lah) A part of the limbic system that plays a role in emotion.

hippocampus
(hip˝o-kam´pus) The part of the limbic system that plays a role in emotional arousal and memory.

septal area
A part of the limbic system that processes cognitive information in emotion.

cingulate cortex
A part of the limbic system lying in the cerebral cortex that processes cognitive information in emotion.

cerebral cortex
(ser´ĕ-bral) The largest structure in the forebrain, controlling conscious experience and intelligence and being involved with the somatic nervous system.

The **thalamus** is a switching station for messages going to and from the brain. It routes incoming stimuli from the sense organs to the appropriate parts of the brain and links the upper and lower centers of the brain. It also plays an important role in the filtering and preliminary processing of sensory information.

The **hypothalamus** is a small, but vitally important, part of the brain. It lies underneath the thalamus, just in front of the midbrain. The hypothalamus is intimately involved in our motives and emotions. It also plays a key role in regulating body temperature, sleep, endocrine gland activity, and resistance to disease; controlling glandular secretions of the stomach and intestines; and maintaining the normal pace and rhythm of such body functions as blood pressure and heartbeat (Brooks, 1988). Thus, the hypothalamus is the brain center most directly linked to the functions of the autonomic nervous system.

The hypothalamus also appears to contain specific pleasure centers. Rats will repeatedly press a lever for hours to receive electrical stimulation in certain parts of the hypothalamus (Olds & Milner, 1954). Jose Delgado (1969), working with humans, appears to have identified parts of the hypothalamus where electrical stimulation produces intense, generalized sensations of pleasure and parts where electrical stimulation produces strong, specific sensations of sexual pleasure. Apparently, these parts of the hypothalamus and related brain structures are active when we experience pleasure in our daily lives.

The hypothalamus plays its role in emotional arousal by working in close harmony with the **limbic system.** This complex neural system is composed of the parts shown in figure 3.13. The **amygdala** plays a key role in aggression and in processing information about stimuli (Canli & others, 2001; Hamann & others, 2002; Tillfors & others, 2001). Because the amygdala is involved in processing emotions, it plays a key role in the formation of memories about emotionally charged events (Adolph, Tranel, & Denburg, 2000; Kandel, 1999).

The **hippocampus** is also involved in the formation of new memories. The hippocampus is believed to "tie together" the elements of memories (their sights, sounds, meaning, etc.) that are stored in various parts of the cerebral cortex (Nadel & Jacobs, 1998). The memory loss experienced by patients suffering from Alzheimer's disease (see p. 102) results in part from damage to the hippocampus. Along with the **septal area** and the **cingulate cortex**, the hippocampus also brings important cognitive elements to the processing of emotion-related information. All three areas play a role in comparing current emotion-related information to information stored in memory.

Cerebral Cortex: Sensory, Cognitive, and Motor Functions

The largest structure in the forebrain is called the **cerebral cortex.** It is involved in conscious experience, voluntary actions, language, and intelligence—many of the things that make us human (Gazzaniga, 2000). As such, it is the primary brain structure related to the somatic nervous system. The word *cortex* means "bark," referring to the fact that the thin outer surface of the cerebrum is a densely packed mass of billions of neurons. The cortex has a gray appearance due to the presence of the cell bodies of the neurons and is often called the gray matter of the brain. The area of the cerebrum beneath the quarter inch of cortex is often referred to as the white matter, because it is composed primarily of the axons of the cortical neurons. The fatty myelin coating of these neurons gives them their white appearance. The gray and white areas of the cerebrum work together, but because of its rich interconnections, it is often said that the "business" of the cerebrum is mostly conducted in the cortex. Hence, we often say that an intelligent per-

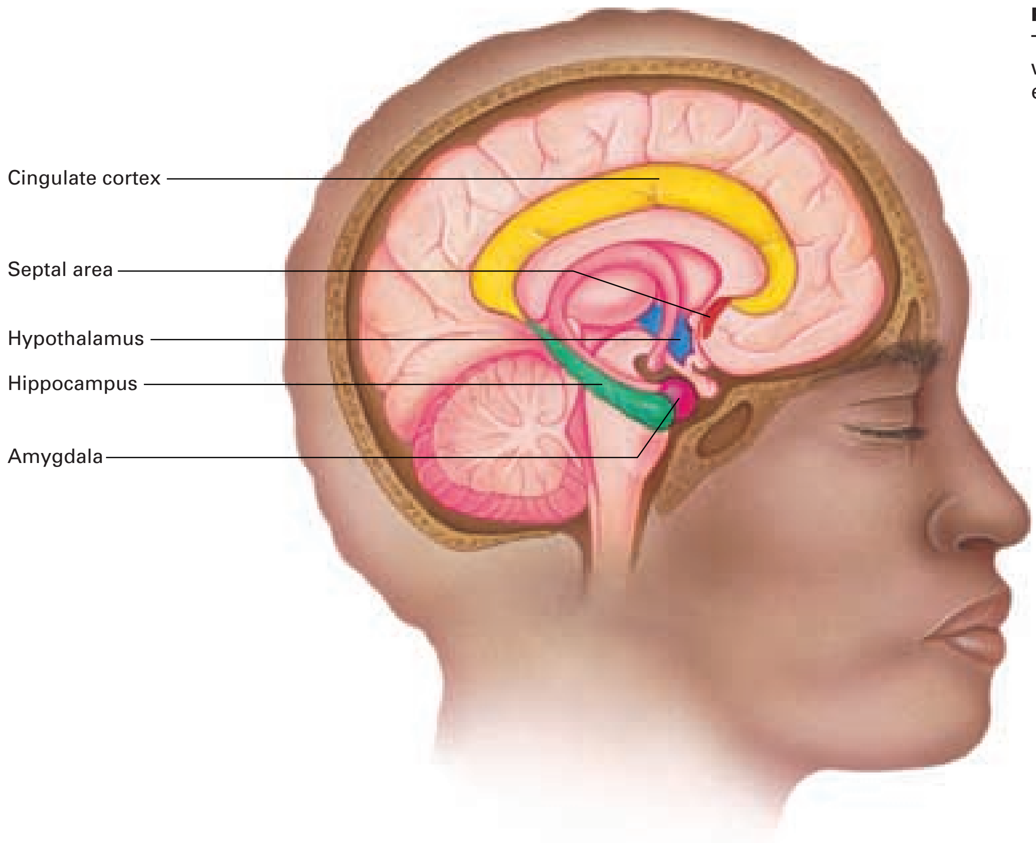


FIGURE 3.13
The structures of the limbic system, which play an important role in emotional arousal.

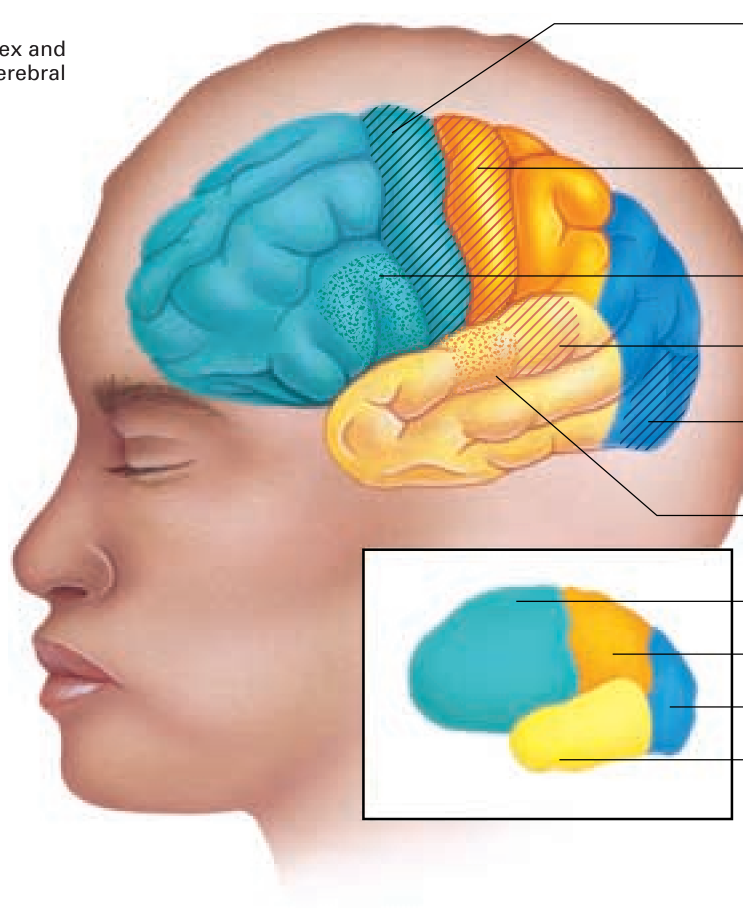
FIGURE 3.14
The gray matter and white matter of the cerebral cortex.

son "has a lot of gray matter." The gray and white matter of the cerebral cortex can be seen clearly in the MRI image in figure 3.14.

Lobes of the Cerebral Cortex

Because of the importance of the cerebral cortex to our psychological functioning, let's look at it in more detail. The cerebral cortex can be thought of as being composed of

FIGURE 3.15
The four lobes of the cerebral cortex and the functions of key areas of the cerebral cortex.



four sections, or *lobes* (see fig. 3.15). Learning the names and locations of these lobes will help us discuss the major functions of the cerebral cortex.

frontal lobes
The part of the cerebral cortex in the front of the skull involved in planning, organization, thinking, decision making, memory, voluntary motor movements, and speech.

Broca's area
An area of the frontal lobe of the left cerebral hemisphere that plays a role in speaking language.

stroke
A rupture or blockage of a blood vessel in the brain that interrupts blood flow and often results in the destruction of a part of the brain.

expressive aphasia
(ah-fā´ze-ah) An impairment of the ability to generate spoken language, but not in the comprehension of language.

1. **Frontal lobes.** The frontal lobes occupy the part of the skull behind your forehead and extend back to the middle of the top of your head. The frontal cortex has a wide variety of functions. The frontal lobes play an important role in thinking, decision making, memory, organizing our behavior, and predicting the consequences of our actions (Kimberg, Esposito, & Farah, 1998; Lewis, 2000; Schachter, 1999).

   The frontal lobe of the left cerebral hemisphere also contains **Broca's area,** which plays a very specific role in our ability to speak language. This area is named for French neurologist Paul Broca, who discovered its function in the late 1800s. He performed autopsies on persons who had earlier had a nonfatal **stroke** that damaged parts of the cerebral cortex and left them with a specific type of language disorder called **expressive aphasia.** Persons with expressive aphasia are able to understand what is said to them but have difficulty speaking. The strokes of persons with expressive aphasia occurred in what is now known as Broca's area. He concluded from his early studies that Broca's area was involved only in generating language and that another area of the brain must have been involved in understanding language.

   The frontal lobes also are the major center for the control of voluntary movements of the limbs and the body. Near the middle of the top of the head, a strip called the motor area runs across the back portion of the frontal lobes. Damage to this area of the cortex from strokes and other causes can result in paralysis and loss of motor control. Not surprisingly, the part of the motor area that serves the mouth, throat, and tongue is located near Broca's area and controls the motor movements required by speech.

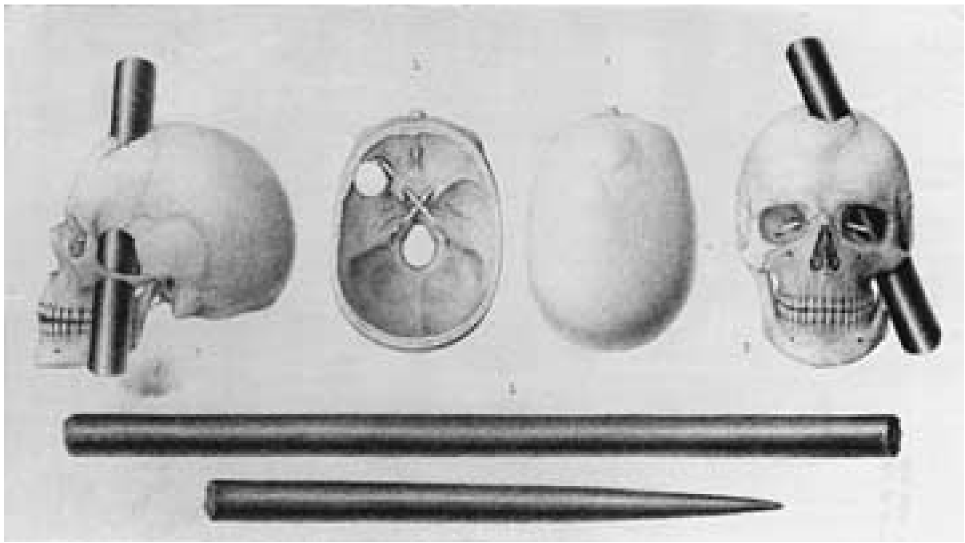


FIGURE 3.16
A drawing of Phineas Gage's skull and the tamping rod that passed through his brain.

In addition, the frontal lobes are believed to play a role in the inhibition of socially inappropriate behavior (Pietrini & others, 2000). This function of the frontal lobes is revealed by the dramatic case of Phineas Gage. In 1848, Gage was excavating rock to make way for a new section of track for the Rutland and Burlington Railroad in Vermont. Gage, known as a reasonable, polite, and hard-working man, had been made a foreman by the railroad. On one particular afternoon, he was hard at work preparing to blast a section of rock when an accident happened. Gage was packing blasting powder into a hole with a long tamping rod when a spark ignited the powder. The explosion shot the rod up through his upper left jaw and completely through his skull. As you can see in figure 3.16, the damage from the rod was to the frontal lobes on his left side (close enough to the front to miss the Broca language area). When Gage's coworkers reached him, he was conscious and able to tell them what had happened. He was rushed to a physician, who was able to stop the bleeding and save his life, but the destruction of such a large amount of his left frontal lobe took a terrific toll on him. Gage became irritable, publicly profane, and impossible to reason with. He also seemed to lose much of his ability to think rationally and plan. As a result, he had trouble holding a job and was regarded as a "totally changed" man by his former friends (Bigelow, 1850).

Nearly 150 years later, psychologist Christina Meyers and her colleagues (1992) at the University of Texas Medical Center described a case that is strikingly similar to Phineas Gage. A 33-year-old man, known to us as J.Z., had surgery to remove a tumor from the same area of the left frontal lobe that was destroyed in Phineas Gage. The lesion is shown clearly in an MRI image of his brain (fig. 3.17). Before the surgery, J.Z. was an "honest, stable and reliable worker and husband" (p. 122). His personality changed dramatically after the surgery, however. Like Phineas Gage, he became irritable, dishonest, irresponsible, and grandiose. In spite of no apparent changes in his intellectual skills, he was no longer employable, and he created serious legal and financial problems for his family. The dramatic changes in the behavior of Phineas Gage and J.Z. tell us that the frontal lobes play an important role in the control of complex aspects of our behavior.

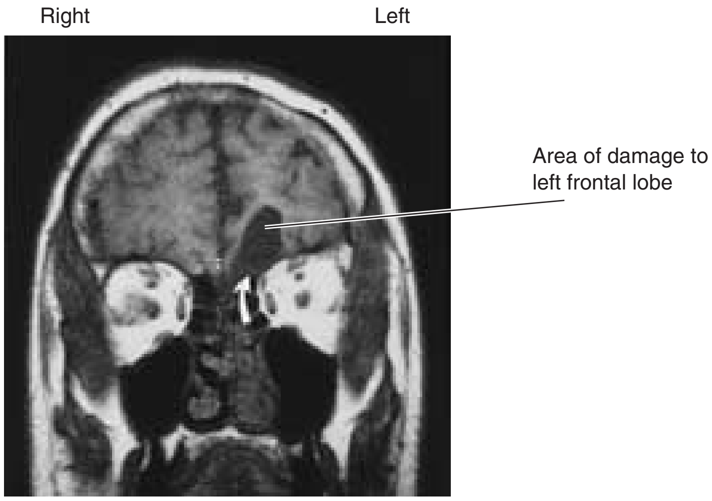


FIGURE 3.17
An MRI image of the brain of J.Z. (viewed from the front) shows the damage to the frontal lobe created when a tumor was removed.

parietal lobes
(pah-rī´e-tal) The part of the cerebral cortex that is located behind the frontal lobes at the top of the skull and that contains the somatosensory area.

somatosensory area
The strip of parietal cortex running parallel to the motor area of the frontal lobes that plays a role in body senses.

temporal lobes
The part of the cerebral cortex that extends back from the area of the temples beneath the frontal and parietal lobes and that contains areas involved in the sense of hearing and understanding language.

Wernicke's area
The language area of the cortex that plays an essential role in understanding spoken language.

2. **Parietal lobes.** The parietal lobes are located just behind the frontal lobes at the top of the skull. The strip of parietal cortex running parallel to the motor area of the frontal lobes is termed the **somatosensory area.** This area is important in the sense of touch and the other body senses that tell us, among other things, where our hands and feet are and what they are doing. It is not surprising, then, that the somatosensory area is located next to the motor area, because their functions clearly go hand in hand. As noted earlier when we discussed brain imaging, the area that was activated when Monte Buchsbaum received a mild shock to his arm was the somatosensory area of the cerebral cortex (see fig. 3.8).

   Different areas of the somatosensory and motor areas serve different parts of the body. The amount of area of the cortex devoted to a particular part of the body is not in proportion to the size of that body part, however. Rather, it is proportional to the number of sensory and motor neurons going to and from that part of the body. Brain scientists have created amusing yet informative drawings of people with body features proportional to the space allocated to them in the somatosensory and motor areas (see fig. 3.18).

3. **Temporal lobes.** As suggested by their name, the temporal lobes extend backward from the area of the temples, occupying the middle area at the base of the brain beneath the frontal and parietal lobes. In both hemispheres, the temporal lobes contain the auditory areas. These areas are located just inside the skull near the ears, immediately below the somatosensory area of the parietal lobes, and are involved in the sense of hearing.

   Wernicke's area is located just behind the auditory area in the left hemisphere. This is the other language area of the cortex, the one that plays an essential role in the understanding of spoken language. In this sense, Wernicke's area further processes the messages arriving from the ears, which are first processed in its next-door neighbor, the auditory area. Damage from strokes and

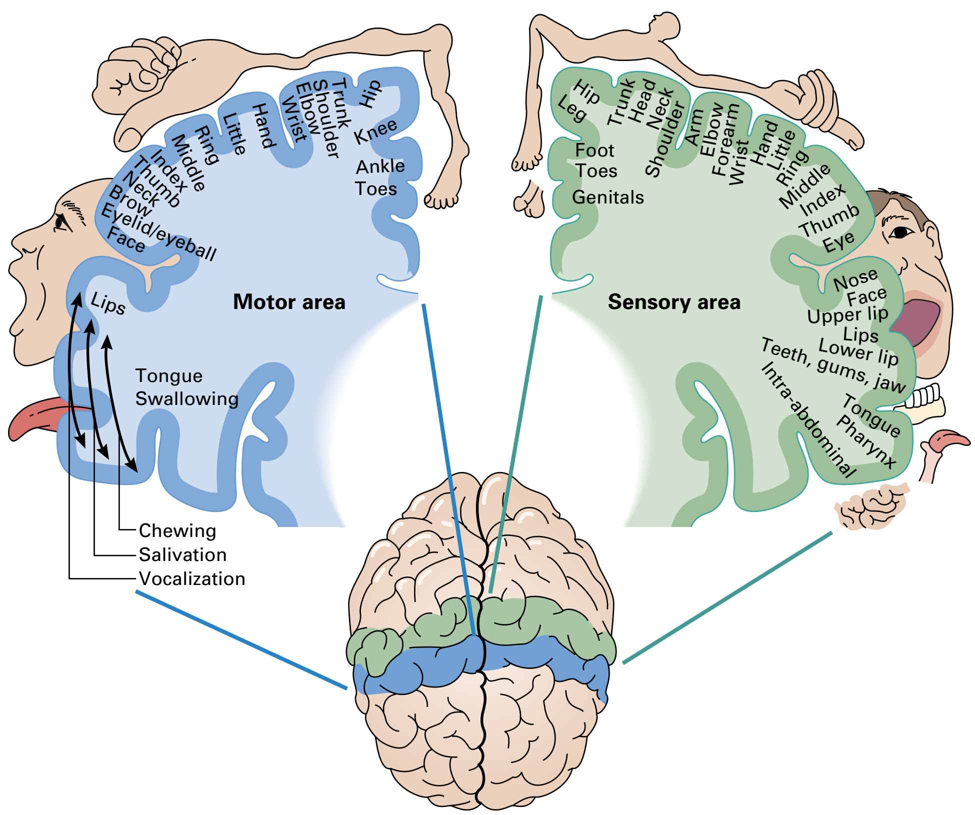


FIGURE 3.18
A cross section of the cerebral cortex in the motor control area and the skin sense area showing the areas in the cortex serving each part of the body. The size of the body feature in the drawing is proportional to the size of the related brain area.
Source: Data from W. Penfield and T. Rasmussen, *The Cerebral Cortex of Man.* Copyright © 1950 Macmillan Publishing Co., New York.

other sources of injury to this area of the cortex result in **Wernicke's aphasia.** Persons with this form of aphasia cannot make sense out of language that is spoken to them by others. In addition, they can make speech sounds normally, but what they say typically makes little sense.

4. **Occipital lobes.** The occipital lobes are located at the base of the back of the head. Although it is the part of the brain that is located farthest from the eyes, the most important part of the occipital lobes is the visual area. The visual area plays an essential role in the processing of sensory information from the eyes. Damage to the visual area of the occipital lobes can result in partial or complete blindness, even though the eyes are able to function normally.

Notice in figure 3.15 that the specific functions of some areas of each of the four lobes of the cerebral hemispheres have been labeled, but many areas of each lobe have been left unlabeled. These unlabeled parts of the cerebral cortex are known as the **association areas.** The association areas play more general roles in cerebral activities, but they often work in close coordination with one of the nearby specific ability areas. This can be seen in the series of PET scan images presented in figure 3.19. The areas of the cerebral cortex that are yellow and red have the greatest amount of neural activity. Notice that, when the person is hearing words, there is activity in and around Wernicke's area and in the association areas just behind it. When the person is seeing words, the visual area in the occipital lobe is activated, along with part of the nearby association area. In contrast, when the person is speaking words, activation is found only in Broca's area and the motor area of the frontal lobes that controls speech movements; when the person is thinking, the frontal lobes are active.

Neurologists sometimes call the association areas the "silent areas" of the cortex because strokes and other damage to them produce no permanent loss of motor control, language, or other specific abilities. They apparently serve the areas of the cortex

Wernicke's aphasia
A form of aphasia in which persons can speak fluently (but nonsensically) and cannot make sense out of language spoken to them by others.

occipital lobes
(ok-sip'ĭ-tal) The part of the cerebral cortex, located at the base of the back of the head, that plays an essential role in the processing of sensory information from the eyes.

association areas
Areas within each lobe of the cerebral cortex believed to play general rather than specific roles.

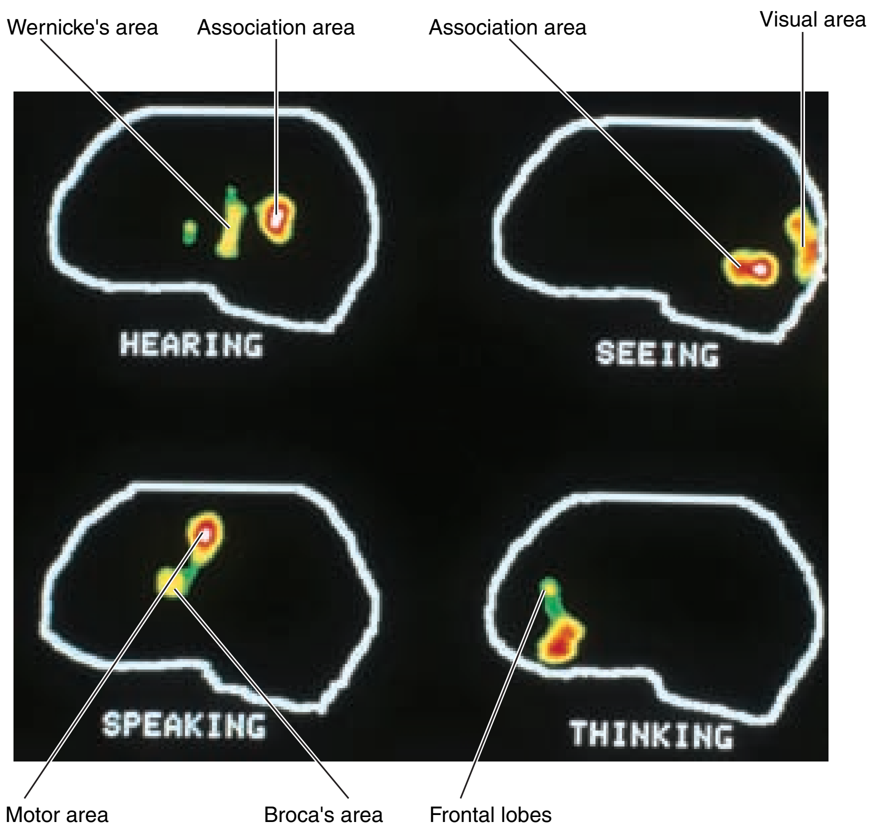


FIGURE 3.19
PET images of the brain at work on four different tasks.

that control specific abilities, but we can function quite adequately after the loss of considerable amounts of the association areas.

Functions of the Hemispheres of the Cerebral Cortex

We just saw that the cerebral cortex is composed of four lobes—each of which is involved in different psychological functions. If we look down at the cerebral cortex from the top, however, we can see that it also is made up of two halves called the **cerebral hemispheres.** These two separate hemispheres are linked by the **corpus callosum,** allowing communication between the two halves of the cortex (see fig. 3.12). Many of the functions of the cerebral cortex are shared by both hemispheres. However, the two hemispheres work together in a way that is different from what we might think. Although there are some exceptions to this rule, input from the senses of vision and touch, for example, generally goes to the *opposite* hemisphere. Stimulation of the skin on the left hand typically goes to the right cerebral hemisphere, visual stimulation falling on the right visual field of each eye goes to the left hemisphere, and wiggling the toes on your left foot is controlled by the right hemisphere. To accomplish this, the major sensory and motor nerves entering and leaving the brain twist and almost completely cross over each other.

cerebral hemispheres
The two main parts of the cerebral cortex, divided into left and right hemispheres.

corpus callosum
(kor´pus kah-lo´-sum) The major neural structure connecting the left and right cerebral hemispheres.

Functions of the Left and Right Cerebral Hemispheres

The left and right cerebral hemispheres play different but complementary roles in processing information. For example, strong evidence suggests that the areas that exercise the greatest control over language are located in the left cerebral hemisphere in over 90 percent of the population (Banich & Heller, 1998; Milner, 1974). The right hemisphere plays a role in processing language, but the left hemisphere is better suited to analyzing logical verbal information (Beeman & Chiarello, 1998). The right cerebral hemisphere, in contrast, appears to play a greater role in processing information about the shapes and locations of things in space. For example, when you study a list of verbal items—such as memorizing the names of the four lobes of the cerebrum—there will be more activity in your left frontal lobe than in your right frontal lobe. On the other hand, if you study a drawing to memorize the shapes and locations of the lobes of the cerebrum, the right side of your frontal lobes will be more involved (Craik & others, 1999; Wheeler, Stuss, & Tulving, 1997). The left side of the cerebral cortex tends to handle verbal information, and the right side tends to handle visual and spatial information.

Split Brains

Coordination of the shared functions of the two cerebral hemispheres is possible because they communicate through structures that connect them. The largest and most important bridge between the two cerebral hemispheres is the *corpus callosum.* It is sometimes necessary, however, to control the neurological disease of epilepsy by surgically cutting the corpus callosum to prevent seizures from spreading from one cerebral hemisphere to the other. When this is done, the right and left hemispheres have much less capacity to exchange information; to a great extent, the left brain does not know what the right brain is doing and vice versa. Experiments performed on these patients (referred to as "split-brain" patients) provide a major source of our knowledge about the different functions of the two cerebral hemispheres (Franz & others, 2000; Gazzaniga, 1967, 1998, 2000).

What would be the result of cutting the primary line of communication between the two cerebral hemispheres? Surprisingly, a patient with a severed corpus callosum changes very little at first glance. But, although it would be difficult for you—or even for the patient—to notice any difference in daily living, clever psychological experiments have revealed the effects of cutting the major connection between the cerebral hemispheres. In one experiment, the split-brain patient was seated in front of a screen and asked to stare at a spot in the middle. A slide projector briefly flashed a word on one side of the screen, so that it was seen by only the left or only the right visual field of the eye. This was done because the left visual field sends information only to the right cerebral hemisphere, and the right visual field sends information only to the left cerebral hemisphere. The nerves from the eyes cross at the optic chiasm (see fig. 3.20 on page 82), which is left uncut.

If the word *pencil* is presented in the right visual field of each eye, the information travels to the language control areas in the left hemisphere. In this situation, the patient has no difficulty reading aloud the word *pencil*. But, if the same word is presented to the left visual field of each eye, the split-brain patient would typically not be able to respond when asked what word had been presented. This does not mean that the right side of the brain does not receive or understand the word *pencil*. Rather, it means that the patient cannot verbalize what she sees. Using the sense of touch, the split-brain patient can easily pick out a pencil as the object that matches the word from among a number of unseen objects—but only if she uses her left hand, which has received the message from the right cerebral cortex.

Leonardo da Vinci (1452–1519).

However, if the split-brain patient holds an unseen pencil in her left hand, she cannot tell you what she is holding. It's not that the right cortex does not know, but because it has no area controlling verbal expression, it cannot tell you what it knows. The left cortex that is "talking" to you cannot tell you either, because information in the right cortex often cannot reach it in the split-brain patient. Such studies with split-brain patients clearly reveal the localization of language expression abilities in the left cerebral hemisphere (Gazzaniga, 1967, 1998).

It is interesting to note that these conclusions apply to right-handed persons but do not always apply to left-handed persons. The language functions of the cerebral hemispheres are often reversed in left-handed persons.

Hemispheres of the Cerebral Cortex and Emotion

In addition to the cerebral cortex's role in sensory, motor, and cognitive processes, it plays a key role in the processing of emotional information. As we have seen, there are marked differences in the cognitive functions of the two cerebral hemispheres. It is of great interest to psychologists, therefore, that the cerebral hemispheres also appear to play different roles in emotion (Davidson, 1992; Voelz & others, 2001).

In general, the right hemisphere plays a greater role in both the expression and perception of emotions. The left side of the face, which is primarily controlled by the right cerebral hemisphere, makes stronger expressions of emotion (Moscovitch & Olds, 1982). In other words, the left side of our mouth "smiles" and "frowns" more dramatically than the right side. One possible reason for our fascination with Da Vinci's painting of "Mona Lisa" is that she smiles more on her right side. We're not used to seeing people smile that way, and it catches our attention. Art historians tell us that Da Vinci finished some features of this painting while studying his own expressions in a mirror. Perhaps the reversed smile that he saw in the mirror became the Mona Lisa's intriguing "right-sided" smile.

In addition to its role in the expression of emotion, the right hemisphere is also essential for understanding the emotions expressed by others (Blonder, Bowers, & Heilman, 1991; Adolph & others, 2000). Beatty (1995) described how patients with right-hemisphere damage failed to match emotional tones of voice to pictures of people expressing anger, happiness, sadness, and

Mona Lisa by Leonardo da Vinci.

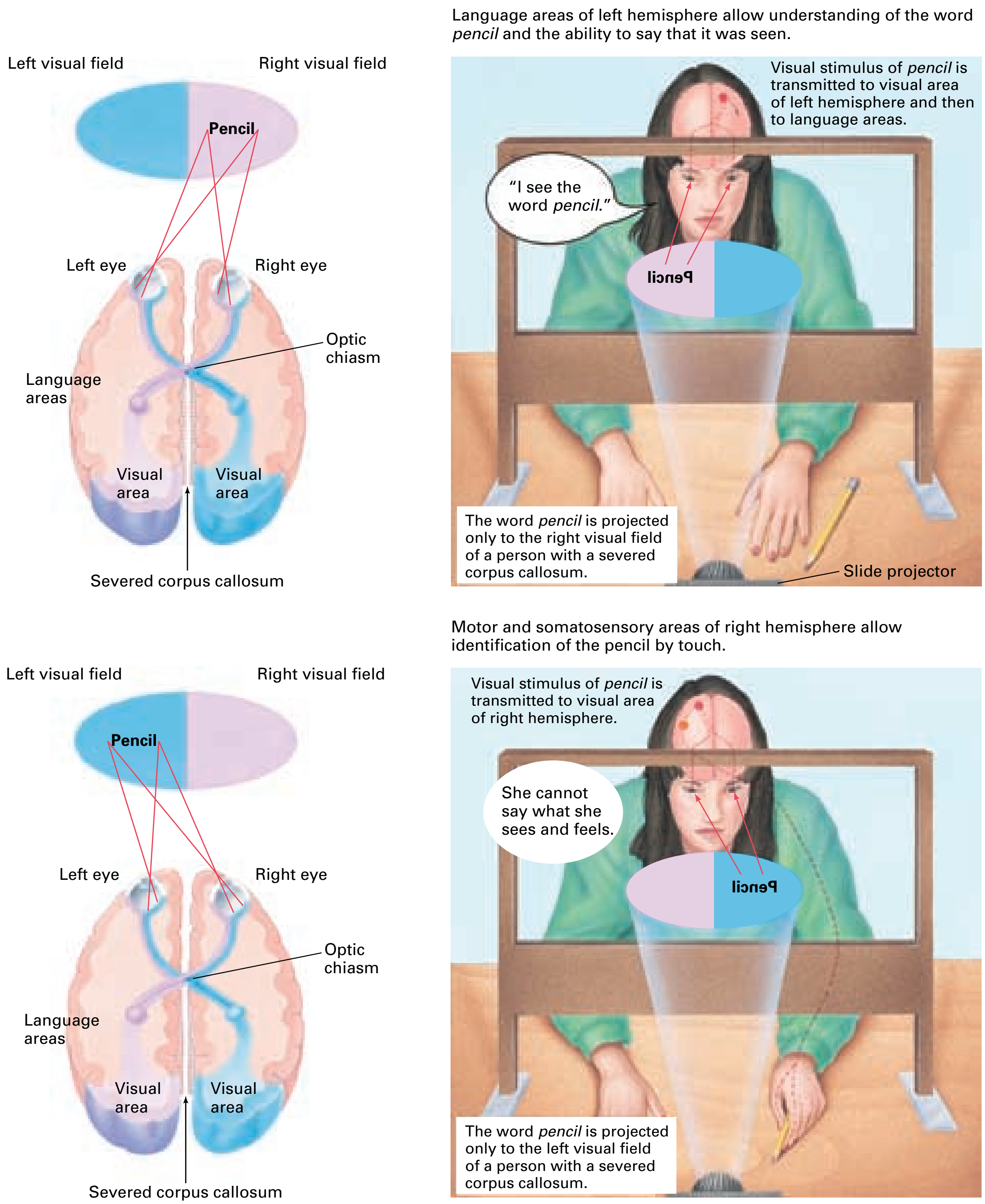


FIGURE 3.20
Studies of persons whose corpus callosum has been surgically cut to treat epilepsy tell us much about the different functions of the cerebral hemispheres and the important role that the corpus callosum normally plays in allowing communication between the hemispheres. When the word *pencil* is shown only to the right visual field, the information is sent only to the left cerebral hemisphere. The language areas in the left hemisphere allow the person to say that the word *pencil* has been seen. But, when the stimulus is shown only to the left visual field, the information is sent only to the right hemisphere, which does not have language areas. In this case, the person cannot confirm verbally that the word has been seen but can identify the pencil as the correct stimulus by the sense of touch.

indifference. Patients with left-hemisphere damage, although they had difficulty understanding the meaning of what was said, had no problems identifying the emotions.

Does this mean that there is no role for the left hemisphere in emotion? Not at all. Think about the implications of the following observation. As long ago as 1861, physician Paul Broca noticed that patients who had suffered strokes in the left cerebral hemisphere often became depressed, whereas patients with right hemisphere strokes were much less likely to do so. Since Broca's time, his observation has been repeated many times (Kinsbourne, 1988; Robinson & Starkstein, 1990; Vataja & others, 2001). For example, the images of the brains shown in figure 3.21 (obtained using computerized X rays) of persons who developed depression following strokes show clearly that the damage to their brains was primarily on the left side of the cortex (Starkstein & others, 1988).

In striking contrast, many patients with right-hemisphere damage are cheerful, happy, and not at all depressed by their disability (Kinsbourne, 1988). It appears that the reason left-hemisphere strokes cause depression has to do with the way in which the two hemispheres process emotional information. The right hemisphere appears to be more involved with the processing of negative emotions, whereas the left hemisphere plays a greater role in the processing of positive emotions. Some theorists believe that, when the left hemisphere is damaged by a stroke, the negative emotions processed in the right hemisphere become dominant and cause depression (Starkstein & Robinson, 1988). This theory is strongly supported by studies in which a sedative injected directly into the artery supplying only the left side of the brain results in a sudden and unexplained sadness. The left side of the brain is sedated, but the "gloomy" right side still functions (Kinsbourne, 1988).

The theory that the left cerebral hemisphere plays a greater role in processing positive emotions, whereas the right cerebral hemisphere is more involved with negative emotions, has been strengthened by findings reported by Richard Davidson of the University of Wisconsin (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). In this study, several short films were shown to college students—some entertaining films of playful animals and some "quite gruesome" films of amputations and burn victims. As the students watched the films, their facial expressions were monitored. When they were smiling, EEG recordings indicated more activity in the left cerebral hemisphere, but when

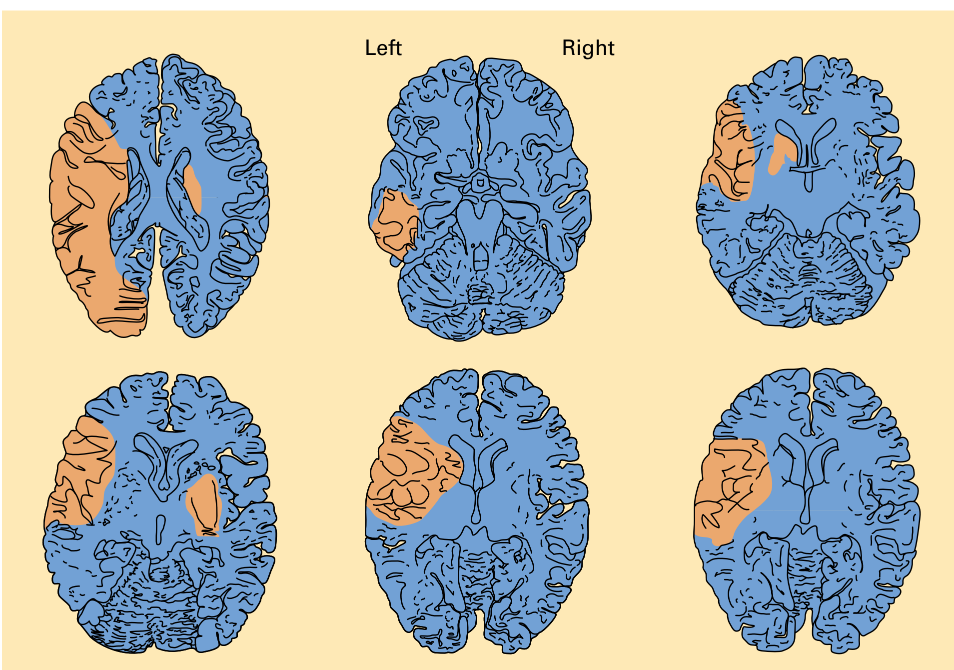


FIGURE 3.21
Drawings from computerized X rays of the brains of individuals who became depressed following a stroke. The shaded areas show the damaged cerebral tissue.

they showed disgust, their right hemisphere was more active. Apparently, positive emotions are processed more in the left hemisphere and negative emotions in the right hemisphere (Heller, Nitscke, & Miller, 1998).

Plasticity of the Cortex

plasticity
The ability of parts of the brain, particularly the cerebral cortex, to acquire new functions that partly or completely replace the functions of a damaged part of the brain.

neural pruning
The normal process of selective loss of gray matter in the brain over time, which is thought to improve the efficiency of neural systems by eliminating unnecessary cells.

neurogenesis
(nu´rō jen´´i sis) The hypothesized growth of new neurons in adult mammals.

Severe damage to the cerebral cortex often results in the loss of important psychological functions. Fortunately, many of these functions can be recovered partially or fully, particularly if the damage occurs early in life. This is because the cortex, and some other parts of the brain, show a high degree of **plasticity,** which means that, over time, other areas of the cortex can take over the functions of the damaged area (Garraghty, Churchill, & Banks, 1998). For example, children with damage to the language areas of the left hemisphere can often relearn language because areas in the right hemisphere take over the functions of the damaged area (Gazzaniga, 1992). Although many areas of the brain are specialized to perform certain tasks, they are not completely dedicated to those tasks. For example, blind individuals who read Braille show activation in the visual cortex when they "read" with their fingers (Cohen & others, 1997). Instead of using areas of the brain that usually serve the sense of touch, the tactile stimuli are interpreted in the area of the cortex that normally interprets visual stimuli.

The Brain Is a Developing System

Although it has long been known that areas of the brain often take on the functions of other damaged areas (brain plasticity), the prevailing view until recently was that the anatomy of the brain changed little from birth through middle adulthood. If the brain changed at all, it declined as the result of trauma, disease, or old age. Dramatic evidence from MRI and other neuroimaging studies have radically changed our view of the brain, however. It is now abundantly clear that the brain continues to change in structure well into the fifth decade of life (Bartzokis & others, 2001; Durston & others, 2001). One reason that scientists were slow to recognize this fact is that the total weight of the brain does not change after 5 years of age. However, this hides the fact that white matter increases in the cerebral cortex (especially the frontal lobes and the corpus callosum that links the right and left hemispheres) from childhood through middle age, while gray matter decreases in the cortex and some subcortical areas at about the same rate. The increase in white matter is due to the continued growth of myelin, which insulates neurons and speeds the transmission of neural impulses (Durston & others, 2001). The amount of white matter begins to decrease after the fifth decade of life, which perhaps reduces some aspects of cognitive speed (Bartzokis & others, 2001). Much of the decrease in gray matter (neural cell bodies) from childhood through middle adulthood results from selective **neural pruning,** which is thought to improve the efficiency of neural systems by eliminating unnecessary cells (Durston & others, 2001). Thus, the increases in white matter and decreases in gray matter that occur through middle age both appear to increase the efficiency of the brain.

Other evidence has emerged that challenges an even more deeply held belief about the brain. We have long accepted that new neurons never grow in the adult brain of mammals. Although new skin cells grow continuously, allowing cuts to be replaced by new skin tissue, neurons that die were thought never to be replaced by new neurons. There is now strong evidence that new neurons do grow in the cortex and hippocampus in rodents and monkeys, a process referred to as **neurogenesis** (Gould, Reeves, Graziano, & Gross, 1999; Gould, Tanapat, Rydel, & Hastings, 2000). Although neurogenesis remains a controversial issue, it appears that the brain can renew itself under some circumstances by growing new neurons and that the new neurons may play a role in learning and memory (Gould, Beylin, Tanapat, Reeves, & Shors, 1999).

This new view of the brain as a dynamic system that develops in healthy ways at least through middle age is a bit unnerving (pardon the pun) to scientists who have long been taught that the brain is an organ that only changes in a negative direction. The new view of the healthy developing brain alters our entire conception of what it means to mature into middle adulthood (the brain may continue to improve) and will undoubtedly open new doors to the prevention and treatment of disorders of the brain.

The Brain Is an Interacting System

Even though it is convenient to think of the brain as being divided into many separate parts, you should know that the parts commonly work together in intellectual and emotional functioning. Consider, for example, your reaction in the following situation. You are waiting at a bus stop late at night. A poorly dressed man approaches, smelling of alcohol. He asks if you can spare five dollars. In his pocket, you see the outline of what might be a gun. Your reaction to this scene would involve many parts of your brain working together. Parts of your cerebral cortex evaluate the possible threat to you and the alternative courses of action open to you. Your limbic system is involved in a process of emotional arousal. If you fight, run, or reach into your pocket to hand over the money, the motor areas of your cortex will work with your hindbrain and midbrain to coordinate the muscular movements involved. The many parts of the brain work together.

Sometimes the many parts of the brain interact because one part of the brain sends a message to another part, which then sends it on to a third part of the brain, and so on. More often, however, several parts of the brain process different kinds of related information at the same time. To use computer language, the brain often uses "parallel" processing (handling different information at the same time) rather than "serial" processing (handling one kind of information at a time) (Rumelhart & McClelland, 1986). The brain's amazing capacity for parallel processing magnifies its ability to use its 100 billion neurons and their trillions of connections to produce our complex actions, emotions, and thoughts.

Review

The brain is a complex system composed of many parts that carry out different functions but work together in an integrated fashion. The hindbrain and midbrain mostly handle the housekeeping responsibilities of the body, such as breathing, posture, reflexes, and other basic processes. The larger forebrain area carries out the more "psychological" functions of the brain: The thalamus integrates sensory input, and the hypothalamus controls motivation, emotion, sleep, and other basic bodily processes. Both the thalamus and the hypothalamus lie beneath the cap of the cerebral cortex. Most of the limbic system, which plays an important role in emotional arousal, is located below the cortex, but lower cortical structures are involved as well. The cerebral cortex provides the neural basis for thinking, language, control of motor movements, perception, and other cognitive processes, but it also processes emotional information. The cortex is composed of two halves, the cerebral hemispheres, which are connected to each other primarily by the corpus callosum. The two cerebral hemispheres are involved in somewhat different aspects of these cognitive processes. The right hemisphere plays a role in spatial and artistic cognitive processes, whereas the left hemisphere is more involved in logical, mathematical, and language-based processes. The two cerebral hemispheres also appear to process different aspects of emotion, with the left hemisphere being more involved in positive emotion and the right hemisphere playing a greater role in negative emotion. Recent evidence shows that the brain continues to develop until middle age and may even be capable of growing new neurons during adulthood.

Check Your Learning

To be sure that you have learned the key points from the preceding section, cover the list of correct answers and try to answer each question. If you give an incorrect answer to any question, return to the page given next to the correct answer to see why your answer was not correct.

1. The midbrain and hindbrain play the greatest role in which functions?

   a) motivation and emotion
   b) learning and thinking
   c) planning for the future
   d) bodily housekeeping and reflexes

2. The small but vitally important part of the forebrain that plays a key role in the control of emotion, endocrine gland activity, blood pressure, and heartbeat (because it is the brain center most linked to the autonomic nervous system) is the

   a) cerebrum.
   b) cerebellum.
   c) hypothalamus.
   d) thalamus.

3. Broca's area, which controls speaking, is located in the ______________ lobe of the left cerebral hemisphere.

   a) frontal
   b) temporal
   c) parietal
   d) occipital

4. The area of the cerebral cortex that is primarily involved in vision is the ______________ lobe.

   a) frontal
   b) temporal
   c) parietal
   d) occipital

5. Positive emotions are processed more by the ______________ cerebral hemisphere.

Thinking Critically about Psychology

1. Imagine that you have put down this book and are taking a huge bite of your favorite kind of pizza. Think of the role that each part of the brain plays in this simple act.

2. Does what you have learned about the two cerebral hemispheres suggest that we should think of ourselves as having "two brains" or one? How about the autonomic nervous system—is that "another brain with a mind of its own"?

Correct Answers: **1. d** (p. 72), **2. c** (p. 71), **3. a** (p. 76), **4. d** (p. 79), **5.** left (p. 83).

Endocrine System: Chemical Messengers of the Body

As we have just seen, the nervous system is the vital computer and communication system that forms the biological basis for behavior and conscious experience. Another biological system also plays an important role in communication and the regulation of bodily processes—the **endocrine system.** This system consists of a number of **glands** that secrete two kinds of chemical messengers. Many endocrine glands secrete *neuropeptides* into the bloodstream. When these neuropeptides reach other endocrine glands, they influence their functions, providing communication and coordination among the endocrine glands. In addition, some neuropeptides secreted by the endocrine glands reach the brain and influence neural systems. Thus, although the brain influences all of the endocrine glands either directly or indirectly, the endocrine glands influence the brain in return. Indeed, as we will see later in this book, some neuropeptides play important roles in the mechanisms underlying stress, emotion, and memory (Izquierdo & Medina, 1997; Kandel & Abel, 1995; Panskepp, 1993).

endocrine system
(en´dō-krin) The system of glands that secretes hormones.

glands
Structures in the body that secrete substances.

hormones
(hor´mōnz) Chemical substances, produced by endocrine glands, that influence internal organs.

In addition, the endocrine glands secrete **hormones** into the bloodstream, where they are carried throughout the body. Hormones influence a wide variety of organ systems. The action of hormones is closely related to that of the nervous system in three ways. First, the hormones are directly regulated by the brain, particularly the hypothalamus. Second, some of the hormones are chemically identical to some of the neurotransmitters. Third, the hormones aid the nervous system's ability to control the body by activating many organs during physical stress or emotional arousal and by influencing such things as metabolism, blood-sugar level, and sexual functioning. Hormones affect target organs by passing into the body of cells and influencing the way in which genetic codes in their nuclei are translated. Let's look briefly at the seven endocrine glands that are most important to our psychological lives (see fig. 3.22).

Pituitary Gland

The **pituitary gland** is located near the bottom of the brain, connected to and largely controlled by the hypothalamus. It is sometimes thought of as the body's master gland because its secretions help regulate the activity of the other glands in the endocrine system. Perhaps its most important function is regulating the body's reactions to stress and resistance to disease (Muller & Nistico, 1989). The pituitary gland secretes hormones that have important effects on the body—notably, in controlling blood pressure, thirst, and body growth. Too little or too much of the pituitary's growth hormone will make a person develop into a "dwarf" or "giant." One special function of the pituitary gland is of particular importance to newborns. When the infant sucks the mother's nipples, a neural message is sent to the mother's hypothalamus, which sends a message to the pituitary gland through a neuropeptide. This causes the pituitary to secrete a hormone that releases breast milk for the baby.

pituitary gland
(pĭ-tu´i-tār˝ē) The body's master gland, located near the bottom of the brain, whose secretions help regulate the activity of the other glands in the endocrine system.

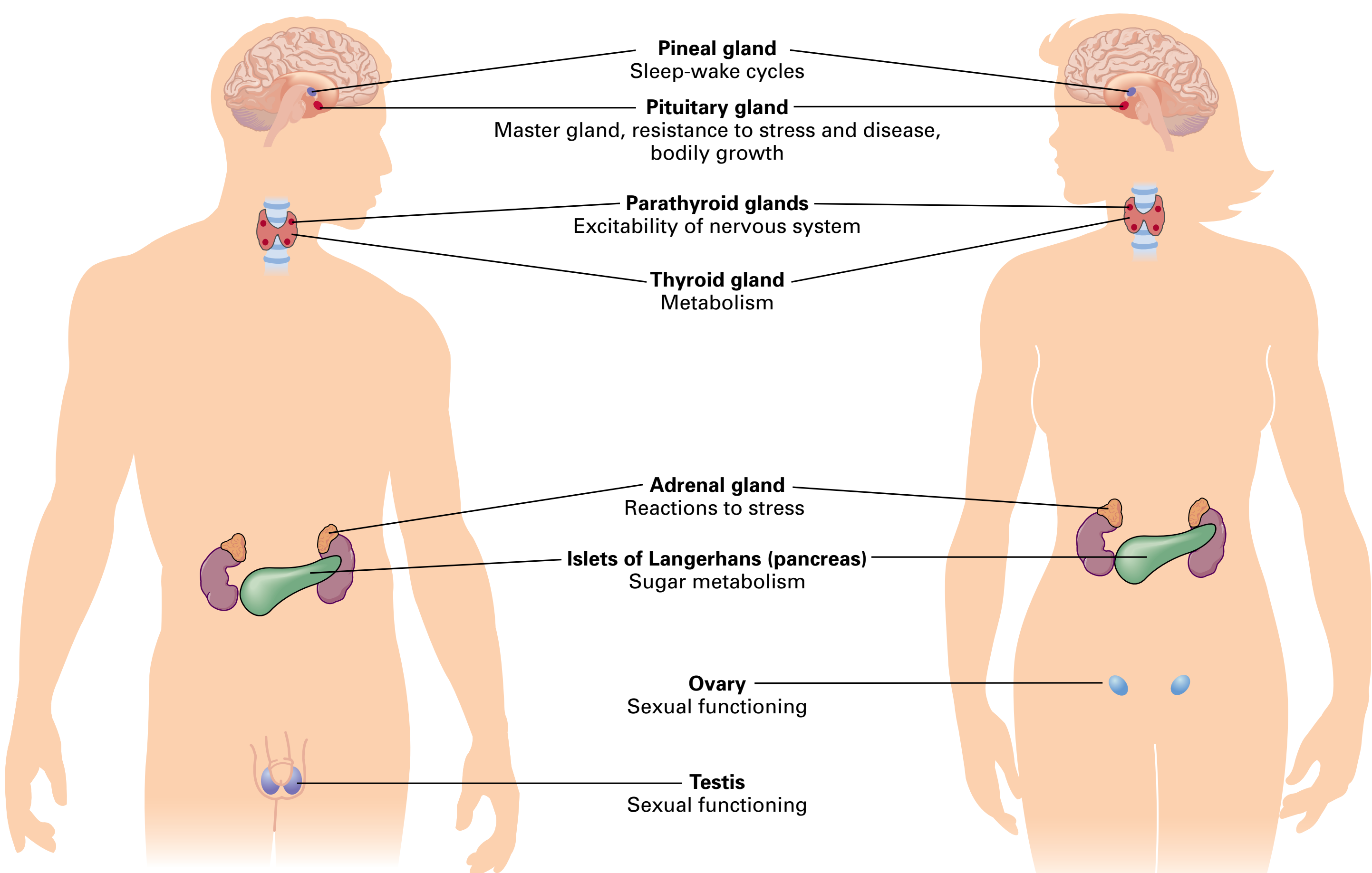


FIGURE 3.22
Locations of major endocrine glands and their principal functions.

Adrenal Glands

adrenal glands
(ah-drē´nal) Two glands on the kidneys that are involved in physical and emotional arousal.

epinephrine
(ep´´i-nef´rin) A hormone produced by the adrenal glands.

norepinephrine
(nor´´ep-i-nef´rin) A hormone produced by the adrenal glands.

cortisol
A stress hormone produced by the adrenal glands.

islets of Langerhans
(i´lets *of* lahng´er-hanz) Endocrine cells in the pancreas that regulate the level of sugar in the blood.

pancreas
(pan´krē-as) The organ near the stomach that contains the islets of Langerhans.

glucagon
(gloo´kah-gon) A hormone produced by the islets of Langerhans that causes the liver to release sugar into the bloodstream.

insulin
(in´su-lin) A hormone produced by the islets of Langerhans that reduces the amount of sugar in the bloodstream.

ovaries
(o´vah-rēz) Female endocrine glands that secrete sex-related hormones and produce ova, or eggs.

testes
(tes´tēz) Male endocrine glands that secrete sex-related hormones and produce sperm cells.

gonads
(gō´nadz) The glands that produce sex cells and hormones important in sexual arousal and that contribute to the development of secondary sex characteristics.

The **adrenal glands** are a pair of glands that sit atop the two kidneys. They play an important role in emotional arousal and secrete a variety of hormones important to metabolism. When stimulated either by a hormone from the pituitary gland or by the sympathetic division of the autonomic nervous system, the adrenal glands secrete three hormones, among others, that are particularly important in reactions to stress. **Epinephrine** and **norepinephrine** (which are also neurotransmitters) stimulate changes to prepare the body to deal with physical demands that require intense body activity, including psychological threats or danger (even when the danger cannot be dealt with physically). The effects of these two adrenal hormones are quite similar, but they can be distinguished in terms of their most potent effects. Epinephrine increases blood pressure by increasing heart rate and blood flow, causes the liver to convert and release some of its supply of stored sugar into the bloodstream, and increases the rate at which the body uses energy (i.e., metabolism), sometimes by as much as 100 percent over normal. Norepinephrine also increases blood pressure, but it does this by constricting the diameter of blood vessels in the body's muscles and by reducing the activity of the digestive system (Groves & Rebec, 1988; Hole, 1990). The adrenal glands also secrete the hormone **cortisol,** which also activates the body in terms of stress (Bandelow & others, 2000) and plays a particularly important role in the regulation of immunity to disease.

Let's look at an example of the action of the adrenal glands during stress. Does giving a speech in public make you tense? Most people find public speaking to be at least mildly stressful. German scientist Ulrich Bolm-Andorff collected blood and urine from 10 physicians and psychologists at two different times: (a) just after they gave an important public speech to their colleagues and (b) at the same time on another day when they were not speaking (Bolm-Andorff, Schwämmle, Ehlenz, Koop, & Kaffarnik, 1986). Three adrenal hormones (epinephrine, norepinephrine, and cortisol) were measured in these fluids. Look at figure 3.23 to see the dramatic increase in the secretion of adrenal hormones during the speech. Notice, too, the corresponding increase in heart rate and blood pressure.

The changes in heart rate and blood pressure were caused by the action of epinephrine and norepinephrine on the heart and blood vessels, but also by the direct action of the autonomic nervous system on these organs. Thus, the autonomic nervous system has two ways of activating the internal organs: (1) by directly affecting the organs and (2) by stimulating the adrenals and other endocrine glands that then influence the organs with their hormones. One reason it takes so long to feel calm after a stressful event has passed is because of this second route to activating the body. It takes quite a while for the hormones to leave the bloodstream, so their effects are rather long lasting.

Islets of Langerhans

The **islets of Langerhans,** which are embedded in the **pancreas,** regulate the level of sugar in the blood by secreting two hormones that have opposing actions. **Glucagon** causes the liver to convert its stored sugar into blood sugar and to dump it into the bloodstream. **Insulin,** in contrast, reduces the amount of blood sugar by helping the body's cells absorb sugar in the form of fat. Blood sugar level is important psychologically because it's one of the factors in the hunger motive, and it helps determine how energetic a person feels.

Gonads

There are two sex glands—the **ovaries** in females, the **testes** in males. The **gonads** produce the sex cells—ova in females, sperm in males. They also secrete hormones that are important in sexual arousal and contribute to the development of so-called secondary sex characteristics (e.g., breast development in women, growth of chest hair in men, deepening of the voice in males at adolescence, and growth of pubic hair in both sexes).

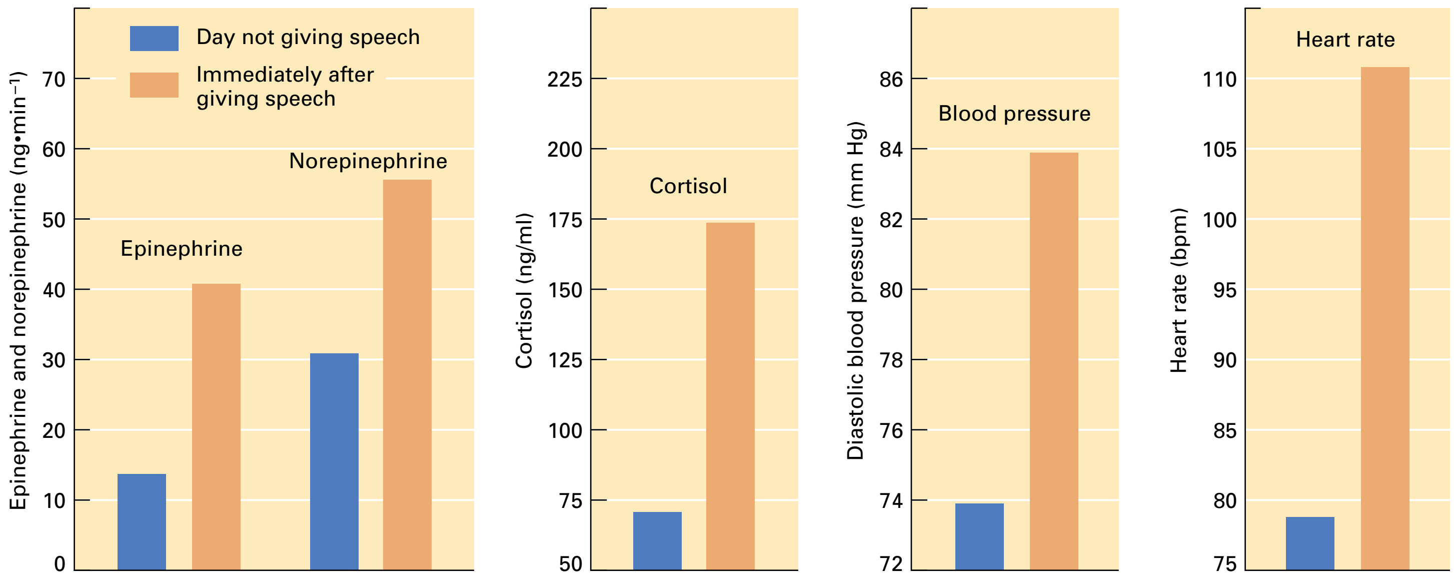


FIGURE 3.23
The effects of the stress of giving a public speech on hormones secreted by the adrenal glands and on heart rate and blood pressure.
Source: Data from V. Bolm-Andorff, et al., "Hormonal and Cardiovascular Variations During a Public Lecture" in *European Journal of Applied Physiology*, 54:669–674. Copyright 1986 Springer-Verlag, New York, NY.

The most important sex hormones are **estrogen** in females and **testosterone** in males. There is emerging evidence that sex hormones play a role in guiding the development of the brain.

Thyroid Gland

The **thyroid gland,** located just below the larynx, or voice box, plays an important role in the regulation of **metabolism.** It does so by secreting a hormone called **thyroxin.** The level of thyroxin in a person's bloodstream and the resulting metabolic rate are important in many ways. In children, proper functioning of the thyroid is necessary for proper mental development. A serious thyroid deficiency in childhood produces sluggishness, poor muscle tone, and a rare type of mental retardation called **cretinism.**

In adults, the thyroxin level helps determine one's weight and level of activity. People whose thyroid glands secrete unusually large amounts of thyroxin are typically very active. They may eat large amounts of food but still not gain weight because their rapid metabolic rate burns off calories so quickly. Conversely, people with low thyroxin levels tend to be inactive and overweight. A "thyroid problem" is rarely the main cause of a weight problem, however. Thyroid disturbances can also lead to depression in adults. But, as with weight problems, most depression is not caused by a malfunctioning thyroid.

Parathyroid Glands

The four small glands embedded in the thyroid gland are the **parathyroid glands.** They secrete **parathormone,** which is important in the functioning of the nervous system. Parathormone controls the excitability of the nervous system by regulating ion levels in the neurons. Too much parathormone inhibits nervous activity and leads to lethargy; too little of it may lead to excessive nervous activity and tension.

Pineal Gland

The **pineal gland** is located between the cerebral hemispheres, attached to the top of the thalamus. Its primary secretion is *melatonin.* Melatonin is important in the regulation of biological rhythms, including the menstrual cycles in females and the daily regulation of

estrogen
(es´tro-jen) A female sex hormone.

testosterone
(tes-tos´ter-ōn) A male sex hormone.

thyroid gland
(thī´roid) The gland below the voice box that regulates metabolism.

metabolism
(me-tab´o-lizm) The process through which the body uses energy.

thyroxin
(thīrok´sin) A hormone produced by the thyroid that is necessary for proper mental development in children and helps determind weight and level of activity in adults.

cretinism
(krĕ´tin-izm) A type of mental retardation in children caused by a deficiency of thyroxin.

parathyroid glands
(par˝ah-thī´roid) Four glands embedded in the thyroid that produce parathormone.

parathormone
(par˝ah-thor´mōn) A hormone that regulates ion levels in neurons and controls excitability of the nervous system.

pineal gland
(pin´e-al) The endocrine gland that is largely responsible for the regulation of biological rhythms.

sleep and wakefulness. Melatonin levels seem to be affected by the amount of exposure to sunlight and, hence, "clock" the time of day partly in that fashion. Melatonin also appears to play a role in regulating moods. Seasonal affective disorder, a type of depression that occurs most frequently in the winter months, can be treated using bright light, which is thought to be effective because of the influence of light on melatonin. Many scientists are concerned about the widespread use of melatonin in pill form to treat sleep disturbances and other problems (Haimov & Lavie, 1996). Melatonin does not appear to be helpful, and there is little evidence on possible harmful side effects of melatonin supplements.

Review

The hormones of the endocrine glands supplement the brain's ability to coordinate the body's reactions and activities. These chemical messengers are involved in the regulation of metabolism, blood-sugar level, sexual functioning, and other body functions. Most important from the viewpoint of psychology is the role of epinephrine and norepinephrine in emotional arousal. These hormones, secreted by the adrenal glands, activate body organs in a diffuse and long-lasting way that is partially responsible for the length of time necessary for us to feel calm following a stressful event.

Check Your Learning

To be sure that you have learned the key points from the preceding section, cover the list of correct answers and try to answer each question. If you give an incorrect answer to any question, return to the page given next to the correct answer to see why your answer was not correct.

1. The ____________ secretes epinephrine, norepinephrine, and cortisol, which activate the body during stress (such as by increasing heart rate and blood pressure).

   a) adrenal gland c) thyroid gland
   b) parathyroid gland d) pituitary gland

2. Sugar metabolism and hunger are influenced by the ____________ in the pancreas.

3. The ____________ gland is called the "master gland" because its secretions influence many other glands.

   a) adrenal c) thyroid
   b) parathyroid d) pituitary

4. The excitability of the nervous system is regulated by parathormone, which is secreted by the

   a) adrenal gland. c) thyroid gland.
   b) parathyroid gland. d) pituitary gland.

Thinking Critically about Psychology

1. In what ways does epinephrine resemble a drug like caffeine?
2. When doing something stressful, such as speaking in public, how do the effects of hormones secreted by the adrenal glands help us—how are they adaptive? Or are they only maladaptive?

Correct Answers: **1.** a (p. 88), **2.** islets of Langerhans (p. 88), **3.** d (p. 87), **4.** b (p. 89).

Genetic Influences on Behavior

If you speak loudly like your father, is it because you inherited a loud voice from him or because you learned to talk that way by living with him? If you are good in math like your mother, was that inherited or learned? In general, what is the role of heredity in human behavior?

What Is Inherited?

It's obvious that children inherit many of their physical characteristics from their parents. Light or dark skin, blue or brown eyes, tall or short stature—these are all traits we routinely expect to be passed from parents to children. Many aspects of human behavior are also influenced by inheritance.

Research on genetic influences on behavior in animals has provided some valuable insights. For example, considerable research has been done on the nest-building behavior of a seabird called the tern. How does every female tern know how to build a nest? Is it a learned skill, or are the instructions for this behavior biologically programmed into the bird from birth? Experiments have made it clear that the latter is the case. If you raise a female tern alone in a laboratory, depriving it of the opportunity to see any tern nests from the time it hatches, it will still build precisely the same kind of nest its mother built.

Inheritance does not play such a direct and complete role in governing the behavior of humans, however. Humans do not inherit specific patterns of behavior, like nest building in terns; rather, inheritance seems to influence *broad* dimensions of our behavior, such as sociability, anxiousness, and intelligence (Plomin, 1989; 1999). Psychologists are not yet sure *how much* heredity influences these dimensions of behavior. It's never the sole cause, however, but always operates in conjunction with the effects of the environment.

Biological Mechanisms of Inheritance: Genetic Codes

People long wondered how inherited characteristics are passed on. For many years, it was thought that they were transmitted through the blood—hence old sayings such as, "He has his family's bad blood." We now know that inheritance operates through genetic material, called genes, found in the nuclei of all human cells. The existence of genes was guessed more than a century ago by Gregor Mendel, an Austrian monk who helped found the science of genetics. It has been only during the last half of the twentieth century, however, that genes have actually been seen with the aid of electron microscopes.

Mendel's theory that there are genes for a wide variety of traits, or characteristics, was based on a study of pea plants. If a pea was wrinkled, it was because it had a gene for wrinkled skin. If a pea plant (or, by extension, a person) was tall, it was because it (or he or she) had a gene for tallness. The genes, Mendel reasoned, were passed on from parents to children. If both parents were to pass on a gene for a particular trait, clearly that trait would be perpetuated. If the parents were to pass on conflicting genes, however, only one of the genes would dominate, and the child would show the trait reflecting the dominant gene. Although Mendel's theory attracted little notice in the nineteenth century, it gained a widespread following in the twentieth century, and research has largely borne it out.

Genes, Chromosomes, and DNA

The cells of the body contain microscopic structures called **chromosomes** (see figure 3.24A). The chromosomes consist of long strands of deoxyribonucleic acid, or **DNA** for short. As shown in figure 3.24B, **DNA** usually takes the form of a curved ladder that doubles back on itself, known as a *double helix.* The outside rails of the ladder, called the "backbone," are composed of a type of sugar. The twin backbones create a structure that is connected at intervals by base pairs of four substances: adenine (A), thymine (T),

chromosomes
(krō′mo-sōmz) Strands of DNA (deoxyribonucleic acid) in cells.

DNA (deoxyribonucleic acid)
Structures in cells in the form of two curved rails of a ladder type connected at intervals by base pairs of adenine, thymine, guanine, and cystine that code genetic information.

FIGURE 3.24A

The nucleus of each human cell contains 46 chromosomes united in pairs, 23 from the sperm and 23 from the ovum. In this photograph, the 23rd pair is labeled X and Y.

guanine (G), and cystine (C) that are held in place by chemical bonds. The many possible sequences of base pairs of A, T, G, and C carry the genetic code, much like the combinations of letters on this page convey information to you, the reader. Sequences of base pairs that contain all the information needed to influence some aspect of a structure or function of the body are called **genes**. For this reason, genes are the basic biological units of inheritance.

Each of the 46 chromosomes of a normal human cell contains thousands of genes. The chromosomes are arranged in 23 pairs. When cells divide in the normal process of tissue growth and repair, they create exact copies of themselves. However, when sex cells (sperm or ova) are formed, the chromosome pairs split, so that the resulting sex cell has only 23 unpaired chromosomes. These sex cells, or **gametes,** are short-lived, but when a sperm unites successfully with an ovum in the act of **fertilization,** a stable cell, capable of life, is formed. The new cell, called a **zygote,** has a full complement of 23 pairs of chromosomes, 23 from the mother (ovum) and 23 from the father (sperm). If conditions are right, the zygote becomes implanted in the lining of the mother's uterus, and the embryo develops.

The chromosomes you receive from each parent are a matter of chance. That is why sisters and brothers can have substantially different genes and substantially different inherited traits. Think of each of your parents' 23 pairs of chromosomes for a moment

genes
(jēnz) Segments of chromosomes made up of sequences of base pairs of adenine, thymine, guanine, and cystine that are the basic biological units of inheritance because they contain all the coded genetic information needed to influence some aspect of a structure or function of the body.

gamete
(gam´ēt) A sex cell, which contains 23 chromosomes instead of the normal 46.

fertilization
(fer´tĭ-li-zā´shun) The uniting of sperm and ovum, which produces a zygote.

zygote
(zī´gōt) The stable cell resulting from fertilization; in humans, it has 46 chromosomes—23 from the sperm and 23 from the ovum.

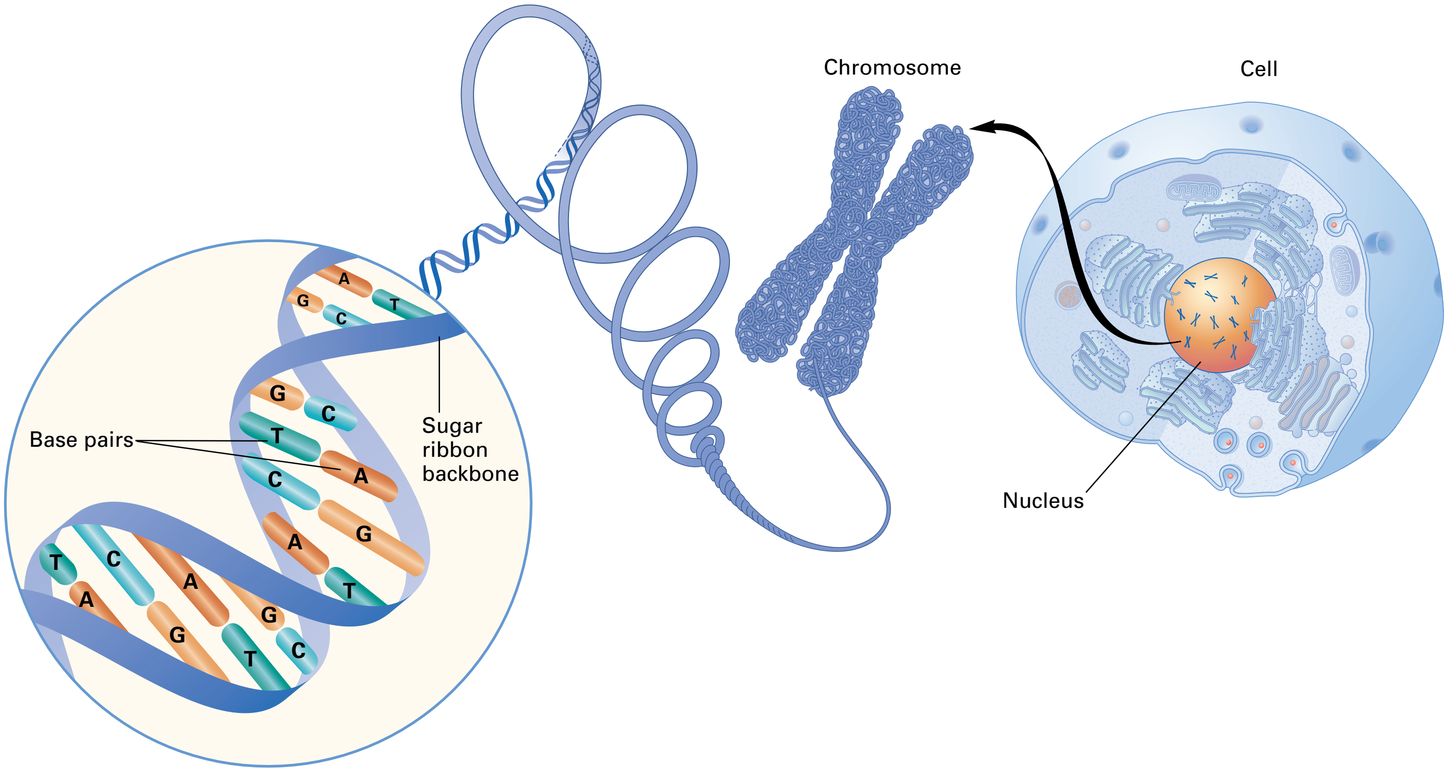


FIGURE 3.24B
DNA in cell bodies typically takes the form of the double helix, which resembles a curved ladder that doubles back on itself. Th outer "rails" of the double helix are made of a type of sugar that provides structure to DNA. The rails are connected at intervals by bonded base pairs of adenine (A), thymine (T), guanine (G), and cystine (C). Different sequences of the base pairs of A, T, G, and C carry the genetic code.

as if they were labeled A and B. Let's say, for the sake of speculation, that the gene for blue eyes is found on chromosome pair 18. You might inherit chromosome 18A from your mother and chromosome 18B from your father. Your sister might inherit 18B from your mother and 18A from your father. In regard to this trait, you and your sister would have no genetic inheritance in common. On the average, brothers and sisters have about 50 percent of their genes in common. The exception is identical (monozygotic) twins. Because they are formed from a single zygote, they share all their genes.

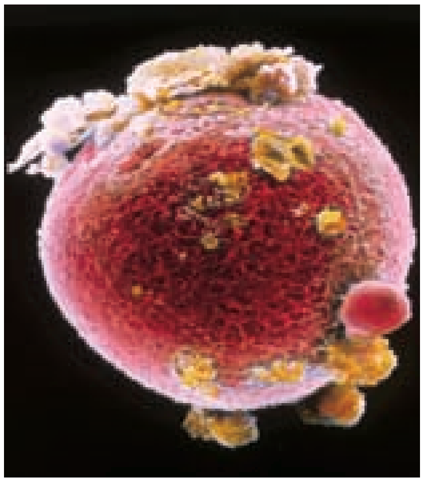
Dominant and Recessive Traits

As we have seen, the 23 chromosomes you get from your mother are matched to the 23 you get from your father. Each pair of chromosomes carries a gene from each of the two parents for the same characteristic. But what if they conflict? What if the gene from the father carries the code for blue eyes and the gene from the mother carries the code for brown eyes? The answer depends on which is the **dominant gene.** In the case of eye color, a gene for brown eyes is typically dominant over one for blue eyes. The gene for blue eyes is said to be **recessive.** A dominant gene normally reveals its trait whenever the gene is present. A recessive gene reveals a trait only when the same recessive gene has been inherited from both parents and there is no dominant gene giving instructions to the contrary. Brown eyes, dark hair, curly hair, farsightedness, and dimples are common examples of dominant traits. On the other hand, blue eyes, light hair, normal vision, and freckles are recessive traits.

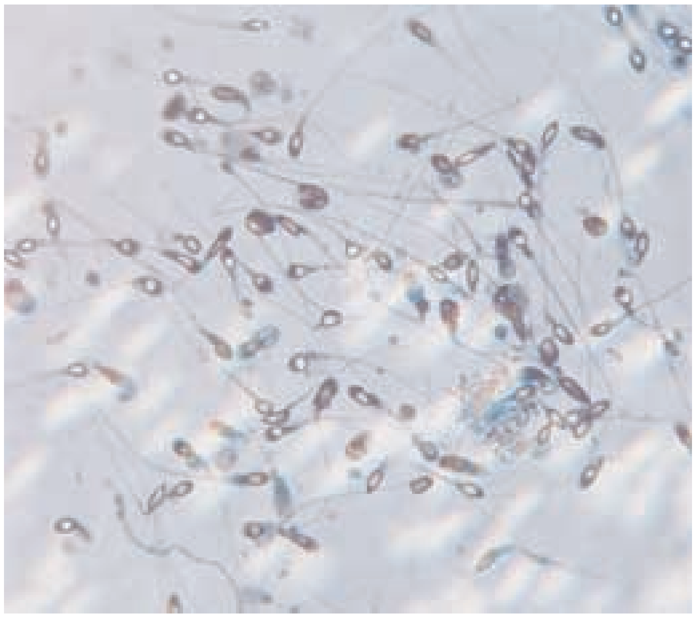
dominant gene
The gene that produces a trait in an individual even when paired with a recessive gene.

recessive gene
The gene that produces a trait in an individual only when the same recessive gene has been inherited from both parents.

This description of genetic inheritance is a simplified one. For example, many physical and behavioral traits appear to be controlled not simply by one gene but by



A human egg cell.



Human sperm, the tiny cells with the long tails.

Down syndrome
An abnormality caused by the presence of an additional 21st chromosome.

monozygotic twins
(mon″ō-zī-got′ik) Twins formed from a single ovum; they are identical in appearance because they have the same genetic structure.

the interaction of several genes. A person's height is controlled by four genes, for example. Still, the basic principles described here are the same in all aspects of genetic inheritance.

Chromosome Abnormalities

Unfortunately, the genetic mechanism does not always work properly. When chromosomes are damaged or malformed, abnormalities of body and behavior often result. A common example is **Down syndrome,** formerly called mongolism, which is caused by the presence of an additional 21st chromosome. Children with Down syndrome have obvious physical irregularities, including a thickened tongue and a skinfold at the corner of the eye. The most serious aspect of Down syndrome, as with many chromosomal abnormalities, is mental retardation.

How Do Genes Influence Our Behavior and Mental Processes?

How can our psychological lives be influenced from within the nuclei of our cells by the microscopic strands of DNA that make up our genes? Figure 3.25 provides a simplified model of the joint action of genes and the environment on behavior (Gottesman, 2001; Johnston & Edwards, 2002). Genes play their role by influencing the synthesis (or creation) of proteins in cells, which influences the nature of the type of cells that are our neurons. The nature of our neurons is not just affected by our genes but is also influenced by our experiences in the environment—experience can and does alter neurons. The nature of our neurons then works with the environment to shape our behavior and mental processes. Differences in our neurons play a role by influencing how we interact with the environment and how the environment influences us.

Research on Inheritance in Humans

When Mendel wanted to study genetic influences on the physical characteristics of pea plants, he was able to breed selectively those plants with a particular characteristic, such as smooth skin, to see what that characteristic would be like in the next generation. That research strategy has been used successfully with animals, showing, for example, that aggressiveness and learning ability in rats and emotionality in monkeys are partially determined by heredity (Ebert & Hyde, 1976; Petitto & others, 1999; Suomi, 1988). Selective breeding experiments cannot be carried out with humans for ethical reasons, of course, so it's much harder to untangle the strands of nature and nurture in human behavior.

Instead, researchers interested in hereditary influences have had to use two descriptive methods of research. These are based on unusual situations that are not contrived by the experimenter but nevertheless allow some conclusions to be reached about the role of the variable being studied. Because these studies do not allow for the same degree of experimental control as do formal experiments, conclusions drawn from them must be viewed cautiously. Still, they are of great importance in research on heredity. The two most common types of naturally occurring experiments in this area involve the study of twins and the study of adopted children (Plomin, 1994; 1999).

Studies of Twins

There are two kinds of twins formed in two very different ways. In the case of *identical,* or **monozygotic twins,** a single fertilized egg begins to grow in the normal way through cell division in the mother's womb. Ordinarily, this cluster of cells grows over the course of

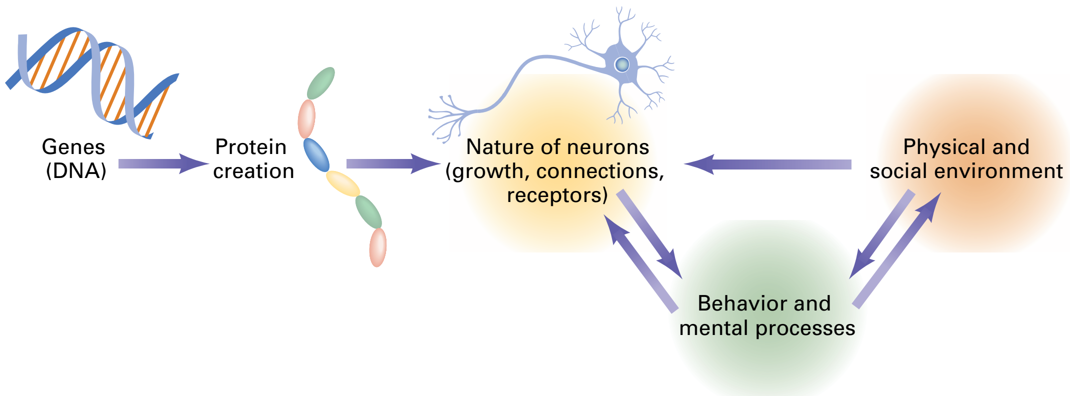


FIGURE 3.25
Genes work with the environment to influence our psychological lives by influencing the synthesis (or creation) of proteins, which influences the nature of neurons. The nature of our neurons (which is also influenced by our experiences in the environment) works with the environment to shape our behavior and mental processes. Our behavior and mental processes often shape our physical and social environment.

about 9 months until it emerges as a baby. Monozygotic twins are formed, however, when that cluster of cells breaks apart into two clusters early in the growth process. If conditions are right, each of these clusters grows into a baby. These infants are "identical" not only in appearance but also identical in genetic structure, since they came from the same fertilized egg.

Dizygotic twins, in contrast, are formed when the female produces two separate eggs that are fertilized by two different sperm cells. These two fertilized eggs grow into two babies that are born at about the same time, but they are not genetically identical. Dizygotic twins are no more alike genetically than are siblings born at different times. Like other siblings, dizygotic twins share 50 percent of their genes on average.

The natural experiment comes from the fact that both types of twins provide us with pairs of children who grow up in essentially the same home environment. They have the same parents, they are reared during the same time period, and they have the same sisters and brothers. On the other hand, the two kinds of twins differ genetically. If a characteristic of behavior is influenced to some degree by heredity, therefore, monozygotic twin pairs will be more similar to one another than would dizygotic twin pairs.

The many experiments conducted using twins have revealed the influence of heredity on behavior (Angoff, 1988). For example, studies of twins have suggested that intelligence, or IQ, is partly determined by heredity (Bartels & others, 2002; Plomin, 1999; Plomin & Petrill, 1997). Figure 3.26 summarizes the findings of a number of studies indicating the degree of similarity in the intelligence test scores among various types of twins and siblings (Bouchard & McGue, 1981). Monozygotic twins who share both identical genetic structure and common environments have almost identical IQ scores. Dizygotic twins, on the other hand, are only slightly more similar in their IQ scores than are other pairs of siblings who are not twins.

Identical, or monozygotic, twins are formed when a single fertilized egg breaks apart into two clusters of cells, each growing into a separate person.

Studies of Adopted Children

Studies of adopted children have also shown that inheritance influences behavior (Angoff, 1988; Plomin, 1994). Take the case of IQ again. It's well known that the IQs of children are pretty similar to those of their parents. But why is this so? Is it because bright parents provide a stimulating intellectual environment that makes their children bright like them, whereas unintelligent parents do just the opposite? Or is it because the children inherit their intellectual potential from their parents? As it turns out, *both* heredity and environment work together to influence IQ, but studies of adopted

dizygotic twins
(dī´´zī-got´ik) Twins formed from the fertilization of two ova by two sperm.

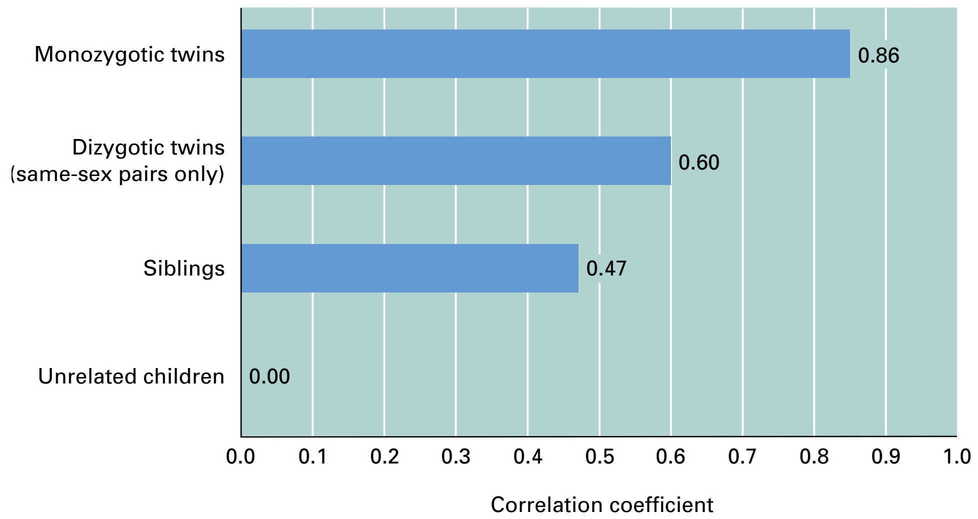


FIGURE 3.26
The degree of similarity among monozygotic twins, dizygotic twins, and other siblings on measures of intelligence.

children have helped show us that the role played by heredity is a strong one. These studies have shown that the IQs of adopted children are more similar to those of their biological parents than to those of the adoptive parents who raised them since infancy (Plomin, 1994). Because the children spent no time living with their biological parents, the only explanation for the similarity in IQs is the link of inheritance.

Genetic Influences on Complex Human Behavior

I have a friend who has an outgoing, dominant personality that makes her the "leader" of almost any group she is in. And her mother is just like her. Does this dominant young woman resemble her mother because she imitated her mother and learned to deal with others in the same dominant way, or did she inherit this personality characteristic in the same way that she inherited her mother's green eyes? Since the time of Plato, it has been suspected that positive and negative characteristics of our personalities—and even psychological disorders—might be influenced by genetic factors. Until recently, however, little solid evidence has been available to test this genetic hypothesis. In recent years, strong evidence from a number of studies from several countries suggests that *both* heredity and experience work together to influence normal and abnormal aspects of personality, including sociability, aggressiveness, alcohol and drug use, kindness, depression, and anxiousness (Dick & others, 2001; Kendler, 2001; Plomin, 1989, 1995).

The fact that an aspect of our physical or psychological selves is influenced by heredity does not mean that it is etched in stone. Even highly heritable characteristics can be influenced to some extent by environmental factors. William Angoff (1988) reminds us that, even though height is strongly influenced by heredity, the average height in some countries has increased by over 3 inches since World War II. He believes that the characteristic of intelligence, in the right circumstances, has the same potential for change over time. Notice, too, that even the strongest estimate of the role of genetics in the formation of our personalities leaves a major role to be played by our child rearing, the stresses and strains of our lives, our social relationships, and other psychological factors. Heredity and experience always work together to influence our psychological characteristics.

Review

Specific patterns of behavior are not inherited by humans, but heredity does influence broad dimensions of behavior. Among the characteristics that appear to be influenced to some degree by inheritance are intelligence, several aspects of personality, and some aspects of abnormal behavior. The hereditary blueprints that exert this influence are coded in thousands of genes arranged on pairs of chromosome strips in the nuclei of cells. One member of each chromosome pair comes from each parent, giving each individual two sets of genes. Sometimes these genes are in conflict, as when a person inherits a gene for blue eyes from the mother and brown eyes from the father. When this happens, some genes are dominant because they suppress the influence of the other conflicting gene for the same trait; other genes are recessive and have an effect only when the same recessive gene is inherited from both parents.

The effects of heredity on human behavior have been examined in studies using twins and adopted children. For example, the fact that monozygotic (identical) twins have exactly the same genes, whereas dizygotic twins share only about 50 percent of their genes, can be used to study the role of heredity. Even though both kinds of twins grow up in comparably similar environments, monozygotic twins are more similar than dizygotic twins on several dimensions of behavior, suggesting that genetics plays some role in behavior. In addition, studies showing that adopted children resemble their biological parents in some ways more than they resemble the adoptive parents who reared them indicate the role of inheritance. Although the influence of heredity on behavior is significant, many other factors influence behavior as well. We are far from being as rigidly programmed by our inheritance as some species of animals are.

Check Your Learning

To be sure that you have learned the key points from the preceding section, cover the list of correct answers and try to answer each question. If you give an incorrect answer to any question, return to the page given next to the correct answer to see why your answer was not correct.

1. The genetic code is contained in segments of DNA called

   a) genes. c) neurons.
   b) mitochondria. d) hormones.

2. A trait that will be found in a child only when the child receives the same gene for the same trait from both parents is a ______________ trait.

   a) recessive c) Mendelian
   b) dominant d) dizygotic

3. To study inheritance in humans, scientists often study twins because one type of twins is genetically identical, whereas the other type shares only about 50 percent of the same genes; the type of twin that is genetically identical is called

   a) Mendelian. c) monozygotic.
   b) adopted. d) dizygotic.

4. The results of a study of adopted children would indicate that a characteristic was influenced by inheritance if the children resembled more their __________ parents.

   a) adoptive c) nonparous
   b) biological d) dizygotic

Thinking Critically about Psychology

1. What are the social implications of research suggesting that intelligence and some personality traits are, to a considerable extent, inherited?
2. What are the advantages of studying twins who have been raised apart? Can such studies give us a complete answer about the influence of heredity on human behavior?

Correct Answers: **1.** a (p. 92), **2.** a (p. 94), **3.** c (p. 95), **4.** b (p. 96).

application of psychology

Madness and the Brain

We began this chapter by stating the obvious fact that the brain is the most important biological organ to psychology. We will end the chapter by looking at two striking and sad examples in which the psychological lives of some people are seriously disturbed because the brain does not function normally—schizophrenia and Alzheimer's disease.

Schizophrenia and the Brain

Schizophrenia is an uncommon disorder that affects a little less than 1 percent of the general population. However, it's a severe psychological disorder that, unless successfully treated, renders normal patterns of living impossible. The central feature of schizophrenia is a marked abnormality in thought processes that leaves the person with schizophrenia "out of touch with reality." Persons with schizophrenia often hold strange and disturbing beliefs (such as believing that they receive telepathic messages from devils in another universe). They also often have strangely distorted perceptual experiences (such as hearing voices that are not really there that tell them to do dangerous things) and think in fragmented and illogical ways. At the same time, the emotions and social relationships of the person with schizophrenia are often severely disturbed.

Great strides have been made recently in understanding the link between schizophrenia and the brain. Although this evidence is strong and impressive, a word of caution might be wise before we look at this topic. Researchers tend to study very severe cases of any disorder, including schizophrenia, to make the difficult task of finding the cause of the disorder a little easier. Therefore, when we look at the striking images in this section of the very abnormal brains of persons with schizophrenia, keep in mind that these are the brains of severe cases. Individuals with milder schizophrenia may have more normal brains.

Remember that there is strong evidence that a predisposition to schizophrenia is inherited. As discussed earlier in this chapter (p. 95), the role of genetics can be examined in studies comparing identical twins (who have identical genes) with fraternal twins (who share only about half of their genes). The fact that about 50 percent of identical twins both have schizophrenia if one has schizophrenia, compared with only about 10 percent of fraternal twins, is strong evidence for a genetic factor in the disorder. However, the fact that not *all* of the identical twins of persons with schizophrenia also have the disorder clearly shows that more than just heredity is involved. Some other factor or factors must play key roles in the cause of schizophrenia (Fowles, 1992).

Images of the Brains of Persons with Schizophrenia

Whatever those factors are that work along with heredity to cause schizophrenia, they produce marked changes in the brains of persons with severe schizophrenia. An impressive number of studies using magnetic resonance imaging (MRI), PET, and other brain-imaging techniques show that the cerebral cortex and key structures of the limbic system are literally "shrunken" in persons with schizophrenia (Andreasen, 1999; Byne & others, 2001; Mathalon, Sullivan, Lim, & Pfefferbaum, 2001; Cannon & others, 1998). The easiest way to see the reduced size of the brain in persons with schizophrenia using MRI is to measure the size of structures called the *ventricles*. The ventricles are fluid-filled passageways located near the center of the brain that bathe the brain in fluid. If the underside of the cortex and nearby structures are shrunken, the ventricles are enlarged.

The enlargement of the ventricles in persons with schizophrenia is shown clearly in the two striking brain images in figure 3.27. These are MRI images of the brains of two identical twins,

(continued)

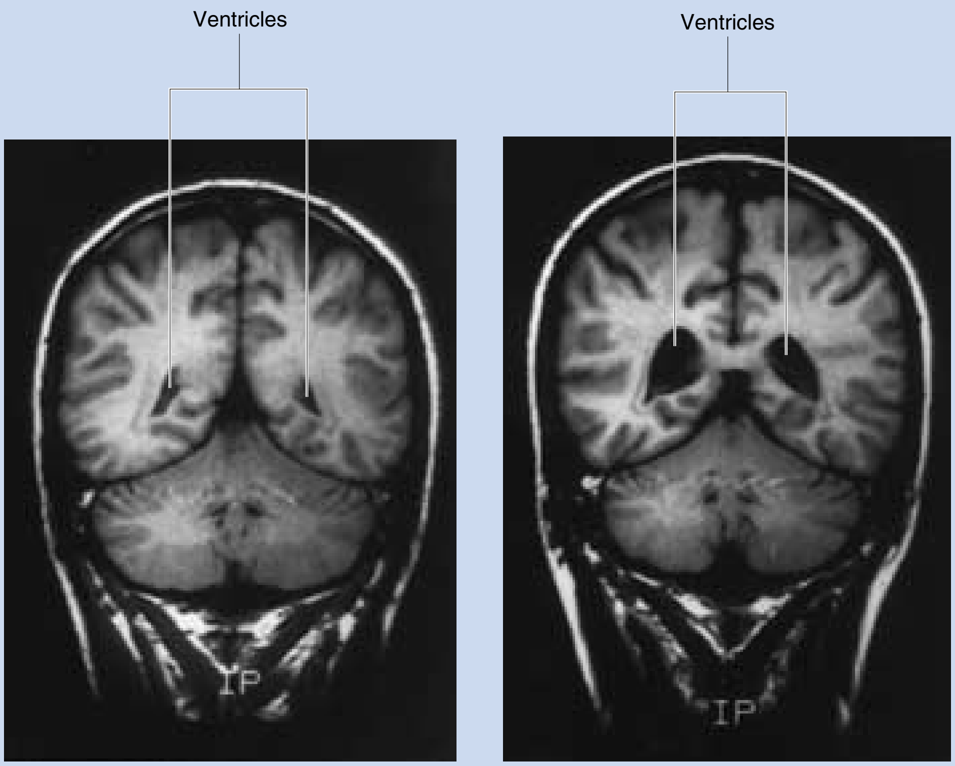


FIGURE 3.27
These are MRI images of the brains of two identical twins viewed from the back. The twin on the right has schizophrenia, but the twin on the left does not. Notice that the open spaces inside the brain, called the ventricles, are enlarged in the schizophrenic because the interior regions of the brain are reduced in size.

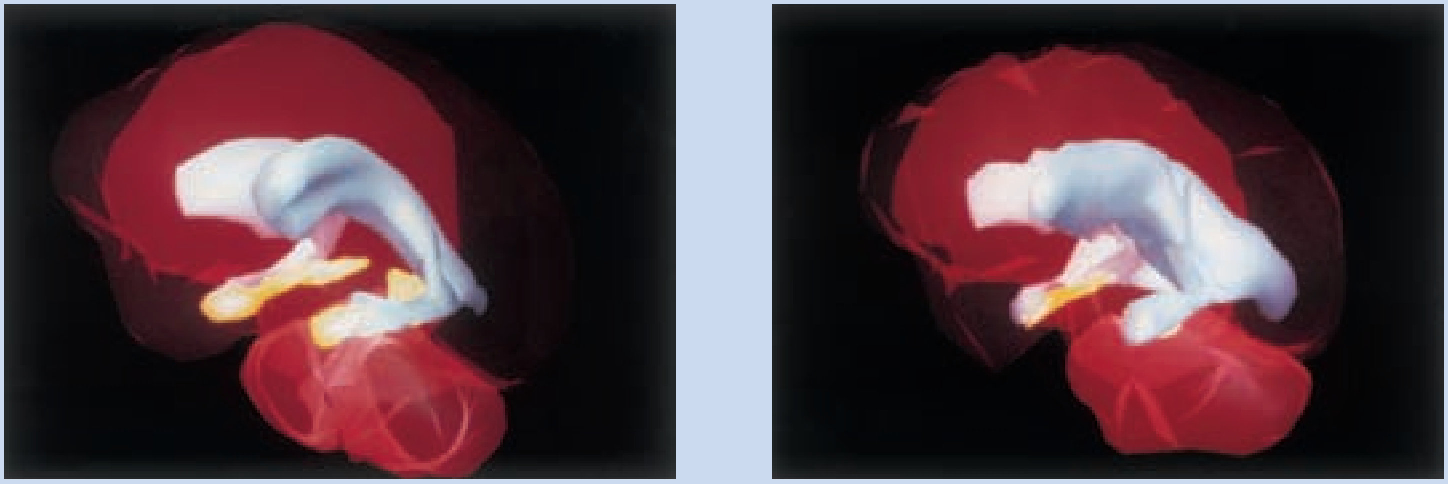


FIGURE 3.28
The brain of a person with schizophrenia (right) shows a shrunken hippocampus (in yellow) and enlarged, fluid-filled ventricles (gray) in comparison with the brain of a person without schizophrenia (left).

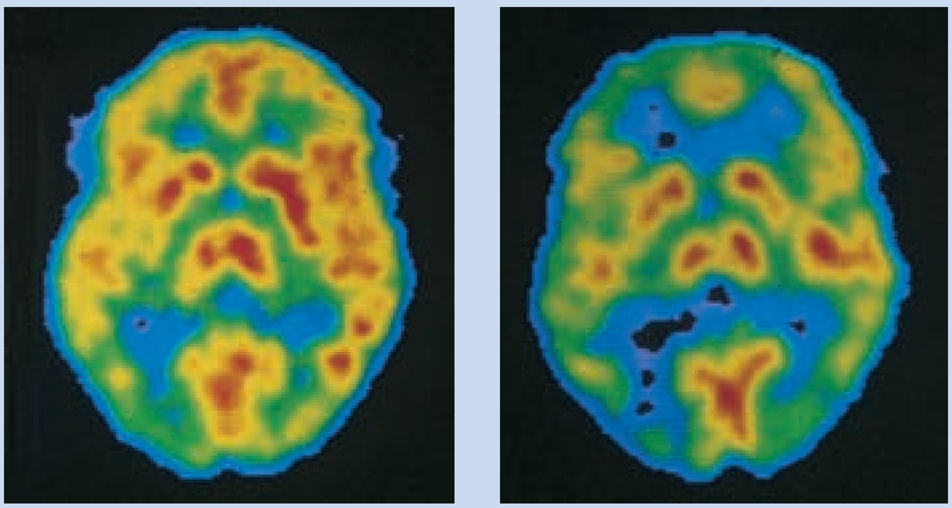


FIGURE 3.29
These PET scans demonstrate how functioning of the cerebral cortex can be affected in schizophrenia. The level of activity in the brain is indicated by the colors on the scan. Yellow and red indicate high levels, whereas green signifies a low activity level. During a task that requires close attention, the frontal lobes of the cerebral cortex (at the top of each scan) are highly active in a person without schizophrenia (left). In contrast, a person with schizophrenia, shown on the right, has little activity in the same area during the same task.

only one of whom has schizophrenia (Horgan, 1993). These images were made looking at the *back* of the head. The two lobes of the cerebral cortex can be seen at the top of the head, with the slightly darker cerebellum clearly visible at the base of the skull. The ventricles are two dark spots toward the bottom of the two hemispheres of the cerebral cortex. Which identical twin has schizophrenia—can you tell? The brain of the twin with schizophrenia is shown on the right. Notice that the ventricles are greatly enlarged because the interior portions of the cerebral cortex and limbic system are reduced in size.

An even more dramatic set of images is shown in figure 3.28. These three-dimensional color photographs were constructed from computer-enhanced MRI images in the laboratory of Nancy Andreasen at the University of Iowa School of Medicine (from Gershon & Rieder, 1992). In these images, the brain is seen from an angle, looking at the head from the front on the left side. In these images, the computer program has colored the ventricle closer to us in silver and the ventricle in the cerebral hemisphere that is farther away from us in white. Both the cerebral cortex and the cerebellum are colored in red. The image at the left is of a person with schizophrenia, whereas the image at the right is of a normal person. Notice that the ventricles of the person with schizophrenia are enlarged in the middle and rear portions of the brain, showing reductions in size of the interior portions of the brain in these areas. Perhaps more interestingly, these color images also allow us to directly measure a key structure in the limbic system, the hippocampus, which is color-coded in yellow. Recall that the hippocampus plays a key role in the regulation of both emotion and memory (see p. 74). In this image, the person with schizophrenia has a markedly smaller hippocampus.

The parts of the brain surrounding the ventricles are important in their own right, but they also are the source of neurons that activate the frontal lobes of the cerebral cortex (p. 75). The frontal lobes play important roles in emotional control and logical planning—two qualities that are quite disturbed in schizophrenia. Look at the two PET images of the cerebral cortex shown in figure 3.29 that reveal more about the level of brain activity than the size of the structures. We are looking at the brain from the top, with the frontal lobes shown at the top of these images. High levels of activity in an area of the brain are shown in yellow and red, whereas cool greens indicate low levels of brain activity. Notice that the level of activity in the frontal lobes of the normal person (the left image) is high during a task that requires close attention. In contrast, the person with schizophrenia in the image on the right shows little activity in the frontal lobes—they appear to be "turned off."

More recent findings indicate that the thalamus may not function normally in individuals with schizophrenia (Hazlett & others, 1999). This is important because, as mentioned earlier in this chapter, the thalamus routes incoming sensory information. Perhaps the hallucinations experienced by schizophrenics result in part because the thalamus does not function normally.

Neurotransmitters and Schizophrenia

These images, and many similar ones from other studies using brain imaging and autopsy studies of schizophrenics who have died, strongly suggest that persons with schizophrenia experience life in abnormal ways partly because they have abnormalities in the hippocampus, the cerebral cortex, and other key brain structures. Interestingly, evidence shows that these abnormalities in brain structure are also reflected in abnormal levels of the neurotransmitter *dopamine* (Albert & others, 2002; Berman & others, 1988; Conklin & Iacono, 2002). This neurotransmitter is involved in the activities of many parts of the brain, including the frontal lobe of the cerebral cortex. For a variety of reasons, researchers have long suspected that dopamine is involved in schizophrenia. For example, great strides were made in the treatment of schizophrenia in the 1950s with the introduction of the *phenothiazine* drugs. The first clue to the specific effects of these drugs on the body was that phenothiazines often produced the serious side effect of muscular control problems such as those found in Parkinson's disease. Since Parkinson's disease is caused by a deterioration of the parts of the brain that use the neurotransmitter dopamine to transmit neural messages, it was hypothesized that the phenothiazine drugs operated by interfering with dopamine. Thus, if drugs that produce improvements alter dopamine transmission, it makes sense to theorize that schizophrenia is caused by abnormal dopamine transmission.

Another sort of evidence that supports the dopamine hypothesis comes from experience with the side effects of the stimulant drugs called *amphetamines.* These drugs are widely abused because of the intense high and feelings of energy they produce. Excessive use of amphetamines, however, can lead to a condition called *amphetamine psychosis,* which closely resembles paranoid schizophrenia. The fact that this condition resembles schizophrenia is important because amphetamines produce this psychotic reaction by altering dopamine transmission (Snyder, 1974). Furthermore, the best treatment for amphetamine psychosis is phenothiazine medication, which is also the best treatment for schizophrenia.

Causes of Schizophrenia

A great deal of evidence suggests that the brains of persons with schizophrenia are abnormal in structure and function. There is evidence that a predisposition to schizophrenia is inherited, but it is also clear that some other factor or factors must play a role in causing schizophrenia because not even all identical twins both exhibit schizophrenia. What might be the other factor or factors that can cause schizophrenia in genetically predisposed persons? For one thing, there is evidence that *stress* causes persons who are genetically predisposed to have episodes of schizophrenia (Ventura, Neuchterlein, Lukoff, & Hardesty, 1989). However, because this chapter covers the biological foundations of behavior, we focus on evidence that the genetic predisposition is most likely to lead to schizophrenia if the predisposed person suffered some disturbance of the development of the *brain* before birth or during birth (Barre & others, 2001; McNeil, Cantor-Graae, & Weinberger, 2000; Mednick, Machon, Huttunen, & Bonett, 1988; Wyatt, 1996).

Studies by Sarnoff Mednick and others (Barr, Mednick, & Munk-Jorgensen, 1990; Cannon, Mednick & others, 1993; Conklin & Iacono, 2002; Mednick & others, 1988) support the so-called *double strike theory* of schizophrenia. Mednick hypothesizes that schizophrenia is most likely in persons with (a) a genetic predisposition to schizophrenia and (b) some form of complication during pregnancy that alters the brains of individuals who are genetically predisposed to schizophrenia. According to this theory, a genetically predisposed individual who has no complications during pregnancy or birth would be unlikely to develop schizophrenia. Similarly, pregnancy complications would be unlikely to cause schizophrenia in individuals who are not genetically predisposed to it.

Emerging evidence suggests that brain development in genetically predisposed infants can be damaged by dehydration of the mother when she contracts influenza during pregnancy, by severe malnutrition of the mother during pregnancy, by an uncommon Rh incompatibility between the blood of the mother and the fetus, and by birth complications that deprive the newborn of oxygen during birth (Kunugi & others, 1995; Susser & others, 1996; van Err & others, 2002; Wyatt, 1996).

For example, studies of large samples suggest that schizophrenia is more common in children whose mothers were pregnant during periods of influenza epidemics. Figure 3.30 on page 102 shows the rates of schizophrenia in the offspring of women whose pregnancies occurred during periods of low, medium, or high rates of influenza. Notice that the highest rates of schizophrenia are for the children of women who were exposed to influenza during the fifth through the seventh months of pregnancy, which is during the period of the most rapid development of the nervous system in the fetus. Other studies show that severe malnutrition of the mother during pregnancy and other pregnancy complications can also cause the same damage to the developing brain that influenza does (Bracha, Torrey, Gottesman, Bigelow, & Cunniff, 1992; Marenco & Weinberger, 2001; McGlashan & Hoffman, 2000; Susser & Lin, 1992).

The clearest evidence in support of Mednick's double strike theory of schizophrenia comes from a long-term study (Cannon & others, 1993). Mednick's research team has been following a group of children of parents with schizophrenia in Denmark for many years and has detailed information on them from birth to adulthood. Some of the children had two schizophrenic parents (and are considered to have an increased genetic predisposition to schizophrenia), whereas others had only one schizophrenic parent. In contrast, a third group of children has been studied who have no schizophrenic parents (and,

(continued)

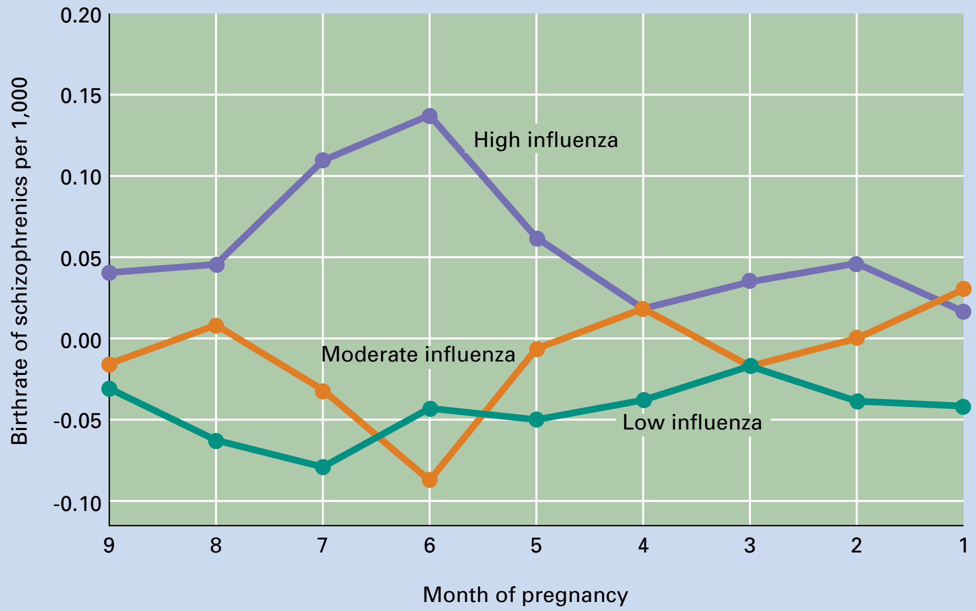


FIGURE 3.30
The average birthrate of persons who later develop schizophrenia when mothers were exposed to low, medium, or high levels of influenza during each month of their pregnancy. Negative birthrates are lower than average; positive birthrates are higher than average.
Source: Data from C. E. Barr, S. A. Mednick, and P. Munk-Jorgensen, "Exposure to Influenza Epidemics during Gestation and Adult Schizophrenia" in *Archives of General Psychiatry,* 47:869–874, 1990.

therefore, are thought to be at low risk for schizophrenia).

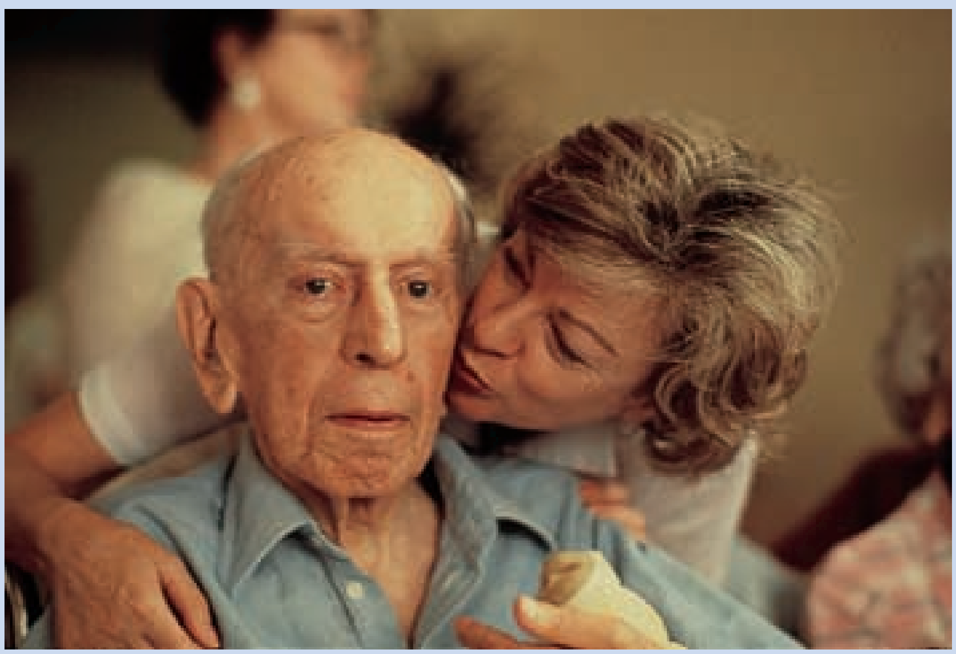
Mednick's research team later obtained brain images of these children at age 29 years using computerized X rays and looked to see whether the persons with the highest genetic predisposition were most likely to have one of the kinds of brain abnormalites associated with schizophrenia (enlarged ventricles). But, because Mednick believes that a person with a genetic predisposition to schizophrenia will develop the disorder only if a pregnancy or birth complication occurred, the researchers looked at birth complications as well.

Mednick found that the ventricles in the children of one parent with schizophrenia were significantly larger than those of the children of no schizophrenic parents, and the ventricles of the children with two schizophrenic parents were significantly larger than those of the children in either of the other two groups, but *only* when a birth complication had occurred. More recently, Mednick's double strike hypothesis of the origins of schizophrenia has been confirmed by a number of independent studies (Dalman & others, 1999; Kinney & others, 1998; Kirkpatrick & others, 1998). Thus, these studies provide strong support for the idea that both genetic predisposition and pregnancy and birth complications operate together to cause schizophrenia.

Alzheimer's Disease and the Brain

Few facts portray the intimate relationship between the brain and our psychological selves more vividly or more sadly than the decline of an individual with Alzheimer's disease. Fully functioning individuals who develop this disorder often fade rapidly in emotional and intellectual functioning, until they are "no longer themselves." Like schizophrenia, Alzheimer's disease results from the deterioration of the cerebral cortex, the hippocampus, and other structures. In Alzheimer's disease, this deterioration is due to the death of neurons, the accumulation of protein deposits, and the development of tangles of neuronal fibers. In most cases, this deterioration can be seen clearly using brain-imaging techniques. Alzheimer's disease is a principal cause of what we commonly refer to as senility.

The loss of brain function results in loss of memory for recent and past events, confusion, and errors in judgment. The individual may no longer recognize close relatives, may forget to turn off the stove, may become lost in a familiar supermarket, and may often lose objects such as keys. Changes in personality are also common. A person who was formerly thought of as polite and socially inhibited may make coarse remarks, lewd jokes, and insulting sexual advances. A formerly shrewd businessperson may make extremely unwise investments. And a happy and loving parent may become apathetic, withdrawn, and unaffectionate.



Individuals who develop Alzheimer's disease often rapidly fade, particularly in intellectual capacity, until they are "no longer themselves."

Alzheimer's disease is uncommon before age 75, but it can develop as early as middle age. The cause of this massive deterioration of the brain is not presently known, but apparently there is an inherited predisposition to develop it. Close relatives of persons with Alzheimer's disease are four times as likely to develop the disorder by age 86 than are individuals without a relative with the disorder (Mohs, Breitner, Silverman, & Davis, 1987). Recent advances in brain-imaging technology using magnetic resonance imaging make it possible to see the deterioration of portions of the cerebral cortex that results in Alzheimer's disease. The image on the left in figure 3.31 is of an older adult with few symptoms; the image on the right shows the dramatic deterioration in both hemispheres of the cortex that accompanies severe symptoms of Alzheimer's disease (Bondareff, Raval, Woo, Hauser, & Colletti, 1990).

I hope this detailed discussion of two ways in which disorders of the brain can alter psychological lives will help give you a better understanding of why we must understand the brain to understand psychology. Also, this discussion will give you a more informed perspective on these two conditions. ■

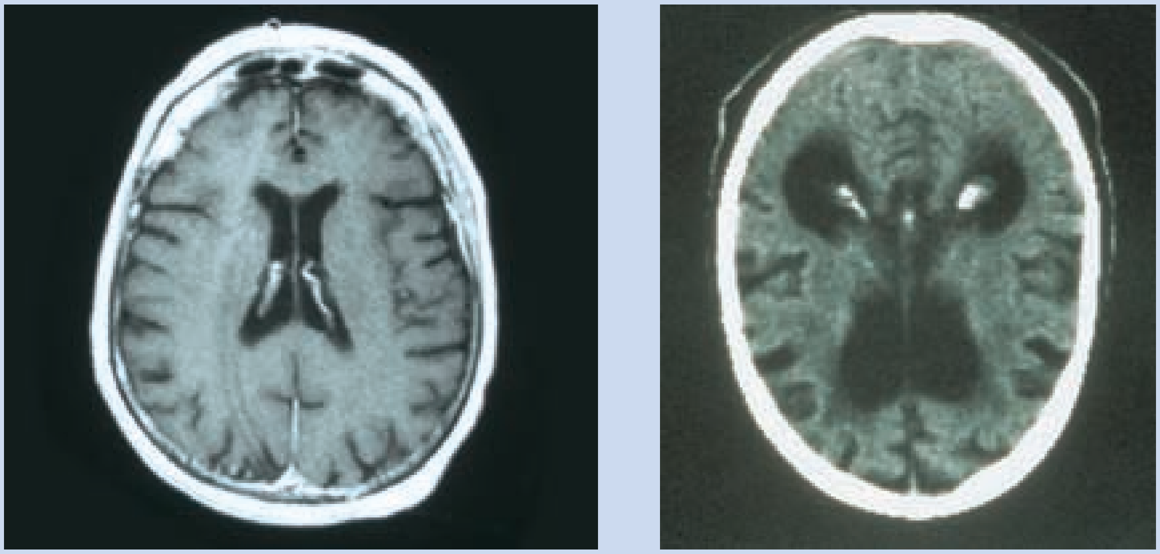


FIGURE 3.31
(Left) MRI scan of a normal older adult. (Right) MRI scan showing the deterioration of the cerebral cortex in both hemispheres (viewed from the top) in a patient with severe Alzheimer's disease.

Summary

Chapter 3 describes people as psychological beings who live in biological bodies; it looks at the role played by the nervous system, the endocrine system, and genetic mechanisms in our behavior and mental processes.

I. The nervous system is a complex network of neural cells that carry messages and regulate body functions and personal behavior.
   A. The individual cells of the nervous system (neurons) transmit electrical signals along their length.
   B. Chemical substances called neurotransmitters transmit neural messages from the axon of one neuron across the gap (synapse) to the next neuron.
   C. The central nervous system is composed of the brain and spinal cord. The peripheral nervous system carries messages between the central nervous system and the rest of the body. It consists of the somatic and autonomic nervous systems.
      1. The somatic nervous system carries messages from the sense organs to the central nervous system, and it carries messages from the central nervous system to the skeletal muscles.

2. The autonomic nervous system regulates the visceral organs and other body functions and plays a role in emotional activity.

II. The brain has three basic parts: the hindbrain, the midbrain, and the forebrain.
   A. The hindbrain consists of the medulla, the pons, and the cerebellum.
      1. The medulla controls breathing and a variety of reflexes.
      2. The pons regulates balance, hearing, and several parasympathetic functions.
      3. The cerebellum is chiefly responsible for maintaining muscle tone and coordination of muscular movements but also plays a role in learning and memory involving sequenced events.
   B. The midbrain is a center for reflexes related to vision and hearing.
   C. Most cognitive, motivational, and emotional activity is controlled by the forebrain, which includes the thalamus, hypothalamus, limbic system, and cerebral cortex.
      1. The thalamus is a switching station for routing sensory information to appropriate areas of the brain.
      2. The hypothalamus and limbic system are involved with motives and emotions.
      3. The largest part of the brain is the cerebral cortex, made up of two cerebral hemispheres, which are primarily connected by the corpus callosum. The cortex controls conscious experience, intellectual activities, the senses, and voluntary functions.
   D. Each part of the brain interacts with the entire nervous system, and the parts work together in intellectual, physical, and emotional functions.
   E. The brain is an organ that is plastic to some degree—it changes over the course of development.

III. Whereas the nervous system forms the primary biological basis for behavior and mental processes, the endocrine system of hormone-secreting glands influences emotional arousal, metabolism, sexual functioning, and other body processes.
   A. Adrenal glands secrete epinephrine and norepinephrine, which are involved in emotional arousal, heart rate, and metabolism.
   B. Islets of Langerhans secrete glucagon and insulin, which control blood-sugar and energy levels.
   C. Gonads produce sex cells (ova and sperm) for human reproduction and estrogen and testosterone, which are hormones important to sexual functioning and the development of secondary sex characteristics.
   D. The thyroid gland secretes thyroxin, which controls the rate of metabolism.
   E. Parathyroid glands secrete parathormone, which controls the level of nervous activity.
   F. The pituitary gland secretes various hormones that control the activities of other endocrine glands and have important effects on general body processes.

IV. Some human characteristics and behaviors are influenced by genetic inheritance.
   A. Inherited characteristics are passed on through genes, which are segments of DNA on the chromosomes.
   B. Most normal human cells contain 46 chromosomes (23 pairs).
   C. The sex cells (sperm and ova) contain only 23 chromosomes each; they are capable of combining into a new zygote during fertilization.

D. Research has shown that inheritance plays a significant role in influencing behavior—including intelligence, some aspects of personality, and some aspects of abnormal behavior—but environmental and other personal factors are very important as well. Genetic and environmental factors always operate together to influence psychological characteristics.

Resources

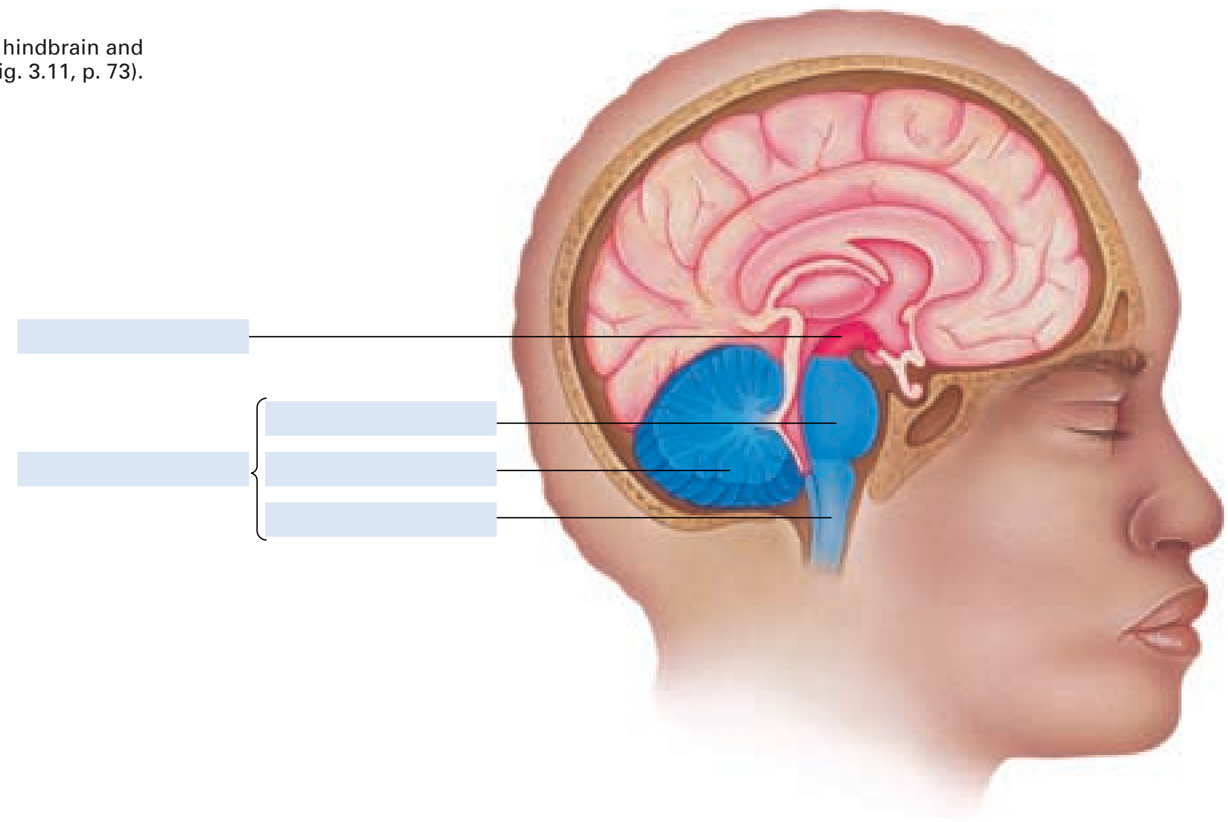
1. For a very readable discussion of the relationship between brain and behavior written for the intelligent public, see LeDoux, J. (1996). *The emotional brain.* New York: Touchstone. A more sophisticated summary for college students is provided by Beatty, J. (1995). *Principles of behavioral neuroscience.* Boston: McGraw-Hill.
2. The classic studies of patients with split brains are described in readable detail in Gazzaniga, M. S. (1992). *Nature's mind: The biological roots of thinking, emotion, sexuality, language, and intelligence.* Boston: Houghton Mifflin. A great collection of papers on the relationship between brain and cognition is found in Gazzaniga, M. S. (2000). *Cognitive neuroscience: A reader.* Malden, MA: Blackwell.
3. A fascinating look at the possible role played by neural factors in mental disorders is provided by Andreasen, N. C. (1983). *The broken brain: The biological revolution in psychiatry.* New York: Harper & Row. She has also published an updated report of such research in Andreasen, N. C. (1999). A unitary model of schizophrenia: Bleuler's "fragmented phrene" as schizoencephaly. *Archives of General Psychiatry, 56,* 781–787.
4. For an elegantly written description of the use of functional magnetic resonance imaging (MRI) in the study of the human brain, see D'Esposito, M. (2000). *Seminars in Neurology*, *20,* 487–498.
5. For more on the interplay of genetic and environmental influences on behavior and mental processes, see Plomin, R. (1994). *Genetics and experience.* Thousand Oaks, CA: Sage.
6. For an easy-to-understand discussion of genetic influences on intelligence and learning problems, see Plomin, R., & DeFries, J. C. (1998, May). The genetics of cognitive abilities and disabilities. *Scientific American,* pp. 62–69.

Visual Review of Brain Structures

Because so much information was covered in chapter 3 on the structures of the brain and endocrine system, a set of unlabeled illustrations (figs. 3.32 through 3.36) has been prepared to help you check your learning of these structures. These reviews will be most helpful if you glance at the first one and then refer back to the illustration on which it is are based to memorize the names of the structures. Then, return to the illustration in this review section and try to write in the names of the brain structures. Check your labels by looking at the original figure once again. When you can label all of the structures in one of the illustrations, you can move on to the next one.

This review section should help you learn the names of the structures of the many parts of the brain. Don't forget, however, to learn what the structures *do* (their functions). After you have mastered the names and locations of the structures, it should be easier for you to remember their functions.

FIGURE 3.32
Key structures of the hindbrain and midbrain (based on fig. 3.11, p. 73).



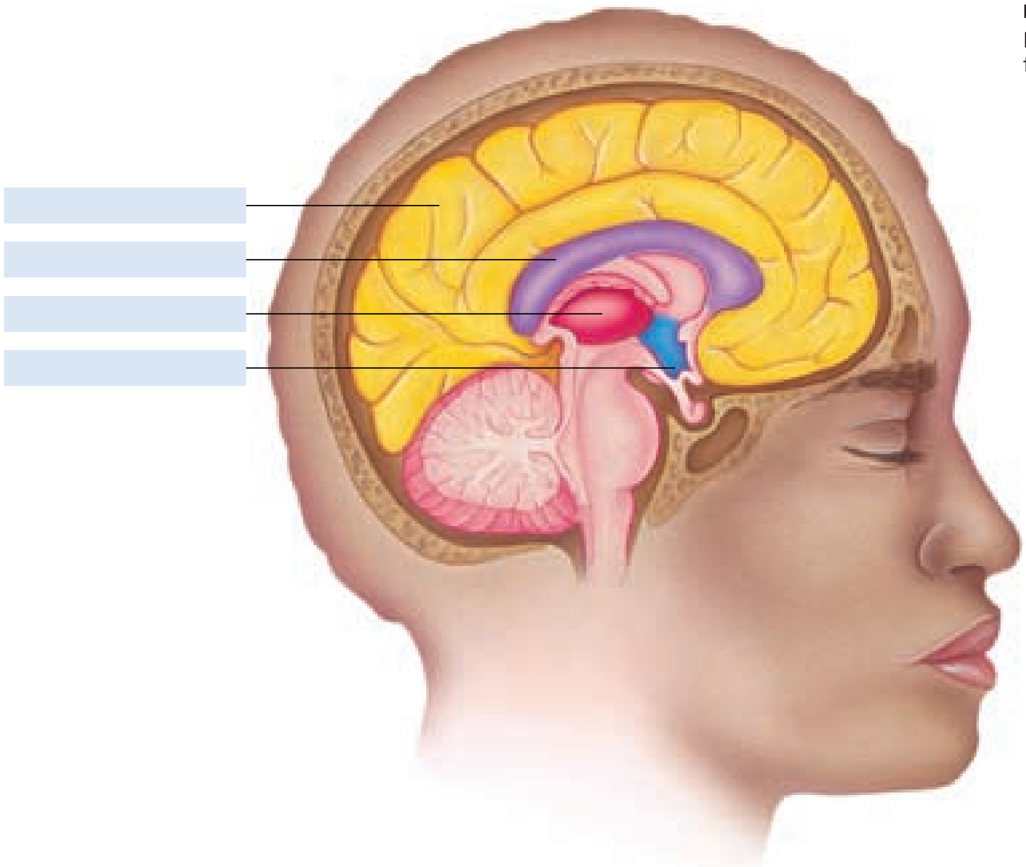


FIGURE 3.33
Key structures of the forebrain (based on fig. 3.12, p. 73).

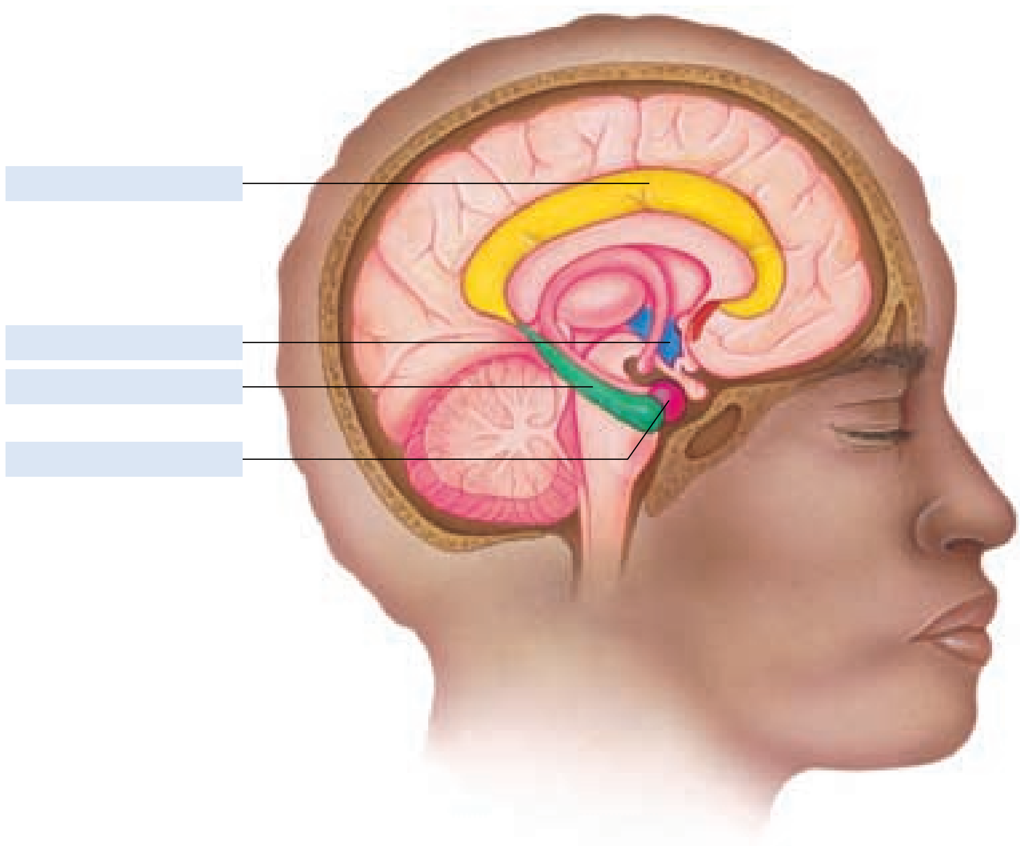
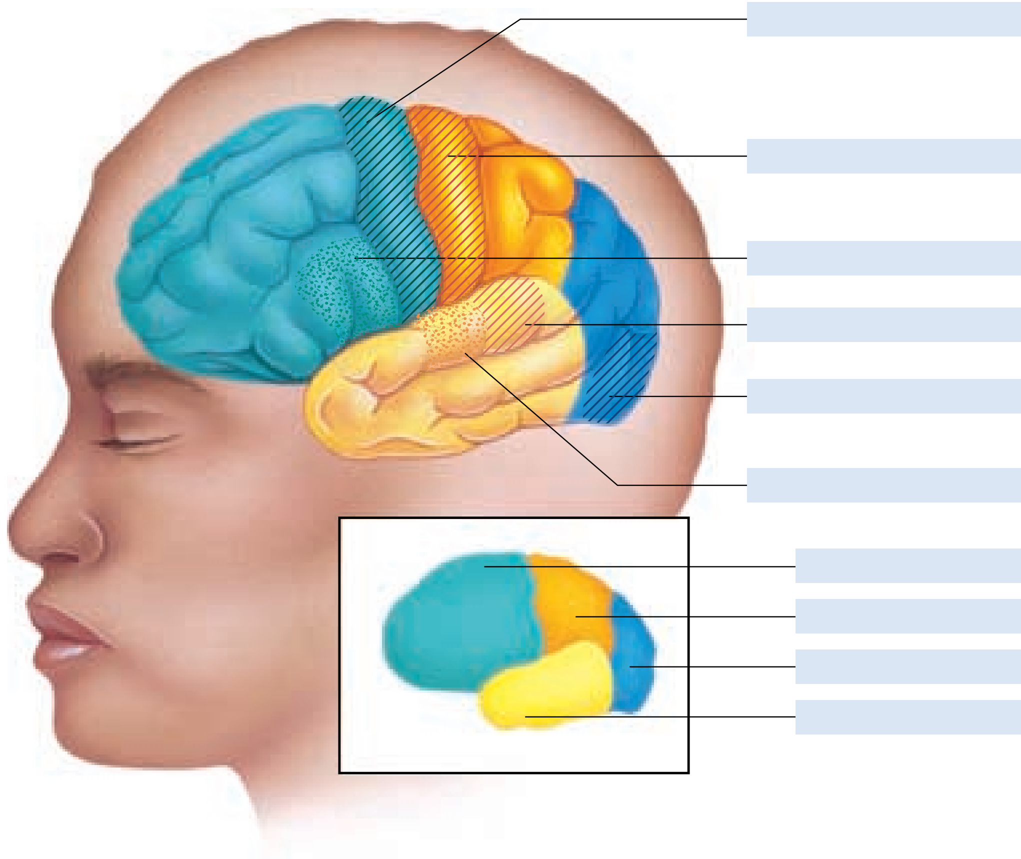


FIGURE 3.34
Key structures of the limbic system (based on fig. 3.13, p. 75).

FIGURE 3.35

The four lobes of the cerebral cortex (box on lower right) and areas with specific functions (top area of illustration) in the cerebral cortex (based on fig. 3.15, p. 76).



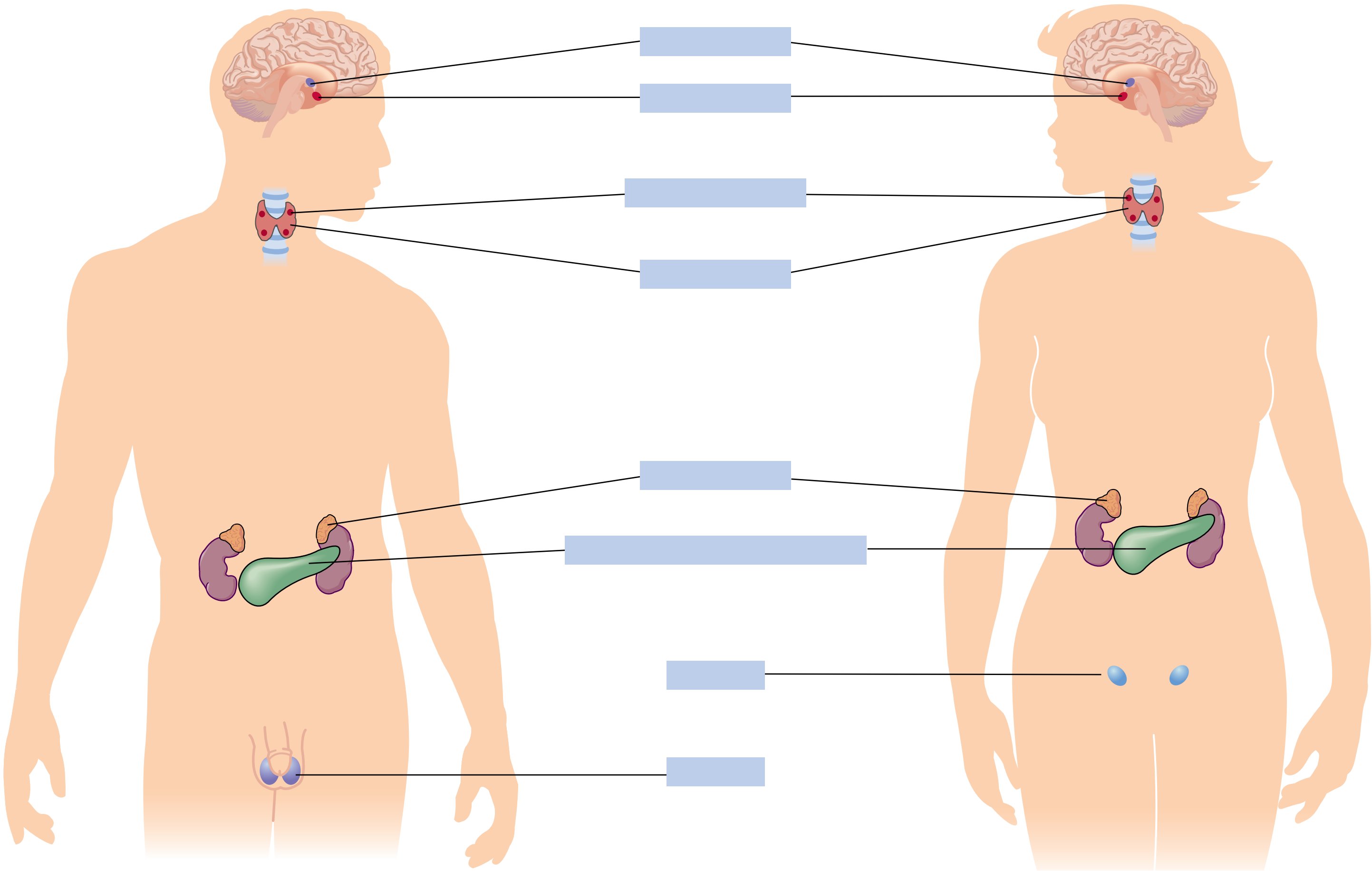


FIGURE 3.36
Endocrine glands (based on fig. 3.22, p. 87).