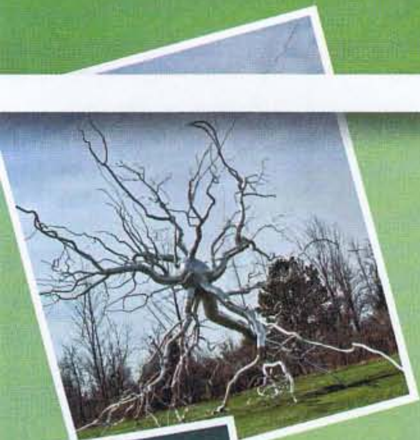
Unit III



Biological Bases of Behavior

Modules

Imagine that just moments before your death, someone removed your brain from your body and kept it alive by floating it in a tank of fluid while feeding it enriched blood. Would you still be in there? Further imagine that your still-living brain was transplanted into the body of a person whose own brain had been severely damaged. To whose home should the recovered patient return? If you say the patient should return to your home, you illustrate what most of us believe—that we reside in our head. An acquaintance of mine received a new heart from a woman who had received a heart-lung transplant. When the two chanced to meet in their hospital ward, she introduced herself: "I think you have my heart." But only her heart; her self, she assumed, still resided inside her skull. We rightly presume that our brain enables our mind. Indeed, no principle is more central to today's psychology, or to this book, than this: *Everything psychological is simultaneously biological.*

Module 9

Biological Psychology and Neurotransmission

AP Photo/Frederik Meijer Gardens & Sculpture Park, Chuck Heiney

Module Learning Objectives

9-1 Explain why psychologists are concerned with human biology.

9-2 Describe the parts of a neuron, and explain how its impulses are generated.

9-3 Describe how nerve cells communicate with other nerve cells.

9-4 Describe how neurotransmitters influence behavior, and explain how drugs and other chemicals affect neurotransmission.

Biology, Behavior, and Mind

9-1 Why are psychologists concerned with human biology?

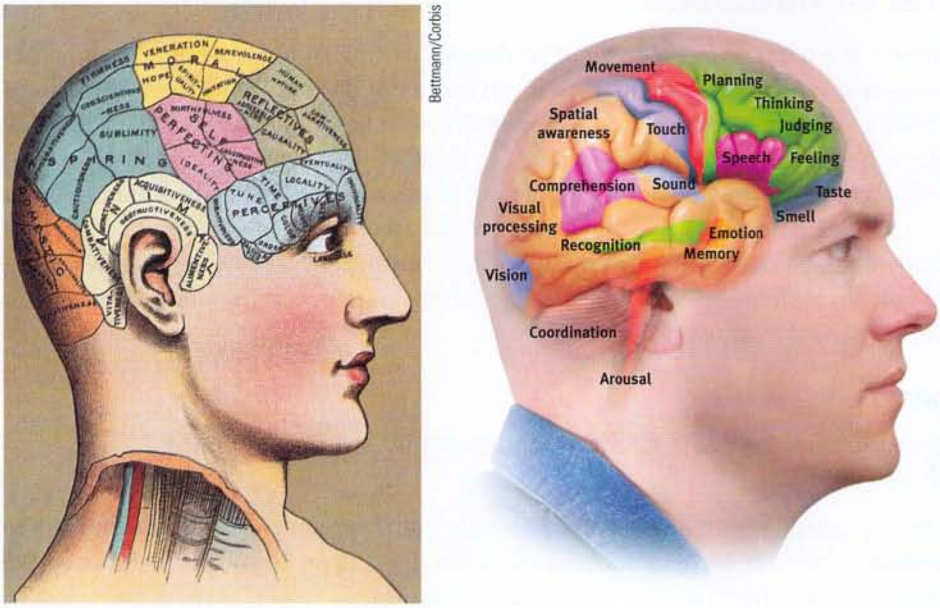
Your every idea, every mood, every urge is a biological happening. You love, laugh, and cry with your body. Without your body—your genes, your brain, your appearance—you would, indeed, be nobody. Although we find it convenient to talk separately of biological and psychological influences on behavior, we need to remember: To think, feel, or act without a body would be like running without legs.

ScienceCartoonsPlus.com

"Then it's agreed—you can't have a mind without a brain, but you can have a brain without a mind."

Our understanding of how the brain gives birth to the mind has come a long way. The ancient Greek philosopher Plato correctly located the mind in the spherical head—his idea of the perfect form. His student, Aristotle, believed the mind was in the heart, which pumps warmth and vitality to the body. The heart remains our symbol for love, but science has long since overtaken philosophy on this issue. It's your brain, not your heart, that falls in love.

In the early 1800s, German physician Franz Gall proposed that *phrenology,* studying bumps on the skull, could reveal a person's mental abilities and character traits (**FIGURE 9.1**). At one point, Britain had 29 phrenological societies, and phrenologists traveled North America giving skull readings (Hunt, 1993).



Bettmann/Corbis

Figure 9.1

A wrongheaded theory Despite initial acceptance of Franz Gall's speculations, bumps on the skull tell us nothing about the brain's underlying functions. Nevertheless, some of his assumptions have held true. Though they are not the functions Gall proposed, different parts of the brain do control different aspects of behavior, as suggested here (from *The Human Brain Book*) and as you will see throughout this unit.

Using a false name, humorist Mark Twain put one famous phrenologist to the test. "He found a cavity [and] startled me by saying that that cavity represented the total absence of the sense of humor!" Three months later, Twain sat for a second reading, this time identifying himself. Now "the cavity was gone, and in its place was . . . the loftiest bump of humor he had ever encountered in his life-long experience!" (Lopez, 2002). Although its initial popularity faded, phrenology succeeded in focusing attention on the *localization of function*—the idea that various brain regions have particular functions.

You and I are living in a time Gall could only dream about. By studying the links between biological activity and psychological events, **biological psychologists** are announcing discoveries about the interplay of our biology and our behavior and mind at an exhilarating pace. Within little more than the past century, researchers seeking to understand the biology of the mind have discovered that

- the body is composed of cells.
- among these are nerve cells that conduct electricity and "talk" to one another by sending chemical messages across a tiny gap that separates them.
- specific brain systems serve specific functions (though not the functions Gall supposed).
- we integrate information processed in these different brain systems to construct our experience of sights and sounds, meanings and memories, pain and passion.
- our adaptive brain is wired by our experience.

We have also realized that we are each a system composed of subsystems that are in turn composed of even smaller subsystems. Tiny cells organize to form body organs. These organs form larger systems for digestion, circulation, and information processing. And those systems are part of an even larger system—the individual, who in turn is a part of a family, culture, and community. Thus, we are *biopsychosocial* systems. To understand our behavior, we need to study how these biological, psychological, and social systems work and interact.

In this unit we start small and build from the bottom up—from nerve cells up to the brain, and then to the environmental influences that interact with our biology. We will also work from the top down, as we consider how our thinking and emotions influence our brain and our health.

AP® Exam Tip

There is a ton of vocabulary in this unit. However, learning vocabulary is really not so hard: The secret is to work on it every day. Try flash cards. Work with a study buddy. Impress your non-psych friends with your new vocabulary. Just don't leave it until the night before the test. If you rehearse the vocabulary throughout the unit, you will do better on the unit test. The big bonus is that you will also retain far more information for the AP® exam.

"If I were a college student today, I don't think I could resist going into neuroscience."
-Novelist Tom Wolfe, 2004

biological psychology
the scientific study of the links between biological (genetic, neural, hormonal) and psychological processes. (Some biological psychologists call themselves *behavioral neuroscientists, neuropsychologists, behavior geneticists, physiological psychologists,* or *biopsychologists.*)

Neural Communication

For scientists, it is a happy fact of nature that the information systems of humans and other animals operate similarly—so similarly that you could not distinguish between small samples of brain tissue from a human and a monkey. This similarity allows researchers to study relatively simple animals, such as squids and sea slugs, to discover how our neural systems operate. It allows them to study other mammals' brains to understand the organization of our own. Cars differ, but all have engines, accelerators, steering wheels, and brakes. An alien could study any one of them and grasp the operating principles. Likewise, animals differ, yet their nervous systems operate similarly. Though the human brain is more complex than a rat's, both follow the same principles.

neuron a nerve cell; the basic building block of the nervous system.

dendrites a neuron's bushy, branching extensions that receive messages and conduct impulses toward the cell body.

axon the neuron extension that passes messages through its branches to other neurons or to muscles or glands.

myelin [MY-uh-lin] **sheath** a fatty tissue layer segmentally encasing the axons of some neurons; enables vastly greater transmission speed as neural impulses hop from one sausage-like node to the next.

action potential a neural impulse; a brief electrical charge that travels down an axon.

"I sing the body electric." -Walt Whitman, "Children of Adam" (1855)

Neurons

9-2 What are the parts of a neuron, and how are neural impulses generated?

Our body's neural information system is complexity built from simplicity. Its building blocks are **neurons,** or nerve cells. To fathom our thoughts and actions, memories and moods, we must first understand how neurons work and communicate.

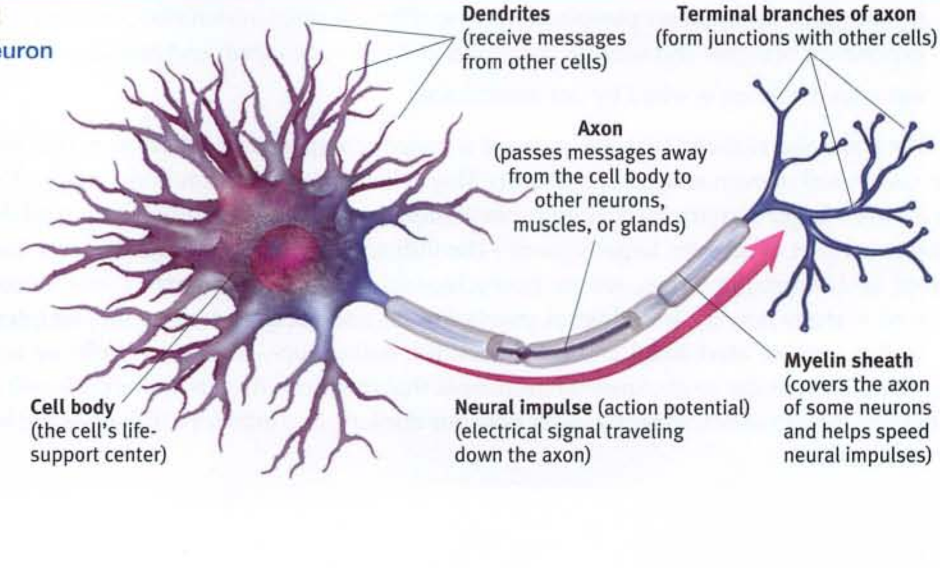
Neurons differ, but all are variations on the same theme (**FIGURE 9.2**). Each consists of a *cell body* and its branching fibers. The bushy **dendrite** fibers receive information and conduct it toward the cell body. From there, the cell's lengthy **axon** fiber passes the message through its terminal branches to other neurons or to muscles or glands. Dendrites listen. Axons speak.

Unlike the short dendrites, axons may be very long, projecting several feet through the body. A neuron carrying orders to a leg muscle, for example, has a cell body and axon roughly on the scale of a basketball attached to a rope 4 miles long. Much as home electrical wire is insulated, some axons are encased in a **myelin sheath,** a layer of fatty tissue that insulates them and speeds their impulses. As myelin is laid down up to about age 25, neural efficiency, judgment, and self-control grow (Fields, 2008). If the myelin sheath degenerates, *multiple sclerosis* results: Communication to muscles slows, with eventual loss of muscle control.

Neurons transmit messages when stimulated by signals from our senses or when triggered by chemical signals from neighboring neurons. In response, a neuron fires an impulse, called the **action potential**—a brief electrical charge that travels down its axon.

Depending on the type of fiber, a neural impulse travels at speeds ranging from a sluggish 2 miles per hour to a breakneck 180 miles per hour. But even this top speed is 3 million times slower than that of electricity through a wire. We measure brain activity in

Figure 9.2
A motor neuron



milliseconds (thousandths of a second) and computer activity in nanoseconds (billionths of a second). Thus, unlike the nearly instantaneous reactions of a high-speed computer, your reaction to a sudden event, such as a book slipping off your desk during class, may take a quarter-second or more. Your brain is vastly more complex than a computer, but slower at executing simple responses. And if you are an elephant—whose round-trip message travel time from a yank on the tail to the brain and back to the tail is 100 times longer than for a tiny shrew—reflexes are slower yet (More et al., 2010).

Like batteries, neurons generate electricity from chemical events. In the neuron's chemistry-to-electricity process, *ions* (electrically charged atoms) are exchanged. The fluid outside an axon's membrane has mostly positively charged ions; a resting axon's fluid interior has mostly negatively charged ions. This positive-outside/negative-inside state is called the *resting potential.* Like a tightly guarded facility, the axon's surface is very selective about what it allows through its gates. We say the axon's surface is *selectively permeable.*

When a neuron fires, however, the security parameters change: The first section of the axon opens its gates, rather like sewer covers flipping open, and positively charged sodium ions flood through the cell membrane (**FIGURE 9.3**). This *depolarizes* that axon section, causing another axon channel to open, and then another, like a line of falling dominos, each tripping the next.

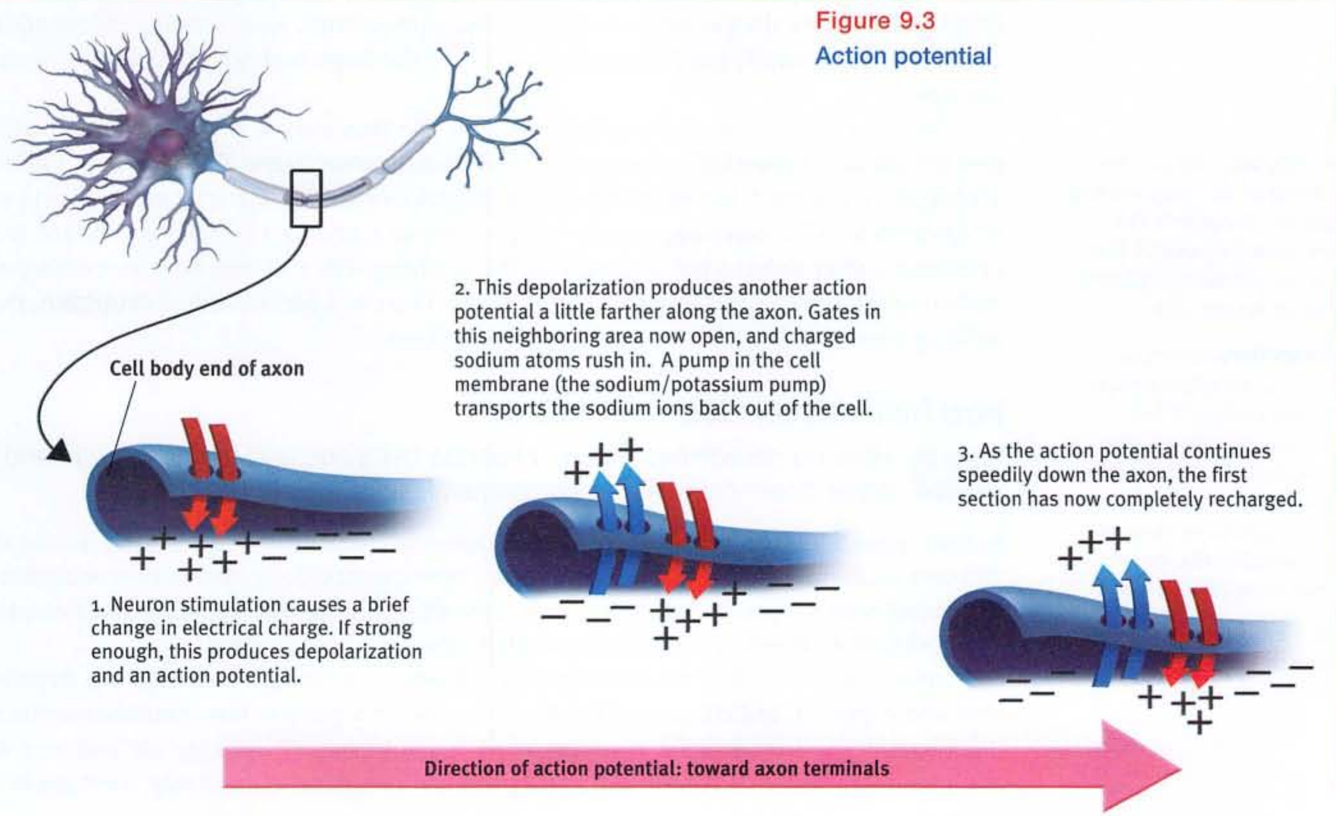
During a resting pause called the **refractory period,** rather like a web page pausing to refresh, the neuron pumps the positively charged sodium ions back outside. Then it can fire again. (In myelinated neurons, as in Figure 9.2, the action potential speeds up by hopping from the end of one myelin "sausage" to the next.) The mind boggles when imagining this electrochemical process repeating up to 100 or even 1000 times a second. But this is just the first of many astonishments.

Each neuron is itself a miniature decision-making device performing complex calculations as it receives signals from hundreds, even thousands, of other neurons. Most signals are *excitatory,* somewhat like pushing a neuron's accelerator. Some are *inhibitory,* more like

refractory period a period of inactivity after a neuron has fired.

"What one neuron tells another neuron is simply how much it is excited." -Francis Crick, *The Astonishing Hypothesis,* 1994

Figure 9.3
Action potential



threshold the level of stimulation required to trigger a neural impulse.

all-or-none response a neuron's reaction of either firing (with a full-strength response) or not firing.

pushing its brake. If excitatory signals exceed inhibitory signals by a minimum intensity, or **threshold,** the combined signals trigger an action potential. (Think of it as a class vote: If the excitatory people with their hands up outvote the inhibitory people with their hands down, then the vote passes.) The action potential then travels down the axon, which branches into junctions with hundreds or thousands of other neurons or with the body's muscles and glands.

Increasing the level of stimulation above the threshold will not increase the neural impulse's intensity. The neuron's reaction is an **all-or-none response:** Like guns, neurons either fire or they don't. How, then, do we detect the intensity of a stimulus? How do we distinguish a gentle touch from a big hug? A strong stimulus can trigger *more* neurons to fire, and to fire more often. But it does not affect the action potential's strength or speed. Squeezing a trigger harder won't make a bullet go faster.

AP® Exam Tip

Note the important shift here. So far, you have been learning about how just one neuron operates. The action potential is the mechanism for communication *within* a single neuron. Now you are moving on to a discussion of two neurons and how communication occurs *between* them. Very different, but equally important.

"All information processing in the brain involves neurons 'talking to' each other at synapses."
-Neuroscientist Solomon H. Snyder (1984)

How Neurons Communicate

9-3 How do nerve cells communicate with other nerve cells?

Neurons interweave so intricately that even with a microscope you would have trouble seeing where one neuron ends and another begins. Scientists once believed that the axon of one cell fused with the dendrites of another in an uninterrupted fabric. Then British physiologist Sir Charles Sherrington (1857–1952) noticed that neural impulses were taking an unexpectedly long time to travel a neural pathway. Inferring that there must be a brief interruption in the transmission, Sherrington called the meeting point between neurons a **synapse.**

We now know that the axon terminal of one neuron is in fact separated from the receiving neuron by a *synaptic gap* (or *synaptic cleft*) less than 1 millionth of an inch wide. Spanish anatomist Santiago Ramón y Cajal (1852–1934) marveled at these near-unions of neurons, calling them "protoplasmic kisses." "Like elegant ladies air-kissing so as not to muss their makeup, dendrites and axons don't quite touch," notes poet Diane Ackerman (2004, p. 37). How do the neurons execute this protoplasmic kiss, sending information across the tiny synaptic gap? The answer is one of the important scientific discoveries of our age.

When an action potential reaches the knob-like terminals at an axon's end, it triggers the release of chemical messengers, called **neurotransmitters** (**FIGURE 9.4**). Within 1/10,000th of a second, the neurotransmitter molecules cross the synaptic gap and bind to receptor sites on the receiving neuron—as precisely as a key fits a lock. For an instant, the neurotransmitter unlocks tiny channels at the receiving site, and ions flow in, exciting or inhibiting the receiving neuron's readiness to fire. Then, in a process called **reuptake,** the sending neuron reabsorbs the excess neurotransmitters.

synapse [SIN-aps] the junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron. The tiny gap at this junction is called the *synaptic gap* or *synaptic cleft.*

neurotransmitters chemical messengers that cross the synaptic gaps between neurons. When released by the sending neuron, neurotransmitters travel across the synapse and bind to receptor sites on the receiving neuron, thereby influencing whether that neuron will generate a neural impulse.

reuptake a neurotransmitter's reabsorption by the sending neuron.

How Neurotransmitters Influence Us

9-4 How do neurotransmitters influence behavior, and how do drugs and other chemicals affect neurotransmission?

In their quest to understand neural communication, researchers have discovered dozens of different neurotransmitters and almost as many new questions: Are certain neurotransmitters found only in specific places? How do they affect our moods, memories, and mental abilities? Can we boost or diminish these effects through drugs or diet?

Later modules explore neurotransmitter influences on hunger and thinking, depression and euphoria, addictions and therapy. For now, let's glimpse how neurotransmitters influence our motions and our emotions. A particular brain pathway may use only one or two neurotransmitters (**FIGURE 9.5**), and particular neurotransmitters may affect specific

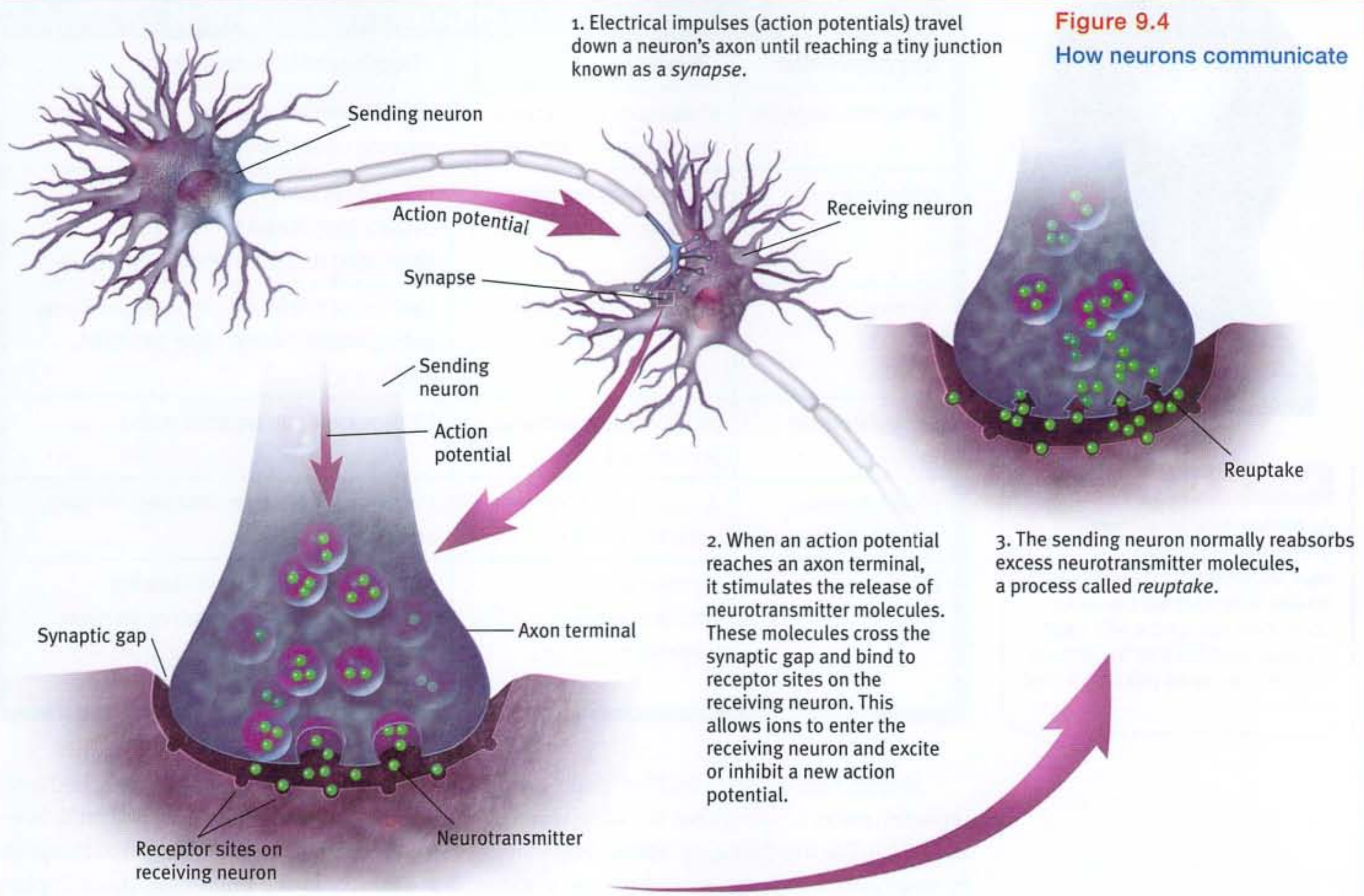
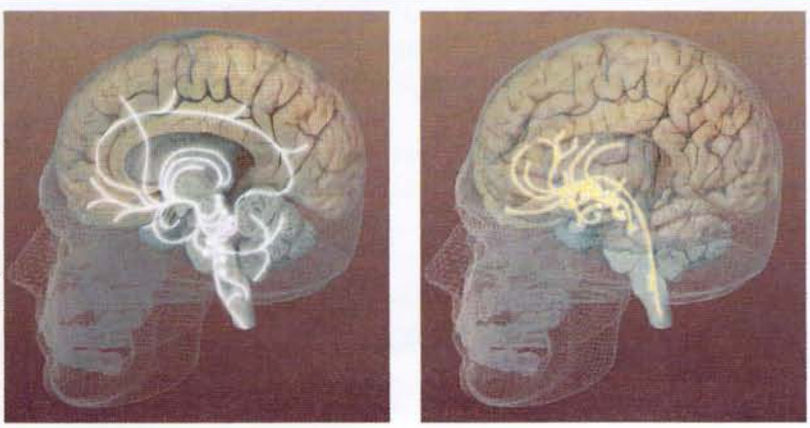


Figure 9.4
How neurons communicate

behaviors and emotions (**TABLE 9.1** on the next page). But neurotransmitter systems don't operate in isolation; they interact, and their effects vary with the receptors they stimulate. *Acetylcholine (ACh),* which is one of the best-understood neurotransmitters, plays a role in learning and memory. In addition, it is the messenger at every junction between motor neurons (which carry information from the brain and spinal cord to the body's tissues) and skeletal muscles. When ACh is released to our muscle cell receptors, the muscle contracts. If ACh transmission is blocked, as happens during some kinds of anesthesia, the muscles cannot contract and we are paralyzed.

"When it comes to the brain, if you want to see the action, follow the neurotransmitters."
-Neuroscientist Floyd Bloom (1993)



Both photos from *Mapping the Mind,* Rita Carter, 1989 Moonrunner Ltd.

Serotonin pathways

Dopamine pathways

Figure 9.5
Neurotransmitter pathways Each of the brain's differing chemical messengers has designated pathways where it operates, as shown here for serotonin and dopamine (Carter, 1998).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AP® Exam Tip

As the text indicates, there are dozens of different neurotransmitters. Though there's no way to predict exactly which ones you'll see on the AP® exam, it's quite possible that the ones in Table 9.1 are ones you'll be asked about.

Table 9.1 Some Neurotransmitters and Their Functions

Neurotransmitter	Function	Examples of Malfunctions
Acetylcholine (ACh)	Enables muscle action, learning, and memory.	With Alzheimer's disease, ACh-producing neurons deteriorate.
Dopamine	Influences movement, learning, attention, and emotion.	Oversupply linked to schizophrenia. Undersupply linked to tremors and decreased mobility in Parkinson's disease.
Serotonin	Affects mood, hunger, sleep, and arousal.	Undersupply linked to depression. Some antidepressant drugs raise serotonin levels.
Norepinephrine	Helps control alertness and arousal.	Undersupply can depress mood.
GABA (gamma-aminobutyric acid)	A major inhibitory neurotransmitter.	Undersupply linked to seizures, tremors, and insomnia.
Glutamate	A major excitatory neurotransmitter; involved in memory.	Oversupply can overstimulate the brain, producing migraines or seizures (which is why some people avoid MSG, monosodium glutamate, in food).

Researchers made an exciting discovery about neurotransmitters when they attached a radioactive tracer to morphine, showing where it was taken up in an animal's brain (Pert & Snyder, 1973). The morphine, an opiate drug that elevates mood and eases pain, bound to receptors in areas linked with mood and pain sensations. But why would the brain have these "opiate receptors"? Why would it have a chemical lock, unless it also had a natural key to open it?

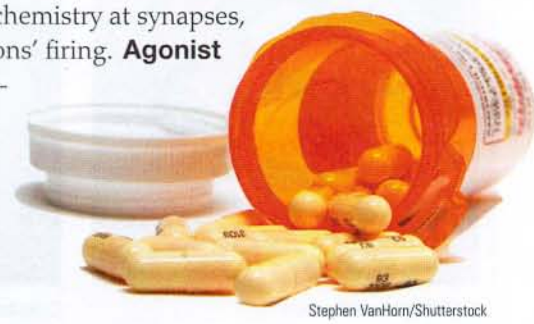
Researchers soon confirmed that the brain does indeed produce its own naturally occurring opiates. Our body releases several types of neurotransmitter molecules similar to morphine in response to pain and vigorous exercise. These **endorphins** (short for *endo*genous [produced within] m*orphine*) help explain good feelings such as the "runner's high," the painkilling effects of acupuncture, and the indifference to pain in some severely injured people. But once again, new knowledge led to new questions.

Physician Lewis Thomas, on the endorphins: "There it is, a biologically universal act of mercy. I cannot explain it, except to say that I would have put it in had I been around at the very beginning, sitting as a member of a planning committee." -*The Youngest Science*, 1983

HOW DRUGS AND OTHER CHEMICALS ALTER NEUROTRANSMISSION

If indeed the endorphins lessen pain and boost mood, why not flood the brain with artificial opiates, thereby intensifying the brain's own "feel-good" chemistry? One problem is that when flooded with opiate drugs such as heroin and morphine, the brain may stop producing its own natural opiates. When the drug is withdrawn, the brain may then be deprived of any form of opiate, causing intense discomfort. For suppressing the body's own neurotransmitter production, nature charges a price.

Drugs and other chemicals affect brain chemistry at synapses, often by either exciting or inhibiting neurons' firing. **Agonist** molecules may be similar enough to a neurotransmitter to bind to its receptor and mimic its effects. Some opiate drugs are agonists and produce a temporary "high" by amplifying normal sensations of arousal or pleasure.


Stephen VanHorn/Shutterstock

endorphins [en-DOR-fins] "morphine within"—natural, opiate-like neurotransmitters linked to pain control and to pleasure.

agonist a molecule that, by binding to a receptor site, stimulates a response.

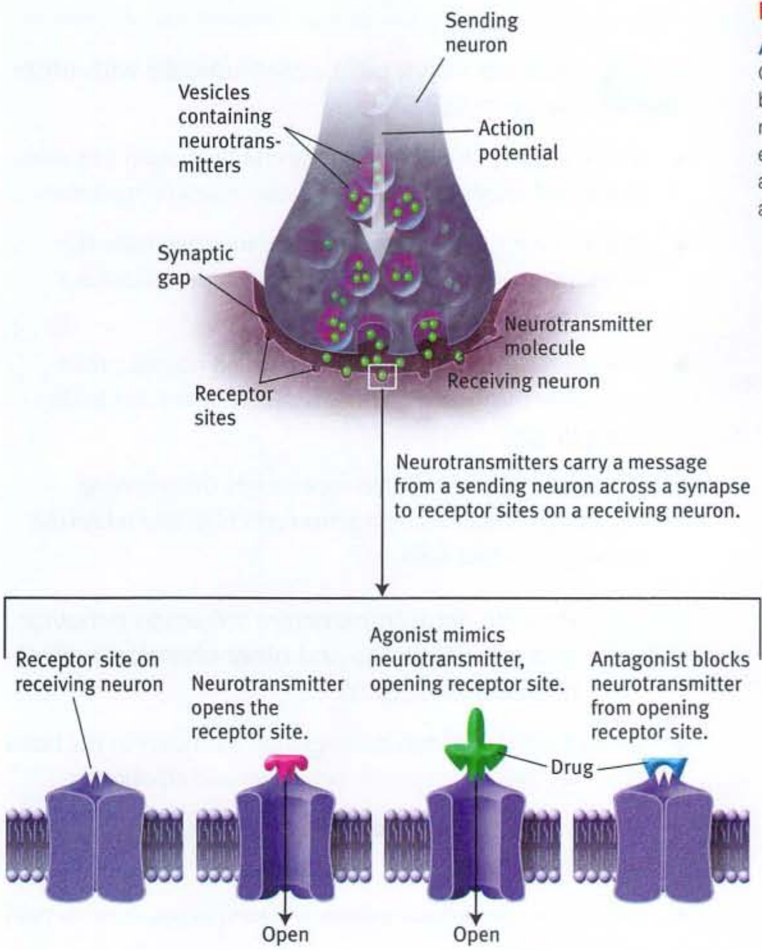


Figure 9.6

Agonists and antagonists
Curare poisoning paralyzes its victims by blocking ACh receptors involved in muscle movements. Morphine mimics endorphin actions. Which is an agonist, and which is an antagonist? (Art adapted from Higgins & George, 2007.)

ANSWER: Morphine is an agonist; curare is an antagonist.

Antagonists also bind to receptors but their effect is instead to block a neurotransmitter's functioning. Botulin, a poison that can form in improperly canned food, causes paralysis by blocking ACh release. (Small injections of botulin—Botox—smooth wrinkles by paralyzing the underlying facial muscles.) These antagonists are enough like the natural neurotransmitter to occupy its receptor site and block its effect, as in **FIGURE 9.6**, but are not similar enough to stimulate the receptor (rather like foreign coins that fit into, but won't operate, a candy machine). Curare, a poison some South American Indians have applied to hunting-dart tips, occupies and blocks ACh receptor sites on muscles, producing paralysis in animals struck by the darts.

antagonist a molecule that, by binding to a receptor site, inhibits or blocks a response.

AP® Exam Tip

Be very clear on this. Neurotransmitters are produced inside the body. They can excite and inhibit neural communication. Drugs and other chemicals come from outside the body. They can have an agonistic effect or an antagonistic effect on neurotransmission.

Before You Move On

► ASK YOURSELF

Can you recall a time when the endorphin response may have protected you from feeling extreme pain?

► TEST YOURSELF

How do neurons communicate with one another?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 9 Review

9-1 Why are psychologists concerned with human biology?

- Psychologists working from a *biological* perspective study the links between biology and behavior.
- We are biopsychosocial systems, in which biological, psychological, and social-cultural factors interact to influence behavior.

9-2 What are the parts of a neuron, and how are neural impulses generated?

- *Neurons* are the elementary components of the nervous system, the body's speedy electrochemical information system.
- A neuron receives signals through its branching *dendrites,* and sends signals through its *axons.*
- Some axons are encased in a *myelin sheath,* which enables faster transmission.
- If the combined received signals exceed a minimum *threshold,* the neuron fires, transmitting an electrical impulse (the *action potential*) down its axon by means of a chemistry-to-electricity process. The neuron's reaction is an *all-or-none process.*

9-3 How do nerve cells communicate with other nerve cells?

- When action potentials reach the end of an axon (the axon terminals), they stimulate the release of *neurotransmitters.*
- These chemical messengers carry a message from the sending neuron across a *synapse* to receptor sites on a receiving neuron.
- The sending neuron, in a process called *reuptake,* then reabsorbs the excess neurotransmitter molecules in the synaptic gap.
- If incoming signals are strong enough, the receiving neuron generates its own action potential and relays the message to other cells.

9-4 How do neurotransmitters influence behavior, and how do drugs and other chemicals affect neurotransmission?

- Neurotransmitters travel designated pathways in the brain and may influence specific behaviors and emotions.
- Acetylcholine (ACh) affects muscle action, learning, and memory.
- *Endorphins* are natural opiates released in response to pain and exercise.
- Drugs and other chemicals affect brain chemistry at synapses.
- *Agonists* excite by mimicking particular neurotransmitters or by blocking their reuptake.
- *Antagonists* inhibit a particular neurotransmitter's release or block its effect.

Multiple-Choice Questions

1. Multiple sclerosis is a result of degeneration in the

a. dendrite.
b. axon.
c. myelin sheath.
d. terminal button.
e. neuron.

2. Junita does not feel like getting out of bed, has lost her appetite, and feels tired for most of the day. Which of the following neurotransmitters likely is in short supply for Junita?

a. Dopamine
b. Serotonin
c. Norephinephrine
d. Acetylcholine
e. Glutamate

3. Which neurotransmitter inhibits CNS activity in order to calm a person down during stressful situations?

a. GABA
b. Norepinephrine
c. Acetylcholine
d. Dopamine
e. Serotonin

4. Phrenology has been discredited, but which of the following ideas has its origins in phrenology?

a. Brain lateralization
b. Brain cavities contributing to sense of humor
c. Bumps in the left hemisphere leading to emotional responses
d. Brain function localization
e. Belief that the mind pumps warmth and vitality into the body

5. When there is a negative charge inside an axon and a positive charge outside it, the neuron is

a. in the process of reuptake.
b. not in the refractory period.
c. said to have a resting potential.
d. said to have an action potential.
e. depolarizing.

6. Morphine elevates mood and eases pain, and is most similar to which of the following?

a. Dopamine
b. Serotonin
c. Endorphins
d. Acetylcholine
e. GABA

7. Neurotransmitters cross the ________ to carry information to the next neuron.

a. synaptic gap
b. axon
c. myelin sheath
d. dendrites
e. cell body

8. What neurotransmitters are most likely in undersupply in someone who is depressed?

a. Dopamine and GABA
b. ACh and norepinephrine
c. Dopamine and norepinephrine
d. Serotonin and norepinephrine
e. Serotonin and glutamate

Practice FRQs

1. While hiking, Ken stumbled and fell down a 10-foot drop-off. Upon landing, he sprained his ankle badly. Ken was surprised that he felt very little pain for the first half hour. Explain how the following helped Ken feel little pain in the moments after the injury.

- Endorphins
- The synapse

Answer

1 point: Endorphins are natural, opiate-like neurotransmitters linked to controlling pain.

1 point: The synapse is the space between neurons where neurotransmitters like the endorphins carry information that influences how Ken feels.

2. Explain the role each of the following plays in sending a message through a neuron.

- Dendrites
- Axon
- Myelin sheath

(3 points)

Module 10

The Nervous and Endocrine Systems

Module Learning Objectives

10-1 Describe the functions of the nervous system's main divisions, and identify the three main types of neurons.

10-2 Describe the nature and functions of the endocrine system and its interaction with the nervous system.


Radius Images/Getty Images

My nervous system recently gave me an emotional roller-coaster ride. Before sending me into an MRI machine for a routine shoulder scan, a technician asked if I had issues with claustrophobia (fear of enclosed spaces). "No, I'm fine," I assured her, with perhaps a hint of macho swagger. Moments later, as I found myself on my back, stuck deep inside a coffin-sized box and unable to move, my nervous system had a different idea. As claustrophobia overtook me, my heart began pounding and I felt a desperate urge to escape. Just as I was about to cry out for release, I suddenly felt my nervous system having a reverse calming influence. My heart rate slowed and my body relaxed, though my arousal surged again before the 20-minute confinement ended. "You did well!" the technician said, unaware of my roller-coaster ride.

What happens inside our brains and bodies to produce such surging and subsiding emotions? Is the nervous system that stirs us the same nervous system that soothes us?

nervous system the body's speedy, electrochemical communication network, consisting of all the nerve cells of the peripheral and central nervous systems.

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

peripheral nervous system (PNS) the sensory and motor neurons that connect the central nervous system (CNS) to the rest of the body.

nerves bundled axons that form neural "cables" connecting the central nervous system with muscles, glands, and sense organs.

sensory (afferent) neurons neurons that carry incoming information from the sensory receptors to the brain and spinal cord.

motor (efferent) neurons neurons that carry outgoing information from the brain and spinal cord to the muscles and glands.

The Nervous System

10-1 What are the functions of the nervous system's main divisions, and what are the three main types of neurons?

To live is to take in information from the world and the body's tissues, to make decisions, and to send back information and orders to the body's tissues. All this happens thanks to our body's **nervous system** (**FIGURE 10.1**). The brain and spinal cord form the **central nervous system (CNS),** the body's decision maker. The **peripheral nervous system (PNS)** is responsible for gathering information and for transmitting CNS decisions to other body parts. **Nerves,** electrical cables formed of bundles of axons, link the CNS with the body's sensory receptors, muscles, and glands. The optic nerve, for example, bundles a million axons into a single cable carrying the messages each eye sends to the brain (Mason & Kandel, 1991).

Information travels in the nervous system through three types of neurons. **Sensory neurons** carry messages from the body's tissues and sensory receptors inward to the brain and spinal cord for processing. **Motor neurons** carry instructions from the central

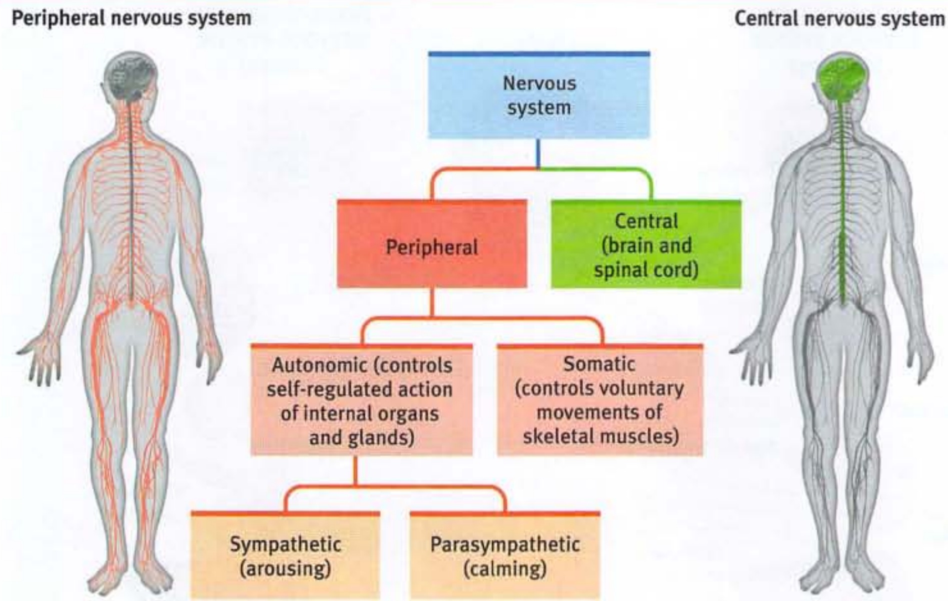


Figure 10.1
The functional divisions of the human nervous system

nervous system out to the body's muscles and glands. Between the sensory input and motor output, information is processed in the brain's internal communication system via its **interneurons.** Our complexity resides mostly in our interneuron systems. Our nervous system has a few million sensory neurons, a few million motor neurons, and billions and billions of interneurons.

AP® Exam Tip

You've heard the word peripheral before, right? How does your knowledge of peripheral vision help you understand what the peripheral nervous system is? It's always good to create mental linkages between what you're learning and what you already know.

The Peripheral Nervous System

Our peripheral nervous system has two components—somatic and autonomic. Our **somatic nervous system** enables voluntary control of our skeletal muscles. As the bell signals the end of class, your somatic nervous system reports to your brain the current state of your skeletal muscles and carries instructions back, triggering your body to rise from your seat.

Our **autonomic nervous system (ANS)** controls our glands and the muscles of our internal organs, influencing such functions as glandular activity, heartbeat, and digestion. Like an automatic pilot, this system may be consciously overridden, but usually operates on its own (autonomously).

The autonomic nervous system serves two important, basic functions (**FIGURE 10.2** on the next page). The **sympathetic nervous system** arouses and expends energy. If something alarms or challenges you (such as taking the AP® Psychology exam, or being stuffed in an MRI machine), your sympathetic nervous system will accelerate your heartbeat, raise your blood pressure, slow your digestion, raise your blood sugar, and cool you with perspiration, making you alert and ready for action. When the stress subsides (the AP® exam or MRI is over), your **parasympathetic nervous system** will produce the opposite effects, conserving energy as it calms you by decreasing your heartbeat, lowering your blood sugar, and so forth. In everyday situations, the sympathetic and parasympathetic nervous systems work together to keep us in a steady internal state.

The Central Nervous System

From the simplicity of neurons "talking" to other neurons arises the complexity of the central nervous system's brain and spinal cord.

interneurons neurons within the brain and spinal cord that communicate internally and intervene between the sensory inputs and motor outputs.

somatic nervous system the division of the peripheral nervous system that controls the body's skeletal muscles. Also called the *skeletal nervous system.*

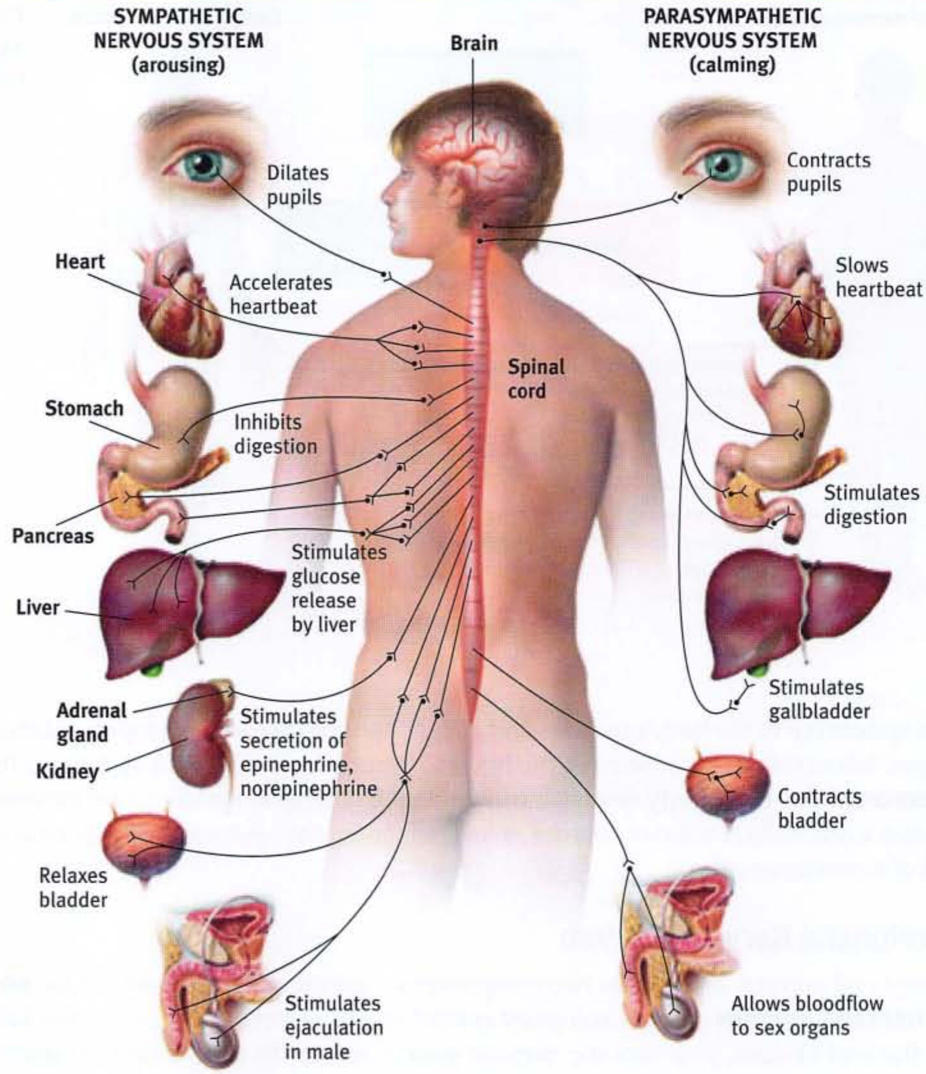
autonomic [aw-tuh-NAHM-ik] **nervous system (ANS)** the part of the peripheral nervous system that controls the glands and the muscles of the internal organs (such as the heart). Its sympathetic division arouses; its parasympathetic division calms.

sympathetic nervous system the division of the autonomic nervous system that arouses the body, mobilizing its energy in stressful situations.

parasympathetic nervous system the division of the autonomic nervous system that calms the body, conserving its energy.

Figure 10.2

The dual functions of the autonomic nervous system The autonomic nervous system controls the more autonomous (or self-regulating) internal functions. Its sympathetic division arouses and expends energy. Its parasympathetic division calms and conserves energy, allowing routine maintenance activity. For example, sympathetic stimulation accelerates heartbeat, whereas parasympathetic stimulation slows it.



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"The body is made up of millions and millions of crumbs."

It is the brain that enables our humanity—our thinking, feeling, and acting. Tens of billions of neurons, each communicating with thousands of other neurons, yield an everchanging wiring diagram. With some 40 billion neurons, each connecting with roughly 10,000 other neurons, we end up with perhaps 400 trillion synapses—places where neurons meet and greet their neighbors (de Courten-Myers, 2005).[1] A grain-of-sand-sized speck of your brain contains some 100,000 neurons and 1 billion "talking" synapses (Ramachandran & Blakeslee, 1998).

The brain's neurons cluster into work groups called *neural networks.* To understand why, Stephen Kosslyn and Olivier Koenig (1992, p. 12) have invited us to "think about why cities exist; why don't people distribute themselves more evenly across the countryside?" Like people networking with people, neurons network with nearby neurons with which they can have short, fast connections. As in **FIGURE 10.3,** each layer's cells connect with various cells in the neural network's next layer. Learning—to play the violin, speak a foreign language, solve a math problem—occurs as experience strengthens connections. Neurons that fire together wire together.

[1] Another research team, projecting from representative tissue samples, has estimated that the adult human male brain contains 86 billion neurons—give or take 8 billion (Azevedo et al., 2009). One moral: Distrust big round numbers, such as the familiar, undocumented claim that the human brain contains 100 billion neurons.

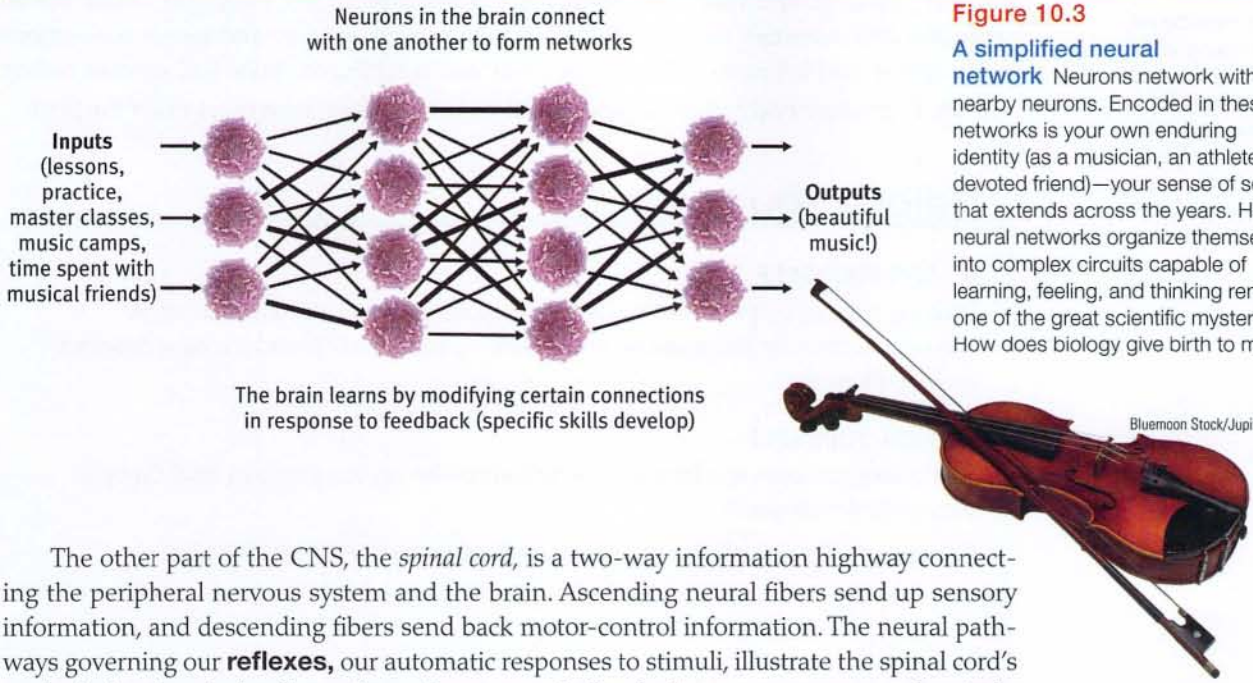

Figure 10.3

A simplified neural network Neurons network with nearby neurons. Encoded in these networks is your own enduring identity (as a musician, an athlete, a devoted friend)—your sense of self that extends across the years. How neural networks organize themselves into complex circuits capable of learning, feeling, and thinking remains one of the great scientific mysteries. How does biology give birth to mind?

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The other part of the CNS, the *spinal cord,* is a two-way information highway connecting the peripheral nervous system and the brain. Ascending neural fibers send up sensory information, and descending fibers send back motor-control information. The neural pathways governing our **reflexes,** our automatic responses to stimuli, illustrate the spinal cord's work. A simple spinal reflex pathway is composed of a single sensory neuron and a single motor neuron. These often communicate through an interneuron. The knee-jerk response, for example, involves one such simple pathway. A headless warm body could do it.

reflex a simple, automatic response to a sensory stimulus, such as the knee-jerk response.

Another such pathway enables the pain reflex (**FIGURE 10.4**). When your finger touches a flame, neural activity (excited by the heat) travels via sensory neurons to interneurons in your spinal cord. These interneurons respond by activating motor neurons leading to the muscles in your arm. Because the simple pain-reflex pathway runs through the spinal cord and right back out, your hand jerks away from the candle's flame *before* your brain receives and responds to the information that causes you to feel pain. That's why it feels as if your hand jerks away not by your choice, but on its own.

Information travels to and from the brain by way of the spinal cord. Were the top of your spinal cord severed, you would not feel pain from your paralyzed body below. Nor would

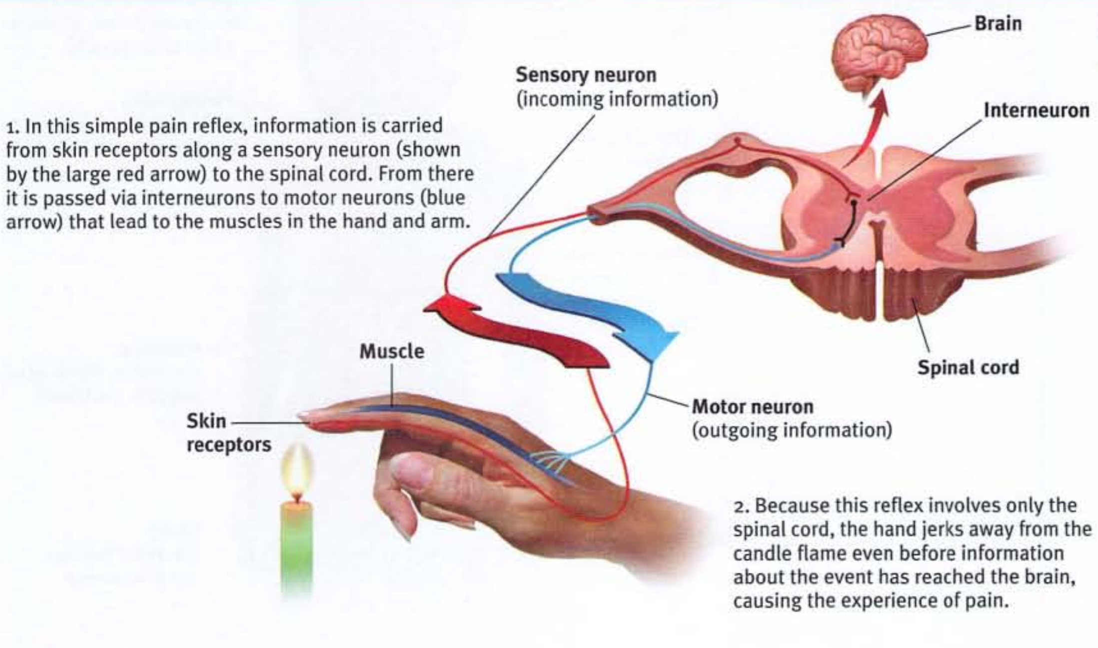


Figure 10.4

A simple reflex

"If the nervous system be cut off between the brain and other parts, the experiences of those other parts are nonexistent for the mind. The eye is blind, the ear deaf, the hand insensible and motionless." -WILLIAM JAMES, *PRINCIPLES OF PSYCHOLOGY*, 1890

you feel pleasure. With your brain literally out of touch with your body, you would lose all sensation and voluntary movement in body regions with sensory and motor connections to the spinal cord below its point of injury. You would exhibit the knee jerk without feeling the tap. To produce bodily pain or pleasure, the sensory information must reach the brain.

Before You Move On

▶ ASK YOURSELF

Does our nervous system's design—with its synaptic gaps that chemical messenger molecules cross in an imperceptibly brief instant—surprise you? Would you have designed yourself differently?

▶ TEST YOURSELF

How does information flow through your nervous system as you pick up a fork? Can you summarize this process?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

endocrine [EN-duh-krin] **system** the body's "slow" chemical communication system; a set of glands that secrete hormones into the bloodstream.

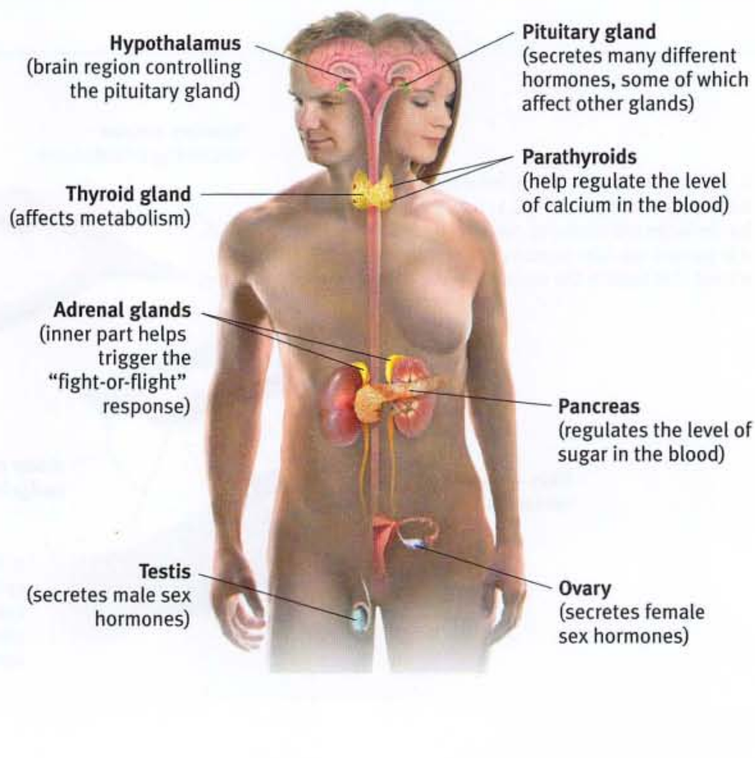
hormones chemical messengers that are manufactured by the endocrine glands travel through the bloodstream and affect other tissues.

The Endocrine System

10-2 What is the nature and what are the functions of the endocrine system, and how does it interact with the nervous system?

So far we have focused on the body's speedy electrochemical information system. Interconnected with your nervous system is a second communication system, the **endocrine system** (**FIGURE 10.5**). The endocrine system's glands secrete another form of chemical messengers, **hormones,** which travel through the bloodstream and affect other tissues, including the brain. When hormones act on the brain, they influence our interest in sex, food, and aggression.

Figure 10.5
The endocrine system



Some hormones are chemically identical to neurotransmitters (the chemical messengers that diffuse across a synapse and excite or inhibit an adjacent neuron). The endocrine system and nervous system are therefore close relatives: Both produce molecules that act on receptors elsewhere. Like many relatives, they also differ. The speedy nervous system zips messages from eyes to brain to hand in a fraction of a second. Endocrine messages trudge along in the bloodstream, taking several seconds or more to travel from the gland to the target tissue. If the nervous system's communication delivers messages with the speed of a text message, the endocrine system is more like sending a letter through the mail.

But slow and steady sometimes wins the race. Endocrine messages tend to outlast the effects of neural messages. That helps explain why upset feelings may linger beyond our awareness of what upset us. When this happens, it takes time for us to "simmer down." In a moment of danger, for example, the ANS orders the **adrenal glands** on top of the kidneys to release *epinephrine* and *norepinephrine* (also called *adrenaline* and *noradrenaline*). These hormones increase heart rate, blood pressure, and blood sugar, providing us with a surge of energy, known as the *fight-or-flight* response. When the emergency passes, the hormones—and the feelings of excitement—linger a while.

The most influential endocrine gland is the **pituitary gland,** a pea-sized structure located in the core of the brain, where it is controlled by an adjacent brain area, the *hypothalamus* (more on that shortly). The pituitary releases certain hormones. One is a growth hormone that stimulates physical development. Another, oxytocin, enables contractions associated with birthing, milk flow during nursing, and orgasm. Oxytocin also promotes pair bonding, group cohesion, and social trust (De Dreu et al., 2010). During a laboratory game, those given a nasal squirt of oxytocin rather than a placebo were more likely to trust strangers with their money (Kosfeld et al., 2005).

adrenal [ah-DREEN-el] **glands** a pair of endocrine glands that sit just above the kidneys and secrete hormones (epinephrine and norepinephrine) that help arouse the body in times of stress.

pituitary gland the endocrine system's most influential gland. Under the influence of the hypothalamus, the pituitary regulates growth and controls other endocrine glands.

Pituitary secretions also influence the release of hormones by other endocrine glands. The pituitary, then, is a sort of master gland (whose own master is the hypothalamus). For example, under the brain's influence, the pituitary triggers your sex glands to release sex hormones. These in turn influence your brain and behavior. So, too, with stress. A stressful event triggers your hypothalamus to instruct your pituitary to release a hormone that causes your adrenal glands to flood your body with cortisol, a stress hormone that increases blood sugar.

This feedback system (brain $\longrightarrow$ pituitary $\longrightarrow$ other glands $\longrightarrow$ hormones $\longrightarrow$ body and brain) reveals the intimate connection of the nervous and endocrine systems. The nervous system directs endocrine secretions, which then affect the nervous system. Conducting and coordinating this whole electrochemical orchestra is that maestro we call the brain.

Before You Move On

▶ ASK YOURSELF

Can you remember feeling an extended period of discomfort after some particularly stressful event? How long did those feelings last?

▶ TEST YOURSELF

Why is the pituitary gland called the "master gland"?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 10 Review

10-1 What are the functions of the nervous system's main divisions, and what are the three main types of neurons?

- The *central nervous system (CNS)*—the brain and the spinal cord—is the *nervous system*'s decision maker.
- The *peripheral nervous system (PNS),* which connects the CNS to the rest of the body by means of *nerves,* gathers information and transmits CNS decisions to the rest of the body.
- The two main PNS divisions are the *somatic nervous system* (which enables voluntary control of the skeletal muscles) and the *autonomic nervous system* (which controls involuntary muscles and glands by means of its *sympathetic* and *parasympathetic divisions*).
- Neurons cluster into working networks.
- There are three types of neurons:

  (1) *Sensory neurons* carry incoming information from sense receptors to the brain and spinal cord.

  (2) *Motor neurons* carry information from the brain and spinal cord out to the muscles and glands.

  (3) *Interneurons* communicate within the brain and spinal cord and between sensory and motor neurons.

10-2 What is the nature and what are the functions of the endocrine system, and how does it interact with the nervous system?

- The *endocrine system* is a set of glands that secrete *hormones* into the bloodstream, where they travel through the body and affect other tissues, including the brain. The *adrenal glands,* for example, release the hormones that trigger the fight-or-flight response.
- The endocrine system's master gland, the *pituitary,* influences hormone release by other glands. In an intricate feedback system, the brain's *hypothalamus* influences the pituitary gland, which influences other glands, which release hormones, which in turn influence the brain.

Multiple-Choice Questions

1. Which of the following carries the information necessary to activate withdrawal of the hand from a hot object?

a. Sensory neuron
b. Motor neuron
c. Interneuron
d. Receptor neuron
e. Reflex

2. Hormones are _________ released into the _________.

a. neurons; neurotransmitters
b. chemical messengers; bloodstream
c. electrical messengers; bloodstream
d. electrical messengers; synapse
e. chemical messengers; synapse

3. Which division of the nervous system produces the startle response?

a. Parasympathetic
b. Central
c. Somatic
d. Sympathetic
e. Autonomic

4. Which of the following endocrine glands may explain unusually tall height in a 12-year-old?

a. Pituitary
b. Adrenal
c. Pancreas
d. Parathyroid
e. Testes

5. Which of the following communicates with the pituitary, which in turn controls the endocrine system?

a. Parathyroids
b. Autonomic nervous system
c. Hypothalamus
d. Spinal cord
e. Pancreas

6. Which branch of the nervous system calms a person?

a. Central nervous system
b. Sympathetic
c. Parasympathetic
d. Somatic
e. Endocrine

7. Epinephrine and norepinephrine increase energy and are released by the

a. thyroid glands.
b. pituitary gland.
c. hypothalamus.
d. thalamus.
e. adrenal glands.

8. Interneurons are said to

a. send messages from specific body parts to the brain.
b. transmit and process information within the brain and spinal cord.
c. act as connectors, supporting other neurons in the brain.
d. send messages from the brain to body parts.
e. influence the pituitary gland.

Practice FRQs

1. While walking barefoot, you step on a piece of glass. Before you have a chance to consciously process what has happened, you draw your foot away from the glass. Identify and explain the three types of neurons that deal with information regarding this painful stimulus.

Answer

1 point: Sensory neurons carry information from the point of the injury to the central nervous system.

1 point: Interneurons are neurons within the brain and spinal cord. Interneurons would help you interpret the pain and enable your brain to send out marching orders.

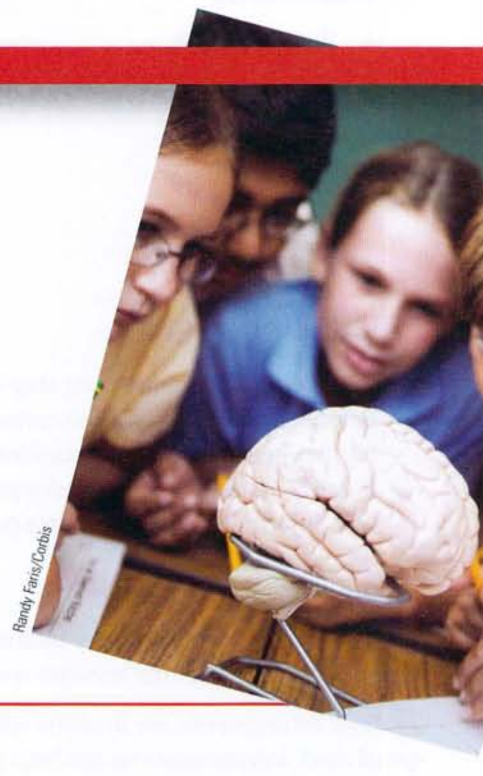
1 point: Motor neurons carry the instruction from the central nervous system to activate the muscles in your leg and foot.

2. Name and describe the components and subcomponents of the peripheral nervous system.

(4 points)

Module 11

Studying the Brain, and Older Brain Structures



Module Learning Objectives

11-1 Describe several techniques for studying the brain's connections to behavior and mind.

11-2 Describe the components of the brainstem, and summarize the functions of the brainstem, thalamus, and cerebellum.

11-3 Describe the limbic system's structures and functions.

The brain enables the mind—seeing, hearing, smelling, feeling, remembering, thinking, speaking, dreaming, loving. Moreover, it is the brain that self-reflectively analyzes the brain. When we're thinking *about* our brain, we're thinking *with* our brain—by firing across millions of synapses and releasing billions of neurotransmitter molecules. Neuroscientists tell us that the *mind is what the brain does.* Brain, behavior, and cognition are an integrated whole. But precisely where and how are the mind's functions tied to the brain? Let's first see how scientists explore such questions.

"I am a brain, Watson. The rest of me is a mere appendix."
-Sherlock Holmes, in Arthur Conan Doyle's "The Adventure of the Mazarin Stone"

The Tools of Discovery: Having Our Head Examined

11-1 How do neuroscientists study the brain's connections to behavior and mind?

A century ago, scientists had no tools high-powered yet gentle enough to explore the living human brain. Early case studies of patients by physicians and others helped localize some of the brain's functions. Damage to one side of the brain often caused numbness or paralysis on the body's opposite side, suggesting that the body's right side is wired to the brain's left side, and vice versa. Damage to the back of the brain disrupted vision, and to the left-front part of the brain produced speech difficulties. Gradually, these early explorers were mapping the brain.

Now, within a lifetime, a new generation of neural cartographers is probing and mapping the known universe's most amazing organ. Scientists can selectively **lesion** (destroy) tiny clusters of brain cells, leaving the surrounding tissue unharmed. In the laboratory, such studies have revealed, for example, that damage to one area of the hypothalamus in a rat's brain reduces eating, to the point of starvation, whereas damage in another area produces overeating.

lesion [LEE-zhuhn] tissue destruction. A brain lesion is a naturally or experimentally caused destruction of brain tissue.

Today's neuroscientists can also electrically, chemically, or magnetically *stimulate* various parts of the brain and note the effect. Depending on the stimulated brain part, people may—to name a few examples—giggle, hear voices, turn their head, feel themselves falling, or have an out-of-body experience (Selimbeyoglu & Parvizi, 2010). Scientists can even snoop on the messages of individual neurons. With tips so small they can detect the electrical pulse in a single neuron, modern microelectrodes can, for example, now detect exactly where the information goes in a cat's brain when someone strokes its whisker. Researchers can also eavesdrop on the chatter of billions of neurons and can see color representations of the brain's energy-consuming activity.

Right now, your mental activity is emitting telltale electrical, metabolic, and magnetic signals that would enable neuroscientists to observe your brain at work. Electrical activity in your brain's billions of neurons sweeps in regular waves across its surface. An **electroencephalogram (EEG)** is an amplified readout of such waves. Researchers record the brain waves through a shower-cap-like hat that is filled with electrodes covered with a conductive gel. Studying an EEG of the brain's activity is like studying a car engine by listening to its hum. With no direct access to the brain, researchers present a stimulus repeatedly and have a computer filter out brain activity unrelated to the stimulus. What remains is the electrical wave evoked by the stimulus (**FIGURE 11.1**).

AJPhoto/Science Source

Figure 11.1

An electroencephalogram providing amplified tracings of waves of electrical activity in the brain Here it is displaying the brain activity of this 4-year-old who has epilepsy.

electroencephalogram (EEG) an amplified recording of the waves of electrical activity sweeping across the brain's surface. These waves are measured by electrodes placed on the scalp.

CT (computed tomography) scan a series of X-ray photographs taken from different angles and combined by computer into a composite representation of a slice of the brain's structure. *(Also called CAT scan.)*

PET (positron emission tomography) scan a visual display of brain activity that detects where a radioactive form of glucose goes while the brain performs a given task.

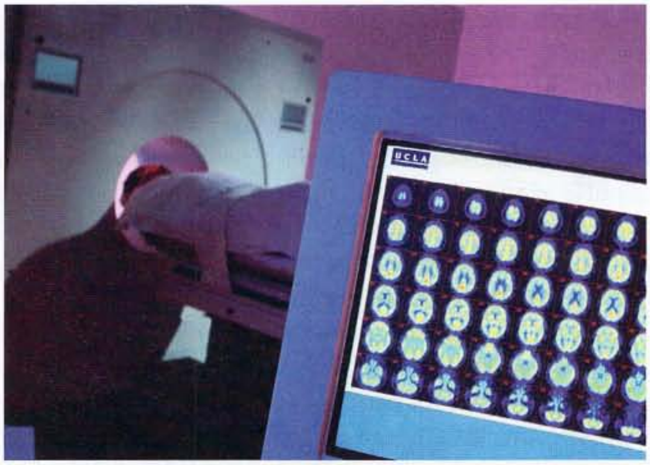
MRI (magnetic resonance imaging) a technique that uses magnetic fields and radio waves to produce computer-generated images of soft tissue. MRI scans show brain anatomy.

"You must look into people, as well as at them," advised Lord Chesterfield in a 1746 letter to his son. Unlike EEGs, newer neuroimaging techniques give us that Superman-like ability to see inside the living brain. For example, the **CT (computed tomography) scan** examines the brain by taking X-ray photographs that can reveal brain damage. Even more dramatic is the **PET (positron emission tomography) scan** (**FIGURE 11.2** on the next page), which depicts brain activity by showing each brain area's consumption of its chemical fuel, the sugar glucose. Active neurons are glucose hogs, and after a person receives temporarily radioactive glucose, the PET scan can track the gamma rays released by this "food for thought" as the person performs a given task. Rather like weather radar showing rain activity, PET-scan "hot spots" show which brain areas are most active as the person does mathematical calculations, looks at images of faces, or daydreams.

In **MRI (magnetic resonance imaging)** brain scans, the person's head is put in a strong magnetic field, which aligns the spinning atoms of brain molecules. Then, a radio-wave pulse momentarily disorients the atoms. When the atoms return to their normal spin, they emit signals that provide a detailed picture of soft tissues, including the brain. MRI scans have revealed a larger-than-average neural area in the left hemisphere of musicians who display perfect pitch (Schlaug et al., 1995). They have also revealed enlarged *ventricles*—fluid-filled brain areas

Figure 11.2

The PET scan To obtain a PET scan, researchers inject volunteers with a low and harmless dose of a short-lived radioactive sugar. Detectors around the person's head pick up the release of gamma rays from the sugar, which has concentrated in active brain areas. A computer then processes and translates these signals into a map of the brain at work.


Mark Harmel/Getty Images

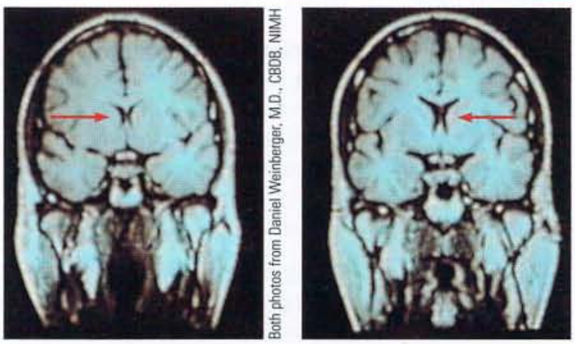

Both photos from Daniel Weinberger, M.D., CBDB, NIMH

Figure 11.3

MRI scan of a healthy individual (left) and a person with schizophrenia (right) Note the enlarged ventricle, the fluid-filled brain region at the tip of the arrow in the image on the right.

(marked by the red arrows in **FIGURE 11.3**)—in some patients who have schizophrenia, a disabling psychological disorder.

A special application of MRI—**fMRI (functional MRI)**—can reveal the brain's functioning as well as its structure. Where the brain is especially active, blood goes. By comparing MRI scans taken less than a second apart, researchers can watch as specific brain areas activate, showing increased oxygen-laden bloodflow. As the person looks at a scene, for example, the fMRI machine detects blood rushing to the back of the brain, which processes visual information (see Figure 12.5, in the discussion of cortex functions in Module 12).

Such snapshots of the brain's changing activity are providing new insights—albeit sometimes overstated (Vul et al., 2009a,b)—into how the brain divides its labor. A mountain of recent fMRI studies suggests which brain areas are most active when people feel pain or rejection, listen to angry voices, think about scary things, feel happy, or become sexually excited. The technology enables a very crude sort of mind reading. After scanning 129 people's brains as they did eight different mental tasks (such as reading, gambling, or rhyming), neuroscientists were able, with 80 percent accuracy, to predict which of these mental activities people were doing (Poldrack et al., 2009). Other studies have explored brain activity associated with religious experience, though without settling the question of whether the brain is producing or perceiving God (Fingelkurts & Fingelkurts, 2009; Inzlicht et al., 2009; Kapogiannis et al., 2009).

fMRI (functional MRI) a technique for revealing bloodflow and, therefore, brain activity by comparing successive MRI scans. fMRI scans show brain function as well as its structure.

* * *

Today's techniques for peering into the thinking, feeling brain are doing for psychology what the microscope did for biology and the telescope did for astronomy. From them we have learned more about the brain in the last 30 years than in the previous 30,000. To be learning about the neurosciences now is like studying world geography while Magellan was exploring the seas. This truly is the golden age of brain science.

Older Brain Structures

11-2 What structures make up the brainstem, and what are the functions of the brainstem, thalamus, and cerebellum?

AP® Exam Tip

Your author, David Myers, is about to take you on a journey through your brain. Focus on the name of each part, its location within the brain, and what it does. Then it's time to practice, practice, practice.

An animal's capacities come from its brain structures. In primitive animals, such as sharks, a not-so-complex brain primarily regulates basic survival functions: breathing, resting, and feeding. In lower mammals, such as rodents, a more complex brain enables emotion and greater memory. In advanced mammals, such as humans, a brain that processes more information enables increased foresight as well.

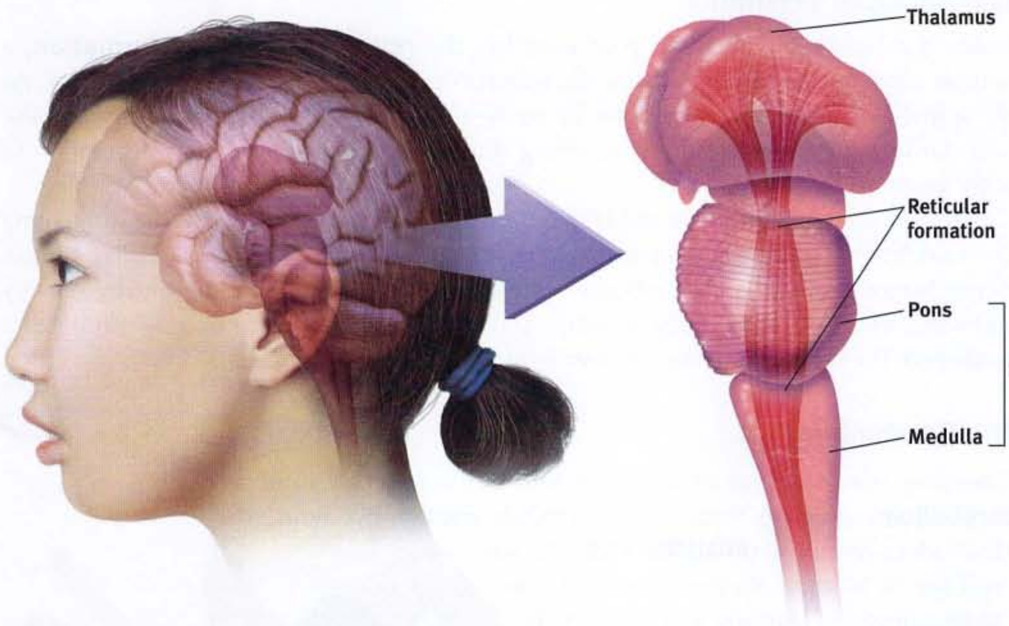


Figure 11.4
The brainstem and thalamus The brainstem, including the pons and medulla, is an extension of the spinal cord. The thalamus is attached to the top of the brainstem. The reticular formation passes through both structures.

brainstem the oldest part and central core of the brain, beginning where the spinal cord swells as it enters the skull; the brainstem is responsible for automatic survival functions.

medulla [muh-DUL-uh] the base of the brainstem; controls heartbeat and breathing.

thalamus [THAL-uh-muss] the brain's sensory control center, located on top of the brainstem; it directs messages to the sensory receiving areas in the cortex and transmits replies to the cerebellum and medulla.

This increasing complexity arises from new brain systems built on top of the old, much as the Earth's landscape covers the old with the new. Digging down, one discovers the fossil remnants of the past—brainstem components performing for us much as they did for our distant ancestors. Let's start with the brain's basement and work up to the newer systems.

The Brainstem

The brain's oldest and innermost region is the **brainstem.** It begins where the spinal cord swells slightly after entering the skull. This slight swelling is the **medulla** (**FIGURE 11.4**). Here lie the controls for your heartbeat and breathing. As some brain-damaged patients in a vegetative state illustrate, we need no higher brain or conscious mind to orchestrate our heart's pumping and lungs' breathing. The brainstem handles those tasks.

Just above the medulla sits the *pons,* which helps coordinate movements. If a cat's brainstem is severed from the rest of the brain above it, the animal will still breathe and live—and even run, climb, and groom (Klemm, 1990). But cut off from the brain's higher regions, it won't *purposefully* run or climb to get food.

The brainstem is a crossover point, where most nerves to and from each side of the brain connect with the body's opposite side (**FIGURE 11.5**). This peculiar cross-wiring is but one of the brain's many surprises.

The Thalamus

Sitting atop the brainstem is the **thalamus,** a pair of egg-shaped structures that act as the brain's sensory control center (Figure 11.4). The thalamus receives information from all the senses except smell and routes it to the higher brain regions that deal with seeing, hearing, tasting, and touching. The thalamus also receives some of the higher brain's replies, which it then directs to the medulla and to the cerebellum (see the next page). Think of the thalamus as being to sensory information what London is to England's trains: a hub through which traffic passes en route to various destinations.

Figure 11.5
The body's wiring Nerves from the left side of the brain are mostly linked to the right side of the body, and vice versa.

reticular formation a nerve network that travels through the brainstem and thalamus and plays an important role in controlling arousal.

The Reticular Formation

Inside the brainstem, between your ears, lies the **reticular** ("netlike") **formation,** a neuron network that extends from the spinal cord right up through the thalamus. As the spinal cord's sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli and relays important information to other brain areas.

In 1949, Giuseppe Moruzzi and Horace Magoun discovered that electrically stimulating the reticular formation of a sleeping cat almost instantly produced an awake, alert animal. When Magoun *severed* a cat's reticular formation without damaging the nearby sensory pathways, the effect was equally dramatic: The cat lapsed into a coma from which it never awakened. The conclusion? The reticular formation enables arousal.

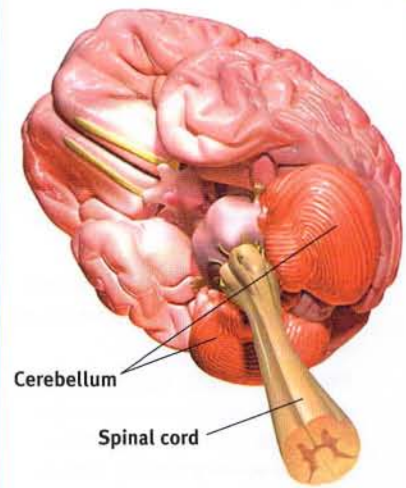
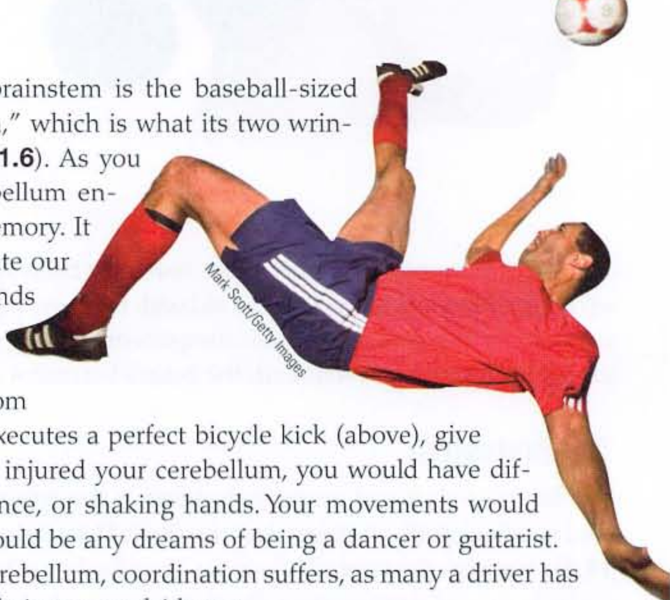


Figure 11.6
The brain's organ of agility Hanging at the back of the brain, the cerebellum coordinates our voluntary movements.

The Cerebellum



Extending from the rear of the brainstem is the baseball-sized **cerebellum,** meaning "little brain," which is what its two wrinkled halves resemble (**FIGURE 11.6**). As you will see in Module 32, the cerebellum enables nonverbal learning and memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures (Bower & Parsons, 2003). And it coordinates voluntary movement (with assistance from the pons). When a soccer player executes a perfect bicycle kick (above), give his cerebellum some credit. If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky and exaggerated. Gone would be any dreams of being a dancer or guitarist. Under alcohol's influence on the cerebellum, coordination suffers, as many a driver has learned after being pulled over and given a roadside test.

* * *

Note: These older brain functions all occur without any conscious effort. This illustrates another of our recurring themes: *Our brain processes most information outside of our awareness.* We are aware of the *results* of our brain's labor (say, our current visual experience) but not of *how* we construct the visual image. Likewise, whether we are asleep or awake, our brainstem manages its life-sustaining functions, freeing our newer brain regions to think, talk, dream, or savor a memory.

cerebellum [sehr-uh-BELL-um] the "little brain" at the rear of the brainstem; functions include processing sensory input, coordinating movement output and balance, and enabling nonverbal learning and memory.

limbic system neural system (including the *hippocampus, amygdala,* and *hypothalamus*) located below the cerebral hemispheres; associated with emotions and drives.

The Limbic System

11-3 What are the limbic system's structures and functions?

We've considered the brain's oldest parts, but we've not yet reached its newest and highest regions, the *cerebral hemispheres* (the two halves of the brain). Between the oldest and newest brain areas lies the **limbic system** (*limbus* means "border"). This system contains the *amygdala,* the *hypothalamus,* and the *hippocampus* (**FIGURE 11.7**). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let's look at the limbic system's links to emotions such as fear and anger, and to basic motives such as those for food and sex.

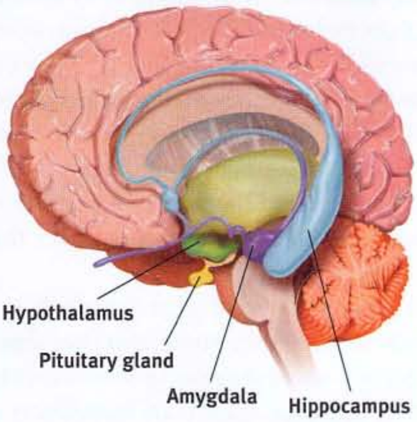


Figure 11.7

The limbic system This neural system sits between the brain's older parts and its cerebral hemispheres. The limbic system's hypothalamus controls the nearby pituitary gland.

amygdala [uh-MIG-duh-la] two lima-bean-sized neural clusters in the limbic system; linked to emotion.

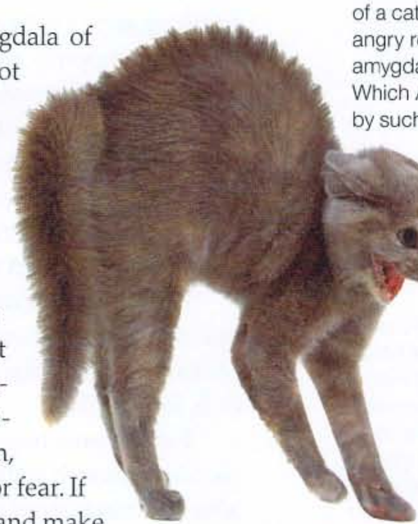
hypothalamus [hi-po-THAL-uh-muss] a neural structure lying below *(hypo)* the thalamus; it directs several maintenance activities (eating, drinking, body temperature), helps govern the endocrine system via the pituitary gland, and is linked to emotion and reward.

THE AMYGDALA

Research has linked the **amygdala,** two lima-bean-sized neural clusters, to aggression and fear. In 1939, psychologist Heinrich Klüver and neurosurgeon Paul Bucy surgically removed a rhesus monkey's amygdala, turning the normally ill-tempered animal into the most mellow of creatures. In studies with other wild animals, including the lynx, wolverine, and wild rat, researchers noted the same effect.

What then might happen if we electrically stimulated the amygdala of a normally placid domestic animal, such as a cat? Do so in one spot and the cat prepares to attack, hissing with its back arched, its pupils dilated, its hair on end. Move the electrode only slightly within the amygdala, cage the cat with a small mouse, and now it cowers in terror.

These and other experiments have confirmed the amygdala's role in rage and fear, including the perception of these emotions and the processing of emotional memories (Anderson & Phelps, 2000; Poremba & Gabriel, 2001). But we must be careful. The brain is not neatly organized into structures that correspond to our behavior categories. When we feel or act in aggressive or fearful ways, there is neural activity in many levels of our brain. Even within the limbic system, stimulating structures other than the amygdala can evoke aggression or fear. If you charge your cell phone's dead battery, you can activate the phone and make a call. Yet the battery is merely one link in an integrated system.



Jane Burton/Dorling Kindersley/Getty Images

Aggression as a brain state Back arched and fur fluffed, this fierce cat is ready to attack. Electrical stimulation of a cat's amygdala provokes angry reactions, suggesting the amygdala's role in aggression. Which ANS division is activated by such stimulation?

ANSWER: The cat would be aroused via its sympathetic nervous system.

THE HYPOTHALAMUS

Just below *(hypo)* the thalamus is the **hypothalamus** (**FIGURE 11.8** on the next page), an important link in the command chain governing bodily maintenance. Some neural clusters in the hypothalamus influence hunger; others regulate thirst, body temperature, and sexual behavior. Together, they help maintain a steady internal state.

As the hypothalamus monitors the state of your body, it tunes into your blood chemistry and any incoming orders from other brain parts. For example, picking up signals from your brain's cerebral cortex that you are thinking about sex, your hypothalamus will secrete hormones. These hormones will in turn trigger the adjacent "master gland," your pituitary (see Figure 11.7), to influence your sex glands to release their hormones. These will intensify the thoughts of sex in your cerebral cortex. (Once again, we see the interplay between the nervous and endocrine systems: The brain influences the endocrine system, which in turn influences the brain.)

AP® Exam Tip

If you ever have to make a guess about brain parts on the AP® exam, the hypothalamus isn't a bad bet. Even though it's small, it has many functions.

ISM/Phototake

Figure 11.8

The hypothalamus This small but important structure, colored yellow/orange in this MRI scan photograph, helps keep the body's internal environment in a steady state.

A remarkable discovery about the hypothalamus illustrates how progress in science often occurs—when curious, open-minded investigators make an unexpected observation. Two young McGill University neuropsychologists, James Olds and Peter Milner (1954), were trying to implant an electrode in a rat's reticular formation when they made a magnificent mistake: They placed the electrode incorrectly (Olds, 1975). Curiously, as if seeking more stimulation, the rat kept returning to the location where it had been stimulated by this misplaced electrode. On discovering that they had actually placed the device in a region of the hypothalamus, Olds and Milner realized they had stumbled upon a brain center that provides pleasurable rewards (Olds, 1975).

In a meticulous series of experiments, Olds (1958) went on to locate other "pleasure centers," as he called them. (What the rats actually experience only they know, and they aren't telling. Rather than attribute human feelings to rats, today's scientists refer to *reward centers,* not "pleasure centers.") When allowed to press pedals to trigger their own stimulation in these areas, rats would sometimes do so at a feverish pace—up to 7000 times per hour—until they dropped from exhaustion. Moreover, to get this stimulation, they would even cross an electrified floor that a starving rat would not cross to reach food (**FIGURE 11.9**).

Other limbic system reward centers, such as the *nucleus accumbens* in front of the hypothalamus, were later discovered in many other species, including dolphins and monkeys. In fact, animal research has revealed both a general dopamine-related reward system and specific centers associated with the pleasures of eating, drinking, and sex. Animals, it seems, come equipped with built-in systems that reward activities essential to survival.

Contemporary researchers are experimenting with new ways of using limbic stimulation to control animals' actions in future applications, such as search-and-rescue operations. By rewarding rats for turning left or right, one research team trained previously caged rats to navigate natural environments (Talwar et al., 2002; **FIGURE 11.10**). By pressing buttons on a laptop, the researchers were then able to direct the rat—which carried a receiver, power source, and video camera on a backpack—to turn on cue, climb trees, scurry along branches, and turn around and come back down.

"If you were designing a robot vehicle to walk into the future and survive, . . . you'd wire it up so that behavior that ensured the survival of the self or the species—like sex and eating—would be naturally reinforcing." -Candace Pert (1986)

Do humans have limbic centers for pleasure? Indeed we do. To calm violent patients, one neurosurgeon implanted electrodes in such areas. Stimulated patients reported mild pleasure; unlike Olds' rats, however, they were not driven to a frenzy (Deutsch, 1972; Hooper & Teresi, 1986).

Experiments have also revealed the effects of a dopamine-related reward system in people. One research team had people rate the desirability of different vacation destinations. Then, after receiving either a dopamine-increasing drug or a sugar pill, they imagined themselves vacationing at half the locations. A day later, when presented with pairs of vacation spots they

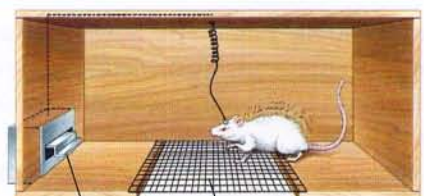


Figure 11.9

Rat with an implanted electrode With an electrode implanted in a reward center of its hypothalamus, the rat readily crosses an electrified grid, accepting the painful shocks, to press a pedal that sends electrical impulses to that center.

Figure 11.10

Ratbot on a pleasure cruise When stimulated by remote control, a rat could be guided to navigate across a field and even up a tree.

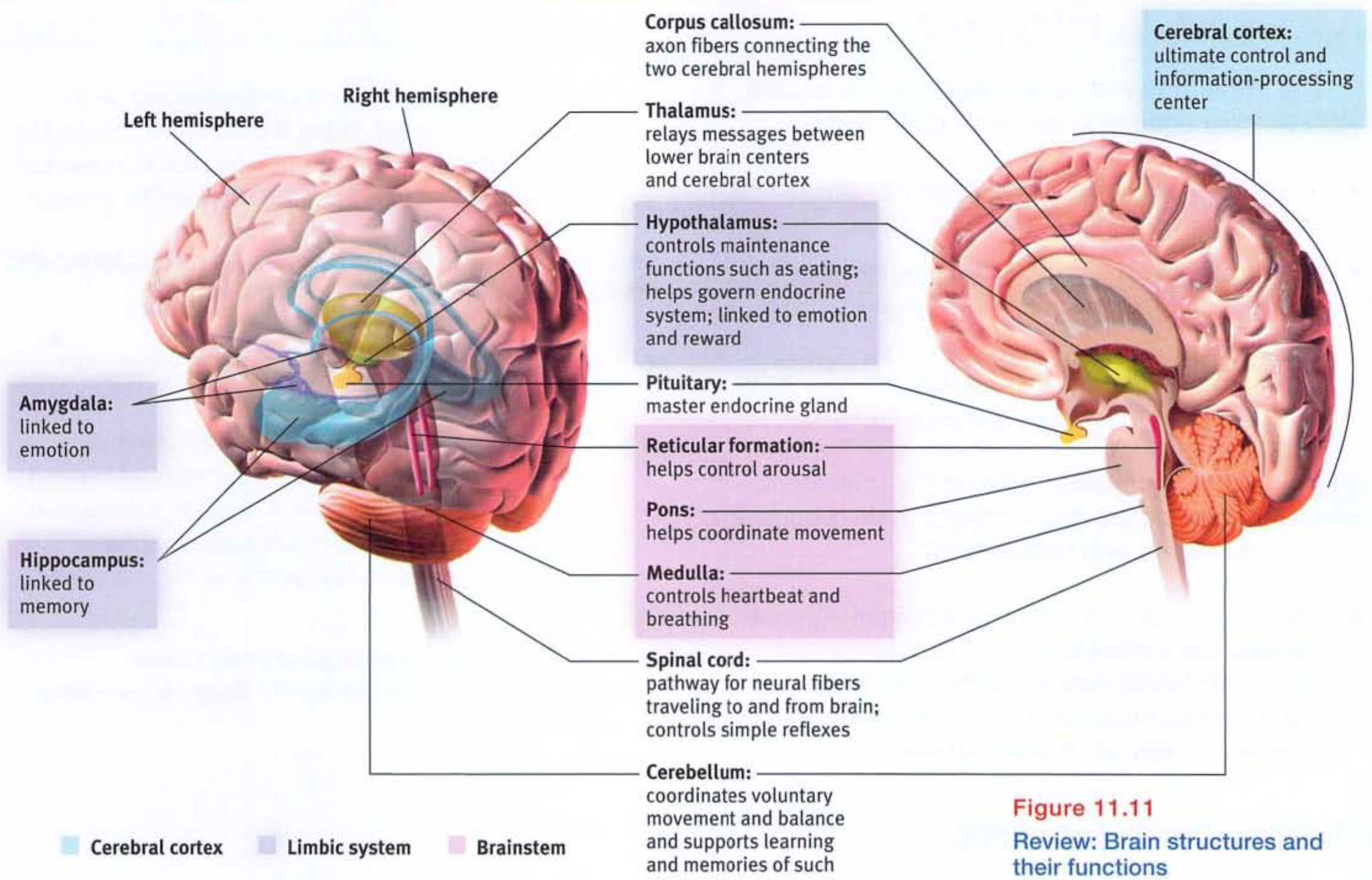


Figure 11.11
Review: Brain structures and their functions

had initially rated equally, only the dopamine takers preferred the places they had imagined under dopamine's influence (Sharot et al., 2009). The participants, it seems, associated the imagined experiences with dopamine-induced pleasant feelings.

Some researchers believe that addictive disorders, such as substance use disorders and binge eating, may stem from malfunctions in natural brain systems for pleasure and well-being. People genetically predisposed to this *reward deficiency syndrome* may crave whatever provides that missing pleasure or relieves negative feelings (Blum et al., 1996).

* * *

FIGURE 11.11 locates the brain areas we've discussed, as well as the *cerebral cortex*, our next topic.

Before You Move On

► ASK YOURSELF

If one day researchers discover how to stimulate human limbic centers to produce as strong a reaction as found in other animals, do you think this process could be used to reduce the incidence of substance use? Could such use have any negative consequences?

► TEST YOURSELF

Within what brain region would damage be most likely to disrupt your ability to skip rope? Your ability to sense tastes or sounds? In what brain region would damage perhaps leave you in a coma? Without the very breath and heartbeat of life?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 11 Review

11-1 How do neuroscientists study the brain's connections to behavior and mind?

- Case studies and *lesioning* first revealed the general effects of brain damage.
- Modern electrical, chemical, or magnetic stimulation has also revealed aspects of information processing in the brain.
- *CT* and *MRI* scans show anatomy. *EEG, PET,* and *fMRI (functional MRI)* recordings reveal brain function.

11-2 What structures make up the brainstem, and what are the functions of the brainstem, thalamus, and cerebellum?

- The *brainstem,* the oldest part of the brain, is responsible for automatic survival functions. Its components are the *medulla* (which controls heartbeat and breathing), the pons (which helps coordinate movements), and the *reticular formation* (which affects arousal).
- The *thalamus,* sitting above the brainstem, acts as the brain's sensory control center. The *cerebellum,* attached to the rear of the brainstem, coordinates muscle movement and balance and also helps process sensory information.

11-3 What are the limbic system's structures and functions?

- The *limbic system* is linked to emotions, memory, and drives.
- Its neural centers include the hippocampus (which processes conscious memories); the *amygdala* (involved in responses of aggression and fear); and the *hypothalamus* (involved in various bodily maintenance functions, pleasurable rewards, and the control of the endocrine system).
- The pituitary (the"master gland") controls the hypothalamus by stimulating it to trigger the release of hormones.

Multiple-Choice Questions

1. Computer-enhanced X-rays used to create brain images are known as
  a. position emission tomography scans.
  b. functional magnetic resonance images.
  c. computed tomography scans.
  d. electroencephalograms.
  e. magnetic resonance images.

2. What part of the brain triggers the release of adrenaline to boost heart rate when you're afraid?
  a. Amygdala
  b. Thalamus
  c. Medulla
  d. Hippocampus
  e. Hypothalamus

3. A gymnast falls and hits her head on the floor. She attempts to continue practicing, but has trouble maintaining balance. What part of her brain has probably been affected?
  a. Reticular formation
  b. Cerebellum
  c. Amygdala
  d. Frontal lobe
  e. Brainstem

4. Which of the following scanning techniques measures glucose consumption as an indicator of brain activity?
  a. CT
  b. MRI
  c. fMRI
  d. PET
  e. EEG

5. Which of the following is sometimes referred to as the brain's train hub, because it directs incoming sensory messages (with the exception of smell) to their proper places in the brain?
  a. Hypothalamus
  b. Pituitary
  c. Cerebellum
  d. Limbic system
  e. Thalamus

6. Which of the following brain areas is responsible for regulating thirst?
  a. Reticular activating system
  b. Amygdala
  c. Hypothalamus
  d. Hippocampus
  e. Brainstem

7. The hypothalamus is a(n) _________ center for the brain.

a. positioning
b. aggression
c. balance
d. memory
e. reward

8. Which of the following's primary function is processing memories?

a. Cerebral cortex
b. Medulla
c. Corpus callosum
d. Hippocampus
e. Hypothalamus

Practice FRQs

1. Following a brain injury, Mike struggles to control his emotions and has difficulty establishing new memories. What parts of Mike's brain have most likely been affected by his injury?

Answer

1 point: Damage to the amygdala would make it difficult for Mike to control his emotions.

1 point: Damage to the hippocampus would affect Mike's ability to establish new memories.

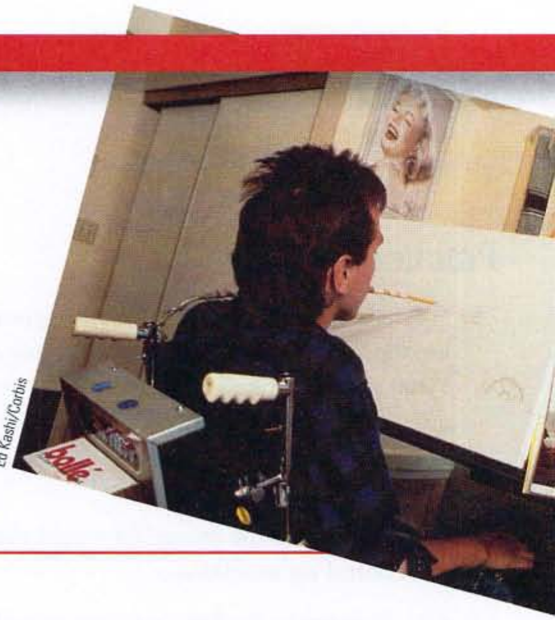
2. Identify the role of each of the following in listening to and taking notes during a psychology lecture.

- Hippocampus
- Cerebellum
- Cerebral cortex

(3 points)

Module 12

The Cerebral Cortex



Ed Kashi/Corbis

Module Learning Objectives

12-1 Identify the various regions of the cerebral cortex, and describe their functions.

12-2 Discuss the brain's ability to reorganize itself, and define neurogenesis.

12-1 What are the functions of the various cerebral cortex regions?

Older brain networks sustain basic life functions and enable memory, emotions, and basic drives. Newer neural networks within the *cerebrum*—the hemispheres that contribute 85 percent of the brain's weight—form specialized work teams that enable our perceiving, thinking, and speaking. Like other structures above the brainstem (including the thalamus, hippocampus, and amygdala), the cerebral hemispheres come as a pair. Covering those hemispheres, like bark on a tree, is the **cerebral cortex,** a thin surface layer of interconnected neural cells. It is your brain's thinking crown, your body's ultimate control and information-processing center.

As we move up the ladder of animal life, the cerebral cortex expands, tight genetic controls relax, and the organism's adaptability increases. Frogs and other small-cortex amphibians operate extensively on preprogrammed genetic instructions. The larger cortex of mammals offers increased capacities for learning and thinking, enabling them to be more adaptable. What makes us distinctively human mostly arises from the complex functions of our cerebral cortex.

FYI

The people who first dissected and labeled the brain used the language of scholars—Latin and Greek. Their words are actually attempts at graphic description: For example, *cortex* means "bark," *cerebellum* is "little brain," and *thalamus* is "inner chamber."

Structure of the Cortex

If you opened a human skull, exposing the brain, you would see a wrinkled organ, shaped somewhat like the meat of an oversized walnut. Without these wrinkles, a flattened cerebral cortex would require triple the area—roughly that of a large pizza. The brain's left and right hemispheres are filled mainly with axons connecting the cortex to the brain's other regions. The cerebral cortex—that thin surface layer—contains some 20 to 23 billion nerve cells and 300 trillion synaptic connections (de Courten-Myers, 2005). Being human takes a lot of nerve.

Supporting these billions of nerve cells are nine times as many spidery **glial cells** ("glue cells"). Neurons are like queen bees; on their own they cannot feed or sheathe themselves. Glial cells are worker bees. They provide nutrients and insulating myelin, guide neural connections, and mop up ions and neurotransmitters. Glia may also play a role in learning and thinking. By "chatting" with neurons they may participate in information transmission and memory (Fields, 2009; Miller, 2005).

cerebral [seh-REE-bruhl] **cortex** the intricate fabric of interconnected neural cells covering the cerebral hemispheres; the body's ultimate control and information-processing center.

glial cells (glia) cells in the nervous system that support, nourish, and protect neurons; they may also play a role in learning and thinking.

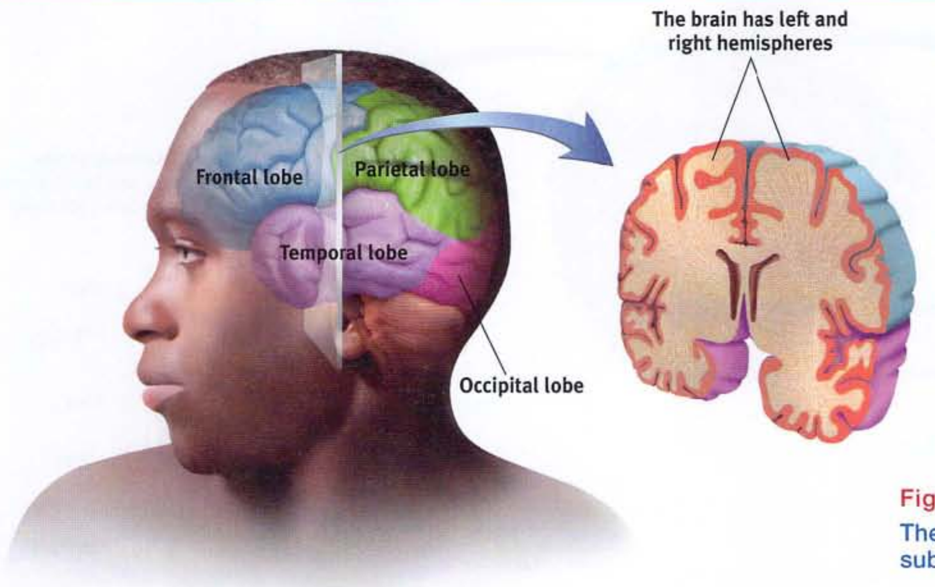


Figure 12.1
The cortex and its basic subdivisions

In more complex animal brains, the proportion of glia to neurons increases. A postmortem analysis of Einstein's brain did not find more or larger-than-usual neurons, but it did reveal a much greater concentration of glial cells than found in an average Albert's head (Fields, 2004).

Each hemisphere's cortex is subdivided into four *lobes,* separated by prominent *fissures,* or folds (**FIGURE 12.1**). Starting at the front of your brain and moving over the top, there are the **frontal lobes** (behind your forehead), the **parietal lobes** (at the top and to the rear), and the **occipital lobes** (at the back of your head). Reversing direction and moving forward, just above your ears, you find the **temporal lobes.** Each of the four lobes carries out many functions, and many functions require the interplay of several lobes.

Functions of the Cortex

More than a century ago, surgeons found damaged cortical areas during autopsies of people who had been partially paralyzed or speechless. This rather crude evidence did not prove that specific parts of the cortex control complex functions like movement or speech. After all, if the entire cortex controlled speech and movement, damage to almost any area might produce the same effect. A TV with its power cord cut would go dead, but we would be fooling ourselves if we thought we had "localized" the picture in the cord.

Motor Functions

Scientists had better luck in localizing simpler brain functions. For example, in 1870, German physicians Gustav Fritsch and Eduard Hitzig made an important discovery: Mild electrical stimulation to parts of an animal's cortex made parts of its body move. The effects were selective: Stimulation caused movement only when applied to an arch-shaped region at the back of the frontal lobe, running roughly ear-to-ear across the top of the brain. Moreover, stimulating parts of this region in the left or right hemisphere caused movements of specific body parts on the *opposite* side of the body. Fritsch and Hitzig had discovered what is now called the **motor cortex.**

MAPPING THE MOTOR CORTEX

Lucky for brain surgeons and their patients, the brain has no sensory receptors. Knowing this, Otfrid Foerster and Wilder Penfield were able to map the motor cortex in hundreds of wide-awake patients by stimulating different cortical areas and observing the body's responses.

frontal lobes portion of the cerebral cortex lying just behind the forehead; involved in speaking and muscle movements and in making plans and judgments.

parietal [puh-RYE-uh-tuhl] **lobes** portion of the cerebral cortex lying at the top of the head and toward the rear; receives sensory input for touch and body position.

occipital [ahk-SIP-uh-tuhl] **lobes** portion of the cerebral cortex lying at the back of the head; includes areas that receive information from the visual fields.

temporal lobes portion of the cerebral cortex lying roughly above the ears; includes the auditory areas, each receiving information primarily from the opposite ear.

motor cortex an area at the rear of the frontal lobes that controls voluntary movements.

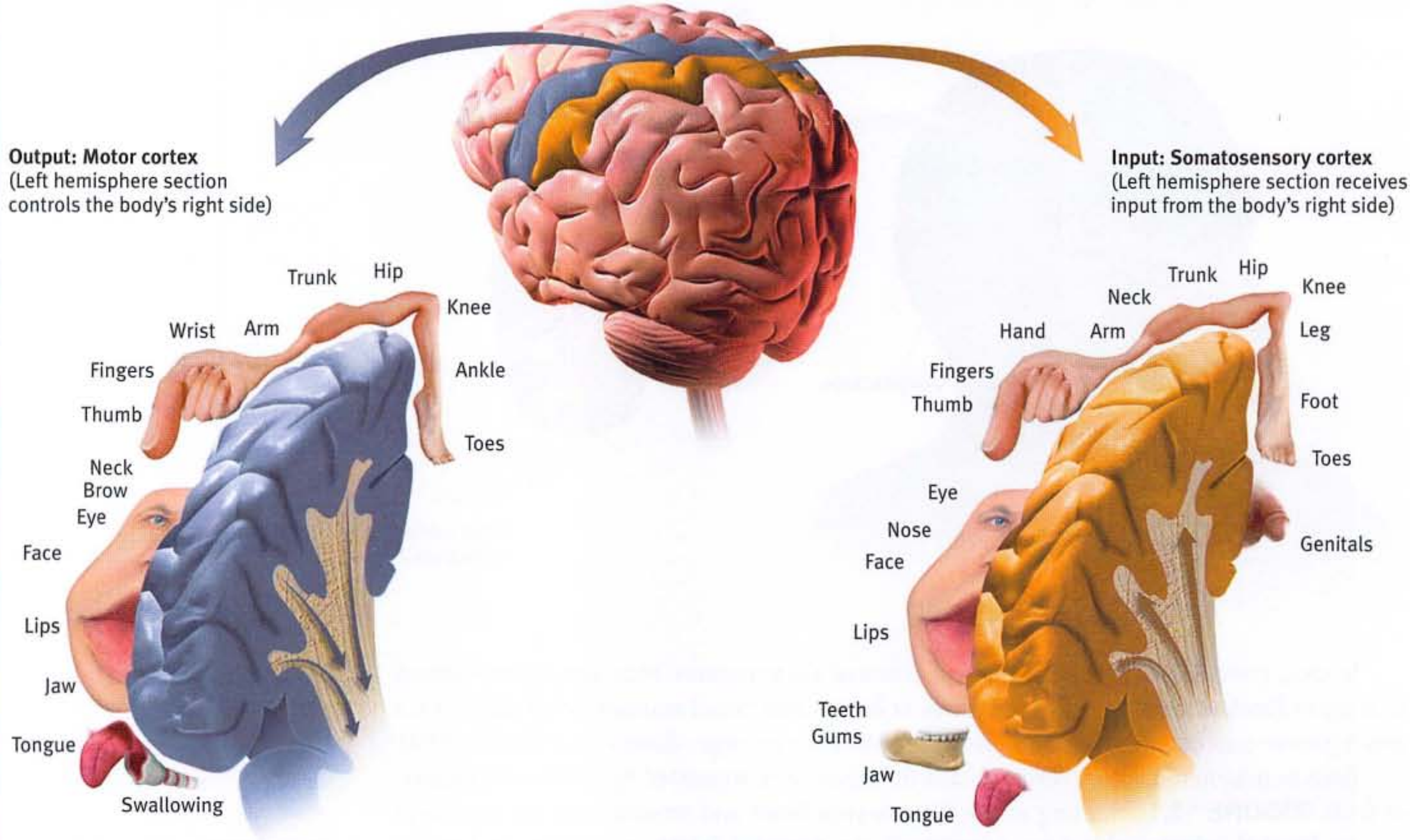


Figure 12.2

Left hemisphere tissue devoted to each body part in the motor cortex and the somatosensory cortex As you can see from this classic though inexact representation, the amount of cortex devoted to a body part in the motor cortex (in the frontal lobes) or in the somatosensory cortex (in the parietal lobes) is not proportional to that body part's size. Rather, the brain devotes more tissue to sensitive areas and to areas requiring precise control. Thus, the fingers have a greater representation in the cortex than does the upper arm.

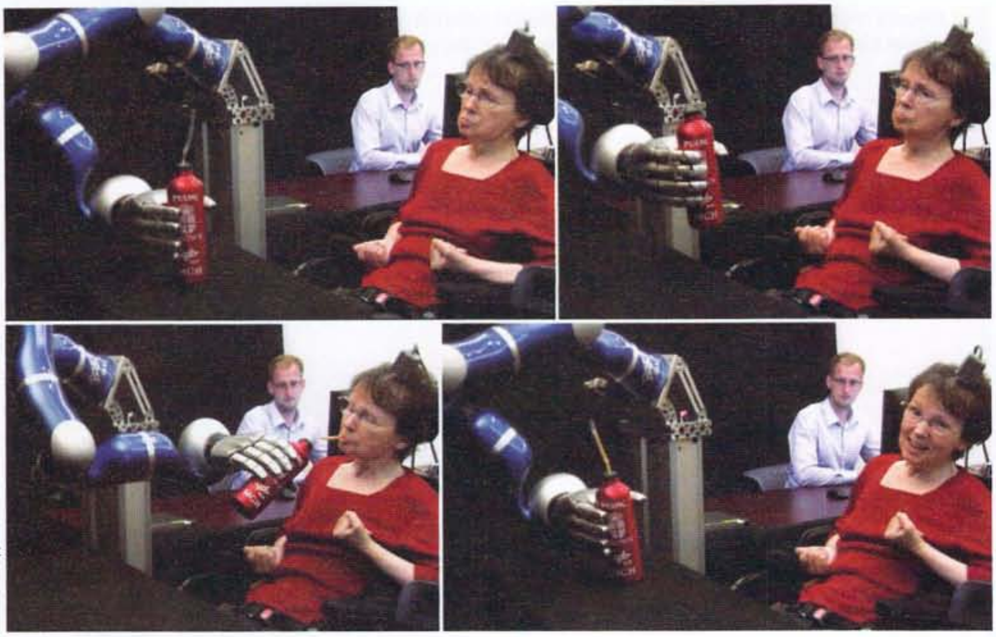
They discovered that body areas requiring precise control, such as the fingers and mouth, occupy the greatest amount of cortical space (**FIGURE 12.2**).

In one of his many demonstrations of motor behavior mechanics, Spanish neuroscientist José Delgado stimulated a spot on a patient's left motor cortex, triggering the right hand to make a fist. Asked to keep the fingers open during the next stimulation, the patient, whose fingers closed despite his best efforts, remarked, "I guess, Doctor, that your electricity is stronger than my will" (Delgado, 1969, p. 114).

More recently, scientists were able to predict a monkey's arm motion a tenth of a second *before* it moved—by repeatedly measuring motor cortex activity preceding specific arm movements (Gibbs, 1996). Such findings have opened the door to research on brain-controlled computers.

BRAIN-COMPUTER INTERFACES

By eavesdropping on the brain, could we enable someone—perhaps a paralyzed person—to move a robotic limb? Could a *brain-computer interface* command a cursor to write an e-mail or search the Internet? To find out, Brown University brain researchers implanted 100 tiny recording electrodes in the motor cortexes of three monkeys (Nicolelis & Chapin, 2002; Serruya et al., 2002). As the monkeys used a joystick to move a cursor to follow a moving red target (to gain rewards), the researchers matched the brain signals with the arm movements. Then they programmed a computer to monitor the signals and operate the joystick. When a monkey merely thought about a move, the mind-reading computer moved the cursor with nearly the same proficiency as had the reward-seeking monkey. In follow-up experiments, two monkeys were trained to control a robot arm that could grasp and deliver food (Velliste et al., 2008), and then a human did the same (**FIGURE 12.3**).



Hochberg et al., 2012. Reach and grasp by people with tetraplegia using a neurally controlled robotic arm. Nature, 485, pp. 372–375

Figure 12.3

Mind over matter A series of strokes left Cathy paralyzed for 15 years, unable to make even simple arm movements. Now, thanks to a tiny, 96-electrode implant in her brain's motor cortex, she is learning to direct a robotic arm with her thoughts (Hochberg et al., 2012).

Clinical trials of such *cognitive neural prosthetics* are now under way with people who have suffered paralysis or amputation (Andersen et al., 2010; Nurmikko et al., 2010). The first patient, a paralyzed 25-year-old man, was able to mentally control a TV, draw shapes on a computer screen, and play video games—all thanks to an aspirin-sized chip with 100 microelectrodes recording activity in his motor cortex (Hochberg et al., 2006). If everything psychological is also biological—if, for example, every thought is also a neural event—then microelectrodes perhaps could detect thoughts well enough to enable people to control events, as suggested by **FIGURE 12.4** on the next page.

Sensory Functions

If the motor cortex sends messages out to the body, where does the cortex receive the incoming messages? Wilder Penfield also identified the cortical area that specializes in receiving information from the skin senses and from the movement of body parts. This area at the front of the parietal lobes, parallel to and just behind the motor cortex, we now call the **somatosensory cortex** (Figure 12.2). Stimulate a point on the top of this band of tissue and a person may report being touched on the shoulder; stimulate some point on the side and the person may feel something on the face.

somatosensory cortex area at the front of the parietal lobes that registers and processes body touch and movement sensations.

The more sensitive the body region, the larger the somatosensory cortex area devoted to it (Figure 12.2). Your supersensitive lips project to a larger brain area than do your toes, which is one reason we kiss with our lips rather than touch toes. Rats have a large area of the brain devoted to their whisker sensations, and owls to their hearing sensations.

Scientists have identified additional areas where the cortex receives input from senses other than touch. At this moment, you are receiving visual information in the visual cortex in your occipital lobes, at the very back of your brain (**FIGURES 12.5** and **12.6** on the next page). A bad enough bash there would make you blind. Stimulated there, you might see flashes of light or dashes of color. (In a sense, we *do* have eyes in the back of our head!) From your occipital lobes, visual information goes to other areas that specialize in tasks such as identifying words, detecting emotions, and recognizing faces.

Any sound you now hear is processed by your auditory cortex in your temporal lobes (just above your ears; see Figure 12.6). Most of this auditory information travels

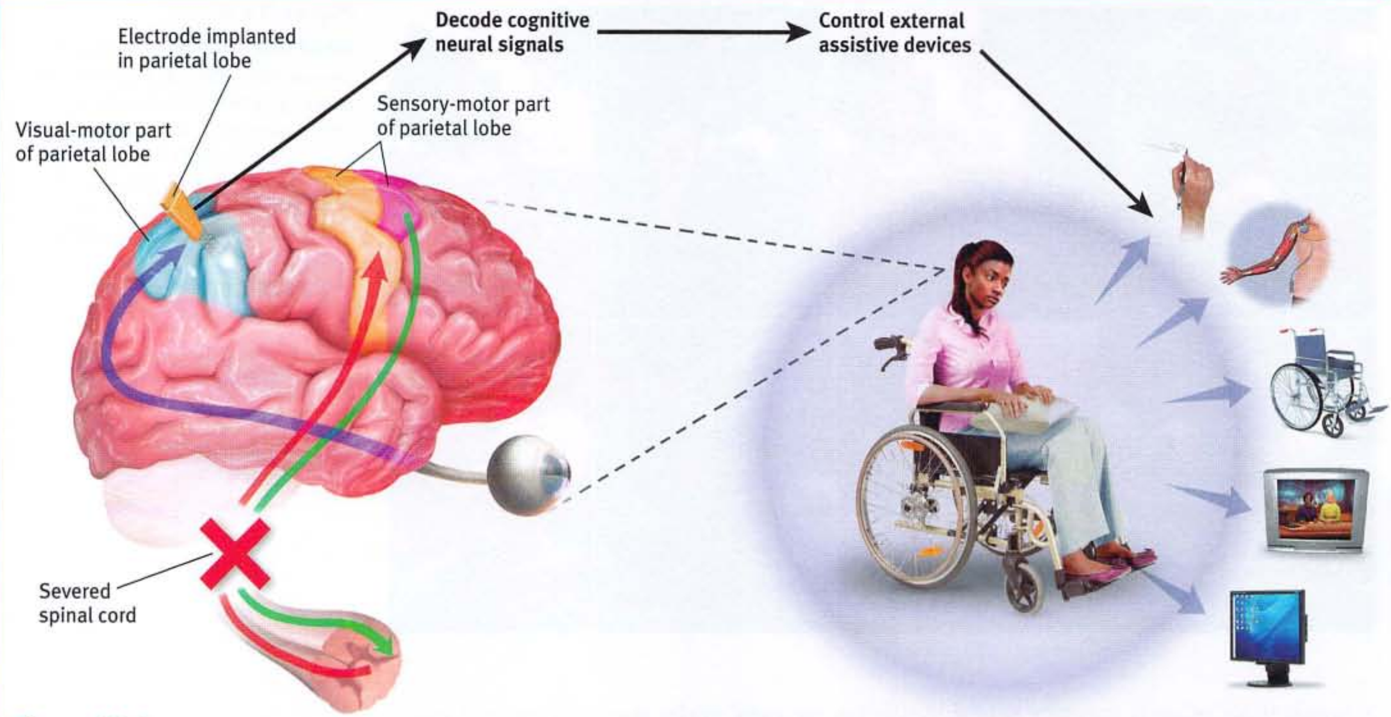
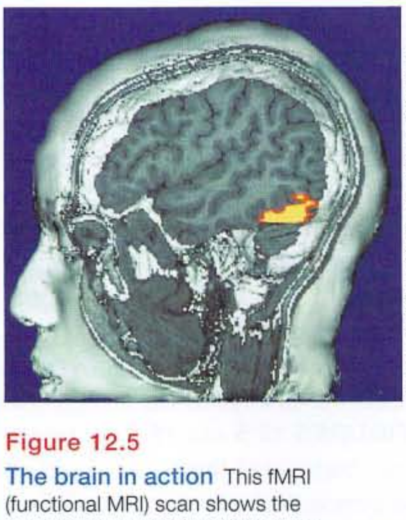


Figure 12.4

Brain-computer interaction A patient with a severed spinal cord has electrodes planted in a parietal lobe region involved with planning to reach out one's arm. The resulting signal can enable the patient to move a robotic limb, stimulate muscles that activate a paralyzed limb, navigate a wheelchair, control a TV, and use the Internet. (Graphic adapted from Andersen et al., 2010.)

a circuitous route from one ear to the auditory receiving area above your opposite ear. If stimulated there, you might hear a sound. MRI scans of people with schizophrenia reveal active auditory areas in the temporal lobes during auditory hallucinations (Lennox et al., 1999). Even the phantom ringing sound experienced by people with hearing loss is—if heard in one ear—associated with activity in the temporal lobe on the brain's opposite side (Muhlnickel, 1998).



Courtesy of V.P. Clark, K. Keill, J. Ma. Maisog, S. Courtney, L. G. Ungerleider, and J. V. Haxby, National Institutes of Health

Figure 12.5

The brain in action This fMRI (functional MRI) scan shows the visual cortex in the occipital lobes activated (color representation of increased bloodflow) as a research participant looks at a photo. When the person stops looking, the region instantly calms down.

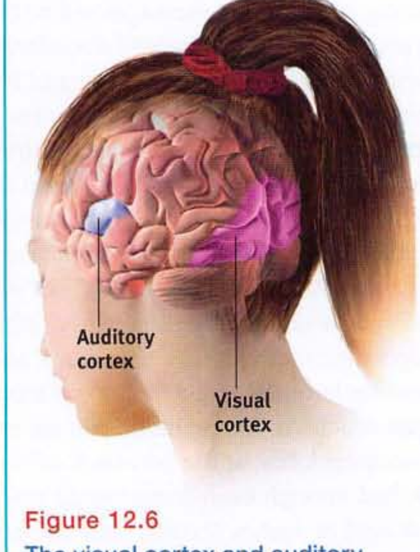


Figure 12.6

The visual cortex and auditory cortex The visual cortex of the occipital lobes at the rear of your brain receives input from your eyes. The auditory cortex, in your temporal lobes—above your ears—receives information from your ears.

Association Areas

So far, we have pointed out small cortical areas that either receive sensory input or direct muscular output. Together, these occupy about one-fourth of the human brain's thin, wrinkled cover. What, then, goes on in the vast regions of the cortex? In these **association areas** (the peach-colored areas in **FIGURE 12.7**), neurons are busy with higher mental functions—many of the tasks that make us human.

association areas areas of the cerebral cortex that are not involved in primary motor or sensory functions; rather, they are involved in higher mental functions such as learning, remembering, thinking, and speaking.

Electrically probing an association area won't trigger any observable response. So, unlike the sensory and motor areas, association area functions cannot be neatly mapped. Their silence has led to what Donald McBurney (1996, p. 44) has called "one of the hardiest weeds in the garden of psychology": the claim that we ordinarily use only 10 percent of our brains. (If true, wouldn't this imply a 90 percent chance that a bullet to your brain would land in an unused area?) Surgically lesioned animals and brain-damaged humans bear witness that association areas are not dormant. Rather, these areas interpret, integrate, and act on sensory information and link it with stored memories—a very important part of thinking.

Association areas are found in all four lobes. The *prefrontal cortex* in the forward part of the frontal lobes enables judgment, planning, and processing of new memories. People with damaged frontal lobes may have intact memories, high scores on intelligence tests, and great cake-baking skills. Yet they would not be able to plan ahead to *begin* baking a cake for a birthday party (Huey et al., 2006).

Figure 12.7
Areas of the cortex in four mammals More intelligent animals have increased "uncommitted" or association areas of the cortex. These vast areas of the brain are responsible for interpreting, integrating, and acting on sensory information and linking it with stored memories.

Frontal lobe damage also can alter personality and remove a person's inhibitions. Consider the classic case of railroad worker Phineas Gage. One afternoon in 1848, Gage, then 25 years old, was packing gunpowder into a rock with a tamping iron. A spark ignited the gunpowder, shooting the rod up through his left cheek and out the top of his skull, leaving his frontal lobes massively damaged (**FIGURE 12.8** on the next page). To everyone's amazement, he was immediately able to sit up and speak, and after the wound healed he returned to work. But the affable, soft-spoken man was now irritable, profane, and dishonest. This person, said his friends, was "no longer Gage." Although his mental abilities and memories were intact, his personality was not. (Although Gage lost his job, he did, over time, adapt to his injury and find work as a stagecoach driver [Macmillan & Lena, 2010].)

More recent studies of people with damaged frontal lobes have revealed similar impairments. Not only may they become less inhibited (without the frontal lobe brakes on their impulses), but their moral judgments may seem unrestrained by normal emotions. Would you advocate pushing someone in front of a runaway boxcar to save five others? Most people do not, but those with damage to a brain area behind the eyes often do (Koenigs et al., 2007). With their frontal lobes ruptured, people's moral compass seems to disconnect from their behavior.

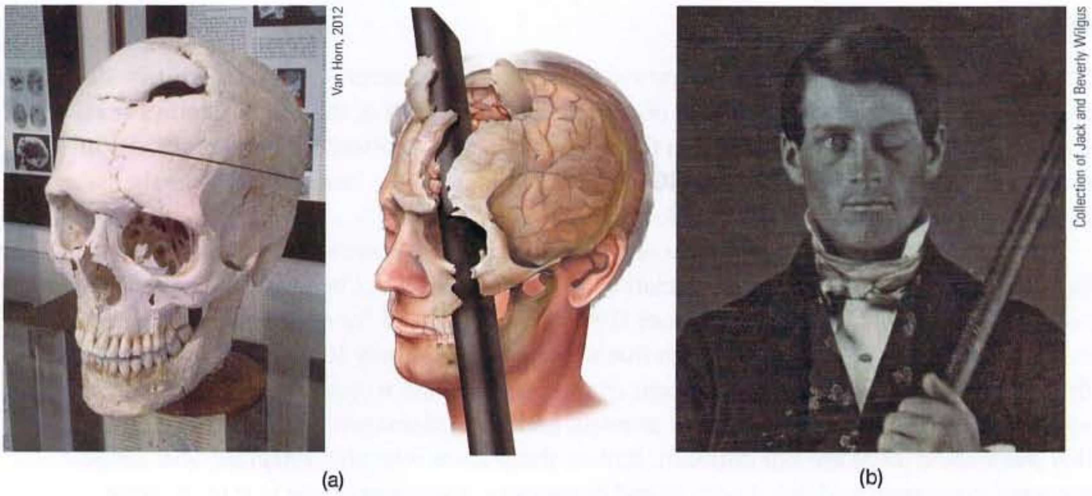


Figure 12.8
A blast from the past
(a) Gage's skull was kept as a medical record. Using measurements and modern neuroimaging techniques, researchers have reconstructed the probable path of the rod through Gage's brain (Damasio et al., 1994). (b) This recently discovered photo shows Gage after his accident. The image has been reversed to show the features correctly. (Early photos, such as this one, were actually mirror images.)

Association areas also perform other mental functions. In the parietal lobes, parts of which were large and unusually shaped in Einstein's normal-weight brain, they enable mathematical and spatial reasoning (Witelson et al., 1999). In patients undergoing brain surgery, stimulation of one parietal lobe area produced a feeling of wanting to move an upper limb, the lips, or the tongue (but without any actual movement). With increased stimulation, patients falsely believed they actually had moved. Curiously, when surgeons stimulated a different association area near the motor cortex in the frontal lobes, the patients did move but had no awareness of doing so (Desmurget et al., 2009). These head-scratching findings suggest that our perception of moving flows not from the movement itself, but rather from our intention and the results we expected.

Yet another association area, on the underside of the right temporal lobe, enables us to recognize faces. If a stroke or head injury destroyed this area of your brain, you would still be able to describe facial features and to recognize someone's gender and approximate age, yet be strangely unable to identify the person as, say, Lady Gaga, or even your grandmother.

Nevertheless, we should be wary of using pictures of brain "hot spots" to create a new phrenology that locates complex functions in precise brain areas (Uttal, 2001). Complex mental functions don't reside in any one place. There is no one spot in a rat's small association cortex that, when damaged, will obliterate its ability to learn or remember a maze.

FYI

For information on how distinct neural networks in your brain coordinate to enable language, see Module 36.

Similarly, the acquisition, development, and use of language depends on both specialized neural networks and their integration. Nineteenth-century research by French physician Paul Broca and German investigator Carl Wernicke led to the discovery of specialized language brain areas. Damage to *Broca's area* disrupts speaking, while damage to *Wernicke's area* disrupts understanding. Today's neuroscience has shown that language functions are distributed across other brain areas as well.

Memory, language, and attention result from the synchronized activity among distinct brain areas (Knight, 2007). Ditto for religious experience. Reports of more than 40 distinct brain regions becoming active in different religious states, such as praying and meditating, indicate that there is no simple "God spot" (Fingelkurts & Fingelkurts, 2009). The big lesson: *Our mental experiences arise from coordinated brain activity.*

The Brain's Plasticity

12-2 To what extent can a damaged brain reorganize itself, and what is neurogenesis?

Our brains are sculpted not only by our genes but also by our experiences. MRI scans show that well-practiced pianists have a larger-than-usual auditory cortex area that encodes piano sounds (Bavelier et al., 2000; Pantev et al., 1998). In Unit IX, we'll focus more on how experience molds the brain. For now, let's turn to another aspect of the brain's **plasticity:** its ability to modify itself after damage.

plasticity the brain's ability to change, especially during childhood, by reorganizing after damage or by building new pathways based on experience.

Some of the effects of brain damage described earlier can be traced to two hard facts: (1) Severed neurons, unlike cut skin, usually do not regenerate. (If your spinal cord were severed, you would probably be permanently paralyzed.) And (2) some brain functions seem preassigned to specific areas. One newborn who suffered damage to temporal lobe facial recognition areas later remained unable to recognize faces (Farah et al., 2000). But there is good news: Some of the brain's neural tissue can *reorganize* in response to damage. Under the surface of our awareness, the brain is constantly changing, building new pathways as it adjusts to little mishaps and new experiences.

Plasticity may also occur after serious damage, especially in young children (Kolb, 1989; see also **FIGURE 12.9**). Constraint-induced therapy aims to rewire brains and improve the dexterity of a brain-damaged child or even an adult stroke victim (Taub, 2004). By restraining a fully functioning limb, therapists force patients to use the "bad" hand or leg, gradually reprogramming the brain. One stroke victim, a surgeon in his fifties, was put to work cleaning tables, with his good arm and hand restrained. Slowly, the bad arm recovered its skills. As damaged-brain functions migrated to other brain regions, he gradually learned to write again and even to play tennis (Doidge, 2007).

The brain's plasticity is good news for those who are blind or deaf. Blindness or deafness makes unused brain areas available for other uses (Amedi et al., 2005). If a blind person uses one finger to read Braille, the brain area dedicated to that finger expands as the sense of touch invades the visual cortex that normally helps people see (Barinaga, 1992a; Sadato et al., 1996). Plasticity also helps explain why some studies find that deaf people have enhanced peripheral vision (Bosworth & Dobkins, 1999). In those people whose native language is sign, the temporal lobe area normally dedicated to hearing waits in vain for stimulation. Finally, it looks for other signals to process, such as those from the visual system.

Similar reassignment may occur when disease or damage frees up other brain areas normally dedicated to specific functions. If a slow-growing left hemisphere tumor disrupts language (which resides mostly in the left hemisphere), the right hemisphere may compensate (Thiel et al., 2006). If a finger is amputated, the somatosensory cortex that received its input will begin to receive input from the adjacent fingers, which then become more sensitive (Fox, 1984).

Although the brain often attempts self-repair by reorganizing existing tissue, it sometimes attempts to mend itself by producing new brain cells. This process, known as

MIKE THEILER/UPI/ Newscom

Figure 12.9

Brain plasticity Although the brains of young children show the greatest ability to reorganize and adapt to damage, adult brains also have some capacity for self-repair. Former Arizona Congresswoman Gabrielle Giffords lost her ability to speak after suffering a left-hemisphere gunshot wound. Her medical care included music therapy, where she worked on forming words to familiar songs such as "Happy Birthday." Giffords has since partly recovered her speaking ability. Two years after the shooting, she was able to speak as a surprise witness at a 2013 U.S. Senate hearing on gun legislation.

neurogenesis the formation of new neurons.

neurogenesis, has been found in adult mice, birds, monkeys, and humans (Jessberger et al., 2008). These baby neurons originate deep in the brain and may then migrate elsewhere and form connections with neighboring neurons (Aimone et al., 2010; Gould, 2007).

Master stem cells that can develop into any type of brain cell have also been discovered in the human embryo. If mass-produced in a lab and injected into a damaged brain, might neural stem cells turn themselves into replacements for lost brain cells? Might we someday be able to rebuild damaged brains, much as we reseed damaged lawns? Might new drugs spur the production of new nerve cells? Stay tuned. Today's biotech companies are hard at work on such possibilities. In the meantime, we can all benefit from other natural promoters of neurogenesis, such as exercise, sleep, and nonstressful but stimulating environments (Iso et al., 2007; Pereira et al., 2007; Stranahan et al., 2006).

Before You Move On

► ASK YOURSELF

Has what you have learned about how our brains enable our minds affected your view of human nature?

► TEST YOURSELF

Try moving your right hand in a circular motion, as if polishing a table. Then start your right foot doing the same motion, synchronized with your hand. Now reverse the right foot's motion, but not the hand's. Finally, try moving the *left* foot opposite to the right hand.

1. Why is reversing the right foot's motion so hard?
2. Why is it easier to move the left foot opposite to the right hand?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 12 Review

12-1 What are the functions of the various cerebral cortex regions?

- The *cerebral cortex* has two hemispheres, and each hemisphere has four lobes: the *frontal, parietal, occipital,* and *temporal.* Each lobe performs many functions and interacts with other areas of the cortex.
- *Glial cells* support, nourish, and protect neurons and may also play a role in learning and thinking.
- The *motor cortex,* at the rear of the frontal lobes, controls voluntary movements.
- The *somatosensory cortex,* at the front of the parietal lobes, registers and processes body touch and movement sensations.
- Body parts requiring precise control or those that are especially sensitive occupy the greatest amount of space in the motor cortex and somatosensory cortex, respectively.
- Most of the brain's cortex—the major portion of each of the four lobes—is devoted to uncommitted *association areas,* which integrate information involved in learning, remembering, thinking, and other higher-level functions.
- Our mental experiences arise from coordinated brain activity.

12-2 To what extent can a damaged brain reorganize itself, and what is neurogenesis?

- If one hemisphere is damaged early in life, the other will pick up many of its functions by reorganizing or building new pathways. This *plasticity* diminishes later in life.
- The brain sometimes mends itself by forming new neurons, a process known as *neurogenesis.*

Multiple-Choice Questions

1. Damage to which of the following could interfere with the ability to plan for the future?
   a. Frontal lobe
   b. Temporal lobe
   c. Parietal lobe
   d. Occipital lobe
   e. Somatosensory cortex

2. In general, damage to _________ disrupts speaking, while damage to _________ disrupts understanding of language.
   a. the frontal lobe; the occipital lobe
   b. the temporal lobe; the frontal lobe
   c. the occipital lobe; the temporal lobe
   d. Wernicke's area; Broca's area
   e. Broca's area; Wernicke's area

3. Stimulation at a point on which of the following may cause a person to report being touched on the knee?
   a. Motor cortex
   b. Cerebellum
   c. Somatosensory cortex
   d. Temporal lobe
   e. Thalamus

4. George can move his hand to sign a document because the _________, located in the _________ lobe of the brain, allows him to activate the proper muscles.
   a. somatosensory cortex; temporal
   b. somatosensory cortex; parietal
   c. motor cortex; parietal
   d. somatosensory cortex; frontal
   e. motor cortex; frontal

5. The most noticeable difference between human brains and other mammalian brains is the size of the
   a. association areas.
   b. frontal lobe.
   c. glial cells.
   d. reticular activating system.
   e. visual cortex.

6. Cognitive neural prosthetics are placed in the brain to help control parts of the
   a. motor cortex.
   b. auditory cortex.
   c. somatosensory cortex.
   d. visual cortex.
   e. parietal lobe.

Practice FRQs

1. Doctors sometimes have to remove a portion of the brain to control life-threatening seizures. Describe what the results of the removal of a portion of the motor cortex would be and explain how this procedure might be affected by brain plasticity.

Answer

1 point: Removing part of the motor cortex will result in paralysis in the parts of the body associated with the removed tissue.

1 point: Because of brain plasticity, the person's brain may be able to change and reorganize new pathways based on experience. This is more likely if the person is a child.

2. Anthony attends a high school band concert. First, identify and explain which two lobes of his brain are most important for watching and listening to the concert. Second, explain which lobe of the brain is most responsible for analyzing the music and finding personal meaning.

(3 points)

Module 13

Brain Hemisphere Organization and the Biology of Consciousness

Module Learning Objectives

13-1 Explain how split-brain research helps us understand the functions of our two brain hemispheres.

13-2 Explain what is meant by "dual processing," as revealed by today's cognitive neuroscience.

Our Divided Brain

13-1 What do split brains reveal about the functions of our two brain hemispheres?

Our brain's look-alike left and right hemispheres serve differing functions. This *lateralization* is apparent after brain damage. Research collected over more than a century has shown that accidents, strokes, and tumors in the left hemisphere can impair reading, writing, speaking, arithmetic reasoning, and understanding. Similar lesions in the right hemisphere have effects that are less visibly dramatic.

Does this mean that the right hemisphere is just along for the ride—a silent, "subordinate" or "minor" hemisphere? Many believed this was the case until 1960, when researchers found that the "minor" right hemisphere was not so limited after all. The story of this discovery is a fascinating episode in psychology's history.

Splitting the Brain

In 1961, two Los Angeles neurosurgeons, Philip Vogel and Joseph Bogen, speculated that major epileptic seizures were caused by an amplification of abnormal brain activity bouncing back and forth between the two cerebral hemispheres. If so, they wondered, could they put an end to this biological tennis game by severing the **corpus callosum** (see **FIGURE 13.1**)? This wide band of axon fibers connects the two hemispheres and carries messages between them. Vogel and Bogen knew that psychologists Roger Sperry, Ronald Myers, and Michael Gazzaniga had divided the brains of cats and monkeys in this manner, with no serious ill effects.

So the surgeons operated. The result? The seizures all but disappeared. The patients with these **split brains** were surprisingly normal, their personality and intellect hardly affected. Waking from surgery, one even joked that he had a "splitting headache" (Gazzaniga, 1967). By sharing their experiences, these patients have greatly expanded our understanding of interactions between the intact brain's two hemispheres.

corpus callosum [KOR-pus kah-LOW-sum] the large band of neural fibers connecting the two brain hemispheres and carrying messages between them.

split brain a condition resulting from surgery that isolates the brain's two hemispheres by cutting the fibers (mainly those of the corpus callosum) connecting them.

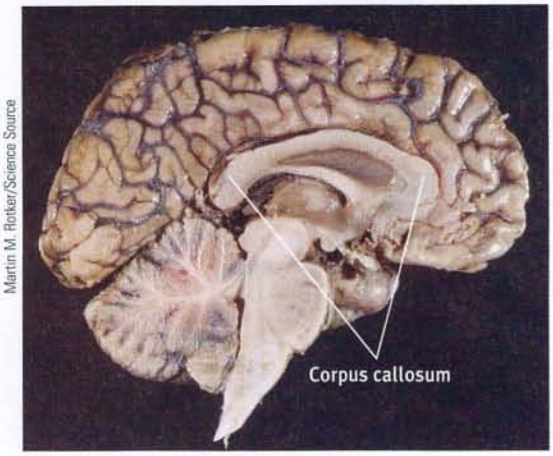


Figure 13.1

The corpus callosum This large band of neural fibers connects the two brain hemispheres. To photograph this half brain, a surgeon separated the hemispheres by cutting through the corpus callosum and lower brain regions.

AP® Exam Tip

The classic split-brain studies are famous in psychology, which means they are likely to show up on the AP® exam.

To appreciate these findings, we need to focus for a minute on the peculiar nature of our visual wiring. As **FIGURE 13.2** illustrates, information from the left half of your field of vision goes to your right hemisphere, and information from the right half of your visual field goes to your left hemisphere, which usually controls speech. (Note, however, that each eye receives sensory information from both the right and left visual fields.) Data received by either hemisphere are quickly transmitted to the other across the corpus callosum. In a person with a severed corpus callosum, this information-sharing does not take place.

Knowing these facts, Sperry and Gazzaniga could send information to a patient's left or right hemisphere. As the person stared at a spot, they flashed a stimulus to its right or left. They could do this with you, too, but in your intact brain, the hemisphere receiving the information would instantly pass the news to the other side. Because the split-brain surgery had cut the communication lines between the hemispheres, the researchers could, with these patients, quiz each hemisphere separately.

In an early experiment, Gazzaniga (1967) asked these people to stare at a dot as he flashed HE·ART on a screen (**FIGURE 13.3** on the next page). Thus, HE appeared in their left visual field (which transmits to the right hemisphere) and ART in the right field (which transmits to the left hemisphere). When he then asked them to *say* what they had seen, the patients reported that they had seen ART. But when asked to *point* to the word they had seen, they were startled when their left hand (controlled by the right hemisphere) pointed to HE. Given an opportunity to express itself, each hemisphere reported what it had seen. The right hemisphere (controlling the left hand) intuitively knew what it could not verbally report.

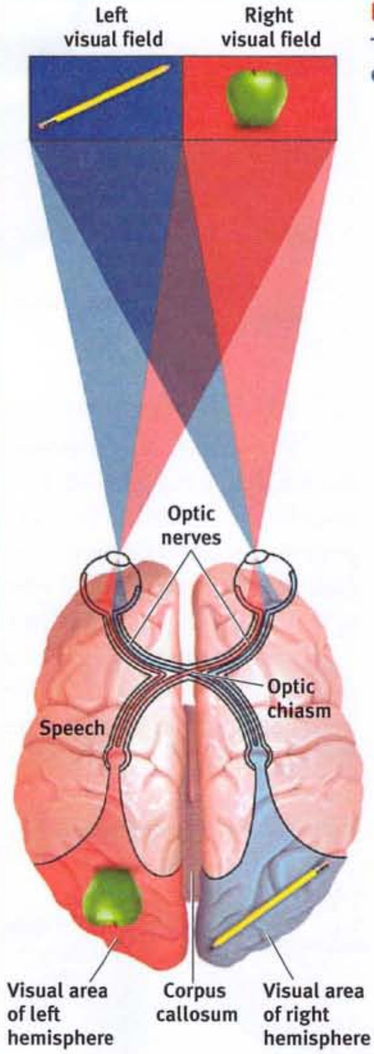


Figure 13.2

The information highway from eye to brain

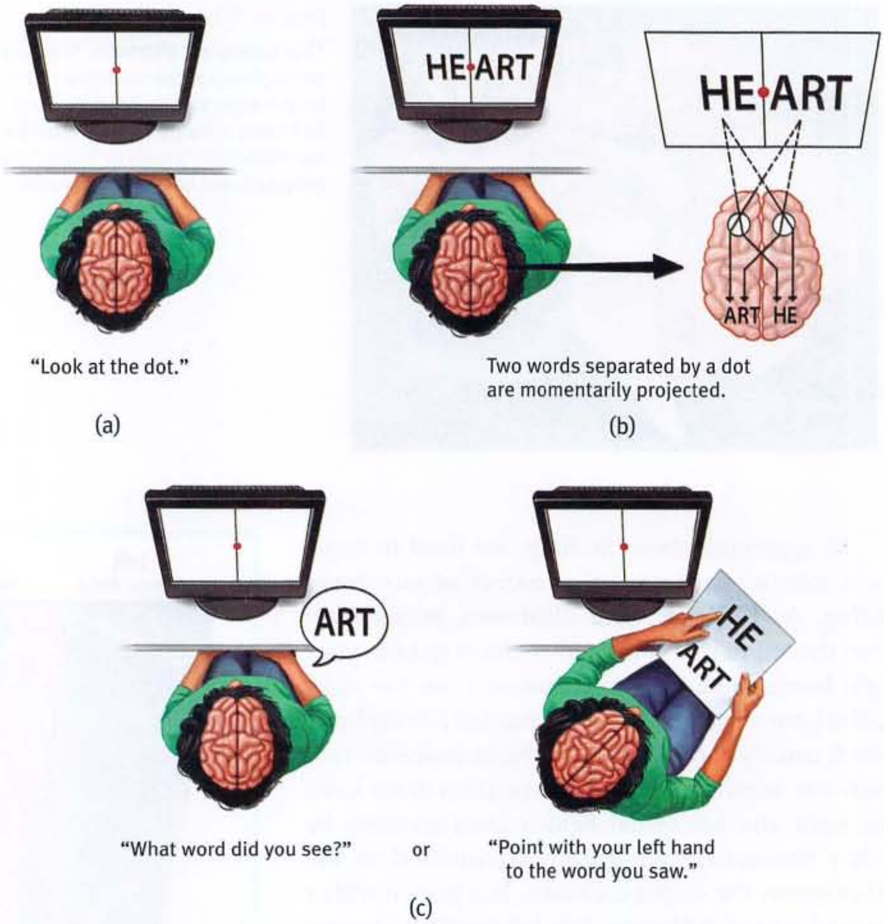


Figure 13.3

Testing the divided brain When an experimenter flashes the word HEART across the visual field, a woman with a split brain reports seeing the portion of the word transmitted to her left hemisphere. However, if asked to indicate with her left hand what she saw, she points to the portion of the word transmitted to her right hemisphere. (From Gazzaniga, 1983.)

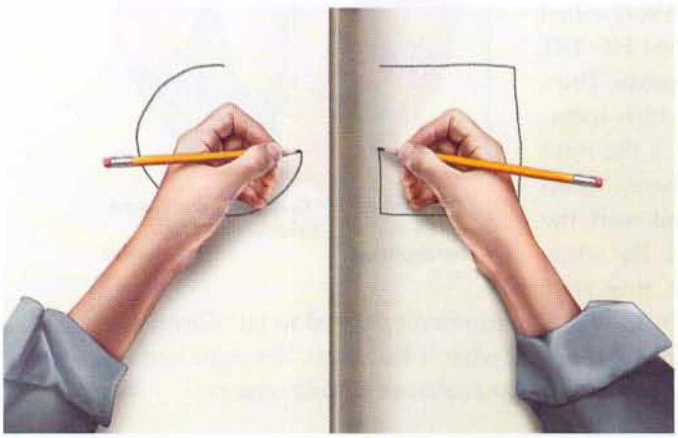
When a picture of a spoon was flashed to their right hemisphere, the patients could not *say* what they had viewed. But when asked to *identify* what they had viewed by feeling an assortment of hidden objects with their left hand, they readily selected the spoon. If the experimenter said, "Correct!" the patient might reply, "What? Correct? How could I possibly pick out the correct object when I don't know what I saw?" It is, of course, the left hemisphere doing the talking here, bewildered by what the nonverbal right hemisphere knows.

"Do not let your left hand know what your right hand is doing."
-Matthew 6:3

A few people who have had split-brain surgery have been for a time bothered by the unruly independence of their left hand, which might unbutton a shirt while the right hand buttoned it, or put grocery store items back on the shelf after the right hand put them in the cart. It was as if each hemisphere was thinking "I've half a mind to wear my green (blue) shirt today." Indeed, said Sperry (1964), split-brain surgery leaves people "with two separate minds." With a split brain, both hemispheres can comprehend and follow an instruction to copy—*simultaneously*—different figures with the left and right hands (Franz et al., 2000; see also **FIGURE 13.4**). (Reading these reports, I fantasize a patient enjoying a solitary game of "rock, paper, scissors"—left versus right hand.)

Figure 13.4

Try this! A person who has undergone split-brain surgery can simultaneously draw two different shapes.



When the "two minds" are at odds, the left hemisphere does mental gymnastics to rationalize reactions it does not understand. If a patient follows an order sent to the right hemisphere ("Walk"), a strange thing happens. Unaware of the order, the left hemisphere doesn't know why the patient begins walking. Yet, when asked why, the patient doesn't say "I don't know." Instead, the interpretive left hemisphere improvises—"I'm going into the house to get a Coke." Gazzaniga (1988), who considers these patients "the most fascinating people on earth," concluded that the conscious left hemisphere is an "interpreter" or press agent that instantly constructs theories to explain our behavior.

Right-Left Differences in the Intact Brain

So, what about the 99.99+ percent of us with undivided brains? Does each of *our* hemispheres also perform distinct functions? Several different types of studies indicate they do. When a person performs a *perceptual* task, for example, brain waves, bloodflow, and glucose consumption reveal increased activity in the *right* hemisphere. When the person speaks or calculates, activity increases in the *left* hemisphere.

A dramatic demonstration of hemispheric specialization happens before some types of brain surgery. To locate the patient's language centers, the surgeon injects a sedative into the neck artery feeding blood to the left hemisphere, which usually controls speech. Before the injection, the patient is lying down, arms in the air, chatting with the doctor. Can you predict what probably happens when the drug puts the left hemisphere to sleep? Within seconds, the person's right arm falls limp. If the left hemisphere is controlling language, the patient will be speechless until the drug wears off. If the drug is injected into the artery to the right hemisphere, the *left* arm will fall limp, but the person will still be able to speak.

To the brain, language is language, whether spoken or signed. Just as hearing people usually use the left hemisphere to process speech, deaf people use the left hemisphere to process sign language (Corina et al., 1992; Hickok et al., 2001). Thus, a left-hemisphere stroke disrupts a deaf person's signing, much as it would disrupt a hearing person's speaking. The same brain area is involved in both (Corina, 1998). (For more on how the brain enables language, see Module 36.)

Although the left hemisphere is adept at making quick, literal interpretations of language, the right hemisphere

- *excels in making inferences* (Beeman & Chiarello, 1998; Bowden & Beeman, 1998; Mason & Just, 2004). Primed with the flashed word *foot,* the left hemisphere will be especially quick to recognize the closely associated word *heel.* But if primed with *foot, cry,* and *glass,* the right hemisphere will more quickly recognize another word distantly related to all three *(cut)*. And if given an insight-like problem—"What word goes with *boot, summer,* and *ground?*"—the right hemisphere more quickly than the left recognizes the solution: *camp.* As one patient explained after a right-hemisphere stroke, "I understand words, but I'm missing the subtleties."
- *helps us modulate our speech* to make meaning clear—as when we ask "What's that in the road ahead?" instead of "What's that in the road, a head?" (Heller, 1990).
- *helps orchestrate our sense of self.* People who suffer partial paralysis will sometimes obstinately deny their impairment—strangely claiming they can move a paralyzed limb—if the damage is to the right hemisphere (Berti et al., 2005).

Simply looking at the two hemispheres, so alike to the naked eye, who would suppose they contribute uniquely to the harmony of the whole? Yet a variety of observations—of people with split brains, of people with normal brains, and even of other species' brains—converge beautifully, leaving little doubt that we have unified brains with specialized parts (Hopkins & Cantalupo, 2008; MacNeilage et al., 2009; and see Close-up: Handedness on the next page).

AP® Exam Tip

Notice that David Myers never refers to your left brain or your right brain. You have two brain hemispheres, each with its own responsibilities, *but you only have one brain.* It's very misleading when the media refers to the left brain and the right brain, and this happens frequently.

Close-up

Handedness

Nearly 90 percent of us are primarily right-handed (Leask & Beaton, 2007; Medland et al., 2004; Peters et al., 2006). Some 10 percent of us (somewhat more among males, somewhat less among females) are left-handed. (A few people write with their right hand and throw a ball with their left, or vice versa.) Almost all right-handers (96 percent) process speech primarily in the left hemisphere, which tends to be the slightly larger hemisphere (Hopkins, 2006). Left-handers are more diverse. Seven in ten process speech in the left hemisphere, as right-handers do. The rest either process language in the right hemisphere or use both hemispheres.

IS HANDEDNESS INHERITED?

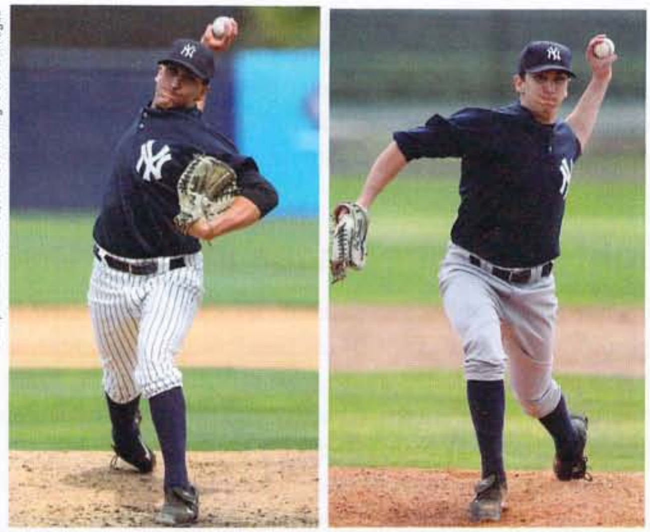
Judging from prehistoric human cave drawings, tools, and hand and arm bones, this veer to the right occurred long ago (Corballis, 1989; MacNeilage et al., 2009). Right-handedness prevails in all human cultures, and even in monkeys and apes. Moreover, it appears prior to culture's impact: More than 9 in 10 fetuses suck the right hand's thumb (Hepper et al., 1990, 2004). Twin studies indicate only a small genetic influence on individual handedness (Vuoksimaa et al., 2009). But the universal prevalence of right-handers in humans and other primates suggests that either genes or some prenatal factors influence handedness.

Most people also kick with their right foot, look through a microscope with their right eye, and (had you noticed?) kiss the right way—with their head tilted right (Güntürkün, 2003).

SO, IS IT ALL RIGHT TO BE LEFT-HANDED?

Judging by our everyday conversation, left-handedness is not all right. To be "coming out of left field" is hardly better than to be "gauche" (derived from the French word for "left"). On the other hand, right-handedness is "right on," which any "righteous," "right-hand man" "in his right mind" usually is.

Left-handers are more numerous than usual among those with reading disabilities, allergies, and migraine headaches (Geschwind & Behan, 1984). But in Iran, where students report which hand they write with when taking the university entrance exam, lefties have outperformed righties in all subjects (Noroozian et al., 2003). Left-handedness is also more common among musicians, mathematicians, professional baseball and cricket players, architects, and artists, including such luminaries as Michelangelo, Leonardo da Vinci, and Picasso.[1] Although left-handers must tolerate elbow jostling at the dinner table, right-handed desks, and awkward scissors, the pros and cons of being a lefty seem roughly equal.



Both photos Mike Janes/Four Seam Images via AP Images

The rarest of baseball players: an ambidextrous pitcher Using a glove with two thumbs, Minor League New York Yankees pitcher Pat Venditte, shown here in 2012, pitches to right-handed batters with his right hand, then switches to face left-handed batters with his left hand. During his college career at Creighton University, after one switch-hitter switched sides of the plate, Venditte switched pitching arms, which triggered the batter to switch again, and so on. The umpires ultimately ended the comedy routine by applying a little-known rule: A pitcher must declare which arm he will use before throwing his first pitch to a batter (Schwarz, 2007).

[1] Strategic factors explain the higher-than-normal percentage of lefties in sports. For example, it helps a soccer team to have left-footed players on the left side of the field (Wood & Aggleton, 1989). In golf, however, no left-hander won the Masters tournament until Canadian Mike Weir did so in 2003.

The Biology of Consciousness

13-2 What is the "dual processing" being revealed by today's cognitive neuroscience?

consciousness our awareness of ourselves and our environment.

Today's science explores the biology of **consciousness.** Evolutionary psychologists speculate that consciousness must offer a reproductive advantage (Barash, 2006). Consciousness helps us act in our long-term interests (by considering consequences) rather than merely seeking short-term pleasure and avoiding pain. Consciousness also promotes our survival by anticipating how we seem to others and helping us read their minds: "He looks really angry! I'd better run!"

Such explanations still leave us with the "hard problem": How do brain cells jabbering to one another create our awareness of the taste of a taco, the idea of infinity, the feeling of fright? Today's scientists are pursuing answers.

Cognitive Neuroscience

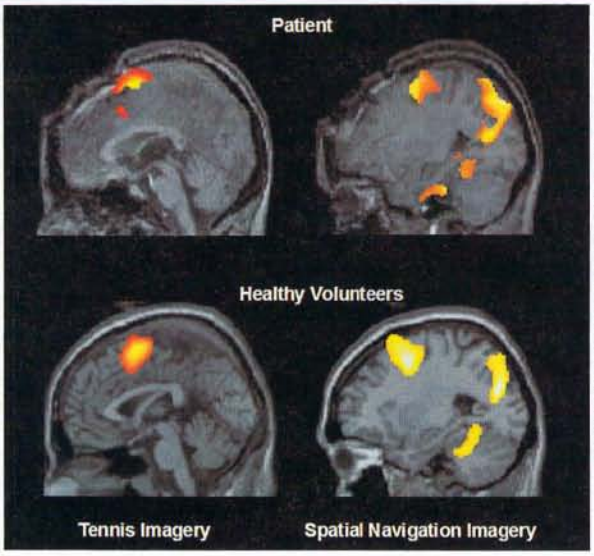
Scientists assume, in the words of neuroscientist Marvin Minsky (1986, p. 287), that "the mind is what the brain does." We just don't know *how* it does it. Even with all the world's chemicals, computer chips, and energy, we still don't have a clue *how* to make a conscious robot. Yet today's **cognitive neuroscience**—the interdisciplinary study of the brain activity linked with our mental processes—is taking the first small step by relating specific brain states to conscious experiences.

cognitive neuroscience the interdisciplinary study of the brain activity linked with cognition (including perception, thinking, memory, and language).

A stunning demonstration of consciousness appeared in brain scans of a noncommunicative patient—a 23-year-old woman who had been in a car accident and showed no outward signs of conscious awareness (Owen et al., 2006). When researchers asked her to *imagine* playing tennis, fMRI scans revealed brain activity in a brain area that normally controls arm and leg movements (**FIGURE 13.5**). Even in a motionless body, the researchers concluded, the brain—and the mind—may still be active. A follow-up study of 22 other "vegetative" patients revealed 3 more who also showed meaningful brain responses to questions (Monti et al., 2010).

Many cognitive neuroscientists are exploring and mapping the conscious functions of the cortex. Based on your cortical activation patterns, they can now, in limited ways, read your mind (Bor, 2010). They can, for example, tell which of 10 similar objects (hammer, drill, and so forth) you are viewing (Shinkareva et al., 2008).

Despite such advances, much disagreement remains. One view sees conscious experiences as produced by the synchronized activity across the brain (Gaillard et al., 2009; Koch & Greenfield, 2007; Schurger et al., 2010). If a stimulus activates enough brainwide coordinated neural activity—with strong signals in one brain area triggering activity elsewhere—it crosses a threshold for consciousness. A weaker stimulus—perhaps a word flashed too briefly to consciously perceive—may trigger localized visual cortex activity that quickly dies out. A stronger stimulus will engage other brain areas, such as those involved with language, attention, and memory. Such reverberating activity (detected by brain scans) is a telltale sign of conscious awareness. How the synchronized activity produces awareness—how matter makes mind—remains a mystery.



Courtesy of Adrian M. Owen, The Brain and Mind Institute, Western University

Figure 13.5

Evidence of awareness? When asked to imagine playing tennis or navigating through her home, a vegetative patient's brain (top) exhibited activity similar to a healthy person's brain (bottom). Researchers wonder if such fMRI scans might enable a "conversation" with some unresponsive patients, by instructing them, for example, to answer *yes* to a question by imagining playing tennis and *no* by imagining walking around their home.

Dual Processing: The Two-Track Mind

Many cognitive neuroscience discoveries tell us of a particular brain region (such as the visual cortex mentioned above) that becomes active with a particular conscious experience. Such findings strike many people as interesting but not mind-blowing. (If everything psychological is simultaneously biological, then our ideas, emotions, and spirituality must all, somehow, be embodied.) What *is* mind-blowing to many of us is the growing evidence that we have, so to speak, two minds, each supported by its own neural equipment.

AP® Exam Tip

Dual processing is another one of those big ideas that shows up in several units. Pay attention!

At any moment, you and I are aware of little more than what's on the screen of our consciousness. But beneath the surface, unconscious information processing occurs simultaneously on many parallel tracks. When we look at a bird flying, we are consciously aware of the result of our cognitive processing ("It's a hummingbird!") but not of our subprocessing of the bird's color, form, movement, and distance. One of the grand ideas of recent cognitive neuroscience is that much of our brain work occurs off stage, out of sight. Perception, memory, thinking, language, and attitudes all operate on two levels—a conscious, deliberate

dual processing the principle that information is often simultaneously processed on separate conscious and unconscious tracks.

"high road" and an unconscious, automatic "low road." Today's researchers call this **dual processing.** We know more than we know we know.

Sometimes science confirms widely held beliefs. Other times, as this next story illustrates, science is stranger than science fiction.

During my sojourns at Scotland's University of St. Andrews, I came to know cognitive neuroscientists David Milner and Melvyn Goodale (2008). When overcome by carbon monoxide, a local woman, whom they call D. F., suffered brain damage that left her unable to recognize and discriminate objects visually. Consciously she could see nothing. Yet she exhibited *blindsight*—she would act as if she could see. Asked to slip a postcard into a vertical or horizontal mail slot, she could do so without error. Although unable to report the width of a block in front of her, she could grasp it with just the right finger-thumb distance. If you were to experience temporary blindness (with magnetic pulses to your brain's primary visual cortex area) this, too, would create blindsight—as you correctly guess the color or orientation of an object that you cannot consciously see (Boyer et al., 2005).

adapted from: Milner, A. D., & Goodale, M.A. (2006). The Visual Brain in Action: 2nd Edition/ Oxford: Oxford University Press, 297 pp. (paperback 2006)

Figure 13.6

When the blind can "see" In a compelling demonstration of blindsight and the two-track mind, a researcher trails a blindsight patient down a cluttered hallway. Although told the hallway was empty, the patient meandered around all the obstacles without any awareness of them.

How could this be? Don't we have one visual system? Goodale and Milner knew from animal research that the eye sends information simultaneously to different brain areas, which support different tasks (Weiskrantz, 2009, 2010). Sure enough, a scan of D. F.'s brain activity revealed normal activity in the area concerned with reaching for, grasping, and navigating objects, but damage in the area concerned with consciously recognizing objects. (See another example in **FIGURE 13.6.**)

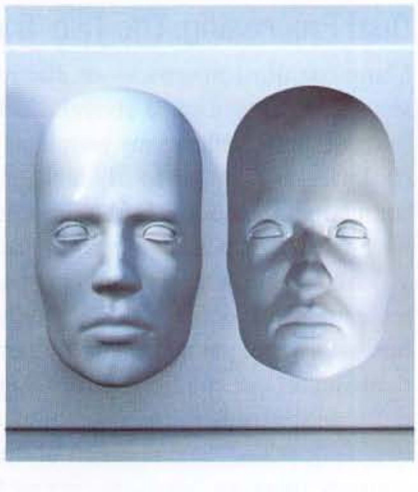
So, would the reverse damage lead to the opposite symptoms? Indeed, there are a few such patients—who can see and recognize objects but have difficulty pointing toward or grasping them.

How strangely intricate is this thing we call vision, conclude Goodale and Milner in their aptly titled book, *Sight Unseen.* We may think of our vision as one system controlling our visually guided actions, but it is actually a dual-processing system. A *visual perception track* enables us "to think about the world"—to recognize things and to plan future actions. A *visual action track* guides our moment-to-moment movements.

On rare occasions, the two conflict. Shown the *hollow face illusion,* people will mistakenly perceive the inside of a mask as a protruding face (**FIGURE 13.7**). Yet they will unhesitatingly and accurately reach into the inverted mask to flick off a buglike target stuck on the face (Króliczak et al., 2006). What their conscious mind doesn't know, their hand does.

Figure 13.7

The hollow face illusion We tend to see an illusory protruding face even on an inverted mask (right). Yet research participants will accurately reach for a speck on the face inside the inverted mask, suggesting that our unconscious mind seems to know the truth of the illusion.



David Mack/Science Source

Another patient, who lost all his left visual cortex—leaving him blind to objects presented on the right side of his field of vision—can nevertheless sense the emotion expressed in faces he does not consciously perceive (De Gelder, 2010). The same is true of normally sighted people whose visual cortex has been disabled with magnetic stimulation. This suggests that brain areas below the cortex are processing emotion-related information.

People often have trouble accepting that much of our everyday thinking, feeling, and acting operates outside our conscious awareness (Bargh & Chartrand, 1999). We are understandably biased to believe that our intentions and deliberate choices rule our lives. But consciousness, though enabling us to exert voluntary control and to communicate our mental states to others, is but the tip of the information-processing iceberg. Being intensely focused on an activity (such as reading this module, I'd love to think) increases your total brain activity no more than 5 percent above its baseline rate. And even when you rest, "hubs of dark energy" are whirling inside your head (Raichle, 2010).

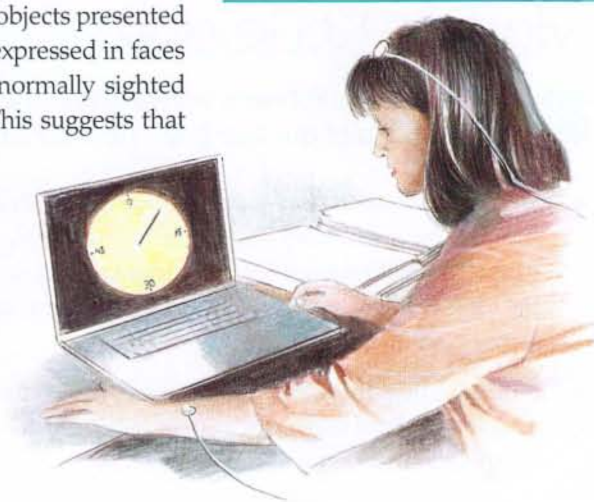


Figure 13.8
Is the brain ahead of the mind? In this study, volunteers watched a computer clock sweep through a full revolution every 2.56 seconds. They noted the time at which they decided to move their wrist. About one-third of a second before that decision, their brain-wave activity jumped, indicating a *readiness potential* to move. Watching a slow-motion replay, the researchers were able to predict when a person was about to decide to move (following which, the wrist did move) (Libet, 1985, 2004). Other researchers, however, question the clock measurement procedure (Miller et al., 2011).

Experiments show that when you move your wrist at will, you consciously experience the decision to move it about 0.2 seconds before the actual movement (Libet, 1985, 2004). No surprise there. But your brain waves jump about 0.35 seconds before you consciously perceive your decision to move (**FIGURE 13.8**)! This readiness potential has enabled researchers (using fMRI brain scans) to predict—with 60 percent accuracy and up to 7 seconds ahead—participants' decisions to press a button with their left or right finger (Soon et al., 2008). The startling conclusion: Consciousness sometimes arrives late to the decision-making party.

Running on automatic pilot allows our consciousness—our mind's CEO—to monitor the whole system and deal with new challenges, while neural assistants automatically take care of routine business. Walking the familiar path to your next class, your feet do the work while your mind rehearses the presentation you're about to give. A skilled tennis player's brain and body respond automatically to an oncoming serve before becoming consciously aware of the ball's trajectory (which takes about three-tenths of a second). Ditto for other skilled athletes, for whom action precedes awareness. *The bottom line:* In everyday life, we mostly function like an automatic point-and-shoot camera, but with a manual (conscious) override.

Our unconscious parallel processing is faster than sequential conscious processing, but both are essential. Sequential processing is skilled at solving new problems, which require our focused attention. Try this: If you are right-handed, you can move your right foot in a smooth counterclockwise circle, and you can write the number 3 repeatedly with your right hand—but probably not at the same time. (Try something equally difficult: Tap a steady beat three times with your left hand while tapping four times with your right hand.) Both tasks require conscious attention, which can be in only one place at a time. If time is nature's way of keeping everything from happening at once, then consciousness is nature's way of keeping us from thinking and doing everything at once.

Before You Move On

▶ ASK YOURSELF

What are some examples of things you do on "automatic pilot"? What behaviors require your conscious attention?

▶ TEST YOURSELF

What are the mind's two tracks, and what is "dual processing"?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 13 Review

13-1 What do split brains reveal about the functions of our two brain hemispheres?

- *Split-brain* research (experiments on people with a severed *corpus callosum*) has confirmed that in most people, the left hemisphere is the more verbal, and that the right hemisphere excels in visual perception and the recognition of emotion.
- Studies of healthy people with intact brains confirm that each hemisphere makes unique contributions to the integrated functioning of the brain.

13-2 What is the "dual processing" being revealed by today's cognitive neuroscience?

- *Cognitive neuroscientists* and others studying the brain mechanisms underlying consciousness and cognition have discovered that the mind processes information on two separate tracks, one operating at an explicit, conscious level and the other at an implicit, unconscious level. This *dual processing* affects our perception, memory, attitudes, and other cognitions.

Multiple-Choice Questions

1. A split-brain patient has a picture of a dog flashed to his right hemisphere and a cat to his left hemisphere. He will be able to identify the

a. cat using his right hand.
b. dog using his right hand.
c. dog using either hand.
d. cat using either hand.
e. cat using his left hand.

2. You are aware that a dog is viciously barking at you, but you are not aware of the type of dog. Later, you are able to describe the type and color of the dog. This ability to process information without conscious awareness best exemplifies which of the following?

a. Split brain
b. Blindsight
c. Consciousness
d. Cognitive neuroscience
e. Dual processing

3. Which of the following is most likely to be a function of the left hemisphere?

a. Speech
b. Evaluating perceptual tasks
c. Making inferences
d. Identifying emotion in other people's faces
e. Identifying one's sense of self

4. The dual-processing model refers to which of the following ideas?

a. The right and left hemispheres of the brain both process incoming messages.
b. Incoming information is processed by both conscious and unconscious tracks.
c. Each lobe of the brain processes incoming information.
d. The brain first processes emotional information and then processes analytical information.
e. The thalamus and hypothalamus work together to analyze incoming sensory information.

Practice FRQs

1. Brain lateralization means that each hemisphere has its own functions. Give an example of both a left hemisphere and a right hemisphere function. Then explain how the two hemispheres communicate with one another.

Answer

1 point: Left hemisphere functions include language, math, and logic.

1 point: Right hemisphere functions include spatial relationships, facial recognition, and patterns.

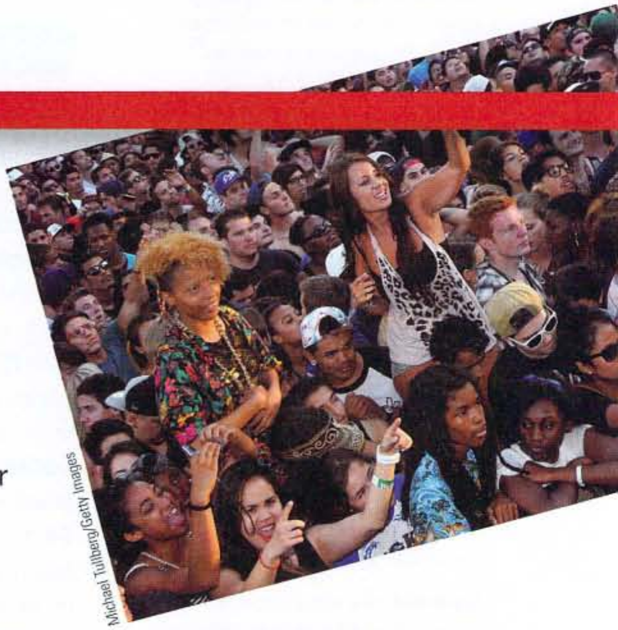
1 point: The corpus callosum carries information back and forth between the two hemispheres.

2. Because Jerry suffered severe seizures, his neurosurgeon decided to "split his brain." What does this mean? How might a psychologist use people who have had split-brain surgery to determine the location of speech control?

(3 points)

Module 14

Behavior Genetics: Predicting Individual Differences



Michael Tullberg/Getty Images

Module Learning Objectives

14-1 Define *genes*, and describe how behavior geneticists explain our individual differences.

14-2 Identify the potential uses of molecular genetics research.

14-3 Explain what is meant by heritability, and discuss how it relates to individuals and groups.

14-4 Discuss the interaction of heredity and environment.

Behind the story of our human brain—surely the most awesome thing on Earth—is the essence of our universal human attributes and our individual traits. What makes you *you?* In important ways, we are each unique. We look different. We sound different. We have varying personalities, interests, and cultural and family backgrounds.

We are also the leaves of one tree. Our human family shares not only a common biological heritage—cut us and we bleed—but also common behavioral tendencies. Our shared brain architecture predisposes us to sense the world, develop language, and feel hunger through identical mechanisms. Whether we live in the Arctic or the tropics, we prefer sweet tastes to sour. We divide the color spectrum into similar colors. And we feel drawn to behaviors that produce and protect offspring.

Our kinship appears in our social behaviors as well. Whether named Wong, Nkomo, Smith, or Gonzales, we start fearing strangers at about eight months, and as adults we prefer the company of those with attitudes and attributes similar to our own. Coming from different parts of the globe, we know how to read one another's smiles and frowns. As members of one species, we affiliate, conform, return favors, punish offenses, organize hierarchies of status, and grieve a child's death. A visitor from outer space could drop in anywhere and find humans dancing and feasting, singing and worshipping, playing sports and games, laughing and crying, living in families and forming groups. Taken together, such universal behaviors define our human nature.

What causes our striking diversity, and also our shared human nature? How much are human differences shaped by our differing genes? And how much by our *environment*—by every external influence, from maternal nutrition while in the womb to social support while nearing the tomb? To what extent are we formed by our upbringing? By our culture? By our current circumstances? By people's reactions to our genetic dispositions? This module and the next begin to tell the complex story of how our genes (nature) and environments (nurture) define us.

Courtesy of Kevin Feyen

The nurture of nature Parents everywhere wonder: Will my baby grow up to be peaceful or aggressive? Homely or attractive? Successful or struggling at every step? What comes built in, and what is nurtured—and how? Research reveals that nature and nurture together shape our development—every step of the way.

behavior genetics the study of the relative power and limits of genetic and environmental influences on behavior.

environment every external influence, from prenatal nutrition to the people and things around us.

chromosomes threadlike structures made of DNA molecules that contain the genes.

DNA *(deoxyribonucleic acid)* a complex molecule containing the genetic information that makes up the chromosomes.

genes the biochemical units of heredity that make up the chromosomes; segments of DNA capable of synthesizing proteins.

genome the complete instructions for making an organism, consisting of all the genetic material in that organism's chromosomes.

"Your DNA and mine are 99.9 percent the same. . . . At the DNA level, we are clearly all part of one big worldwide family." -Francis Collins, Human Genome Project director, 2007

"Thanks for almost everything, Dad."

Genes: Our Codes for Life

14-1 What are genes, and how do behavior geneticists explain our individual differences?

If Jaden Agassi, son of tennis stars Andre Agassi and Steffi Graf, grows up to be a tennis star, should we attribute his superior talent to his Grand Slam genes? To his growing up in a tennis-rich environment? To high expectations? Such questions intrigue **behavior geneticists,** who study our differences and weigh the effects and interplay of heredity and **environment.**

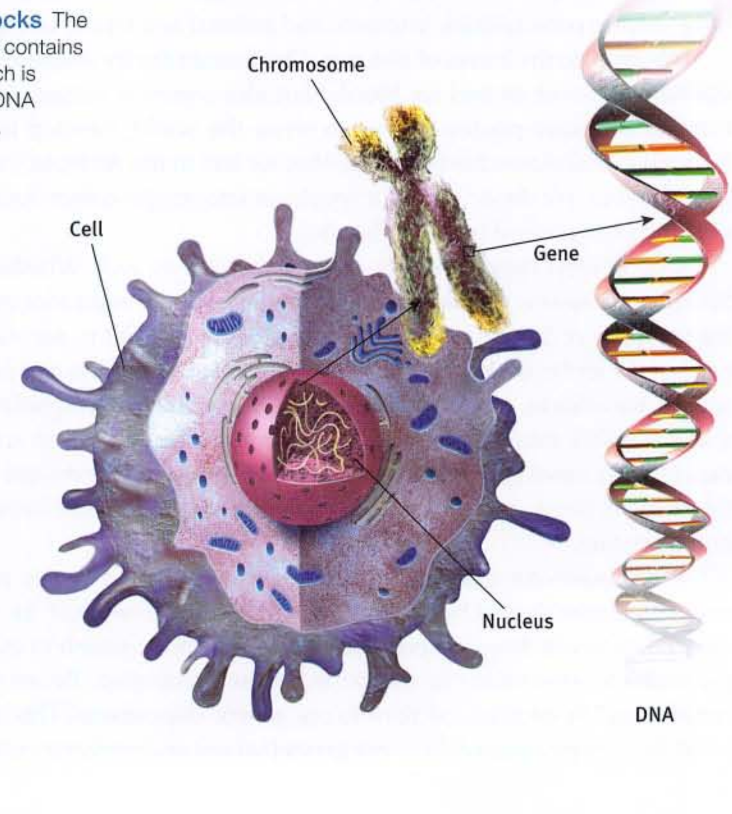
Barely more than a century ago, few would have guessed that every cell nucleus in your body contains the genetic master code for your entire body. It's as if every room in Dubai's Burj Khalifa (the world's tallest building) had a book containing the architect's plans for the entire structure. The plans for your own book of life run to 46 chapters—23 donated by your mother's egg and 23 by your father's sperm. Each of these 46 chapters, called a **chromosome,** is composed of a coiled chain of the molecule **DNA** *(deoxyribonucleic acid).* **Genes,** small segments of the giant DNA molecules, form the words of those chapters (**FIGURE 14.1**). All told, you have 20,000 to 25,000 genes. Genes can be either active *(expressed)* or inactive. Environmental events "turn on" genes, rather like hot water enabling a tea bag to express its flavor. When turned on, genes provide the code for creating *protein molecules,* our body's building blocks.

Genetically speaking, every other human is nearly your identical twin. Human **genome** researchers have discovered the common sequence within human DNA. It is this shared genetic profile that makes us humans, rather than chimpanzees or tulips.

Actually, we aren't all that different from our chimpanzee cousins; with them we share about 96 percent of our DNA sequence (Mikkelsen et al., 2005). At "functionally important" DNA sites, reported one molecular genetics team, the human-chimpanzee DNA similarity is 99.4 percent (Wildman et al., 2003). Yet that wee difference matters. Despite

Figure 14.1

The human building blocks The nucleus of every human cell contains chromosomes, each of which is made up of two strands of DNA connected in a double helix.



some remarkable abilities, chimpanzees grunt. Shakespeare intricately wove 17,677 words to form his literary masterpieces.

Small differences matter among chimpanzees, too. Two species, common chimpanzees and bonobos, differ by much less than 1 percent of their genomes, yet they display markedly differing behaviors. Chimpanzees are aggressive and male dominated. Bonobos are peaceable and female led.

Geneticists and psychologists are interested in the occasional variations found at particular gene sites in human DNA. Slight person-to-person variations from the common pattern give clues to our uniqueness—why one person has a disease that another does not, why one person is short and another tall, why one is outgoing and another shy.

Most of our traits are influenced by many genes. How tall you are, for example, reflects the size of your face, vertebrae, leg bones, and so forth—each of which may be influenced by different genes interacting with your environment. Complex traits such as intelligence, happiness, and aggressiveness are similarly influenced by groups of genes. Thus our genetic predispositions—our genetically influenced traits—help explain both our shared human nature and our human diversity.

"We share half our genes with the banana." -Evolutionary biologist Robert May, president of Britain's Royal Society, 2001

Twin and Adoption Studies

To scientifically tease apart the influences of environment and heredity, behavior geneticists would need to design two types of experiments. The first would control the home environment while varying heredity. The second would control heredity while varying the home environment. Such experiments with human infants would be unethical, but happily for our purposes, nature has done this work for us.

identical twins *(monozygotic twins)* twins who develop from a single fertilized egg that splits in two, creating two genetically identical organisms.

fraternal twins *(dizygotic twins)* twins who develop from separate fertilized eggs. They are genetically no closer than brothers and sisters, but they share a fetal environment.

Identical Versus Fraternal Twins

Identical *(monozygotic)* **twins** develop from a single fertilized egg that splits in two. Thus they are *genetically* identical—nature's own human clones (**FIGURE 14.2**). Indeed, they are clones who share not only the same genes but the same conception and uterus, and usually the same birth date and cultural history. Two slight qualifications:

- Although identical twins have the same genes, they don't always have the same *number of copies* of those genes. That helps explain why one twin may be more at risk for certain illnesses (Bruder et al., 2008).
- Most identical twins share a placenta during prenatal development, but one of every three sets has two separate placentas. One twin's placenta may provide slightly better nourishment, which may contribute to identical twin differences (Davis et al., 1995; Phelps et al., 1997; Sokol et al., 1995).

Fraternal *(dizygotic)* **twins** develop from separate fertilized eggs. As womb-mates, they share a fetal environment, but they are genetically no more similar than ordinary brothers and sisters.

Shared genes can translate into shared experiences. A person whose identical twin has Alzheimer's disease, for example, has a 60 percent risk of getting the disease; if the affected twin is fraternal, the risk is 30 percent (Plomin et al., 1997). To study the effects of genes and environments, hundreds of researchers have studied some 800,000 identical and fraternal twin pairs (Johnson et al., 2009).

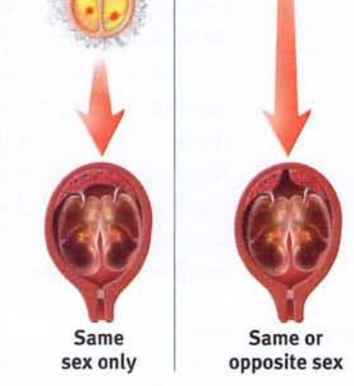


Figure 14.2
Same fertilized egg, same genes; different eggs, different genes Identical twins develop from a single fertilized egg, fraternal twins from two.

Ethel Wolvitz/The Image Works

© Lee Snider / The Image Works

Belinda Images/SuperStock

More twins Curiously, twinning rates vary by race. The rate among Caucasians is roughly twice that of Asians and half that of Africans. In Africa and Asia, most twins are identical. In Western countries, most twins are fraternal, and fraternal twins are increasing with the use of fertility drugs (Hall, 2003; Steinhauer, 1999).

Are identical twins, being genetic clones of each other, also behaviorally more similar than fraternal twins? Studies of thousands of twin pairs in Sweden, Finland, and Australia find that on both extraversion (outgoingness) and neuroticism (emotional instability), identical twins are much more similar than fraternal twins. If genes influence traits such as emotional instability, might they also influence the social effects of such traits? To find out, researchers studied divorce rates among 1500 same-sex, middle-aged twin pairs (McGue & Lykken, 1992). Their result: If you have a fraternal twin who has divorced, the odds of your divorcing are 1.6 times greater than if you have a not-divorced twin. If you have an identical twin who has divorced, the odds of your divorcing are 5.5 times greater. From such data, the researchers estimate that people's differing divorce risks are about 50 percent attributable to genetic factors.

Identical twins, more than fraternal twins, also report being treated alike. So, do their experiences rather than their genes account for their similarity? *No.* Studies have shown that identical twins whose parents treated them alike were not psychologically more alike than identical twins who were treated less similarly (Loehlin & Nichols, 1976). In explaining individual differences, genes matter.

Separated Twins

Imagine the following science fiction experiment: A mad scientist decides to separate identical twins at birth, then rear them in differing environments. Better yet, consider a *true* story:

On a chilly February morning in 1979, some time after divorcing his first wife, Linda, Jim Lewis awoke in his modest home next to his second wife, Betty. Determined that this marriage would work, Jim made a habit of leaving love notes to Betty around the house. As he lay in bed he thought about others he had loved, including his son, James Alan, and his faithful dog, Toy.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circling a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

What was extraordinary about Jim Lewis, however, was that at that same moment (I am not making this up) there existed another man—also named Jim—for whom all these things (right down to the dog's name) were also true.[1] This other Jim—Jim Springer—just happened, 38 years earlier, to have been his fetal partner. Thirty-seven days after their birth, these genetically identical twins were separated, adopted by blue-collar families, and reared with no contact or knowledge of each other's whereabouts until the day Jim Lewis received a call from his genetic clone (who, having been told he had a twin, set out to find him).

FYI

Sweden has the world's largest national twin registry—140,000 living and dead twin pairs—which forms part of a massive registry of 600,000 twins currently being sampled in the world's largest twin study (Wheelwright, 2004; www.genomeutwin.org).

FYI

Twins Lorraine and Levinia Christmas, driving to deliver Christmas presents to each other near Flitcham, England, collided (Shepherd, 1997).

"In some domains it looks as though our identical twins reared apart are . . . just as similar as identical twins reared together. Now that's an amazing finding and I can assure you none of us would have expected that degree of similarity."
-Thomas Bouchard (1981)

[1] Actually, this description of the two Jims errs in one respect: Jim Lewis named his son James Alan. Jim Springer named his James Allan.

One month later, the brothers became the first twin pair tested by University of Minnesota psychologist Thomas Bouchard and his colleagues, beginning a study of separated twins that extends to the present (Holden, 1980a,b; Wright, 1998). Their voice intonations and inflections were so similar that, hearing a playback of an earlier interview, Jim Springer guessed "That's me." Wrong—it was his brother. Given tests measuring their personality, intelligence, heart rate, and brain waves, the Jim twins—despite 38 years of separation—were virtually as alike as the same person tested twice. Both married women named Dorothy Jane Scheckelburger. Okay, the last item is a joke. But as Judith Rich Harris (2006) notes, it is hardly weirder than some other reported similarities.

Aided by publicity in magazine and newspaper stories, Bouchard (2009) and his colleagues located and studied 74 pairs of identical twins reared apart. They continued to find similarities not only of tastes and physical attributes but also of personality (characteristic patterns of thinking, feeling, and acting), abilities, attitudes, interests, and even fears.

In Sweden, Nancy Pedersen and her co-workers (1988) identified 99 separated identical twin pairs and more than 200 separated fraternal twin pairs. Compared with equivalent samples of identical twins reared together, the separated identical twins had somewhat less identical personalities. Still, separated twins were more alike if genetically identical than if fraternal. And separation shortly after birth (rather than, say, at age 8) did not amplify their personality differences.

Stories of startling twin similarities do not impress Bouchard's critics, who remind us that "the plural of *anecdote* is not *data.*" They contend that if any two strangers were to spend hours comparing their behaviors and life histories, they would probably discover many coincidental similarities. If researchers created a control group of biologically unrelated pairs of the same age, sex, and ethnicity, who had not grown up together but who were as similar to one another in economic and cultural background as are many of the separated twin pairs, wouldn't these pairs also exhibit striking similarities (Joseph, 2001)? Bouchard replies that separated fraternal twins do not exhibit similarities comparable to those of separated identical twins.

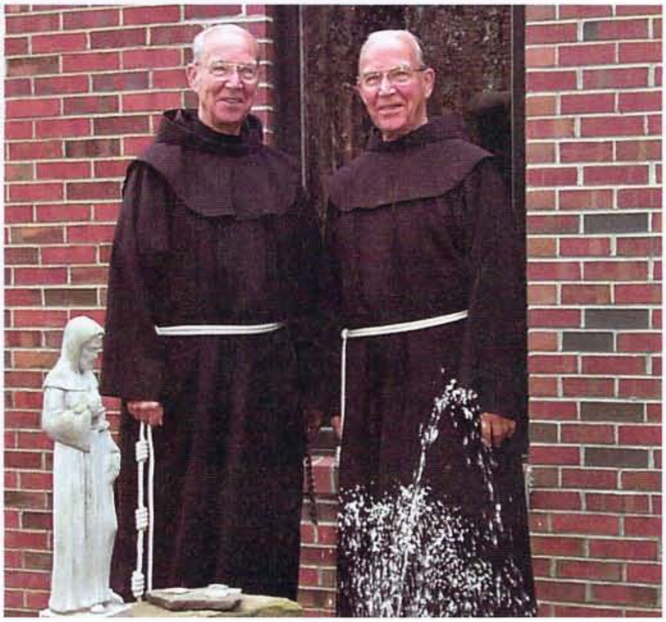
Even the more impressive data from personality assessments are clouded by the reunion of many of the separated twins some years before they were tested. Moreover, identical twins share an appearance, and the responses it evokes. Adoption agencies also tend to place separated twins in similar homes. Despite these criticisms, the striking twin-study results helped shift scientific thinking toward a greater appreciation of genetic influences.

FYI

Bouchard's famous twin research was, appropriately enough, conducted in Minneapolis, the "Twin City" (with St. Paul), and home to the Minnesota Twins baseball team.

FYI

Coincidences are not unique to twins. Patricia Kern of Colorado was born March 13, 1941, and named Patricia Ann Campbell. Patricia DiBiasi of Oregon also was born March 13, 1941, and named Patricia Ann Campbell. Both had fathers named Robert, worked as bookkeepers, and at the time of this comparison had children ages 21 and 19. Both studied cosmetology, enjoyed oil painting as a hobby, and married military men, within 11 days of each other. They are not genetically related. (From an AP report, May 2, 1983.)



St. Bonaventure University

The twin friars Julian and Adrian Reister—two "quiet, gentle souls"—both died of heart failure, at age 92, on the same day in 2011.

Biological Versus Adoptive Relatives

For behavior geneticists, nature's second real-life experiment—adoption—creates two groups: *genetic relatives* (biological parents and siblings) and *environmental relatives* (adoptive parents and siblings). For any given trait, we can therefore ask whether adopted children are more like their biological parents, who contributed their genes, or their adoptive parents, who contribute a home environment. While sharing that home environment, do adopted siblings also come to share traits?

The stunning finding from studies of hundreds of adoptive families is that people who grow up together, whether biologically related or not, do not much resemble one another in personality (McGue & Bouchard, 1998; Plomin, 2011; Rowe, 1990). In traits such as extraversion and agreeableness, adoptees are more similar to their biological parents than to their caregiving adoptive parents.

"We carry to our graves the essence of the zygote that was first us." -Mary Pipher, *Seeking Peace: Chronicles of the Worst Buddhist in the World*, 2009

The finding is important enough to bear repeating: *The environment shared by a family's children has virtually no discernible impact on their personalities.* Two adopted children reared in the same home are no more likely to share personality traits with each other than with the child down the block. Heredity shapes other primates' personalities, too. Macaque monkeys raised by foster mothers exhibit social behaviors that resemble their biological, rather than foster, mothers (Maestripieri, 2003). Add all this to the similarity of identical twins, whether they grow up together or apart, and the effect of a shared rearing environment seems shockingly modest.

"Mom may be holding a full house while Dad has a straight flush, yet when Junior gets a random half of each of their cards his poker hand may be a loser." -David Lykken (2001)

What we have here is perhaps "the most important puzzle in the history of psychology," contended Steven Pinker (2002): *Why are children in the same family so different?* Why does shared family environment have so little effect on children's personalities? Is it because each sibling experiences unique peer influences and life events? Because sibling relationships ricochet off each other, amplifying their differences? Because siblings—despite sharing half their genes—have very different combinations of genes and may evoke very different kinds of parenting? Such questions fuel behavior geneticists' curiosity.

FYI

The greater uniformity of adoptive homes—mostly healthy, nurturing homes—helps explain the lack of striking differences when comparing child outcomes of different adoptive homes (Stoolmiller, 1999).

The minimal shared-environment effect does not mean that adoptive parenting is a fruitless venture. The genetic leash may limit the family environment's influence on personality, but parents do influence their children's attitudes, values, manners, faith, and politics (Reifman & Cleveland, 2007). A pair of adopted children or identical twins *will*, especially during adolescence, have more similar religious beliefs if reared together (Koenig et al., 2005). Parenting matters!

Moreover, in adoptive homes, child neglect and abuse and even parental divorce are rare. (Adoptive parents are carefully screened; natural parents are not.) So it is not surprising that, despite a somewhat greater risk of psychological disorder, most adopted children thrive, especially when adopted as infants (Loehlin et al., 2007; van IJzendoorn & Juffer, 2006; Wierzbicki, 1993). Seven in eight report feeling strongly attached to one or both adoptive parents. As children of self-giving parents, they grow up to be more self-giving and altruistic than average (Sharma et al., 1998). Many score higher than their biological parents on intelligence tests, and most grow into happier and more stable adults. In one Swedish study, infant adoptees grew up with fewer problems than were experienced by children whose biological mothers had initially registered them for adoption but then decided to raise the children themselves (Bohman & Sigvardsson, 1990). Regardless of personality differences between parents and their adoptees, most children benefit from adoption.

LUIS ACOSTA/AFP/Getty Images

Nature or nurture or both? When talent runs in families, as with the Williams sisters for tennis, how do heredity and environment together do their work?

The New Frontier: Molecular Genetics

14-2 What is the promise of molecular genetics research?

Behavior geneticists have progressed beyond asking, "Do genes influence behavior?" The new frontier of behavior-genetics research draws on "bottom-up" **molecular genetics** as it seeks to identify *specific genes* influencing behavior.

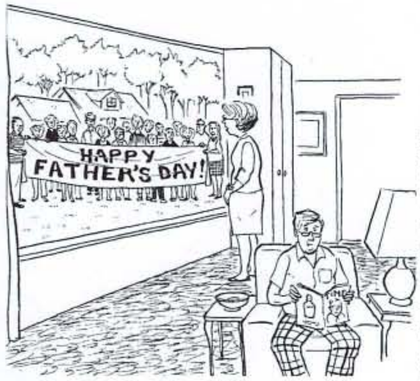
molecular genetics the subfield of biology that studies the molecular structure and function of genes.

As we have already seen, most human traits are influenced by teams of genes. For example, twin and adoption studies tell us that heredity influences body weight, but there is no single "obesity gene." More likely, some genes influence how quickly the stomach tells the brain, "I'm full." Others might dictate how much fuel the muscles need, how many calories are burned off by fidgeting, and how efficiently the body converts extra calories into fat (Vogel, 1999). Given that genes typically are not solo players, a goal of *molecular behavior genetics* is to find some of the many genes that together orchestrate traits such as body weight, sexual orientation, and extraversion (Holden, 2008; Tsankova et al., 2007).

Genetic tests can now reveal at-risk populations for many dozens of diseases. The search continues in labs worldwide, where molecular geneticists are teaming with psychologists to pinpoint genes that put people at risk for such genetically influenced disorders as learning disorder, depression, schizophrenia, and alcohol use disorder. (In Module 67, for example, we will take note of a worldwide research effort to sleuth the genes that make people vulnerable to the emotional swings of bipolar disorder, formerly called manic-depressive disorder.) To tease out the implicated genes, molecular behavior geneticists find families that have had the disorder across several generations. They draw blood or take cheek swabs from both affected and unaffected family members. Then they examine their DNA, looking for differences. "The most powerful potential for DNA," note Robert Plomin and John Crabbe (2000), "is to predict risk so that steps can be taken to prevent problems before they happen."

Aided by inexpensive DNA-scanning techniques, medical personnel are becoming able to give would-be parents a readout on how their fetus' genes differ from the normal pattern and what this might mean. With this benefit come risks. Might labeling a fetus "at risk for a learning disorder" lead to discrimination? Prenatal screening poses ethical dilemmas. In China and India, where boys are highly valued, testing for an offspring's sex has enabled selective abortions resulting in millions—yes, millions—of "missing women."

Assuming it were possible, should prospective parents take their eggs and sperm to a genetics lab for screening before combining them to produce an embryo? Should we enable parents to screen their fertilized eggs for health—and for brains or beauty? Progress is a double-edged sword, raising both hopeful possibilities and difficult problems. By selecting out certain traits, we may deprive ourselves of future Handels and van Goghs, Churchills and Lincolns, Tolstoys and Dickinsons—troubled people all.



"I thought that sperm-bank donors remained anonymous."

Heritability

14-3 What is heritability, and how does it relate to individuals and groups?

Using twin and adoption studies, behavior geneticists can mathematically estimate the **heritability** of a trait—the extent to which variation among individuals can be attributed to their differing genes. As Modules 63 and 64 will emphasize, if the heritability of intelligence is, say, 50 percent, this does *not* mean that *your* intelligence is 50 percent genetic. (The heritability of height is 90 percent, but this does not mean that a 60-inch-tall woman can credit

heritability the proportion of variation among individuals that we can attribute to genes. The heritability of a trait may vary, depending on the range of populations and environments studied.

AP® Exam Tip

Heritability is likely to show up on the AP® exam because it's confusing. The key thing to remember is that heritability refers to variation within a group. It does not refer to the impact of nature on an individual. Be clear on both what it is and what it isn't.

her genes for 54 inches and her environment for the other 6 inches.) Rather, it means that genetic influence explains 50 percent of the observed *variation among people.* This point is so often misunderstood that I repeat: We can never say what percentage of an *individual's* personality or intelligence is inherited. It makes no sense to say that your personality is due x percent to your heredity and y percent to your environment. Heritability refers instead to the extent to which *differences among people* are attributable to genes.

Even this conclusion must be qualified, because heritability can vary from study to study. Consider humorist Mark Twain's (1835–1910) fantasy of raising boys in barrels to age 12, feeding them through a hole. If we were to follow his suggestion, the boys would all emerge with lower-than-normal intelligence scores at age 12. Yet, given their equal environments, their test score differences could be explained only by their heredity. In this case, heritability—differences due to genes—would be near 100 percent.

As environments become more similar, heredity as a source of differences necessarily becomes more important. If all schools were of uniform quality, all families equally loving, and all neighborhoods equally healthy, then heritability would *increase* (because differences due to environment would *decrease*). At the other extreme, if all people had similar heredities but were raised in drastically different environments (some in barrels, some in luxury homes), heritability would be much lower.

"The title of my science project is 'My Little Brother: Nature or Nurture.'"

Can we extend this thinking to differences between groups? If genetic influences help explain individual diversity in traits such as aggressiveness, for example, can the same be said of group differences between men and women, or between people of different races? Not necessarily. Individual differences in height and weight, for example, are highly heritable; yet nutritional rather than genetic influences explain why, as a group, today's adults are taller and heavier than those of a century ago. The two groups differ, but not because human genes have changed in a mere century's eyeblink of time. Although height is 90 percent heritable, South Koreans, with their better diets, average six inches taller than North Koreans, who come from the same genetic stock (Johnson et al., 2009).

As with height and weight, so with personality and intelligence scores: Heritable individual differences need not imply heritable group differences. If some individuals are genetically disposed to be more aggressive than others, that needn't explain why some groups are more aggressive than others. Putting people in a new social context can change their aggressiveness. Today's peaceful Scandinavians carry many genes inherited from their Viking warrior ancestors.

Gene-Environment Interaction

14-4 How do heredity and environment work together?

Among our similarities, the most important—the behavioral hallmark of our species—is our enormous adaptive capacity. Some human traits, such as having two eyes, develop the same in virtually every environment. But other traits are expressed only in particular environments. Go barefoot for a summer and you will develop toughened, callused feet—a biological adaptation to friction. Meanwhile, your shod neighbor will remain a tenderfoot. The difference between the two of you is, of course, an effect of environment. But it is also the product of a biological mechanism—adaptation. Our shared biology enables our developed diversity (Buss, 1991).

"Men's natures are alike; it is their habits that carry them far apart."
-Confucius, *Analects*, 500 B.C.E.

An analogy may help: Genes and environment—nature and nurture—work together like two hands clapping. Genes are *self-regulating.* Rather than acting as blueprints that lead to the same result no matter the context, genes react. An African butterfly that is green in summer turns brown in fall, thanks to a temperature-controlled genetic switch. The genes that produce brown in one situation produce green in another. So, too, people with identical genes but differing experiences will have similar but not identical minds. One twin may fall in love with someone quite different from the co-twin's love.

Dim154/Shutterstock

Asking whether our personality is more a product of our genes or our environment is like asking whether the area of a field is more the result of its length or its width. We could, however, ask whether the differing areas of various fields are more the result of *differences* in their length or their width, and also whether person-to-person personality differences are influenced more by nature or nurture.

"Heredity deals the cards; environment plays the hand." -PSYCHOLOGIST CHARLES L. BREWER (1990)

To say that genes and experience are *both* important is true. But more precisely, they **interact.** Imagine two babies, one genetically predisposed to be attractive, sociable, and easygoing, the other less so. Assume further that the first baby attracts more affectionate and stimulating care and so develops into a warmer and more outgoing person. As the two children grow older, the more naturally outgoing child more often seeks activities and friends that encourage further social confidence.

interaction the interplay that occurs when the effect of one factor (such as environment) depends on another factor (such as heredity).

epigenetics the study of environmental influences on gene expression that occur without a DNA change.

What has caused their resulting personality differences? Neither heredity nor experience dances alone. Environments trigger gene activity. And our genetically influenced traits *evoke* significant responses in others. Thus, a child's impulsivity and aggression may evoke an angry response from a teacher who reacts warmly to the child's model classmates. Parents, too, may treat their own children differently; one child elicits punishment, another does not. In such cases, the child's nature and the parents' nurture interact. Neither operates apart from the other. Gene and scene dance together.

Evocative interactions may help explain why identical twins reared in different families recall their parents' warmth as remarkably similar—almost as similar as if they had had the same parents (Plomin et al., 1988, 1991, 1994). Fraternal twins have more differing recollections of their early family life—even if reared in the same family! "Children experience us as different parents, depending on their own qualities," noted Sandra Scarr (1990). Moreover, a selection effect may be at work. As we grow older, we select environments well suited to our natures.

Recall that genes can be either active (expressed, as the hot water activates the tea bag) or inactive. A new field, **epigenetics** (meaning "in addition to" or "above and beyond" genetics), is studying the molecular mechanisms by which environments trigger genetic expression. Although genes have the potential to influence development, environmental triggers can switch them on or off, much as your computer's software directs your printer. One such *epigenetic mark* is an organic methyl molecule attached to part of a DNA strand (**FIGURE 14.3**). It instructs the cell to ignore any gene present in that DNA segment, thereby preventing the DNA from producing the proteins coded by that gene.

Environmental factors such as diet, drugs, and stress can affect the epigenetic molecules that regulate gene expression. In one experiment, infant rats deprived of their mothers' normal licking had more molecules that blocked

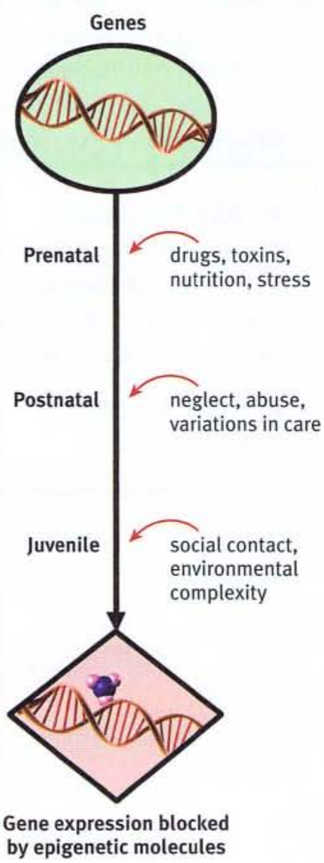


Figure 14.3

Epigenetics influences gene expression Life experiences beginning in the womb lay down *epigenetic marks*—often organic methyl molecules—that can block the expression of any gene in the associated DNA segment (from Champagne, 2010).

Gene-environment interaction
Biological appearances have social consequences. People respond differently to recording artist Nicki Minaj and concert violinist Hilary Hahn.

FilmMagic/Getty Images

Saverkin Alexsander/TAR-TASS/Landov

access to the "on" switch for developing the brain's stress hormone receptors. When stressed, the animals had more free-floating stress hormones and were more stressed out (Champagne et al., 2003; Champagne & Mashoodh, 2009). Child abuse may similarly affect its victims. Humans who have committed suicide exhibit the same epigenetic effect if they had suffered a history of child abuse (McGowan et al., 2009). Researchers now wonder if epigenetics might help solve some scientific mysteries, such as why only one member of an identical twin pair may develop a genetically influenced mental disorder, and how experience leaves its fingerprints in our brains.

So, from conception onward, we are the product of a cascade of interactions between our genetic predispositions and our surrounding environments (McGue, 2010). Our genes affect how people react to and influence us. Biological appearances have social consequences. So, forget nature *versus* nurture; think nature *via* nurture.

Before You Move On

▶ ASK YOURSELF

Would you want genetic tests on your unborn offspring? What would you do if you knew your child would be destined for hemophilia (a medical condition that interferes with blood clotting)? A specific learning disorder? A high risk of depression? Do you think society would benefit or lose if such embryos were aborted?

▶ TEST YOURSELF

What is *heritability*?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Module 14 Review

14-1 What are genes, and how do behavior geneticists explain our individual differences?

- *Genes* are the biochemical units of heredity that make up *chromosomes,* the threadlike coils of *DNA.*
- When genes are "turned on" (expressed), they provide the code for creating the proteins that form our body's building blocks.
- Most human traits are influenced by many genes acting together.
- *Behavior geneticists* seek to quantify genetic and *environmental* influences on our traits, in part through studies of *identical* (monozygotic) *twins, fraternal* (dizygotic) *twins,* and adoptive families.
- Shared family environments have little effect on personality, and the stability of personality suggests a genetic predisposition.

14-2 What is the promise of molecular genetics research?

- *Molecular geneticists* study the molecular structure and function of genes, including those that affect behavior.
- Psychologists and molecular geneticists are cooperating to identify specific genes—or more often, teams of genes—that put people at risk for disorders.

14-3 What is heritability, and how does it relate to individuals and groups?

- *Heritability* describes the extent to which variation among members of a group can be attributed to genes.
- Heritable individual differences (in traits such as height or intelligence) do not necessarily imply heritable group differences. Genes mostly explain why some people are taller than others, but not why people are taller today than they were a century ago.

14-4 How do heredity and environment work together?

- Our genetic predispositions and our surrounding environments *interact.* Environments can trigger gene activity, and genetically influenced traits can evoke responses from others.
- The field of *epigenetics* studies the influences on gene expression that occur without changes in DNA.

Multiple-Choice Questions

1. Human genome (DNA) researchers have discovered that

a. chimpanzees are completely different than humans, sharing a small DNA sequence percentage.
b. the occasional variations found at particular gene sites in human DNA are of no interest to science.
c. many genes do not influence most of our traits.
d. nearly every other human is your genetically identical twin.
e. genetic predispositions do not help explain our shared human nature and our human diversity.

2. One reason that identical twins might show slight differences at birth is

a. they did not develop from a single fertilized egg.
b. one twin's placenta may have provided slightly better nourishment.
c. they develop from different sperm.
d. one twin gestated much longer in the uterus than the other.
e. their relative positions in the uterus.

3. Generally speaking, heritability is the extent to which

a. differences among people are accounted for by genes.
b. an individual's specific traits are due to genes or the environment.
c. differences among people are due to the environment.
d. differences among people are due to their cultural heritage.
e. an individual's height is related to the height of his or her parents.

4. Which of the following is most closely associated with the idea of epigenetics?

a. Eye color
b. Gene display based on environmental factors
c. IQ as a function of educational experiences
d. Height at birth
e. Shoe size

5. Which of the following is an example of gene-environment interaction?

a. Yeh Lin experiences flushing syndrome, which mostly occurs in those of Asian heritage.
b. Alfonso gets food poisoning from eating undercooked meat.
c. Ted gets diabetes, which runs in his family, because he eats too much sugary food.
d. Samantha has a food allergy to shellfish.
e. Jordan has an autoimmune disorder that causes him to lose hair.

Practice FRQs

1. Explain the two positions in the nature–nurture debate.

Answer (2 points)

1 point: Nature refers to the contributions of heredity and inborn, biologically determined aspects of behavior and mental processes.

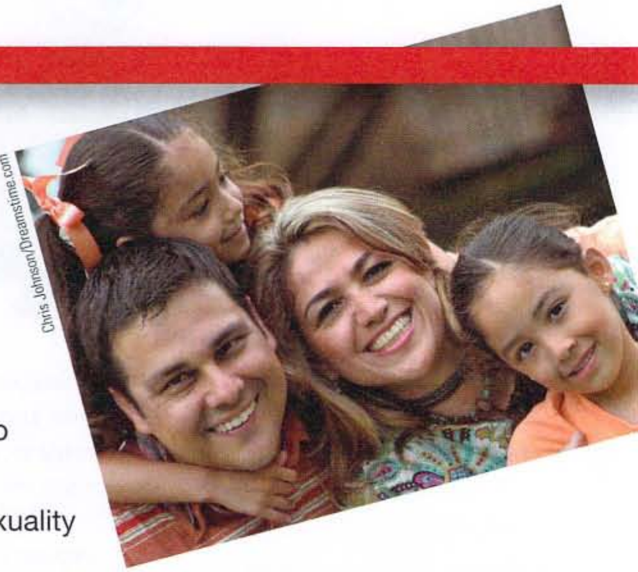
1 point: Nurture refers to the contributions of environment and the way individuals are raised.

2. What does it mean to say that the heritability of height is 90 percent? What does that tell us about the contribution of genetics to any one person's height?

(2 points)

Module 15

Evolutionary Psychology: Understanding Human Nature


Chris Johnson/Dreamstime.com

Module Learning Objectives

15-1 Describe evolutionary psychologists' use of natural selection to explain behavior tendencies.

15-2 Discuss evolutionary explanations for gender differences in sexuality and mating preferences.

15-3 Summarize the key criticisms of evolutionary psychology, and describe how evolutionary psychologists respond.

15-4 Describe the biopsychosocial approach to individual development.

15-1 How do evolutionary psychologists use natural selection to explain behavior tendencies?

Behavior geneticists explore the genetic and environmental roots of human differences. **Evolutionary psychologists** instead focus mostly on what makes us so much alike. They use Charles Darwin's principle of natural selection to understand the roots of behavior and mental processes. Richard Dawkins (2007) calls **natural selection** "arguably the most momentous idea ever to occur to a human mind." The idea, simplified, is this:

- Organisms' varied offspring compete for survival.
- Certain biological and behavioral variations increase organisms' reproductive and survival chances in their particular environment.
- Offspring that survive are more likely to pass their genes to ensuing generations.
- Thus, over time, population characteristics may change.

To see these principles at work, let's consider a straightforward example in foxes.

evolutionary psychology the study of the evolution of behavior and the mind, using principles of natural selection.

natural selection the principle that, among the range of inherited trait variations, those contributing to reproduction and survival will most likely be passed on to succeeding generations.

Natural Selection and Adaptation

A fox is a wild and wary animal. If you capture a fox and try to befriend it, be careful. Stick your hand in the cage and, if the timid fox cannot flee, it may snack on your fingers. Russian scientist Dmitry Belyaev wondered how our human ancestors had domesticated dogs from their equally wild wolf forebears. Might he, within a comparatively short stretch of time, accomplish a similar feat by transforming the fearful fox into a friendly fox?

Eric Isselée/Shutterstock

To find out, Belyaev set to work with 30 male and 100 female foxes. From their offspring he selected and mated the tamest 5 percent of males and 20 percent of females. (He measured tameness by the foxes' responses to attempts to feed, handle, and stroke them.) Over more than 30 generations of foxes, Belyaev and his successor, Lyudmila Trut, repeated that simple procedure. Forty years and 45,000 foxes later, they had a new breed of foxes that, in Trut's (1999) words, are "docile, eager to please, and unmistakably domesticated. . . . Before our eyes, 'the Beast' has turned into 'beauty,' as the aggressive behavior of our herd's wild [ancestors] entirely disappeared." So friendly and eager for human contact are they, so inclined to whimper to attract attention and to lick people like affectionate dogs, that the cash-strapped institute seized on a way to raise funds—marketing its foxes to people as house pets.

Over time, traits that are *selected* confer a reproductive advantage on an individual or a species and will prevail. Animal breeding experiments manipulate genetic selection and show its powers. Dog breeders have given us sheepdogs that herd, retrievers that retrieve, trackers that track, and pointers that point (Plomin et al., 1997). Psychologists, too, have bred animals to be serene or reactive, quick learners or slow.

mutation a random error in gene replication that leads to a change.

Does the same process work with naturally occurring selection? Does natural selection explain our human tendencies? Nature has indeed selected advantageous variations from the new gene combinations produced at each human conception and the **mutations** (random errors in gene replication) that sometimes result. But the tight genetic leash that predisposes a dog's retrieving, a cat's pouncing, or an ant's nest building is looser on humans. The genes selected during our ancestral history provide more than a long leash; they endow us with a great capacity to learn and therefore to *adapt* to life in varied environments, from the tundra to the jungle. Genes and experience together wire the brain. Our adaptive flexibility in responding to different environments contributes to our *fitness*—our ability to survive and reproduce.

Evolutionary Success Helps Explain Similarities

Although our person-to-person differences grab attention, we humans are also strikingly alike. As brothers and sisters in one great human family, we all wake and sleep, think and speak, hunger and thirst. We smile when happy and favor what's familiar more than what is foreign. We return favors, fear snakes, grieve death, and, as social animals, have a need to belong. Beneath our differing skin, we all are kin. Evolutionary psychologist Steven Pinker (2002, p. 73) has noted that it is no wonder our emotions, drives, and reasoning "have a common logic across cultures": Our shared human traits "were shaped by natural selection acting over the course of human evolution."

Our Genetic Legacy

Our behavioral and biological similarities arise from our shared human *genome,* our common genetic profile. No more than 5 percent of the genetic differences among humans arise from population group differences. Some 95 percent of genetic variation exists *within* populations (Rosenberg et al., 2002). The typical genetic difference between two Icelandic villagers or between two Kenyans is much greater than the *average* difference between the two groups. Thus, if after a worldwide catastrophe only Icelanders or Kenyans survived, the human species would suffer only "a trivial reduction" in its genetic diversity (Lewontin, 1982).

And how did we develop this shared human genome? At the dawn of human history, our ancestors faced certain questions: Who is my ally, who my foe? What food should I eat? With whom should I mate? Some individuals answered those questions more successfully than others. For example, women who experienced nausea in the critical first three months of pregnancy were predisposed to avoid certain bitter, strongly flavored, and novel foods. Avoiding such foods has survival value, since they are the very foods most often toxic to embryonic development (Schmitt & Pilcher, 2004). Early humans disposed to eat nourishing rather than poisonous foods survived to contribute their genes to later generations. Those who deemed leopards "nice to pet" often did not.

Similarly successful were those whose mating helped them produce and nurture offspring. Over generations, the genes of individuals not so disposed tended to be lost from the human gene pool. As success-enhancing genes continued to be selected, behavioral tendencies and thinking and learning capacities emerged that prepared our Stone Age ancestors to survive, reproduce, and send their genes into the future, and into you.

Across our cultural differences, we even share "a universal moral grammar," notes evolutionary psychologist Marc Hauser (2006, 2009). Men and women, young and old, liberal and conservative, living in Sydney or Seoul, all respond negatively when asked, "If a lethal gas is leaking into a vent and is headed toward a room with seven people, is it okay to push someone into the vent—saving the seven but killing the one?" And they all respond more approvingly when asked if it's okay to allow someone to fall into the vent, again sacrificing one life but saving seven. Our shared moral instincts survive from a distant past where we lived in small groups in which direct harm-doing was punished, argues Hauser. For all such universal human tendencies, from our intense need to give parental care to our shared fears and lusts, evolutionary theory proposes a one-stop shopping explanation (Schloss, 2009).

As inheritors of this prehistoric genetic legacy, we are predisposed to behave in ways that promoted our ancestors' surviving and reproducing. But in some ways, we are biologically prepared for a world that no longer exists. We love the taste of sweets and fats, which prepared our ancestors to survive famines, and we heed their call from school cafeterias, fast-food outlets, and vending machines. With famine now rare in Western cultures, obesity is truly a growing problem. Our natural dispositions, rooted deep in history, are mismatched with today's junk-food environment and today's threats such as climate change (Colarelli & Dettman, 2003).

FYI

Despite high infant mortality and rampant disease in past millennia, not one of your countless ancestors died childless.

Evolutionary Psychology Today

Darwin's theory of evolution has been an organizing principle for biology for a long time. Jared Diamond (2001) noted, "Virtually no contemporary scientists believe that Darwin was basically wrong." Today, Darwin's theory lives on in the *second Darwinian revolution:* the application of evolutionary principles to psychology. In concluding *On the Origin of Species,* Darwin anticipated this, foreseeing "open fields for far more important researches. Psychology will be based on a new foundation" (1859, p. 346).

In modules to come, we'll address questions that intrigue evolutionary psychologists, such as why infants start to fear strangers about the time they become mobile. Why are biological fathers so much less likely than unrelated boyfriends to abuse and murder the children with whom they share a home? Why do so many more people have phobias about spiders, snakes, and heights than about more dangerous threats, such as guns and electricity? And why do we fear air travel so much more than driving?

To see how evolutionary psychologists think and reason, let's pause now to explore their answers to these two questions: How are men and women alike? How and why does men's and women's sexuality differ?

FYI

Those who are troubled by an apparent conflict between scientific and religious accounts of human origins may find it helpful to recall from Module 2 that different perspectives of life can be complementary. For example, the scientific account attempts to tell us *when* and *how;* religious creation stories usually aim to tell about an ultimate *who* and *why.* As Galileo explained to the Grand Duchess Christina, "The Bible teaches how to go to heaven, not how the heavens go."

An Evolutionary Explanation of Human Sexuality

15-2 How might an evolutionary psychologist explain gender differences in sexuality and mating preferences?

Having faced many similar challenges throughout history, men and women have adapted in similar ways. Whether male or female, we eat the same foods, avoid the same predators, and perceive, learn, and remember similarly. It is only in those domains where we have faced differing adaptive challenges—most obviously in behaviors related to reproduction—that we differ, say evolutionary psychologists.

What evolutionary psychologists study Each word's size in this "word cloud" shows how frequently it has appeared in evolutionary psychology article titles. (Derived by Gregory Webster, Peter Jonason, and Tatiana Schember [2009] from all articles published in *Evolution and Human Behavior* between 1979 and 2008.) Webster, G. D., Jonason, P. K., & Schember, T. O. (2009). Hot topics and popular papers in evolutionary psychology: Analyses of title words and citation counts in *Evolution and Human Behavior*, 1979–2008. *Evolutionary Psychology, 7*, 348–362.

Gender Differences in Sexuality

And differ we do. Consider men's and women's sex drives. Who thinks more about sex? Masturbates more often? Initiates more sex? Views more pornography? The answers worldwide: *men, men, men,* and *men* (Baumeister et al., 2001; Lippa, 2009; Petersen & Hyde, 2009). No surprise, then, that in one BBC survey of more than 200,000 people in 53 nations, men everywhere more strongly agreed that "I have a strong sex drive" and "It doesn't take much to get me sexually excited" (Lippa, 2008).

Indeed, "with few exceptions anywhere in the world," reported cross-cultural psychologist Marshall Segall and his colleagues (1990, p. 244), "males are more likely than females to initiate sexual activity."

Men also have a lower threshold for perceiving warm responses as a sexual come-on. In study after study, men more often than women attribute a woman's friendliness to sexual interest (Abbey, 1987; Johnson et al., 1991). Misattributing women's cordiality as a come-on helps explain—but does not excuse—men's greater sexual assertiveness (Kolivas & Gross, 2007). The unfortunate results can range from sexual harassment to date rape.

Natural Selection and Mating Preferences

Evolutionary psychologists use natural selection to explain why—worldwide—women's approach to sex is usually more relational, and men's more recreational (Schmitt, 2005, 2007). The explanation goes like this: While a woman usually incubates and nurses one infant at a time, a male can spread his genes through other females. Our natural yearnings are our genes' way of reproducing themselves. In our ancestral history, women most often sent their genes into the future by pairing wisely, men by pairing widely. "Humans are living fossils—collections of mechanisms produced by prior selection pressures," said evolutionary psychologist David Buss (1995).

And what do heterosexual men and women find attractive in a mate? Some desired traits, such as a woman's youthful appearance, cross place and time (Buss, 1994). Evolutionary psychologists say that men who were drawn to healthy, fertile-appearing women—women with smooth skin and a youthful shape suggesting many childbearing years to come—stood a better chance of sending their genes into the future. And sure enough, men feel most attracted to women whose waists (thanks to their genes or their surgeons) are roughly a third narrower than their hips—a sign of future fertility (Perilloux et al., 2010). Moreover, just as evolutionary psychology predicts, men are most attracted to women whose ages in the ancestral past (when ovulation began later than today) would be associated with peak fertility (Kenrick et al., 2009). Thus, teen boys are most excited by a woman several years older than themselves, mid-twenties men prefer women around their own age, and older men prefer younger women. This pattern consistently appears across European singles ads, Indian marital ads, and marriage records from North and South America, Africa, and the Philippines (Singh, 1993; Singh & Randall, 2007).

Women, in turn, prefer stick-around dads over likely cads. They are attracted to men who seem mature, dominant, bold, and affluent, with a potential for long-term mating and investment in their joint offspring (Gangestad & Simpson, 2000; Singh, 1995). In one study of hundreds of Welsh pedestrians, men rated a woman as equally attractive whether pictured at a wheel of a humble Ford Fiesta or a swanky Bentley. Women, however, found the man more attractive if he was in the luxury car (Dunn & Searle, 2010). In another experiment, women skillfully discerned which men most liked looking at baby pictures, and they rated those men higher as potential long-term mates (Roney et al., 2006). From an evolutionary perspective, such attributes connote a man's capacity to support and protect a family (Buss, 1996, 2009; Geary, 1998).

"I had a nice time, Steve. Would you like to come in, settle down, and raise a family?"

There is a principle at work here, say evolutionary psychologists: Nature selects behaviors that increase the likelihood of sending one's genes into the future. As mobile gene machines, we are designed to prefer whatever worked for our ancestors in their environments. They were predisposed to act in ways that would produce grandchildren—had they not been, we wouldn't be here. And as carriers of their genetic legacy, we are similarly predisposed.

Without disputing nature's selection of traits that enhance gene survival, critics see some problems with this explanation of our mating preferences. They believe that the evolutionary perspective overlooks some important influences on human sexuality (see Thinking Critically About: The Evolutionary Perspective on Human Sexuality).

Thinking Critically About

The Evolutionary Perspective on Human Sexuality

15-3 What are the key criticisms of evolutionary psychology, and how do evolutionary psychologists respond?

Evolutionary psychology, say some critics, starts with an effect (such as the gender sexuality difference) and works backward to propose an explanation. They invite us to imagine a different result and reason backward. If men were uniformly loyal to their mates, might we not reason that the children of these committed, supportive fathers would more often survive to perpetuate their genes? Might not men also be better off bonded to one woman—both to increase their odds of impregnation and to keep her from the advances of competing men? Might not a ritualized bond—a marriage—also spare women from chronic male harassment? Such suggestions are, in fact, evolutionary explanations for why humans tend to pair off monogamously (Gray & Anderson, 2010). One can hardly lose at hindsight explanation, which is, said paleontologist Stephen Jay Gould (1997), mere "speculation [and] guesswork in the cocktail party mode."

Some also worry about the social consequences of evolutionary psychology. Does it suggest a genetic determinism that strikes at the heart of progressive efforts to remake society (Rose, 1999)? Does it undercut moral responsibility (Buller, 2005, 2009)? Could it be used to rationalize "high-status men marrying a series of young, fertile women" (Looy, 2001)?

Others argue that evolutionary explanations blur the line between genetic legacy and social-cultural tradition. Show Alice Eagly and Wendy Wood (1999; Eagly, 2009) a culture with gender inequality—where men are providers and women are homemakers—and they will show you a culture where men strongly desire youth and domestic skill in their potential mates, and where women seek status and earning potential in their mates. Show Eagly and Wood a culture with gender equality, and they will show you a culture with smaller gender differences in mate preferences.

Much of who we are is *not* hard-wired, agree evolutionary psychologists. "Evolution forcefully rejects a genetic determinism," insists one research team (Confer et al., 2010). Evolutionary psychologists reassure us that men and women, having faced similar adaptive problems, are far more alike than different, and that humans have a great capacity for learning and social progress. Indeed, natural selection has prepared us to flexibly adjust and respond to varied environments, to adapt and survive, whether we live in igloos or tree houses. Further, they agree that cultures vary, cultures change, and cultural expectations can bend the genders. If socialized to value lifelong commitment, men may sexually bond with one partner; if socialized to accept casual sex, women may willingly have sex with many partners.

Evolutionary psychologists acknowledge struggling to explain some traits and behaviors such as same-sex attraction and suicide (Confer et al., 2010). But they also point to the explanatory and predictive power of evolutionary principles. Evolutionary psychologists predict, and have confirmed, that we tend to favor others to the extent that they share our genes or can later return our favors. They predict, and have confirmed, that human memory should be well-suited to retaining survival-relevant information (such as food locations, for which females exhibit superiority). They predict, and have confirmed, various other male and female mating strategies.

Evolutionary psychologists also remind us that the study of how we came to be need not dictate how we ought to be. Understanding our propensities sometimes helps us overcome them.

> "It is dangerous to show a man too clearly how much he resembles the beast, without at the same time showing him his greatness. It is also dangerous to allow him too clear a vision of his greatness without his baseness. It is even more dangerous to leave him in ignorance of both." -Blaise Pascal, Pensées, 1659

Before You Move On

▶ ASK YOURSELF

Whose reasoning do you find most persuasive—that of evolutionary psychologists or their critics? Why?

▶ TEST YOURSELF

What are the three main criticisms of evolutionary psychology's explanations?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

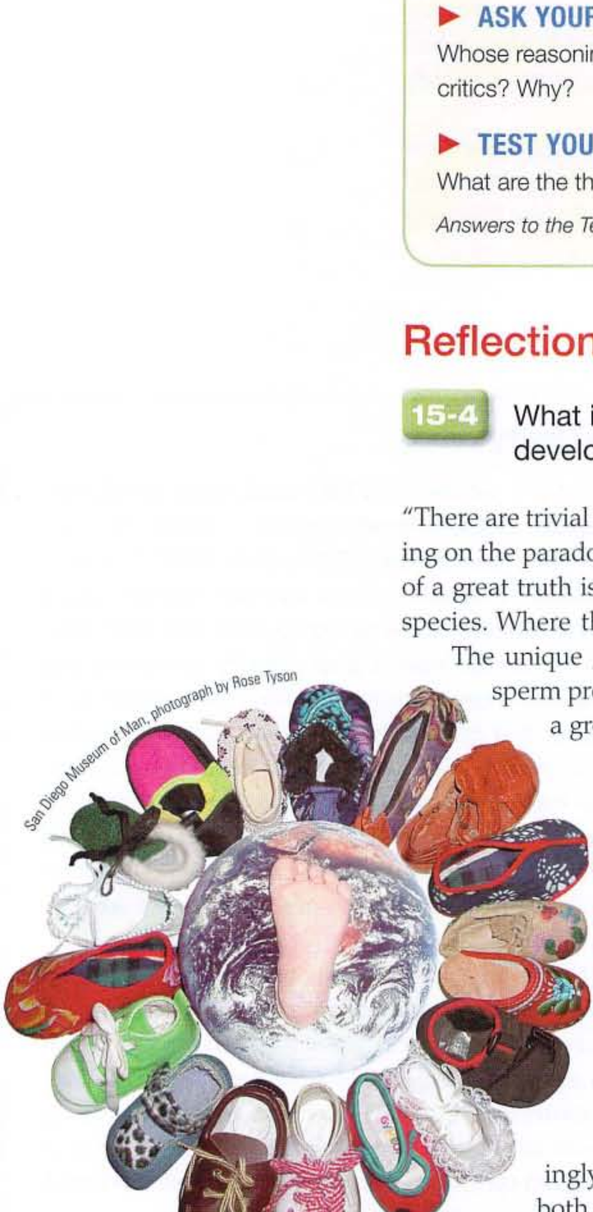
Reflections on Nature and Nurture

15-4 What is included in the biopsychosocial approach to individual development?

"There are trivial truths and great truths," the physicist Niels Bohr reportedly said in reflecting on the paradoxes of science. "The opposite of a trivial truth is plainly false. The opposite of a great truth is also true." It appears true that our ancestral history helped form us as a species. Where there is variation, natural selection, and heredity, there will be evolution. The unique gene combination created when our mother's egg engulfed our father's sperm predisposed both our shared humanity and our individual differences. This is a great truth about human nature. Genes form us.

But it also is true that our experiences form us. In our families and in our peer relationships, we learn ways of thinking and acting. Differences initiated by our nature may be amplified by our nurture. If genes and hormones predispose males to be more physically aggressive than females, culture may magnify this gender difference through norms that encourage males to be macho and females to be the kinder, gentler sex. If men are encouraged toward roles that demand physical power, and women toward more nurturing roles, each may then exhibit the actions expected of them and find themselves shaped accordingly. Roles remake their players. Presidents in time become more presidential, servants more servile. Gender roles similarly shape us.

But gender roles are converging. Brute strength has become increasingly irrelevant to power and status (think Bill Gates and Hillary Clinton). Thus both women and men are now seen as "fully capable of effectively carrying out organizational roles at all levels," note Wendy Wood and Alice Eagly (2002). And as women's employment in formerly male occupations has increased, gender differences in traditional masculinity or femininity and in what one seeks in a mate have diminished (Twenge, 1997). As the roles we play change over time, we change with them.



Culture matters As this exhibit at San Diego's Museum of Man illustrates, children learn their culture. A baby's foot can step into any culture.

* * *

If nature and nurture jointly form us, are we "nothing but" the product of nature and nurture? Are we rigidly determined?

We are the product of nature and nurture (**FIGURE 15.1**), but we are also an open system, as suggested by the biopsychosocial approach (see Module 2). Genes are all pervasive but not all powerful; people may defy their genetic bent to reproduce by electing celibacy. Culture, too, is all pervasive but not all powerful; people may defy peer pressures and do the opposite of the expected. To excuse our failings by blaming our nature and nurture is what philosopher-novelist Jean-Paul Sartre called "bad faith"—attributing responsibility for one's fate to bad genes or bad influences.

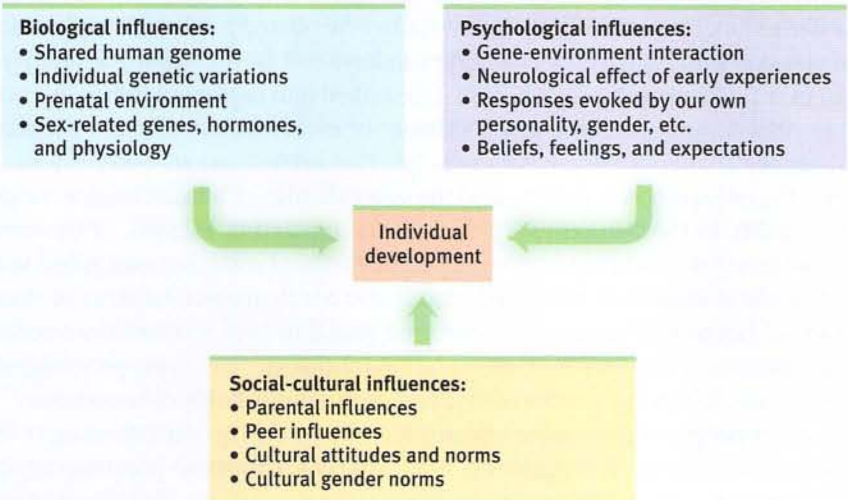


Figure 15.1
The biopsychosocial approach to individual development

In reality, we are both the creatures and the creators of our worlds. We are—it is a great truth—the products of our genes and environments. Nevertheless (another great truth), the stream of causation that shapes the future runs through our present choices. Our decisions today design our environments tomorrow. Mind matters. The human environment is not like the weather—something that just happens. We are its architects. Our hopes, goals, and expectations influence our future. And that is what enables cultures to vary and to change so quickly.

* * *

I know from my mail and from public opinion surveys that some readers feel troubled by the naturalism and evolutionism of contemporary science. Readers from other nations bear with me, but in the United States there is a wide gulf between scientific and lay thinking about evolution. "The idea that human minds are the product of evolution is . . . unassailable fact," declared a 2007 editorial in *Nature,* a leading science magazine. That sentiment concurs with a 2006 statement of "evidence-based facts" about evolution jointly issued by the national science academies of 66 nations (IAP, 2006). In *The Language of God,* Human Genome Project director Francis Collins (2006, pp. 141, 146), a self-described evangelical Christian, compiles the "utterly compelling" evidence that leads him to conclude that Darwin's big idea is "unquestionably correct." Yet Gallup reports that half of U.S. adults do not believe in evolution's role in "how human beings came to exist on Earth" (Newport, 2007). Many of those who dispute the scientific story worry that a science of behavior (and evolutionary science in particular) will destroy our sense of the beauty, mystery, and spiritual significance of the human creature. For those concerned, I offer some reassuring thoughts.

"Let's hope that it's not true; but if it is true, let's hope that it doesn't become widely known." -LADY ASHLEY, COMMENTING ON DARWIN'S THEORY

When Isaac Newton explained the rainbow in terms of light of differing wavelengths, the poet Keats feared that Newton had destroyed the rainbow's mysterious beauty. Yet, noted Richard Dawkins (1998) in *Unweaving the Rainbow,* Newton's analysis led to an even deeper mystery—Einstein's theory of special relativity. Moreover, nothing about Newton's optics need diminish our appreciation for the dramatic elegance of a rainbow arching across a brightening sky.

Tetyana Kochneva | Dreamstime.com

"Is it not stirring to understand how the world actually works—that white light is made of colors, that color measures light waves, that transparent air reflects light . . . ? It does no harm to the romance of the sunset to know a little about it." -Carl Sagan, *Skies of Other Worlds*, 1988

When Galileo assembled evidence that the Earth revolved around the Sun, not vice versa, he did not offer irrefutable proof for his theory. Rather, he offered a coherent explanation for a variety of observations, such as the changing shadows cast by the Moon's mountains. His explanation eventually won the day because it described and explained things in a way that made sense, that hung together. Darwin's theory of evolution likewise is a coherent view of natural history. It offers an organizing principle that unifies various observations.

Collins is not the only person of faith to find the scientific idea of human origins congenial with his spirituality. In the fifth century, St. Augustine (quoted by Wilford, 1999) wrote, "The universe was brought into being in a less than fully formed state, but was gifted with the capacity to transform itself from unformed matter into a truly marvelous array of structures and life forms." Some 1600 years later, Pope John Paul II in 1996 welcomed a science-religion dialogue, finding it noteworthy that evolutionary theory "has been progressively accepted by researchers, following a series of discoveries in various fields of knowledge."

Meanwhile, many people of science are awestruck at the emerging understanding of the universe and the human creature. It boggles the mind—the entire universe popping out of a point some 14 billion years ago, and instantly inflating to cosmological size. Had the energy of this Big Bang been the tiniest bit less, the universe would have collapsed back on itself. Had it been the tiniest bit more, the result would have been a soup too thin to support life. Astronomer Sir Martin Rees has described *Just Six Numbers* (1999), any one of which, if changed ever so slightly, would produce a cosmos in which life could not exist. Had gravity been a tad bit stronger or weaker, or had the weight of a carbon proton been a wee bit different, our universe just wouldn't have worked.

What caused this almost-too-good-to-be-true, finely tuned universe? Why is there something rather than nothing? How did it come to be, in the words of Harvard-Smithsonian astrophysicist Owen Gingerich (1999), "so extraordinarily right, that it seemed the universe had been expressly designed to produce intelligent, sentient beings"? Is there a benevolent superintelligence behind it all? Have there instead been an infinite number of universes born and we just happen to be the lucky inhabitants of one that, by chance, was exquisitely fine-tuned to give birth to us? Or does that idea violate *Occam's razor,* the principle that we should prefer the simplest of competing explanations? On such matters, a humble, awed, scientific silence is appropriate, suggested philosopher Ludwig Wittgenstein: "Whereof one cannot speak, thereof one must be silent" (1922, p. 189).

Rather than fearing science, we can welcome its enlarging our understanding and awakening our sense of awe. In *The Fragile Species,* Lewis Thomas (1992) described his utter amazement that the Earth in time gave rise to bacteria and eventually to Bach's Mass in B Minor. In a short 4 billion years, life on Earth has come from nothing to structures as complex as a 6-billion-unit strand of DNA and the incomprehensible intricacy of the human brain. Atoms no different from those in a rock somehow formed dynamic entities that became conscious. Nature, says cosmologist Paul Davies (2007), seems cunningly and ingeniously devised to produce extraordinary, self-replicating, information-processing systems—us. Although we appear to have been created from dust, over eons of time, the end result is a priceless creature, one rich with potential beyond our imagining.

"The causes of life's history [cannot] resolve the riddle of life's meaning." -Stephen Jay Gould, *Rocks of Ages: Science and Religion in the Fullness of Life*, 1999

Before You Move On

▶ ASK YOURSELF

How have your heredity and your environment influenced who you are today? Can you recall an important time when you determined your own fate in a way that was at odds with pressure you felt from either your heredity or your environment?

▶ TEST YOURSELF

How does the biopsychosocial approach explain our individual development?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

* * *

In this unit we have glimpsed an overriding principle: Everything psychological is simultaneously biological. We have focused on how our thoughts, feelings, and actions arise from our specialized yet integrated brain. In modules to come, we will further explore the significance of the biological revolution in psychology.

From nineteenth-century phrenology to today's neuroscience, we have come a long way. Yet what is unknown still dwarfs what is known. We can describe the brain. We can learn the functions of its parts. We can study how the parts communicate. But how do we get mind out of meat? How does the electrochemical whir in a hunk of tissue the size of a head of lettuce give rise to elation, a creative idea, or that memory of Grandmother?

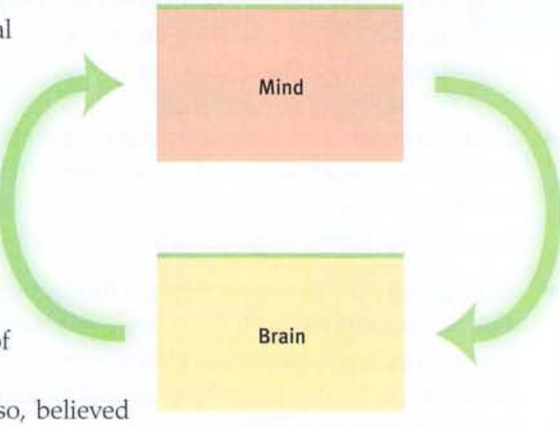


Figure 15.2
Mind and brain as holistic system In Roger Sperry's view, the brain creates and controls the emergent mind, which in turn influences the brain. (Think vividly about biting into a lemon and you may salivate.)

Much as gas and air can give rise to something different—fire—so also, believed Roger Sperry, does the complex human brain give rise to something different: *consciousness*. The mind, he argued, emerges from the brain's dance of ions, yet is not reducible to it. Cells cannot be fully explained by the actions of atoms, nor minds by the activity of cells. Psychology is rooted in biology, which is rooted in chemistry, which is rooted in physics. Yet psychology is more than applied physics. As Jerome Kagan (1998) reminded us, the meaning of the Gettysburg Address is not reducible to neural activity. Communication is more than air flowing over our vocal cords. Morality and responsibility become possible when we understand the mind as a "holistic system," said Sperry (1992) (**FIGURE 15.2**). We are not mere jabbering robots.

The mind seeking to understand the brain—that is indeed among the ultimate scientific challenges. And so it will always be. To paraphrase cosmologist John Barrow, a brain simple enough to be understood is too simple to produce a mind able to understand it.

Module 15 Review

15-1 How do evolutionary psychologists use natural selection to explain behavior tendencies?

- *Evolutionary psychologists* seek to understand how our traits and behavior tendencies are shaped by *natural selection,* as genetic variations increasing the odds of reproducing and surviving are most likely to be passed on to future generations.
- Some genetic variations arise from *mutations* (random errors in gene replication), others from new gene combinations at conception.
- Humans share a genetic legacy and are predisposed to behave in ways that promoted our ancestors' surviving and reproducing.
- Charles Darwin's theory of evolution is an organizing principle in biology. He anticipated today's application of evolutionary principles in psychology.

15-2 How might an evolutionary psychologist explain gender differences in sexuality and mating preferences?

- Men tend to have a recreational view of sexual activity; women tend to have a relational view.
- Evolutionary psychologists reason that men's attraction to multiple healthy, fertile-appearing partners increases their chances of spreading their genes widely.
- Because women incubate and nurse babies, they increase their own and their children's chances of survival by searching for mates with the potential for long-term investment in their joint offspring.

15-3 What are the key criticisms of evolutionary psychology, and how do evolutionary psychologists respond?

- Critics argue that evolutionary psychologists (1) start with an effect and work backward to an explanation, (2) do not recognize social and cultural influences, and (3) absolve people from taking responsibility for their sexual behavior.
- Evolutionary psychologists respond that understanding our predispositions can help us overcome them. They also cite the value of testable predictions based on evolutionary principles, as well as the coherence and explanatory power of those principles.

15-4 What is included in the biopsychosocial approach to individual development?

- Individual development results from the interaction of biological, psychological, and social-cultural influences.
- Biological influences include our shared human *genome;* individual variations; prenatal environment; and sex-related genes, hormones, and physiology.
- Psychological influences include gene-environment interactions; the effect of early experiences on neural networks; responses evoked by our own characteristics, such as gender and personality; and personal beliefs, feelings, and expectations.
- Social-cultural influences include parental and peer influences; cultural traditions and values; and cultural gender norms.

Multiple-Choice Questions

1. Which of the following refers to an effect of life experience that leaves a molecular mark that affects gene expression?

a. Epigenetics
b. Adaptation
c. Evolution
d. Natural selection
e. Universal moral grammar

2. Which of the following best describes genetic mutation?

a. Random errors in gene replication
b. The study of the mind's evolution
c. The study of behavioral evolution
d. Passing on successful, inherited traits
e. Survival of the genetically successful

3. Which of the following is true regarding the initiation of sexual activity?

a. Men are more likely to initiate sexual activity than women.
b. Women are more likely to initiate sexual activity than men.
c. The initiation of sexual activity for both men and women correlates with how many television sitcoms they viewed as children.
d. Men and women are equally likely to initiate sexual activity.
e. Who initiates sexual activity is largely determined by culture.

Practice FRQs

1. Explain four of the important ideas behind natural selection.

Answer

1 point: Organisms' varied offspring compete for survival.

1 point: Certain biological and behavioral variations increase an organism's reproductive and survival chances in a particular environment.

1 point: Offspring that survive are more likely to pass their genes to ensuing generations.

1 point: Over time, population characteristics may change.

2. Explain the three major influences on individual development, according to the biopsychosocial approach.

(3 points)

Unit III Review

Key Terms and Concepts to Remember

biological psychology, p. 77
neuron, p. 78
dendrites, p. 78
axon, p. 78
myelin [MY-uh-lin] sheath, p. 78
action potential, p. 78
refractory period, p. 79
threshold, p. 80
all-or-none response, p. 80
synapse [SIN-aps], p. 80
neurotransmitters, p. 80
reuptake, p. 80
endorphins [en-DOR-fins], p. 82
agonist, p. 82
antagonist, p. 83
nervous system, p. 86
central nervous system (CNS), p. 86
peripheral nervous system (PNS), p. 86
nerves, p. 86
sensory (afferent) neurons, p. 86
motor (efferent) neurons, p. 86
interneurons, p. 87
somatic nervous system, p. 87
autonomic [aw-tuh-NAHM-ik] nervous system (ANS), p. 87
sympathetic nervous system, p. 87
parasympathetic nervous system, p. 87
reflex, p. 89
endocrine [EN-duh-krin] system, p. 90
hormones, p. 90
adrenal [ah-DREEN-el] glands, p. 91
pituitary gland, p. 91
lesion [LEE-zhuhn], p. 94
electroencephalogram (EEG), p. 95
CT (computed tomography) scan, p. 95
PET (positron emission tomography) scan, p. 95
MRI (magnetic resonance imaging), p. 95
fMRI (functional MRI), p. 96
brainstem, p. 97
medulla [muh-DUL-uh], p. 97
thalamus [THAL-uh-muss], p. 97
reticular formation, p. 98
cerebellum [sehr-uh-BELL-um], p. 98
limbic system, p. 98
amygdala [uh-MIG-duh-la], p. 99
hypothalamus [hi-po-THAL-uh-muss], p. 99
cerebral [seh-REE-bruhl] cortex, p. 104
glial cells (glia), p. 104
frontal lobes, p. 105
parietal [puh-RYE-uh-tuhl] lobes, p. 105
occipital [ahk-SIP-uh-tuhl] lobes, p. 105
temporal lobes, p. 1050
motor cortex, p. 105
somatosensory cortex, p. 107
association areas, p. 109
plasticity, p. 111
neurogenesis, p. 112
corpus callosum [KOR-pus kah-LOW-sum], p. 114
split brain, p. 114
consciousness, p. 118
cognitive neuroscience, p. 119
dual processing, p. 120
behavior genetics, p. 124
environment, p. 124
chromosomes, p. 124
DNA (deoxyribonucleic acid), p. 124
genes, p. 124
genome, p. 124
identical twins, p. 125
fraternal twins, p. 125
molecular genetics, p. 129
heritability, p. 129
interaction, p. 131
epigenetics, p. 131
evolutionary psychology, p. 135
natural selection, p. 135
mutation, p. 136

Key Contributors to Remember

Paul Broca, p. 110
Carl Wernicke, p. 110
Roger Sperry, p. 114
Michael Gazzaniga, p. 114
Charles Darwin, p. 135

AP® Exam Practice Questions

Multiple-Choice Questions

1. Why do researchers study the brains of nonhuman animals?

a. It is not ethical to study human brains.
b. Human brains are too complex to study meaningfully.
c. The same principles govern neural functioning in all species.
d. It is too expensive to study human brains.
e. The technology is still being developed for the study of human brains.

2. What is the brief electrical charge that travels down an axon called?

a. Action potential
b. Resting potential
c. All-or-none impulse
d. Refractory period
e. Myelination response

3. An individual is having trouble with cognitive tasks related to learning and memory. Which of the following neurotransmitters is most likely to be involved with the problem?

a. Acetylcholine
b. Dopamine
c. Serotonin
d. The endorphins
e. GABA

4. Which is the most influential of the endocrine glands?

a. Pituitary gland
b. Adrenal glands
c. Dendrites
d. Threshold glands
e. Parasympathetic

5. What is the purpose of the myelin sheath?

a. Make the transfer of information across a synapse more efficient
b. Increase the amount of neurotransmitter available in the neuron
c. Reduce the antagonistic effect of certain drugs
d. Establish a resting potential in the axon
e. Speed the transmission of information within a neuron

6. The peripheral nervous system

a. connects the brain to the spinal cord.
b. calms the body after an emergency.
c. is limited to the control of voluntary movement.
d. controls only the arms and the legs.
e. is the part of the nervous system that does not include the brain and the spinal cord.

7. To walk across a street, a person would rely most directly on which division of the nervous system?

a. Central nervous system
b. Sympathetic nervous system
c. Peripheral nervous system
d. Autonomic nervous system
e. Parasympathetic nervous system

8. Opiate drugs such as morphine are classified as what?

a. Antagonists, because they block neurotransmitter receptors for pain
b. Agonists, because they mimic other neurotransmitters' pain-diminishing effects
c. Excitatory neurotransmitters, because they activate pain-control mechanisms
d. Sympathetic nervous system agents, because they prepare the body for a challenge
e. Parasympathetic nervous system agents, because they calm the body

9. Which region of the brain controls our breathing and heartbeat?

a. Pons
b. Corpus callosum
c. Parietal lobe
d. Hippocampus
e. Medulla

10. Which of the following does a PET scan best allow researchers to examine?

a. The presence of tumors in the brain
b. Electrical activity on the surface of the brain
c. The size of the internal structures of the brain
d. The location of strokes
e. The functions of various brain regions

11. A researcher interested in determining the size of a particular area of the brain would be most likely to use what kind of test?

a. Lesion
b. EEG
c. MRI
d. fMRI
e. PET scan

12. Damage to the hippocampus would result in what?

a. Difficulties with balance and coordination
b. Memory problems
c. The false sensation of burning in parts of the body
d. Emotional outbursts
e. Death

13. Surgical stimulation of the somatosensory cortex might result in the false sensation of what?

a. Music
b. Flashes of colored light
c. Someone whispering your name
d. Someone tickling you
e. A bad odor

14. During which task might the right hemisphere of the brain be most active?

a. Solving a mathematical equation
b. Reading
c. Making a brief oral presentation to a class
d. Imagining what a dress would look like on a friend
e. Solving a logic problem

15. Brain plasticity refers to which of the following?

a. Healthy human brain tissue
b. The ability of the brain to transfer information from one hemisphere to the other
c. How a brain gets larger as a child grows
d. A wide variety of functions performed by the human brain
e. The ability of brain tissue to take on new functions

16. When Klüver and Bucy surgically lesioned the amygdala of a rhesus monkey's brain, what was the impact on the monkey's behavior?

a. Lost its ability to coordinate movement
b. Died because its heartbeat became irregular
c. Became less aggressive
d. Lost its memory of where food was stored
e. Sank into an irreversible coma

17. An individual experiences brain damage that produces a coma. Which part of the brain was probably damaged?

a. Corpus callosum
b. Reticular formation
c. Frontal lobe
d. Cerebellum
e. Limbic system

18. Evolutionary psychologists seek to understand how traits and behavioral tendencies have been shaped by what?

a. Natural selection
b. Genes
c. Prenatal nutrition
d. DNA
e. Chromosomes

19. Which is one of the major criticisms of the evolutionary perspective in psychology?

a. It analyzes after the fact using hindsight.
b. It attempts to extend a biological theory into a psychological realm.
c. There is very little evidence to support it.
d. It has not been around long enough to "stand the test of time."
e. It seems to apply in certain cultures but not in others.

20. What was one of the major findings of Thomas Bouchard's study of twins?

a. It demonstrated that peer influence is more important than parental influence in the development of personality traits.
b. It proved that the influence of parental environment becomes more and more important as children grow into adults.
c. He discovered almost unbelievable similarities between adult identical twins who had been separated near birth.
d. Fraternal twins showed almost as much similarity as identical twins when they reached adulthood.
e. It provided evidence that heritability is less important than researchers previously suspected.

21. Which of the following statements has been supported by the research of evolutionary psychologists?

a. Women are attracted to men who appear virile.
b. Men are attracted to women who appear fertile and capable of bearing children.
c. The connection between sex and pleasure is mostly determined by culture.
d. The same factors determine sexual attraction in both males and females.
e. Most adults are attracted to partners that in some way remind them of their parents.

22. Why do researchers find the study of fraternal twins important?

a. They share similar environments and the same genetic code.
b. Data collected concerning their similarities is necessary for calculating heritability.
c. They are the same age and are usually raised in similar environments, but they do not have the same genetic code.
d. Results allow us to determine exactly how disorders ranging from heart disease to schizophrenia are inherited.
e. They are typically raised in less similar environments than nontwin siblings.

23. Heritability refers to the percentage of what?

a. Group variation in a trait that can be explained by environment
b. Traits shared by identical twins
c. Traits shared by fraternal twins
d. Traits shared by adopted children and their birth parents
e. Group variation in a trait that can be explained by genetics

24. What is the study of specific genes and teams of genes that influence behavior called?

a. Molecular genetics
b. Evolutionary psychology
c. Behavior genetics
d. Heritability
e. Natural selection

25. In an effort to reveal genetic influences on personality, researchers use adoption studies mainly for what purpose?

a. To compare adopted children with nonadopted children
b. To study the effect of prior neglect on adopted children
c. To study the effect of a child's age at adoption
d. To evaluate whether adopted children more closely resemble their adoptive parents or their biological parents
e. To consider the effects of adoption on a child's manners and values

Free-Response Questions

1. Charlotte is 88 years old and is feeling the effects of her long life. She suffered a stroke five years ago, which left the right side of her body limp. She also sometimes has trouble understanding when she is asked questions. Her doctors believe that she also may be suffering from the beginning stages of Alzheimer's disease. Define each of the following terms and explain how each might contribute to Charlotte's current circumstance.

- Motor cortex
- Acetylcholine
- Association areas
- Plasticity
- Epigenetics

Rubric for Free Response Question 1

1 point: The motor cortex is responsible for directing movements. The left motor cortex controls the right side of the body while the right motor cortex controls the left side of the body. Page 105

1 point: Because Charlotte's right side is limp, the damage from her stroke most likely occurred in the left hemisphere and potentially in her left motor cortex, which would leave her with little muscular control over the right side of her body. Page 105

1 point: Acetylcholine is a neurotransmitter that plays a role in muscle action, learning, and memory. Page 81

1 point: If Charlotte suffers from Alzheimer's disease, it is possible that the neurons responsible for producing acetylcholine have deteriorated. Page 81

1 point: Association areas are the areas of the cerebral cortex not directly involved in motor or sensory functions; rather they are involved in higher-order thought processes such as learning, memory, and thinking. Page 109

1 point: If Charlotte's association areas have been damaged, it may be difficult for her to integrate new ideas. She may also have trouble retrieving memories that were once easily recalled. Page 109

1 point: Plasticity is the brain's ability to create new neural pathways. This often occurs in response to brain injuries and occurs most efficiently in children. Page 111

1 point: Because of Charlotte's age, her brain will not have the ability to build an abundance of new neural networks, and if she has not recovered from her injury in a few months time, she is likely to make little progress in her recovery. Page 111

1 point: Epigenetics is the study of environmental influences on gene expression, which occur without DNA change. Page 131

1 point: Perhaps Charlotte has a predisposition for Alzheimer's disease. If she was in an environment which was not enriching and cognitively engaging, it may have made Alzheimer's disease more likely. On the other hand, despite having a genetic predisposition for Alzheimer's disease, if Charlotte was exposed to an enriching environment, her disposition may not have been expressed. Page 125

2. If a person accidentally touches a pan filled with hot water on the stove, they will immediately move their hand away from the hot pan before yelling out in pain. Use the following terms to explain what is involved in this reaction.

- Neurotransmitters
- The endocrine system
- Thalamus
- Amygdala
- Sensory cortex
- Pain reflex

(6 points)

3. Dr. Nation is a biopsychologist interested in studying genetic influences on brain development. Briefly describe a twin study Dr. Nation might design to investigate the research question: "How do genetics and early environmental influences interact to impact how brains develop?" Use the following terms in context in your description:

- Genes
- Heritability
- Epigenetics
- Fraternal or identical twins
- fMRI

(5 points)

Multiple-choice self-tests and more may be found at www.worthpublishers.com/MyersAP2e

Unit IV

Sensation and Perception

Modules

"I have perfect vision," explains my colleague, Heather Sellers, an acclaimed writer and teacher. Her vision may be fine, but there is a problem with her perception. She cannot recognize faces.

In her memoir, *You Don't Look Like Anyone I Know,* Sellers (2010) tells of awkward moments resulting from her lifelong *prosopagnosia*—face blindness.

> In college, on a date at the Spaghetti Station, I returned from the bathroom and plunked myself down in the wrong booth, facing the wrong man. I remained unaware he was not my date even as my date (a stranger to me) accosted Wrong Booth Guy, and then stormed out of the Station. I can't distinguish actors in movies and on television. I do not recognize myself in photos or videos. I can't recognize my stepsons in the soccer pick-up line; I failed to determine which husband was mine at a party, in the mall, at the market.

Her inability to recognize faces means that people sometimes perceive her as snobby or aloof. "Why did you walk past me?" a neighbor might later ask. Similar to those of us with hearing loss who fake hearing during trite social conversation, Sellers sometimes fakes recognition. She often smiles at people she passes, in case she knows them. Or she pretends to know the person with whom she is talking. (To avoid the stress associated with such perception failures, people with serious hearing loss or with prosopagnosia often shy away from busy social situations.) But