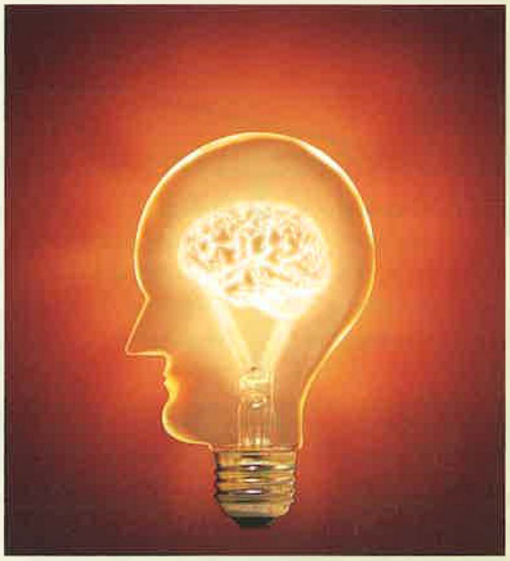
Unit 4

Biological



Core Learning Objectives

As you read Chapter 2, keep the following questions in mind and answer them in your own words:

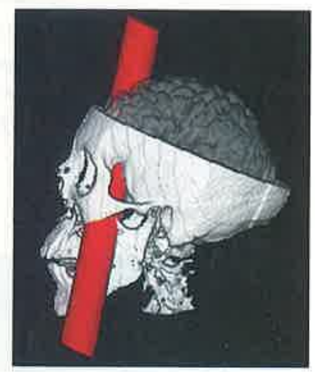
- How is the nervous system organized?
- What are neurons, and how do they communicate information throughout the body?
- What are the best tools for studying the brain?
- What are the lower-level structures of the brain, and what are their roles in behavior and mental processes?
- How does the cortex control behavior and mental processes?
- How do the left and right hemispheres of the brain affect behavior and mental processes?
- How are heredity and evolution linked to human behavior?

In 1848, when the Rutland and Burlington Railroad was laying new track through Vermont, 25-year-old Phineas P. Gage was a foreman in charge of blasting through the rocky terrain. Blasting a boulder into smaller, more easily removed rocks was a dangerous job, but not very complicated. First, a hole was drilled into the boulder and partially filled with blasting powder. Then a fuse was run into the blasting powder that was carefully tamped down, and the hole was filled with sand. The sand was tamped again with a metal rod to remove any air pockets that might diminish the blast, the fuse was lit, and everyone ran for cover.

Gage had done this hundreds of times, but on September 13, 1848, he failed to notice that his assistant had not yet put sand into the hole. So when Gage put down the tamping rod, it scraped against the rock and created sparks that ignited the blasting powder. But instead of shattering the boulder, the blast turned the iron rod into a missile. The 13-pound metal rod, $1\frac{1}{4}$ inches in diameter and $3\frac{1}{2}$ feet long, rocketed out of the hole and shot through Gage's head. Entering under his left cheekbone, the rod slammed through his brain, exiting out the top of his skull into the air, and eventually landing 60 to 80 feet away. Portions of his brain's frontal lobes littered the ground and smeared the tamping iron. This should have been the end of the story, but it wasn't.

Gage was stunned and his extremities shook convulsively. But in just a few minutes, he was able to talk to his men, and he even walked with little or no assistance up a flight of stairs before receiving medical treatment $1\frac{1}{2}$ hours later. Although his mind was "clear" and Gage insisted he would be back at work in a day or two, the attending physician, John Harlow, doubted that he would recover and the town cabinetmaker even measured Gage so there would be a coffin "in readiness to use" (Harlow, 1848, 1868; Macmillan, 1986, 2000).

Gage did survive physically, but not psychologically. A serious personality transformation had occurred. Before the accident, Gage was "the most efficient and capable foreman," "a shrewd, smart business man," and very energetic and persistent in executing all his plans. After the accident, Gage "frequently changed what he proposed doing, and was, among other things, fitful, capricious, impatient of advice, obstinate, and lacking in deference to his fellows" (Macmillan, 2000, p. 13). In the words of his friends and acquaintances, "Gage was no longer Gage" (Harlow, 1868). Following months of recuperation, Gage attempted to return to work but was refused his old job. The damage to his brain had changed him too profoundly.



According to historical records by his physician, Gage never again held a job equal to that of foreman. He supported himself with odd jobs and traveled around New England, exhibiting himself and the tamping iron, and for a time he did the same at Barnum Museum. He even lived in Chile for 7 years before ill health forced a return to the United States. Near the end of his life, Gage experienced numerous epileptic seizures of increasing severity and frequency. Despite the massive damage to his frontal lobes caused by the tamping iron, Phineas Gage lived on for another $11\frac{1}{2}$ years, eventually dying from the epileptic seizures.

How did Gage physically survive? What accounts for his radical change in personality? If the tamping iron had traveled through the brain at a slightly different angle, Gage would have immediately died. But as you can see in the photos above, the rod entered and exited the front part of the brain, a section unnecessary for physical survival but intimately involved in motivation, emotion, and a host of other cognitive activities.

Neuroscience *An interdisciplinary field studying how biological processes, especially activity in the brain and nervous system, relate to behavior*

Phineas Gage's injury and "recovery" is a classic example from the field of **neuroscience** and *biopsychology*, the scientific study of the *biology* of behavior and mental processes. Most beginning psychology students expect to study only abnormal behavior and are surprised by the amount of biology. Obviously, the brain is critical to survival, but have you thought about how it is also responsible for all your thoughts, fears, loves, and other behavior and mental processes? Your brain and nervous system control everything you do, feel, see, or think. *You are your brain.*

To help you fully understand and appreciate the wonders of your brain and nervous system, this chapter provides a basic overview and lays the foundation for the biological processes discussed throughout the text. We begin with a brief overview of the nervous system. Then we examine the *neuron*, or nerve cell, and the way neurons communicate with one another to produce thinking, feeling, and behavior. The bulk of the chapter explores the brain itself. We conclude with a look at heredity and evolutionary processes.

Neuroscience and you. All behavior and mental processes require a complex interaction between the brain, nervous system, and body.

BIOLOGICAL FOUNDATIONS

One of the many advantages of taking this psychology course is learning about yourself and how you learn. As you'll discover in Chapter 7, when you are introduced to a large set of new terms and concepts, the best way to master this material (and get it "permanently" stored in long-term memory) is through *organization*. A broad overview showing the "big picture" helps you organize and file specific details. Just as you would use a large globe of the world that shows all the continents to learn about individual countries, you need a "map" of the entire nervous system before studying the individual parts. Thus, we begin with this broad overview, followed by a close examination of the neuron itself, communication between neurons, and chemical messengers in the nervous system.

An Overview of the Nervous System: The Central Nervous System and Peripheral Nervous System

How is the nervous system organized?

Have you heard the expression "Information is power?" Nowhere is this truer than in the human body. Without information we could not survive. Our brain and bodies must take in information from the outside world, decide what to do with the information, and then follow through. Just as the circulatory system handles blood, our nervous system handles information.

To fully comprehend the intricacies of the nervous system, it helps to know the names of its major parts and how they are interrelated. Take a look at Figure 2.1. The nervous system has two major divisions, the *Central Nervous System* (CNS), which processes and organizes information, and the *Peripheral Nervous System* (PNS), which serves primarily as a relay system getting information to and from the CNS.

Central Nervous System (CNS)

Central Nervous System (CNS) *The brain and spinal cord.*

The **central nervous system (CNS)** consists of the *brain* and the *spinal cord*, both of which are surrounded by a protective bony structure — the skull and spinal column. Unlike neurons in the PNS that can regenerate and require less protection, serious damage to cells in the CNS is usually permanent. However, the brain may not be as "hard wired" as we once believed. As you will discover throughout this chapter and the text, the brain changes with learning and experience. In response to environmental demands (and some injuries), the brain can reorganize its functions, rewire itself with new connections, possibly reroute neurons around damaged areas, and even generate new brain cells (Begley, 2000; Gage, 2000; Kempermann & Gage, 1999; Taub, Crago, & Uswatte, 1998; Taub & Uswatte, 2000; Travis, 2000; Vogel, 2000).

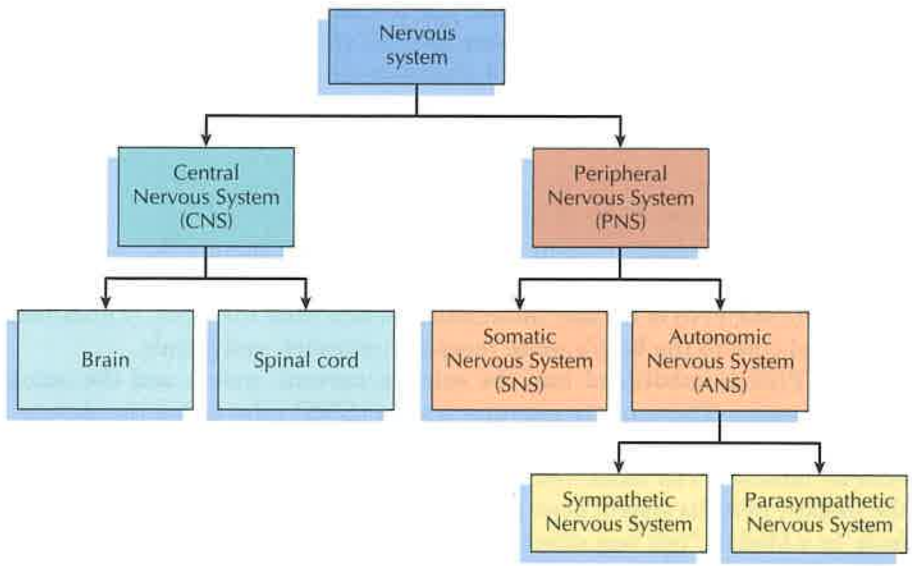


Figure 2.1 ***The nervous system.*** Note how the nervous system is divided and subdivided into various subsystems according to their differing functions. Review this diagram often as you study upcoming sections.

Because of its central importance for psychology and behavior, the brain is the major subject of this chapter, but the spinal cord is also important. Beginning at the base of the brain and continuing down the back, the spinal cord contains nerve fibers that link the brain to other parts of the body. These fibers relay incoming sensory information to the brain and send messages from the brain to muscles and glands.

The spinal cord is also responsible for one of our simplest behavior patterns-the *reflex arc,* which occurs when a stimulus provokes an automatic response. Have you ever noticed that you automatically jerk your hand away from a hot pan *before* your brain has a chance to respond? Reflexes occur within the spinal cord, without any help from the brain (Figure 2.2). It is only later, when the spinal cord transfers the

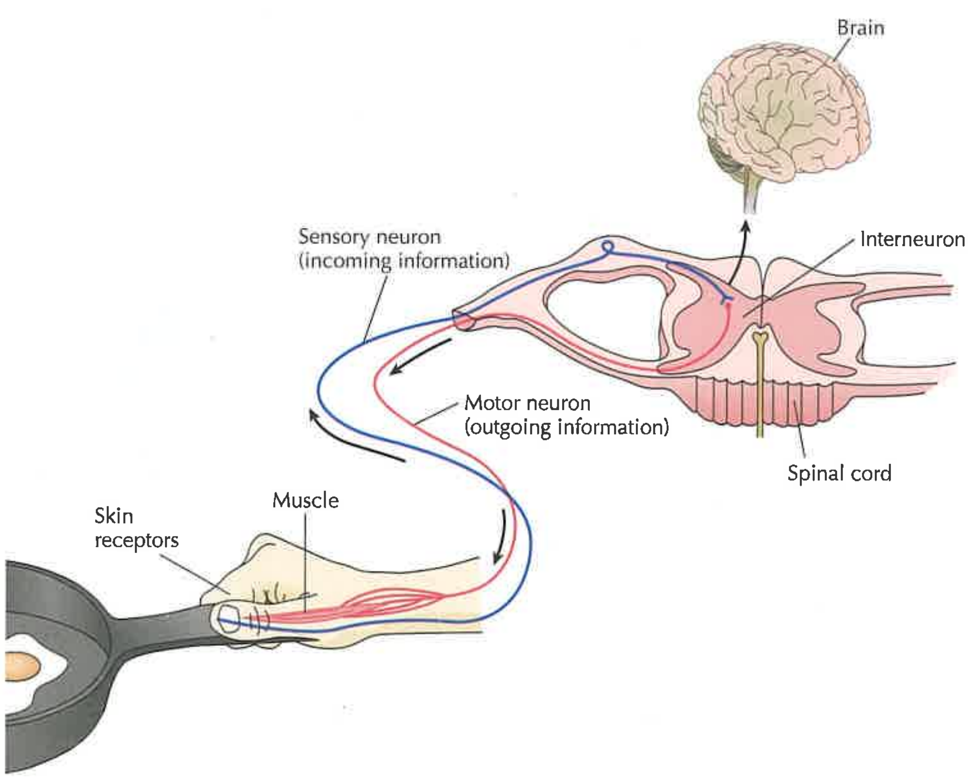


Figure 2.2 ***The workings of the spinal cord*** In a simple reflex arc, a sensory receptor initiates a neural impulse that travels to the spinal cord. The signal then travels back to the appropriate muscle, which then contracts. Action is automatic and immediate in a reflex because the signal only travels as far as the spinal cord before action is initiated, not all the way to the brain. The brain is later "notified" of the action when the spinal cord sends along the message.

sensory information to the brain, that you actually experience the sensation called *pain*. If the top of your spinal cord were severed, you would not feel pain — or pleasure. As you will discover in Chapter 4, the brain receives and interprets sensory messages, while the independently operating spinal cord allows us to react automatically and protect ourselves.

Peripheral Nervous System (PNS)

Peripheral Nervous System (PNS) *All nerves and neurons outside the brain and spinal cord. Its major function is to connect the CNS to the rest of the body.*

Somatic Nervous System (SNS) *A subdivision of the peripheral nervous system (PNS) that connects to sensory receptors and controls skeletal muscles.*

The **peripheral nervous system (PNS)** is just what it sounds like — the part that involves nerves *peripheral* to (or outside of) the brain and spinal cord. The chief function of the PNS is to carry information to and from the CNS. It links the brain and spinal cord to the body's sense receptors, muscles, and glands.

The PNS is subdivided into the somatic nervous system and the autonomic nervous system. The **somatic nervous system (SNS)** (also called the skeletal nervous system) consists of all the nerves that connect to sensory receptors and control skeletal muscles. The name comes from the term soma, which means "body," and the somatic nervous system plays a key role in communication throughout the entire *body*. In a kind of "two way street," the somatic nervous system first carries sensory information to the CNS, and then carries messages from the CNS to skeletal muscles. When you hear a question from your instructor and then raise your hand to volunteer an answer, it is chiefly due to your *somatic nervous system*.

Autonomic Nervous System (ANS) *Subdivision of the peripheral nervous system (PNS) that controls involuntary functions, such as heart rate and digestion. It is further subdivided into the sympathetic nervous system, which arouses, and the parasympathetic nervous system, which calms.*

Sympathetic Nervous System *Subdivision of the autonomic nervous system (ANS) responsible for arousing the body and mobilizing its energy during times of stress; also called the "fight or flight" system.*

Parasympathetic Nervous System *Subdivision of the autonomic nervous system (ANS) responsible for calming the body and conserving energy.*

Although the somatic system can help you respond to your college instructor's questions, it cannot make your pupils dilate or your heartbeat respond to the attractive classmate sitting beside you. For this, you need the other subdivision of the PNS known as the **autonomic** (or self-governing) **nervous system (ANS)**. The ANS is responsible for *involuntary* tasks, such as heart rate, digestion, pupil dilation, and breathing. One function of the ANS is to maintain *homeostasis*, the body's steady state of normal functioning. It does this by regulating the endocrine glands, the heart muscle, and the smooth muscles of the blood vessels and internal organs

The autonomic nervous system is itself further divided into two branches, the **sympathetic** and **parasympathetic.** These tend to work in opposition to each other to regulate the functioning of such target organs as the heart, the intestines, and the lungs (Figure 2.3). A convenient, if somewhat oversimplified, distinction is that the sympathetic branch arouses the body for action (often called the "fight or flight" response), whereas the parasympathetic branch relaxes it. It's important to note, however, that these two systems are not an either/or arrangement. Like two children

The fight-or-flight response of the sympathetic nervous system is activated in both of these animals.

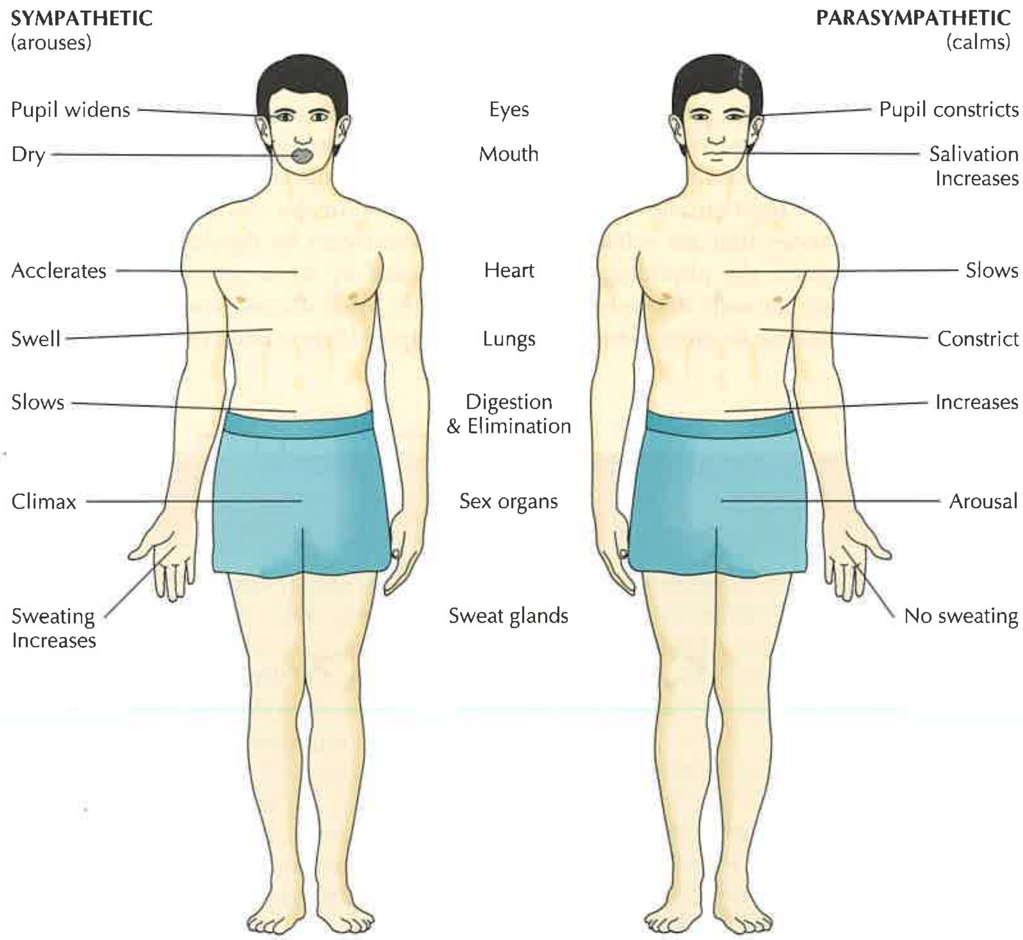


Figure 2.3 ***Actions of the autonomic nervous system (ANS).*** This figure illustrates the chief functions of the parasympathetic and sympathetic branches of the ANS.

on a teeter-totter, one will be up while the other is down, but they essentially balance each other out. If either one of them truly took over, you would die. Your heart would either slow down and stop (parasympathetic complete dominance), or speed out of control and stop (sympathetic system complete dominance).

The *parasympathetic nervous system* dominates when you are in a relaxed, low-stress physical and mental state — when you calmly smell the roses in your garden. Its major task is to conserve energy by slowing your heart rate, lowering your blood pressure, and increasing your digestive and eliminative processes. It is definitely healthier to have the parasympathetic system dominant.

During stressful times, either mental or physical, the *sympathetic nervous system* dominates. If you noticed a dangerous snake coiled around the base of the rose bush, your sympathetic nervous system would increase your heart rate, respiration, and blood pressure, stop your digestive and eliminative processes, and cause several hormones, such as epinephrine and cortisol to be released into the bloodstream. The net result of sympathetic activation is to get more oxygenated blood and energy to the skeletal muscles, thus allowing you to cope with the stress-to "fight or flight." (Study tip: One way to differentiate the two subdivisions of the ANS is to imagine yourself jumping out of an airplane. When you initially jump, your *sympathetic* nervous system would be in charge. When your "para" chute opens, your "para"sympathetic nervous system also "opens" to help calm you and return normal functioning.)

Can you see how the fight-flight system provides an adaptive, evolutionary advantage? At the beginning of human evolution, when we faced a dangerous bear or aggressive human intruder, there were only two reasonable responses — fight or flight! The automatic mobilization of bodily resources and increased energy gained through activation of the sympathetic nervous system had significant survival value. Today, we have the same autonomic responses as our ancient ancestors, but our world is quite different. Now when we face stressful situations, we rarely respond by taking physical action. If our boss yells at us or makes unreasonable demands, we've learned not to fight or take flight. We have little use for the increased heart rate and stress hormones that are released into the bloodstream by the autonomic nervous system. In fact, the physiological changes caused by stress-activated sympathetic responses are actually detrimental to our health. We'll discuss stress and the fight-or-flight response in more detail in the next chapter (Stress and Health Psychology).

Check & Review

AN OVERVIEW OF THE NERVOUS SYSTEM

Neuroscience is an interdisciplinary field that studies how biological processes, especially activity in the brain and nervous system, relate to behavior. The **central nervous system** is composed of the brain and the spinal cord. The spinal cord is the communications link between the brain and the rest of the body below the neck. It is involved in all voluntary and reflex responses of the body below the neck.

The **peripheral nervous system** includes all nerves going to and from the brain and spinal cord. Its two major subdivisions are the **somatic nervous system** and the **autonomic nervous system**.

The somatic nervous system includes all nerves carrying incoming sensory information and outgoing motor information to and from the sense organs and skeletal muscles. The autonomic nervous system includes the nerves outside the brain and spinal cord that maintain normal functioning of glands, heart muscle, and the smooth muscle of blood vessels and internal organs.

The autonomic nervous system is further divided into two branches, the **parasympathetic** and the **sympathetic**, which tend to work in opposition to one another. The parasympathetic nervous system normally dominates when a person is relaxed. The sympathetic nervous system dominates when a person is under physical or mental stress. It mobilizes the body for fight or flight by increasing heart rate and blood pressure and slowing digestive processes.

Questions

1. The nervous system is separated into two major divisions: the ________ nervous system, which consists of the brain and spinal cord, and the ________ nervous system, which consists of all the nerves going to and from the brain and spinal cord.
2. The autonomic nervous system is subdivided into two branches called the ________ and ________ systems. (a) automatic, semiautomatic; (b) somatic, peripheral; (c) afferent, efferent; (d) sympathetic, parasympathetic
3. If you are startled by the sound of a loud explosion, the ________ nervous system will become dominant. (a) peripheral; (b) somatic; (c) parasympathetic; (d) sympathetic
4. What is the major difference between the sympathetic and parasympathetic nervous systems?

Answers to Questions can be found in Appendix B.

What are neurons, and how do they convey information throughout the body?

Neuron *Individual nerve cell responsible for processing, storing, and transmitting information throughout the body.*

Neurons as the Basic Building Blocks: We Are Our Neurons

Your brain and the rest of your nervous system essentially consist of **neurons**, individual cells that communicate information throughout the body, as well as within the brain. Each neuron is a tiny information processing system with thousands of connections for receiving and sending signals to other neurons. Although nobody knows for sure, one well-educated guess is that a human has 100 billion to 150 billion neurons, about the same number as there are stars in our galaxy.

Neurons are held in place and supported by **glial cells** (from the Greek for "glue"). They surround neurons, control their supply of chemicals, perform clean-up tasks, and even insulate one neuron from another so their neural messages do not get scrambled. Although glial cells greatly outnumber neurons and interact in ways that make information transfer and the brain more efficient, they are only supporting players. The "star" is the neuron. Most neuroscientists believe that all behavior — every move you make, every thought you have, and every heartbeat — ultimately depends on what happens at the level of the neuron.

Glial Cells *Nervous system cells that provide structural, nutritional, and other support for the neuron; also called* glia *or* neuroglia.

Basic Parts of a Neuron

Just as no two people are alike, no two neurons are exactly alike, although most share three basic features: dendrites, the cell body, and an axon (Figure 2.4). Information from other cells normally enters the neuron via numerous dendrites, passes through the cell body, and is transmitted to other cells by the axon.

Dendrites look like leafless branches of a tree; in fact, the word *dendrite* means "little tree" in Greek. Dendrites act like antennas, receiving electrochemical information from other neurons and transmitting it to the cell body. Current research suggests that dendrites not only send information to the cell body but also relay information from the cell body back down to the ends of the dendrites, which modifies the dendrites' responses to further signals (Sejnowski, 1997). Each neuron may have hundreds or thousands of dendrites.

From the many dendrites, information flows into the cell body and then to the axon. The **cell body**, or *soma*, contains the biochemical machinery that keeps the neuron alive. The **axon** (from the Greek word for "axle") is a long, tubelike structure specialized for carrying information away from the cell body, toward other neurons or to muscles and glands. The **myelin sheath**, a white, fatty coating derived from glial cells, surrounds the axons of some neurons, helping to insulate and speed neural messages. (Study tip: To remember how information travels through the neuron, think of the three parts in reverse alphabetical order: *d*endrite, cell *b*ody, *a*xon.)

Dendrites *Branching neuron structures that receive neural impulses from other neurons and convey impulses toward the cell body*

Cell Body *The part of the neuron that contains the cell nucleus, as well as other structures that help the neuron carry out its functions.*

Axon *A long, tubelike structure that conveys impulses away from the neuron's cell body toward other neurons or to muscles or glands*

Myelin [MY-uh-lin] Sheath *A layer of fatty insulation wrapped around the axon of some neurons, which increases the rate at which nerve impulses travel along the axon.*

How Neurons Communicate: An Electrical and Chemical Language

The basic function of neurons is to transmit information throughout the nervous system. Neurons "speak" to each other or, in some cases, to muscles or glands, in a

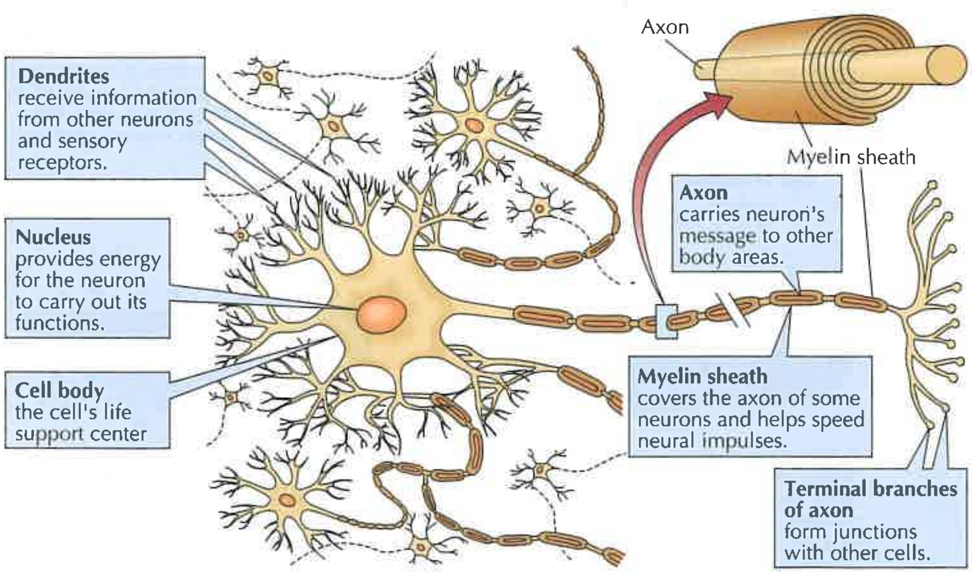


Figure 2.4 ***The structure of a neuron.*** Information enters the neuron through the dendrites, is integrated in the cell body, and then transmitted to other neurons via the axon. The myelin sheath is a fatty insulation wrapping around the axon that greatly increases the speed of the neural impulse.

type of electrical and chemical language. We begin our discussion by looking at communication *within* the neuron itself. Then we explore how communication occurs *between* neurons.

Action Potential *A neural impulse that carries information along the axon of a neuron. The action potential is generated when positively charged ions move in and out of channels in the axon's membrane.*

Action Potential — How a Neuron "Talks" to Itself

The process of neural communication begins within the neuron itself, when messages are received by the dendrites and cell body. These messages are passed along the axon in the form of a neural impulse or **action potential** (Figure 2.5).

Because the neural impulse that travels down the axon is chemical, the axon does not transmit it in the same way a wire conducts an electrical current. The movement down the axon actually results from a change in the permeability of the cell membrane. Picture the axon as a tube of membranous tissue filled with chemicals. This tube is floating in a sea of still more chemicals. The chemicals both inside and outside the tube are *ions,* molecules that carry an electrical charge, either positive or negative.

When the neuron is inactive, or *resting,* it is said to be *polarized.* That is, the fluid inside has mostly negatively charged ions, whereas the fluid outside the axon is the "polar opposite" — primarily positive. When the neuron is activated by sufficient stimulation from other neurons or sensory receptors, the electrical potential between the inside and the outside of the cell changes. A sudden inflow of positive ions *depolarizes* that first, small section of the axon, so that it becomes "overly positive." This change then causes nearby ion channels to open and also become depolarized, and then the next channel, and the next. In short, a chemical chain reaction occurs. The neural impulse (or action potential) travels down the axon, one section at a time, until it reaches the end of the axon.

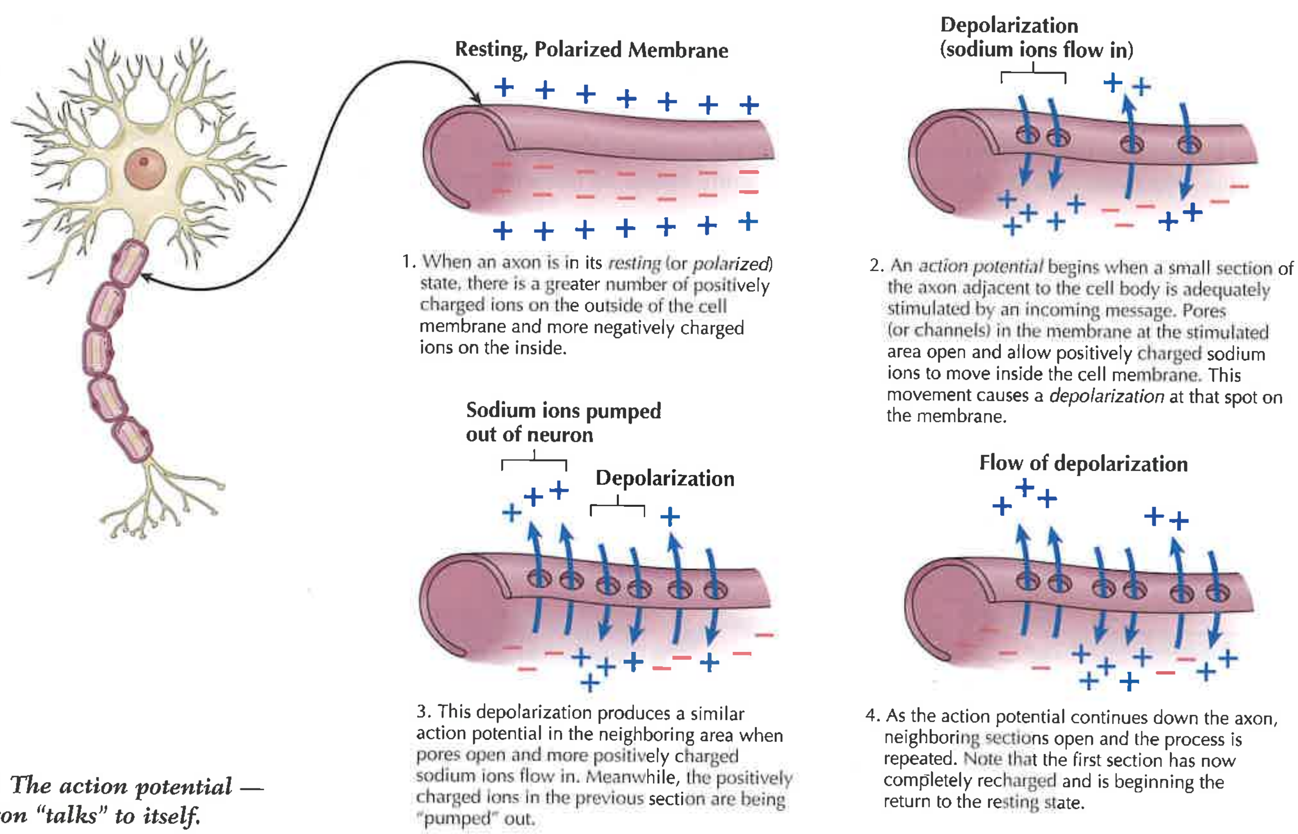


Figure 2.5 ***The action potential — How a neuron "talks" to itself.***

How fast does a neural impulse travel? Actually, a nerve impulse moves slowly, much more slowly than electricity through a wire. Because electricity travels by a purely physical process, it can move through a wire at 97 percent of the speed of light, approximately 300 million meters per second. A neural impulse, on the other hand, travels along a bare axon at only about 10 meters per second.

Some axons, however, are enveloped in fatty insulation, the myelin sheath, which greatly increases the speed of an action potential. The myelin blankets the axon, with the exception of periodic *nodes,* points at which the myelin is very thin or absent (see again Figure 2.4). In a myelinated axon, the speed of the nerve impulse increases because the action potential jumps from node to node rather than traveling point by point along the entire axon. An action potential in a myelinated axon moves about 10 times faster than in a bare axon, at over 100 meters per second. The importance of the myelin sheath becomes apparent when it is destroyed in certain diseases such as multiple sclerosis. The greatly slowed rate of conduction of action potentials affects the person's movement and coordination.

It is important to remember that once the action potential is started, it continues. There's no such thing as a "partial" action potential. Similar to the firing of a bullet from a gun, the action potential fires either completely or not at all. This is referred to as the *all-or-none law.* Immediately after a neuron fires, it enters a brief *refractory period* where it cannot fire again. During the refractory period, the neuron *repolarizes*: The resting balance is restored with negative ions inside and positive ions outside. Now the neuron is free to fire again.

Neurotransmitters — How Neurons "Talk" to One Another

Now that you understand the basic structure of the neuron and how the neuron communicates with itself (by passing electrochemical messages along its length), we can examine how neurons communicate with other neurons, which is primarily through neurotransmitters.

Communication between one neuron and the next begins at the junction between neurons, known as the **synapse**. This synaptic juncture includes the axon terminal of the sending neuron, the tiny space between neurons (the *synaptic gap*), and the covering membrane of the receiving neuron (Figure 2.6). When the action potential reaches the knoblike terminals at the axon's end, it causes tiny sacs, called *synaptic vesicles,* to open and release a few thousand molecules of a chemical substance known as a **neurotransmitter**. These molecules then flow across the synaptic gap. If the adjacent, receiving neuron receives sufficient neurotransmitter stimulation, a follow-up action potential is initiated along its membrane and communication is "successful."

Synapse [SIN-aps] *The junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron; during an action potential, chemicals called neurotransmitters are released and flow across the synaptic gap*

Neurotransmitter *Chemicals manufactured and released by neurons that alter activity in other neurons.*

Although communication is said to be successful when the neurotransmitter reaches its target cell, it is important to note that action potentials do not always occur in the receiving neuron. Neurotransmitters have either an *excitatory* or *inhibitory* effect on their target cells.

Think of the case of a sculptor welding the final touches on to her masterpiece. As the heat soaks through her glove, she almost drops the very expensive part. However, this excitation is counteracted by inhibition, supplied by her brain. Recognizing that dropping the piece would be a very costly mistake, her brain sends information to the spinal cord inhibiting the withdrawal reflex. When neurotransmitters are excitatory, they make the target neuron more likely to fire an action potential; when they are inhibitory, they make the target neuron less likely to fire. In short, neurotransmitters carry one of two messages — "fire" or "don't fire."

Both types of messages are critical to your survival. Just as driving a car requires both an accelerator and brakes, your body needs both "on" and "off" neural switches. Your nervous system manages an amazing balancing act between *overexcitation*, leading to seizures, and *underexcitation*, leading to coma and death. In fact, poisons, such as strychnine, work by disabling many inhibitory messages, leading to overexcitation and uncontrollable, possibly fatal convulsions.

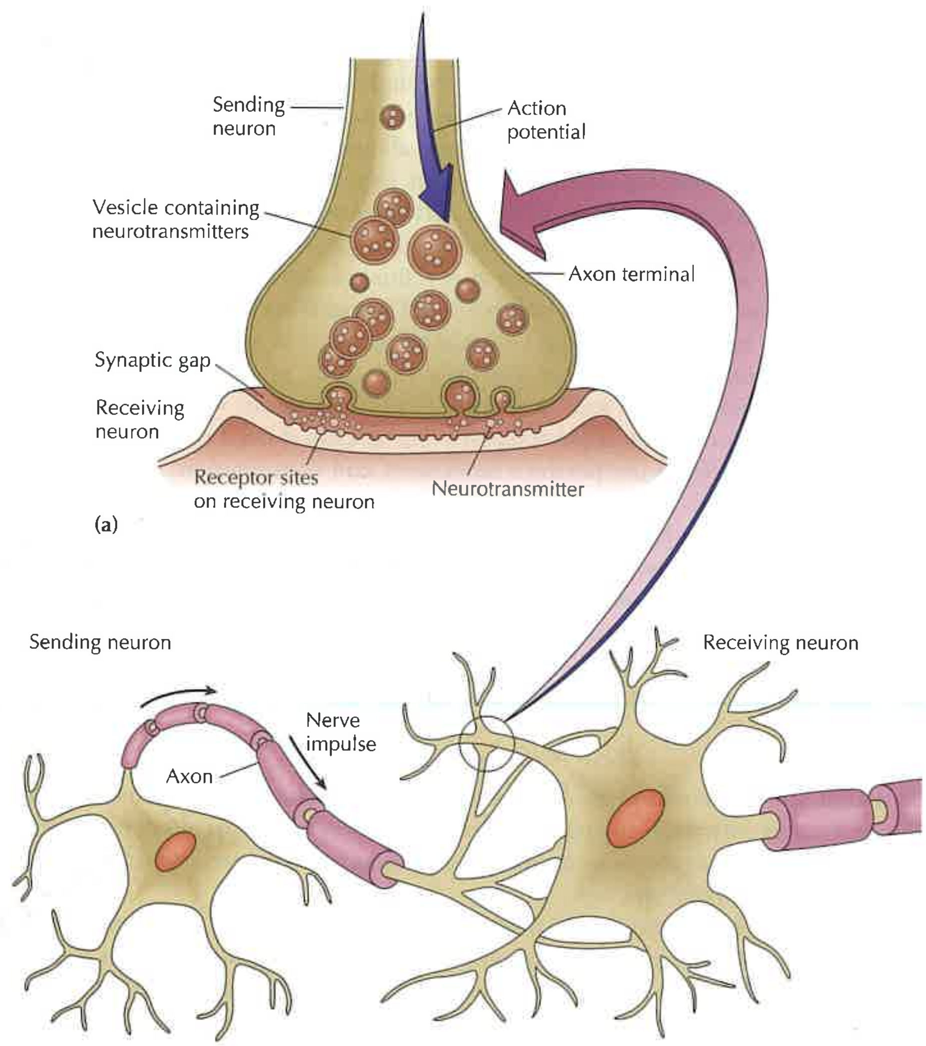


Figure 2.6 ***Neurotransmitters — How neurons "talk" to one another.*** (a) In this schematic view of a synapse, neurotransmitter chemicals are stored in small synaptic vesicles at the end of the axon. When action potentials reach the axon terminal, they stimulate the release of neurotransmitter molecules into the synaptic gap. The neurotransmitter chemicals then travel across the synaptic gap, and bind to receptor sites on the dendrites or cell body of the receiving neuron. (b) If the receiving neuron is sufficiently stimulated, a new action potential is generated and communication is successful.

Chemical Messengers in the Nervous System: Neurotransmitters, Endorphins, and Hormones

Our brains and nervous systems would be lifeless without communication. The major chemical messengers responsible for communication are the *neurotransmitters*, *endorphins*, and *hormones*.

Neurotransmitters

Researchers have discovered hundreds of substances known or suspected to be neurotransmitters. Some neurotransmitters regulate the actions of glands and muscles; others promote sleep or stimulate mental and physical alertness; others affect learning and memory; and still others affect motivation, emotions, and psychological disorders, including schizophrenia and depression. Table 2.1 lists a few of the better-understood neurotransmitters and their known or suspected effects.

Neurotransmitters and Disease

One of the many advantages of studying your brain and its neurotransmitters is an increased understanding of your own or others' medical problems and their treatment. For example, do you remember why actor Michael J. Fox retired from his popular TV sitcom, *Spin City*? It was because of muscle tremors and movement problems related to a poorly understood condition called *Parkinson's disease* (PD). As Table 2.1 shows, the neurotransmitter *dopamine* is a suspected factor in PD, and its

TABLE 2.1 HOW NEUROTRANSMITTERS AFFECT US

Neurotransmitter	Known or Suspected Effects
Serotonin	Affects mood, sleep, appetite, sensory perception, temperature regulation, pain suppression, impulsivity, and aggression; may play a role in some psychological disorders, such as depression
Acetylcholine (ACh)	Affects muscle action, cognitive functioning, memory, REM (rapid-eye-movement) sleep, emotion. Suspected role in Alzheimer's disease
Dopamine (DA)	Affects movement, attention, memory, learning, and emotion. Plays a role in both schizophrenia and Parkinson's disease.
Norepinephrine (NE) (or noradrenaline)	Affects learning, memory, dreaming, emotion, waking from sleep, eating, alertness, wakefulness, reactions to stress
Epinephrine (or adrenaline)	Affects emotional arousal, memory storage, and metabolism of glucose necessary for energy release
GABA (gamma aminobutyric acid)	Neural inhibition in the central nervous system; Tranquilizing drugs act on GABA to decrease anxiety

symptoms are reduced with L-dopa (levodopa), a drug that increases dopamine levels in the brain (Brundin et al., 2000; Diederich & Goetz, 2000).

Interestingly, when some Parkinson's patients are adjusting to L-dopa and higher levels of dopamine, they may experience symptoms that mimic schizophrenia, a serious psychological disorder that disrupts thought processes and produces delusions and hallucination. As you will see in Chapter 15, excessively high levels of *dopamine* are a suspected contributor to some forms of *schizophrenia*, and when patients take antipsychotic drugs that suppress dopamine, their symptoms are sometimes reduced or even eliminated (Laruelle, Abi-Dargham, Gil, Kegeles, & Innis, 1999; Reynolds, 1999). In sum, *decreased* levels of dopamine are associated with Parkinson's disease, whereas *increased* levels are related to some forms of schizophrenia.

Another neurotransmitter, *serotonin* (Table 2.1), may also be involved in the depression that often accompanies Parkinson's disease. Although some researchers believe Parkinson's patients become depressed in reaction to the motor disabilities of the disorder, others think the depression is directly related to lower levels of serotonin (Schapira, 1999). As Chapter 15 discusses, certain forms of depression are indeed related to lowered levels of serotonin. And popular antidepressant drugs, like *Prozac* and *Zoloft*, work by boosting levels of available serotonin (Margolis & Swartz, 2001; Tauscher et al., 1999; Wegerer et al., 1999). Even without medication, serotonin levels increase after successful psychotherapy for depression (Bransfod, 2000). (Recall from Chapter 1 that scientific research is "circular and cumulative" and that basic and applied research often overlap. Research with Parkinson's disease demonstrates these principles.)

Why study neurotransmitters? Actor Michael J. Fox suffers from Parkinson's disease, which involves a decrease in cells that produce dopamine. In this photo, he is testifying before a U.S. subcommittee to urge increased funding for research on Parkinson's and other medical conditions.

Neurotransmitters, Poisons, and Mind-Altering Drugs

An understanding of neurotransmitters explains not only the origin of certain diseases and their pharmaceutical drug treatments but also how poisons, such as snake venom, and mind-altering drugs, such as nicotine, alcohol, caffeine, and cocaine, affect the brain (see also Chapter 5).

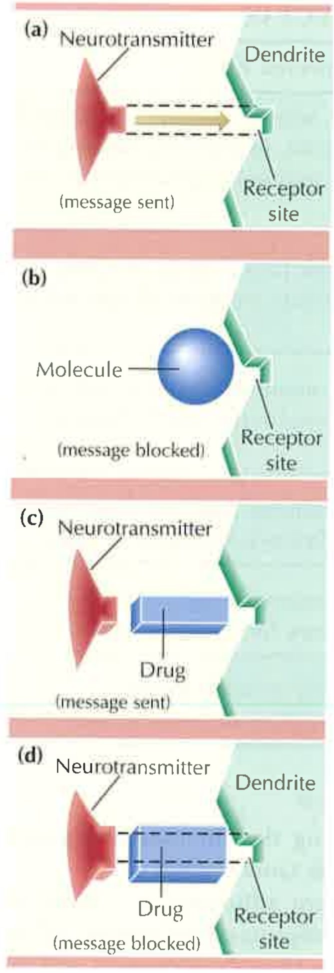


Figure 2.7 ***Receptor sites.*** (a) Receptor sites on the dendrite recognize neurotransmitters because of their three-dimensional shape. (b) Molecules without the correct shape will not fit the receptors and therefore will not stimulate the dendrite. (c) Some *agonist* drugs, like nicotine, are similar enough in structure to a certain neurotransmitter (in this case, acetylcholine) that they mimic its effects on the receiving neuron. (d) Some *antagonist* drugs, like curare, block the action of neurotransmitters (again, acetylcholine) by filling a receptor site and thus not allowing the neurotransmitter to stimulate the receptor.

Most poisons and drugs act at the synapse by replacing, decreasing, or enhancing the amount of neurotransmitter. Given that transmission of messages *between* neurons is chemical, many chemicals that we ingest can significantly affect neurotransmission. They can do this because their molecules have shapes similar to various neurotransmitters.

Neurotransmitters communicate with other neurons by binding to receptor sites in much the same way that a key fits into a lock. Just as different keys have distinct three-dimensional shapes, various chemical molecules, including neurotransmitters, have distinguishing three-dimensional characteristics. If a neurotransmitter has the proper shape, it will bind to the receptor site (Figure 2.7a and 2.7b) and thereby influence the firing of the receiving cell.

Some drugs, called *agonists* (from the Greek *agon,* meaning "contest, struggle"), mimic or enhance the action of neurotransmitters (Figure 2.7c). For example, both the poison in the black widow spider and the nicotine in cigarettes have a molecular shape similar enough to the neurotransmitter *acetylcholine* (*ACh*) that they can mimic its effect, including increasing the heart rate. Amphetamines have a similar excitatory effect by mimicking the neurotransmitter *norepinephrine.*

In contrast, *antagonist* drugs (from the Greek word meaning "a member of the opposing team"), work by opposing or blocking neurotransmitters (Figure 2.7d). Most snake venom and some poisons, like the lethal drug *curare* that South American hunters use, act as antagonists to ACh. Because ACh is vital in muscle action, blocking it paralyzes muscles, including those involved in breathing, which can be fatal.

Neurotransmitters, poisons, and drugs. Most poisons and psychoactive drugs work by replacing, decreasing, or increasing the amount of certain neurotransmitters. The neurotransmitter acetylcholine (ACh) is responsible for muscular contraction, including the muscles responsible for breathing. The poison curare blocks the action of ACh and South American hunters sometimes apply it to the tips of blowgun darts or arrows to paralyze their prey. In contrast, nicotine in cigarettes increases the effects of ACh and smokers experience increased heart and respiration rates.

Endorphins

In addition to neurotransmitters, the body also has chemical messengers called *endogenous opioid peptides*, more commonly known as **endorphins**. These chemicals produce effects similar to those of opium-based drugs such as morphine — they reduce pain and promote pleasure. (Some endorphins work as neurotransmitters, but most act as *neuromodulators* that increase or decrease [modulate] the effects of neurotransmitters.)

Endorphins [en-DOR-fins] *Chemical substances in the nervous system that are similar in structure and action to opiates and are involved in pain control, pleasure, and memory*

Endorphins were discovered in the early 1970s, when Candace Pert and Soloman Snyder (1973) were doing research on morphine, a pain-relieving and mood-elevating opiate derived from opium, which is made from poppies. They found that the morphine was taken up by specialized receptors in areas of the brain linked with mood and pain sensations.

But why would the brain have special receptors for morphine — a powerfully addicting drug? Pert and Snyder reasoned that the brain must have its own internally produced, or *endogenous*, morphinelike chemicals. They later confirmed that such chemicals do exist and named them *endorphins* (a contraction of *endogenous* [self-produced] and *morphine*). The brain evidently produces its own naturally occurring chemical messengers that elevate mood and reduce pain, as well as affect memory, learning, blood pressure, appetite, and sexual activity (Chapters 3, 4, 11, and 12). Endorphins also help explain why soldiers and athletes continue to fight or play the game despite horrific injuries.

Hormones

The neural system communicates through the production and circulation of *neurotransmitters, endorphins,* and **hormones**. On receiving signals from the brain, glands within the **endocrine system** release these chemicals into the bloodstream, which circulates them throughout the body. Like neurotransmitters, hormones affect the nervous system, and sometimes the same chemical functions as both a hormone and a neurotransmitter. But unlike neurotransmitters that are released immediately adjacent to the cells they are to excite or inhibit, hormones are released into the blood, thus taking more time to diffuse throughout the body.

Hormones *Chemicals manufactured by endocrine glands and circulated in the bloodstream to produce bodily changes or maintain normal bodily functions*

Endocrine [EN-doh-krin] System *A system of glands located throughout the body that secrete hormones into the bloodstream*

The nervous system and the endocrine system work hand in hand to direct our behavior and maintain our body's normal functioning. This interplay between the two systems is most evident in the fight-or-flight response of the sympathetic branch of the ANS, discussed earlier. The major functions of many endocrine glands, including the pituitary, the thyroid, the adrenals, and the pancreas (Figure 2.8), is to help the ANS respond to emergencies and maintain *homeostasis*, establishing a balance and normal functioning of bodily processes.

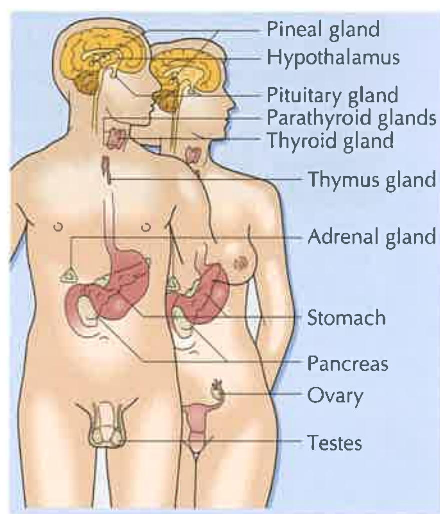


Figure 2.8 ***The endocrine system.*** The major endocrine glands are shown along with some internal organs to help you locate the glands.

In times of emergency, chemical messengers travel along two paths — the ANS and the pituitary gland. The pituitary gland is sometimes referred to as the "master gland" because it releases a large variety of hormones throughout the body, which stimulate action in the other endocrine glands. In response to stressful situations, the pituitary sends messages to the adrenal glands (organs that are right above the kidneys). The adrenal glands then release *cortisol*, which boosts energy and blood sugar levels, *epinephrine* (commonly called *adrenaline*), and *norepinephrine*. When these adrenal hormones are released into your system, they activate the sympathetic branch of the ANS — thus preparing your body for "fight or flight."

Hormones produced by the endocrine system also help preserve *homeostasis* (or balance). They accomplish this by maintaining the tissue and blood levels of certain chemicals within a specific range. For example, sugar is a chemical that the body needs to function normally. But if too much sugar enters the bloodstream, the pancreas (an endocrine gland) secretes the hormone *insulin* to lower the blood sugar level to a more normal, safer level. When the insulin level is extremely low, as in people with diabetes, blood sugar levels may be three or more times higher than normal.

Abnormally high levels of blood sugar can lead to dangerous changes in body tissues, including diabetes-related blindness.

Hormones also influence our growth, reproduction, moods, and response to stress. As you will see in a later section of this chapter, the amount of sex hormone (testosterone) present during prenatal development even determines whether the fetus develops a penis and scrotum or a clitoris and labia. The "sex hormones" are discussed further in Chapter 11, whereas *melatonin*, discovered somewhat recently, is explored in Chapter 5.

Before closing, we want to emphasize that our discussion of neurotransmitters, endorphins, and hormones is greatly simplified. Diseases like Parkinson's, schizophrenia, depression, and diabetes are complex and involve interacting, multiple causes and treatment. Similarly, neurotransmitters, endorphins, and hormones all play multiple, overlapping roles. However, even this limited coverage gives you a foundation for understanding the brain and nervous system — topics in our upcoming section.

Check & Review

NEURONS, NEURAL COMMUNICATION, AND CHEMICAL MESSENGERS

Neurons are cells that transmit information throughout the body. They have three main parts: **dendrites**, which receive information from other neurons; the **cell body**, which provides nourishment and "decides" whether the axon should fire; and the **axon**, which sends along the neural information. **Glial cells** support and provide nutrients for neurons in the central nervous system (CNS).

The axon is specialized for transmitting neural impulses, or **action potentials**. During times when no action potential is moving down the axon, the axon is at rest. The neuron is activated, and an action potential occurs, when the charge within the neuron becomes more positive than the charge outside the cell's membrane. Action potentials travel more quickly down myelinated axons because the **myelin sheath** serves as insulation.

Information is transferred from one neuron to another at synapses by chemicals called **neurotransmitters**. Neurotransmitters bind to receptor sites much as a key fits into a lock, and their effects can be *excitatory* or *inhibitory*. Most psychoactive drugs affect the nervous system by acting directly on receptor sites for specific neurotransmitters or by increasing or decreasing the amount of neurotransmitter that crosses the **synapse**.

In addition to neurotransmitters, there are two other important chemical messengers — endorphins and hormones. Neuromodulators (such as **endorphins**) — increase or decrease the effects of neurotransmitters. **Hormones** are released from glands in the **endocrine system** directly into the bloodstream. They regulate levels of critical chemicals in the body.

Questions

1. Draw and label the three major parts of a neuron and the myelin sheath.
2. An impulse travels through the structures of the neuron in the following order: (a) cell body, axon, dendrites; (b) cell body, dendrites, axon; (c) dendrites, cell body, axon; (d) axon, cell body, dendrites
3. Chemical messengers that are released by axons and stimulate dendrites are called ________. (a) chemical messengers; (b) neurotransmitters; (c) synaptic transmitters; (d) neuromessengers
4. Explain how neurotransmitters, endorphins, and hormones carry messages throughout the body.

Answers to Questions can be found in Appendix B.

A TOUR THROUGH THE BRAIN

Having covered basic, biological foundations (neurons, neurotransmitters, divisions of the neural system, and hormones), we come now to the "main event" of neuroscience — the brain itself. We began this chapter with the tale of Phineas Gage and his horrible brain injury because it emphasized the vital importance of this relatively tiny three-pound organ that sits atop your shoulders. Who would you be without your brain? Without its lower-level structures, you would not be alive. Without your cortex, you would not be capable of thinking, speaking, or perceiving. And as we saw with Phineas Gage, when the cortex is damaged, we lose much of what we define as "self."

We begin our study of the brain with a look at the tools neural cartographers have used to study and map it. Then we start our exploration of the brain at the lower end, where the spinal cord joins the brainstem, and move upward toward the cerebral cortex. Note as we move from the brainstem to the cortex that the functions of brain structures change from regulating "lower," basic functions like survival to controlling "higher," more complex mental processes such as thinking.

Tools for Exploration: Mapping the Brain

What are the best tools for studying the brain?

The earliest explorers of the brain dissected the brains of deceased humans and conducted experiments on other animals using *lesioning techniques* (systematically destroying brain tissue to study the effects on behavior and mental processes) (Table 2.2). By the mid-1800s, this early research had produced a basic map of the peripheral nervous system and some areas of the brain. Early researchers also relied on clinical observations and case studies of living people. Tragic accidents, as in the case of Phineas Gage, and diseases or other brain disorders also offered valuable insights into brain functioning. The story of Phineas Gage might have ended with his death were it not for his doctor, John Harlow (1848), who wrote a detailed account of the accident. Years later, when he learned of Gage's death, he also petitioned Phineas's family to exhume the body and allow him to keep Phineas Gage's skull as a medical record. Today, both the skull and the tamping iron that had been buried with Gage are on display at Harvard University's Warren Anatomical Medical Museum.

Modern researchers still use dissection, lesioning, clinical observation, and case studies, but they also employ other techniques such as electrical recording and electrical brain stimulation. *Electrodes* (tiny electrified disks or wires) pasted to the skin or skull translate brain waves (electrical energy from the brain) to produce wavy lines on a moving piece of paper; this report is called an *electroencephalogram* (*electro-* means "electrical," *encephalon* means "brain," and *gram* means "record"). The electroencephalograph (EEG) is a major research tool for studying changes in brain waves during sleep and dreaming. For even more precise information, researchers can use *electrical stimulation of the brain* (ESB). Electrodes are inserted into the brain to record the naturally occurring electrical activity of neurons or to stimulate certain areas with weak electrical currents.

In recent years, advances in brain science have led to exciting, new techniques, including various types of brain-imaging scans (see again Table 2.2). Most of these methods are relatively *noninvasive*. That is, they are performed without breaking the skin or entering the body. They can be used both in clinical settings to examine suspected brain damage and disease, and in laboratory settings to study brain function during ordinary activities like sleeping, eating, reading, speaking, and so on (Goldman, Nahas, & George, 2000; Robertson et al., 2000). For example, computed tomography (CT) scans (a computer-enhanced series of X-rays of the brain) have been used to look for abnormalities in brain structures among people suffering from mental illness, whereas positron emission tomography (PET) scans map actual *activity* in the brain and can be used to pinpoint brain areas that handle various activities, such as singing or fist clenching, and even areas responsible for different emotions (Craik et al., 1999; Mayberg et al., 1999).

It is important to note that each method has its particular strengths and weaknesses, but all provide invaluable insights and information. We'll discuss findings from these research tools in upcoming chapters on sleep and dreaming (Chapter 5), memory (Chapter 7), thinking and intelligence (Chapter 8), and abnormal behavior and its treatment (Chapters 14 and 15).

Lower-Level Brain Structures: The Oldest Parts of the Brain

What are the lower-level structures of the brain, and what are their roles in behavior and mental processes?

Brain size and complexity vary significantly from species to species. Lower species such as fish and reptiles have smaller, less complex brains than do higher species

TABLE 2.2 TOOLS FOR STUDYING THE BRAIN

Method	Description	Sample Results
Brain dissection	Careful cutting and study of a cadaver brain to reveal structural details	Brain dissections of Alzheimer's disease victims often show identifiable changes in various parts of the brain (Chapter 7).
Ablation/lesions	Surgically removing parts of the brain (ablation), or destroying specific areas of the brain (lesioning), is followed by observation for changes in behavior or mental processes.	Lesioning specific parts of the rat's hypothalamus greatly affects its eating behavior (Chapter 12).
Clinical observations/ case studies	Observing and recording changes in personality, behavior, or sensory capacity associated with brain diseases or injuries	Damage to one side of the brain often causes numbness or paralysis on the body's opposite side; also Phineas Gage's injury and subsequent changes.
Electrical recordings	Using electrodes attached to a person or animal's skin or scalp, brain activity is recorded to produce an electroencephalogram.	Reveals areas of the brain most active during a particular task or changes in mental states, like sleeping and hypnosis (Chapter 5); also traces abnormal brain waves caused by brain malfunctions, like epilepsy or tumors
Electrical stimulation of the brain (ESB)	Using an electrode, a weak electric current stimulates specific areas or structures of the brain.	Penfield (1958) mapped the surface of the brain and found that different areas have different functions.

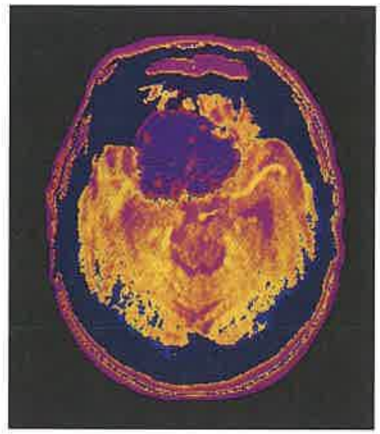
(Table continues)

Brain dissection. Structures of the brain can be examined by dissecting the brains of deceased people who donated their bodies for scientific study.

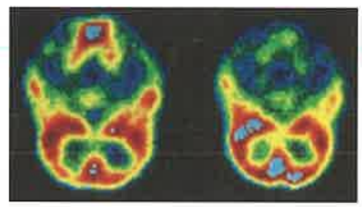
Electroencephalograph (EEG). Electrodes are attached to the patient's scalp, and the brain's electrical activity is displayed on a computer monitor or recorded on a paper chart.

TABLE 2.2 CONTINUED

Method	Description	Sample Results
Brain imaging	Studies intact, living brains by taking pictures	Reveals various brain structures, their functions, and changes associated with disease or injury
Types of images:		
• CT (computed tomography) scan	A computer that creates cross-sectional pictures of the brain reads X-rays directed through the brain at different angles; least expensive type of imaging and widely used in research	Reveals the effects of strokes, injuries, tumors, and other brain disorders
• PET (positron emission tomography) scan	Radioactive form of glucose is injected into the bloodstream; scanner records amount of glucose used in particularly active areas of the brain and produces computer-constructed picture of the brain	Originally designed to detect abnormalities, also used to identify brain areas active during ordinary activities (reading, singing, etc.)
• MRI (magnetic resonance imaging) scan	A high-frequency magnetic field is passed through the brain by means of electromagnets.	Produces high-resolution three-dimensional pictures of the brain useful for identifying abnormalities and mapping brain structures and function
• fMRI (functional magnetic resonance imaging) scan	A newer, faster version of the MRI that detects blood flow by picking up magnetic signals from blood that has given up its oxygen to activate brain cells	Indicates which areas of the brain are active or inactive during ordinary activities or responses (like reading or talking); also, shows changes associated with disorders



This false color CT scan used X rays to locate a brain tumor. The tumor is the deep purple mass at the top left.



PET scans and brain functions. In these two scans, the left one shows brain activity when the eyes are open, whereas the one on the right is with the eyes closed. Note the increased activity, red and yellow, in the occipital lobe (the top of the photo) when the eyes are open.

Magnetic resonance imaging (MRI). Note the fissures and internal structures of the cerebral cortex, as well as the cerebellum and the brain stem. The throat, nasal airways, and cerebrospinal fluid surrounding the brain are dark.

such as cats and dogs. The most complex brains belong to whales, dolphins, and higher primates such as chimps, gorillas, and humans. The billions of neurons that make up the human brain control much of what we think, feel, and do.

As we begin our tour of the brain, keep in mind that certain brain structures are specialized to perform certain tasks, a process known as **localization of function.** Don't, however, exaggerate the differences. Most parts of the brain perform integrating, overlapping functions. Figure 2.9 shows the major structures of the brain. You should refer to it as you read.

Localization of Function *Specialization of various parts of the brain for particular functions*

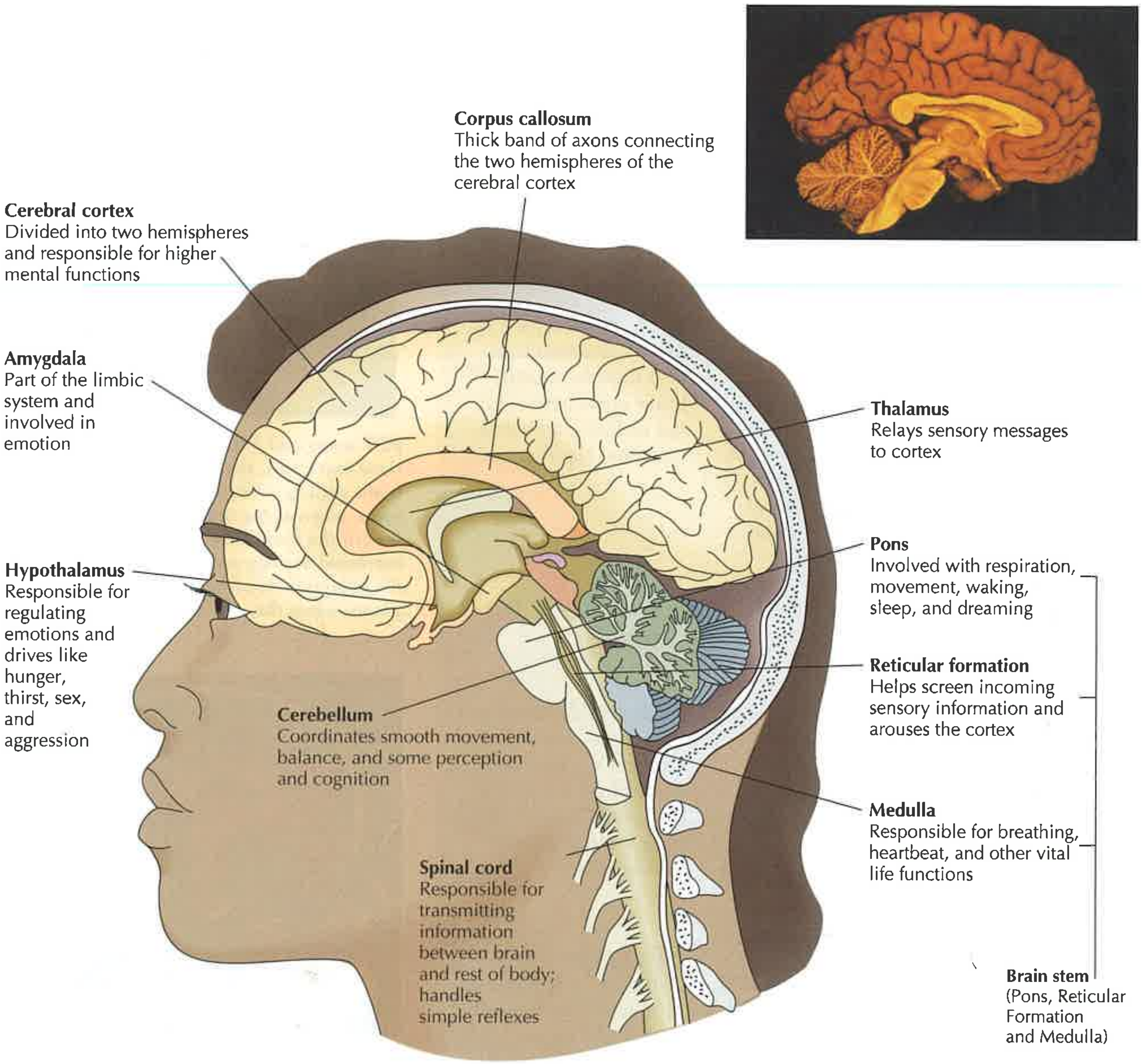


Figure 2.9 ***The human brain.*** If your brain were sliced down the center, lengthwise, it would look like the top right photo. Although you wouldn't be alive to read this, the drawing on the lower half of the page would depict what the inside surface of the left half of your brain would look like. It highlights key structures and some of their principal functions. As you read about each of these structures, you may find it helpful to keep this drawing in mind or to refer back to it as necessary.

The Brainstem

You are sleeping. Your eyes dart back and forth as you begin your last dream of the night. Your heart rate, blood pressure, and respiration increase as the dream gets more exciting. But then your dream is shattered by a buzzing alarm clock. All your automatic behaviors and survival responses in this scenario have been either controlled by or influenced by parts of the brainstem. The **brainstem** looks like its name. The lower-end "stem" is a continuation of the spinal cord, and the higher end lies deep within the brain. Three structures generally are associated with the brainstem — the pons, the medulla, and the reticular formation.

Messages to and from upper-level brain structures pass through two major structures in the brainstem — the pons and medulla. The **pons**, located in the upper portion of the brainstem, is involved in respiration, movement, sleeping, waking, and dreaming (among other things). The **medulla** is below the pons, at the bottom of the brainstem and just above the spinal cord. Its functions are similar to those of the pons. Because the medulla is essentially an extension of the spinal cord, many nerve fibers pass through it carrying information to and from the brain. The medulla also contains many nerve fibers that control automatic bodily functions such as respiration and heart rate. Damage to the medulla can lead to failure of bodily functions and death. This is the area of the brain that was damaged when Senator Robert Kennedy was assassinated in 1968.

Running through the core of the brainstem and extending upward is the **reticular** (netlike) **formation** (RF). This dense, finger-shaped network of neurons filters incoming sensory information and arouses the higher centers of the brain when something happens that demands their attention. Basically, without your RF, you would not be alert or perhaps even conscious. Damage to this area can cause a coma.

Brainstem *An area at the base of the brain in front of the cerebellum responsible for automatic, survival functions*

Pons *A structure at the top of the brainstem involved in respiration, movement, waking, sleep, and dreaming*

Medulla [muh-DUL-uh] *A structure at the base of the brainstem responsible for automatic body functions such as breathing and heart rate*

Reticular Formation (RF) *A diffuse set of neurons in the core of the brainstem that screens incoming information and arouses the cortex*

The Cerebellum

The **cerebellum** ("little brain") is located at the base of the brain behind the brainstem. (Some say it looks like a cauliflower.) In evolutionary terms, it is a very old structure responsible for maintaining smooth movement and coordinating motor activity. Although the actual commands for movement come from higher brain centers in the cortex, the cerebellum coordinates the muscles so that movement is smooth and precise. The cerebellum is also involved with the sense of balance. In fact, roadside tests for drunken driving are essentially testing the cerebellum, because it is one of the first structures depressed by alcohol.

Research suggests that the cerebellum does much more than just coordinate movement and maintain physical balance. It may also have a role in perception and cognition. Using magnetic resonance imaging (MRI), researchers have documented that parts of the cerebellum are very active during perceptual and cognitive activities that require the processing of sensory data (Luft, Skalej, Stefanou, Klose, & Voight, 1998).

The cerebellum at work. Can you see why the cerebellum might be important to this construction worker? It is responsible for coordinating movement and maintaining posture and balance.

Cerebellum [sehr-uh-BELL-um] *Structure at the base of the brain, behind the brainstem, responsible for maintaining smooth movement, balance, and some aspects of perception and cognition*

The Thalamus

Thalamus [THAL-uh-muss] *A brain structure at the top of the brainstem that relays sensory messages to the cerebral cortex*

The **thalamus** lies at the top of the brainstem. Resembling two little footballs, one on each side of the brain, connected by a thin group of nerve fibers, it serves as the major sensory relay center for the brain. Like an air traffic control center that receives information from all aircraft, and then directs them to the appropriate landing or take off areas, the thalamus receives input from nearly all the sensory systems and then directs this information to the appropriate cortical areas. For example, while reading this page, your thalamus sends incoming visual signals to the visual area of your cortex. When your ears receive sound, the information is transferred to the auditory (or hearing) area of your cortex.

The thalamus plays an active role in integrating information from various senses and may be involved in learning and memory (Crosson, 1999). Injury to the thalamus can cause deafness, blindness, or loss of any other sense (except smell). This suggests that some analysis of sensory messages may occur here. Because the thalamus is the major sensory relay area to the cerebral cortex, damage or abnormalities also might cause the cortex to misinterpret or not receive vital sensory information. Other research using brain-imaging techniques links abnormalities in the thalamus to schizophrenia (Andreasen, 1999, 2000; Hazlett et al., 2000; Omori et al., 2000). Schizophrenia is a serious psychological disorder characterized by problems with sensory filtering and perception (Chapter 14). Can you see how a defective thalamus might produce characteristics of schizophrenia, such as hallucinations and delusion?

The Hypothalamus

Hypothalamus [hi-poh-THAL-uh-muss] *A small brain structure beneath the thalamus that maintains homeostasis and regulates emotions and drives, such as hunger, thirst, sex, and aggression*

Beneath the thalamus lies the **hypothalamus** (*hypo-* means "under"). Although no larger than a kidney bean, it has been called the "master control center" for emotions and many basic motives such as hunger, thirst, sex, and aggression (Fulton, Woodside, & Shizgal; Meston & Frohlich, 2000). Its general function is *homeostasis,* including temperature control, which it accomplishes by regulating the endocrine system. Hanging down from the hypothalamus, the *pituitary gland* is usually considered the master endocrine gland because it releases hormones that activate the other endocrine glands. The hypothalamus influences the pituitary through direct neural connections and by releasing its own hormones into the blood supply of the pituitary.

Despite its relatively small size, the hypothalamus influences important aspects of behavior either *directly,* by generating some behaviors itself, or *indirectly* by controlling parts of the autonomic nervous system (ANS) and endocrine system. An example of its direct effects are found when animals exhibit increased or decreased eating and drinking patterns depending on what area of the hypothalamus is affected (Chapter 12). The indirect effects of the hypothalamus are seen in the interaction of stress and the ANS (Chapter 3).

The Limbic System

Limbic System *An interconnected group of lower-level brain structures involved with the arousal and regulation of emotion, motivation, memory, and many other aspects of behavior and mental processes*

The **limbic system** is an interconnected group of structures located roughly along the border between the cerebral cortex and the lower-level brain structures (hence the term *limbic*, which means "edge" or "border"). The limbic system includes the *fornix*, the *hippocampus*, the *amygdala*, and the *septum* (Figure 2.10). Scientists disagree about which structures should be included in the limbic system, and many also include the hypothalamus, parts of the thalamus, and parts of the cerebral cortex.

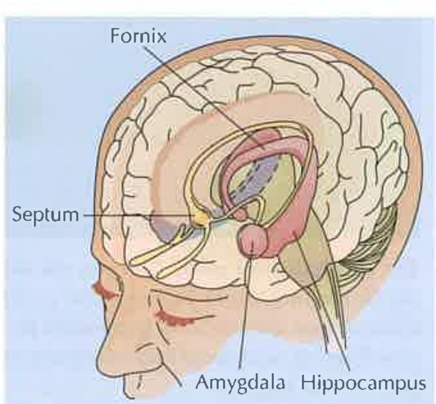


Figure 2.10 ***The major brain structures associated with the limbic system.***

Recent research studying the fornix and hippocampus suggests that they, along with the amygdala, are involved in the formation of new and short-term memories

(Chin, 2000; Giovagnoli, 2001; McGaugh, 2000). However, the major focus of interest in the limbic system, and particularly the **amygdala**, has been its production and regulation of emotional behavior, particularly aggression and fear. Research on cats and rats shows that stimulating the amygdala increases aggressive behavior, and research on the human amygdala demonstrates its role in aggression and violence, as well as, the learning and expression of fear and the ability to recognize fear in the faces of others (Adolphs, Tranel, & Damasio, 1998; Cahill, Vazdarjanova, & Setlow, 2000; Davidson, Putnam, & Larson, 2000; Schmolck & Squire, 2001).

Amygdala [uh-MIG-dull-uh] *An almond-shaped lower-level brain structure that is part of the limbic system and is involved in emotion*

Perhaps one of the best-known functions of the limbic system is its role in pleasure or reward. James Olds and Peter Milner (1954) were the first to note that electrically stimulating certain areas of the limbic system caused a "pleasure" response in rats. The feeling was apparently so rewarding that the rats would cross electrified grids, swim through water (which they normally avoid), and press a lever thousands of times until they collapsed from exhaustion — just to have their brains stimulated. Follow-up studies found somewhat similar responses in other animals and even among human volunteers (Blum, Cull, Braverman, & Comings, 1996; Wise & Rompre, 1989). Modern research suggests that brain stimulation activates neurotransmitters or neuromodulators rather than discrete "pleasure centers."

Keep in mind that even though limbic system structures and neurotransmitters are instrumental in emotional behavior, emotion in humans is also tempered by the cerebral cortex, especially the frontal lobes. As the case of Phineas Gage shows, damage to the frontal lobes, which have neural connections to the amygdala and other parts of the limbic system, can permanently impair social and emotional behavior. This is yet another example of the inseparable interconnectivity of the entire brain.

Check & Review

TOOLS FOR EXPLORATION AND LOWER-LEVEL BRAIN STRUCTURES

Researchers study the brain through dissection of brains of cadavers, lesion techniques (which involve destroying part of an animal's brain to study resultant changes in behavior), and direct observation or case studies. Electrical recording techniques involve implanting electrodes into the brain or on its surface to study the brain's electrical activity. Computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and functional magnectic resonance imaging (fMRI) scans are sophisticated techniques for studying intact, living brains.

The most important lower-level brain structures are the brainstem, cerebellum, thalamus, hypothalamus, and limbic system. The **brainstem** controls automatic functions such as heartbeat and breathing; the cerebellum contributes to balance, muscle coordination, and some higher mental operations. Parts of the brain stem (the **pons** and **medulla**) are involved in sleeping, waking, dreaming, and control of automatic bodily functions, whereas the **reticular formation** screens incoming information and arouses the cortex. The **cerebellum** maintains smooth movement, balance, and some aspects of perception and cognition. The **thalamus** is the major incoming sensory relay area of the brain. The **hypothalamus** is involved in emotion and in drives associated with survival, such as regulation of body temperature, thirst, hunger, sex, and aggression.

The **limbic system** is a group of brain structures (including the **amygdala**) involved with emotional behavior and memory.

Questions

1. What is the difference between electrical recording and electrical stimulation of the brain?
2. The four major techniques used for scanning the brain are ________, ________, ________, and ________.
3. Roadside test for drunk driving primarily test responses of the ________.
4. What is the major sensory relay area for the brain? (a) hypothalamus; (b) thalamus; (c) cortex; (d) hindbrain

Answers to Questions can be found in Appendix B.

The Cerebral Cortex: The Center of "Higher" Processes

How does the cortex control behavior and mental processes?

Above the lower-level brain structures, such as the brainstem, thalamus, and limbic system, lie the two *cerebral hemispheres*, the outer surface of which is called the

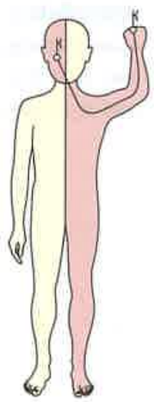


Figure 2.11 ***Information crossover.*** Information from left side of the body crosses over to the right brain.

cerebral cortex. (The word *cortex* means "bark," and the cerebral cortex surrounds most of the brain like the bark on a tree.) In general, the right hemisphere is in charge of the left side of the body, whereas the left hemisphere controls the right side of the body (Figure 2.11). We will later discuss how the two hemispheres have somewhat different tasks and special functions.

Cerebral Cortex *The bumpy, convoluted area on the outside surface of the two cerebral hemispheres that regulates most complex behavior, including receiving sensations, motor control, and higher mental processes*

If you were able to open your skull and look inside at your own brain, you would note that the two hemispheres take up most of the room. They balloon out and cover most of the lower-level structures from view. The hemispheres together are slightly larger than two clenched fists. The thin surface layer of the cerebral hemispheres (the cortex) contains approximately 30 billion neurons and nine times as many glial cells. If the cortex of both hemispheres were spread out, they would cover an area almost the size of a standard newspaper page and be about a quarter of an inch thick. How does all this material fit inside our skull? Imagine crumpling the newspaper sheet into a loose ball. You would retain the same surface area but in a much smaller space. The cortex contains numerous "wrinkles" (called *convolutions*), which allow it to hold billions of neurons in the restricted space of the skull.

Each of the two cerebral hemispheres is divided into four areas, or *lobes*: frontal (behind your forehead), parietal (at the top and to the rear of your skull), temporal (in the "temple" region above your ears), and occipital (at the back of your head). Divisions of these lobes are marked by prominent folds, which provide convenient geographic landmarks (Figure 2.12). Like the lower-level brain parts discussed earlier, each lobe specializes in somewhat different tasks — another example of *localization of function*. At the same time, some functions overlap between lobes. As we describe each lobe and its functions, you may want to refer frequently to Figure 2.12.

The Frontal Lobes

Frontal Lobes *Cortical lobes in front of the brain, which govern motor control, speech production, and higher functions, such as thinking, personality, emotion, and memory*

By far the largest of the cortical lobes, the **frontal lobes** are located at the top front portion of the two brain hemispheres — right behind your forehead. The frontal lobes receive and coordinate messages from the other three lobes of the cortex and are responsible for at least three additional major functions:

1. ***Motor control.*** At the very back of the frontal lobes lies the *motor cortex*, which sends messages to the various muscles and glands in the body. All neural signals that instigate voluntary movement originate here. For instance, when you reach out to

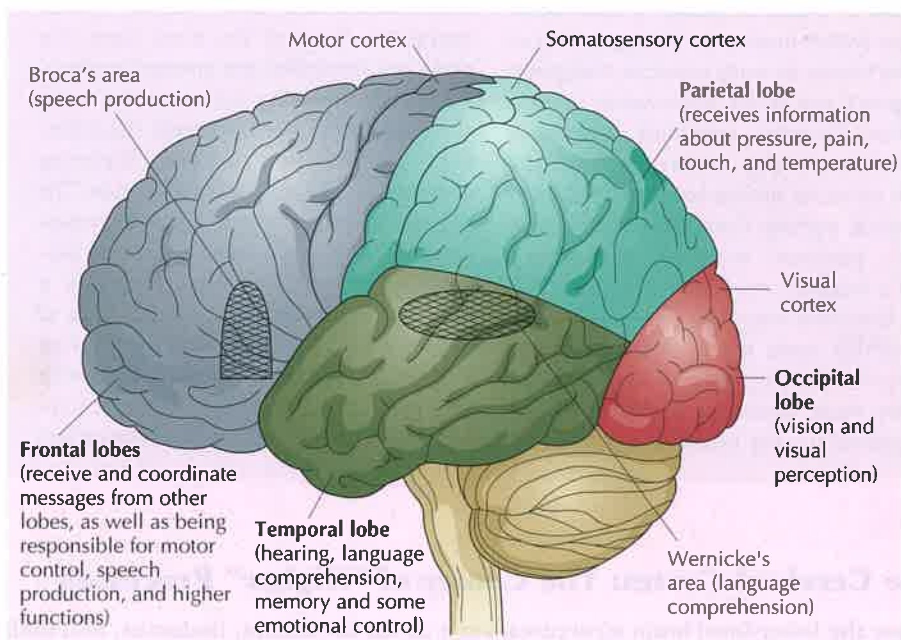


Figure 2.12 ***The cerebral cortex.*** This is a view of the left hemisphere with its four lobes, the frontal, parietal, temporal, and occipital, along with their major functions.

choose a candy bar from a vending machine, it is the motor control area of the frontal lobes that guides your hand in pulling the proper lever.

2. ***Speech production.*** In the *left* frontal lobe, on the surface of the brain near the bottom of the motor control area, lies *Broca's area*, which is known to play a crucial role in speech production. In 1865, French physician Paul Broca was the first to note that patients with damage to this area had great difficulty speaking but could comprehend written or spoken language. This type of aphasia (or impaired language ability) has come to be known as *Broca's aphasia.*

"Whoa! That was a good one! Try it, Hobbs – just poke his brain right where my finger is."

3. ***Higher functions.*** Most functions that distinguish humans from other animals, such as thinking, personality, emotion, and memory, are controlled primarily by the frontal lobes. Abnormalities in the frontal lobes are often observed in patients with schizophrenia (Chapter 14). And as we discovered in the story of Phineas Gage, damage to the frontal lobe affects motivation, drives, creativity, self-awareness, initiative, and the ability to plan ahead. Damage in this area also affects emotional behavior.

Using advanced research techniques, Hanna Damasio and her colleagues (1994) constructed computer images of Gage's brain, which showed the tamping iron most likely destroyed frontal lobe areas governing emotional control, social behavior, and decision-making. As Gage's case and other research indicates, what makes us uniquely human and what makes up our individual personalities is regulated by our frontal lobes.

A recent case reminiscent of Phineas Gage's experience also suggests that a person's short-term or "working memory" (Chapter 7) is located in the very front of the frontal lobes. In 1998, a construction worker named Travis Bogumill was accidentally shot in the head with a nail gun. The nail entered the right side of his brain near the rear of the frontal lobe. Like Gage, Bogumill was able to walk and talk after the accident. The nail was removed and, so far, Bogumill seems to be doing well. The only damage seems to be an impaired ability to perform complex mathematical problems in his head. Before the accident, Bogumill was able to easily multiply two-digit numbers in his head. After the accident, he was barely able to multiply two-digit numbers with a paper and pencil. This case supports other experimental research that shows that the frontal lobes and the working memory are responsible for reasoning, problem solving, mathematical calculation, and thinking about future rewards or actions (Giovagnoli, 2001; Hazlett, 2000; Koechlin, Basso, Pietrini, Panzer, & Grafman, 1999; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001).

A modern day Phineas Gage? Construction worker Travis Bogumill was accidentally shot in the head with a nail gun. Like Phineas Gage, he was able to walk and talk immediately after the accident but also suffered some damage to his frontal lobes. The x-ray in the bottom photo shows the 3¼ inch nail that was removed from his brain.

Parietal Lobes

At the top of the brain just behind the frontal lobes are the **parietal lobes**, the seat of body sensations and much of our memory about the environment. At the front of the parietal lobes is the *somatosensory cortex*, which receives information about pressure, pain, touch, and temperature. When you step on a sharp nail, you quickly (and reflexively) withdraw your foot because the messages travel directly to and from your spinal cord. However, you don't experience "pain" until the neural messages reach the parietal lobes of the brain.

Parietal [puh-RYE-uh-tuhl] Lobes *Cortical lobes at the top of the brain where bodily sensations are interpreted.*

TRY THIS *Yourself*

Would you like a quick way to understand both your motor cortex and your sensory cortex?

1. *Motor cortex.* Try wiggling each of your fingers one at a time. Now try wiggling each of your toes. Note on Figure 2.13 how the area of your motor cortex is much larger for your fingers than for your toes, which correlates with your greater sensitivity and precise control in your fingers.
2. *Somatosensory cortex.* Ask a friend to close his or her eyes. Using a random number of fingers (one to four), press down on the skin of your friend's back for 1 or 2 seconds and ask your friend to report how many fingers you are using. Now repeat the same procedure on the palm or back of your friend's hand. Your friend should be much better at guessing when you're pressing on his or her hand than on his or her back. Again as in Figure 2.13, the area of the somatosensory cortex is much larger for the hands than for the back, which reflects more sensitivity and higher accuracy in detecting the finger pressure on the hand.

As you can see in Figure 2.13, the more sensitive a body part is, the greater the area of sensory cortex devoted to it. Note how the face and hands receive the largest share of cortical tissue. These areas are much more sensitive than the rest of the body and require more precise control. Note also that the greater the area of motor cortex, the finer the motor control.

Temporal Lobes *Cortical lobes above the ears involved in audition (hearing), language comprehension, memory, and some emotional control*

The Temporal Lobes

The **temporal lobes** (Latin for "pertaining to the temples") are found on the sides of the brain right above your ears. Their major functions are auditory perception (hearing), language comprehension, memory, and some emotional control. An area called the *auditory cortex* (which processes sound) is located at the top front of each temporal lobe. Incoming sensory information from the ears is processed in this area and then sent to the parietal lobes, where it is combined with visual and other body sensation information.

An area of the *left* temporal lobe, *Wernicke's area*, is involved in language comprehension. About a decade after Broca's discovery, German neurologist Carl Wernicke noted that patients with damage in this area could not understand what they read or heard, but they could speak quickly and easily. However, their speech was often unintelligible because it contained made-up words, like *chipecke*, sound substitutions (*girl* became *curl*), and word substitutions (*bread* became *cake*). This syndrome is now referred to as *Wernicke's aphasia.* (Study tip: Remember that *Broca's area* in the left frontal lobes is responsible for *speech* production, whereas *Wernicke's area* in the left temporal lobe is involved in *language* comprehension.)

David Hubel and Thorsten Wiesel received the Nobel Prize for their work in mapping visual areas in the occipital cortex of the brain.

Occipital [ahk-SIP-uh-tuhl] Lobes *Cortical lobes at the back of the brain responsible for vision and visual perception*

Occipital Lobes

As the name implies, the **occipital lobes** (Latin for *ob,* "in back of," and *caput,* "head") are located at the lower back of the brain. Among other things, the occipital lobes are responsible for vision and visual perception. Damage to the occipital lobe can produce blindness, even though the eyes and their neural connection to the brain are perfectly healthy. The occipital lobes are also involved in shape, color, and motion perception.

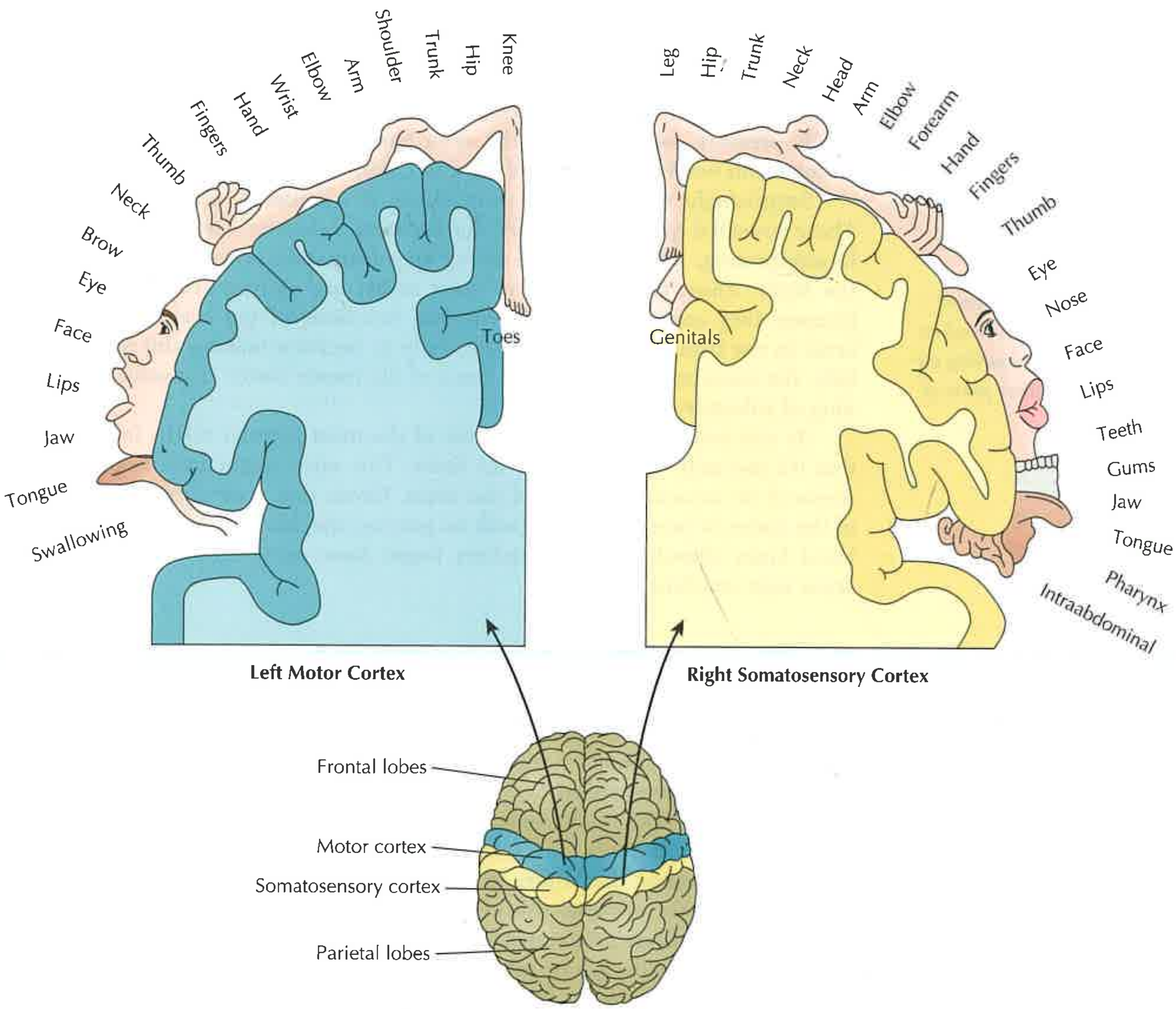


Figure 2.13 ***Body representation on the motor cortex and somatosensory cortex.*** This drawing represents a vertical cross-section taken from the left hemisphere's motor cortex and right hemisphere's somatosensory cortex. The amount of cortex devoted to a specific body part is depicted by the oddly shaped human figures draped around the outside edge of the cortex. (These figures are sometimes referred to as the "motor homunculus" and "somatosensory homunculus.") Note the disproportionate size of the hands and faces on each of these figures. The larger sizes reflect the larger cortical area necessary for the precise motor control and greater sensitivity of the hands and face.

The motor and somatosensory cortex. This fanciful representation of a human suggests the overriding importance of the hands and the mouth by the amount of cortex that is dedicated to them.

Association Areas

Thus far, we have focused on relatively small areas of the four lobes of the cortex that have specific functions. If a surgeon were to administer ESB to the parietal lobe area of your brain, you would most likely report physical sensations, such as feeling touch, pressure, and so on. On the other hand, if ESB were applied to your occipital lobe, you would see flashes of light or color.

Surprisingly, most areas of your cortex, if stimulated, produce nothing at all. These so-called quiet sections are not dormant, however. They are clearly involved in interpreting, integrating, and acting on information processed by other parts of the brain. Thus, these collective "quiet areas" are aptly called **association areas** because they *associate* various areas and functions of the brain. The association areas in the frontal lobe, for example, help in decision making and planning. Similarly, the association area right in front of the motor cortex is involved in the planning of voluntary movement.

Association Areas *So-called quiet areas in the cerebral cortex involved in interpreting, integrating, and acting on information processed by other parts of the brain*

As you recall from Chapter 1, one of the most popular myths in psychology is that we use only 10 percent of our brain. This myth might have begun with early research on association areas of the brain. Given that approximately three-fourths of the cortex is "uncommitted" (with no precise, specific function responsive to electrical brain stimulation), researchers might have mistakenly assumed that these areas were nonfunctional.

Two Brains in One? A House Divided

How do the left and right hemispheres of the brain affect behavior and mental processes?

We mentioned earlier that the cerebral cortex is divided into two hemispheres that control opposite sides of the body. Each hemisphere also has separate areas of specialization. (This is another example of *localization of function*, yet it is technically referred to as **lateralization**.)

Lateralization *Specialization of the left and right hemispheres of the brain for particular operations*

By the mid-1800s, early researchers had discovered that the left and right hemispheres carry out different tasks. In addition to mapping the brain and nervous system, they also noted that injury to one side of the brain produced paralysis or loss of sensation on the opposite side of the body. Also around this same time, case studies like Phineas Gage's documented that accidents, strokes, and tumors in the left hemisphere generally led to problems with language, reading, writing, speaking, arithmetic reasoning, and other higher mental processes. The "silent" right hemisphere came to be viewed as the "subordinate" or "nondominant" half, lacking special functions or abilities.

Split-Brain Research

In the 1960s, this portrayal of the left and right hemispheres as dominant and subordinate players began to change as a result of landmark research with **split-brain** patients.

Split-Brain *A surgical separation of the brain's two hemispheres used medically to treat severe epilepsy; split-brain patients provide data on the functions of the two hemispheres*

The two cerebral hemispheres are normally connected at several places, but the primary connection between the left and right halves is a thick, ribbonlike band of nerve fibers under the cortex called the **corpus callosum**. (See Figure 2.9 on page 62.) In some cases of *severe* epilepsy, surgeons cut the corpus callosum to stop the spread of epileptic seizures from the cortex of one hemisphere to the other. Given that brain surgery is a radical and permanent procedure, such an operation is always a last resort and is performed only when patients' conditions have not responded to other forms of treatment. However, the results are generally successful — epileptic seizures are reduced and sometimes disappear entirely.

Corpus Callosum [CORE-puss] [cah-LOH-suhm] *Bundle of nerve fibers connecting the brain's left and right hemispheres.*

Split-brain patients also provide an unintended, dramatic side benefit to scientific research. Because this operation cuts the only direct communication link between the two hemispheres, it reveals what each half of the brain can do when it is quite literally cut off from the other. Although relatively few split-brain operations have been conducted since 1961, the resulting research has profoundly improved our understanding of how the two halves of the brain function. In fact, in 1981 Roger Sperry received a Nobel Prize in physiology/medicine for his split-brain research.

How do these patients function after the split-brain surgery? The surgery does create a few unusual responses. For example, one split-brain patient reported that when he dressed himself, he sometimes pulled his pants down with his left hand and up with his right (Gazzaniga, 2000). However, patients generally show very few outward changes in their behavior, other than fewer epileptic seizures. If you met and talked with a split-brain patient, you probably wouldn't even know he or she had had the operation. In fact, one famous psychologist, Karl Lashley, joked that the only function of the corpus callosum seemed to be to keep the two hemispheres from sagging (Gazzaniga, 1995).

The subtle changes in split-brain patients normally appear with simple but specialized testing. For example, when a split-brain patient is asked to stare straight ahead while a photo of a fork is flashed to his left visual field, he cannot name it, although he can point to a similar photo with his left hand. Can you explain why?

To answer this question, you need to understand two major points about your brain. First, as you know, the left hemisphere receives and sends messages from and to the right side of the body, and vice versa. However, vision is different. Your eyes connect to your brain in such a way that, when you look straight ahead, the left half of your field of vision sends an image through both eyes to your right hemisphere (Figure 2.14). Likewise, the right side of your visual field is transmitted to your left hemisphere.

Assuming you don't have a split-brain, if information were presented only to your right hemisphere, it would be quickly sent to your left hemisphere — where the language center could name it. However, when the corpus callosum is split and experimenters present an image to only the left visual field, information cannot be transferred from the right hemisphere to the left. Thus, the patient cannot say what he saw, but he can point to a photo of the same object with his left hand. (Figure 2.15 offers a further example of split-brain testing.)

Keep in mind that split-brain surgery is a last resort medical treatment, which reduces the severity of epileptic seizures and generally has few effects on everyday functioning. An unexpected benefit of this surgery is that it has allowed researchers to demon-

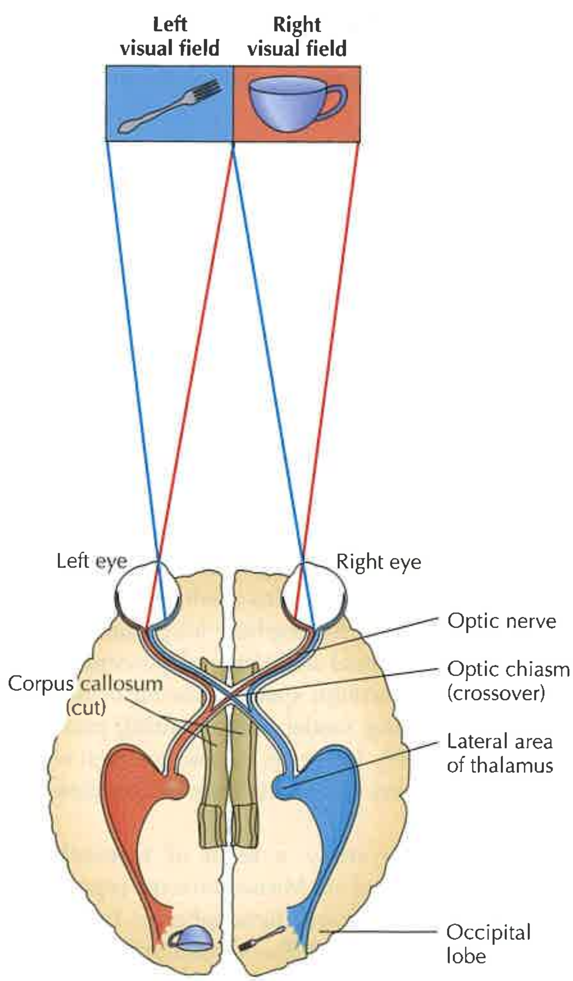


Figure 2.14 ***Crisscrossing of visual information.*** Imagine this as a drawing of your brain, and that you are being asked to stare straight ahead. Note how visual images from the left half of each eye connect only to the left half of your brain; whereas, images from the right half of each eye connect to the right half. The information received by either hemisphere is normally transmitted across your corpus callosum to the other side. When the corpus callosum is cut, however, the "split-brain" patient does not receive the shared information.

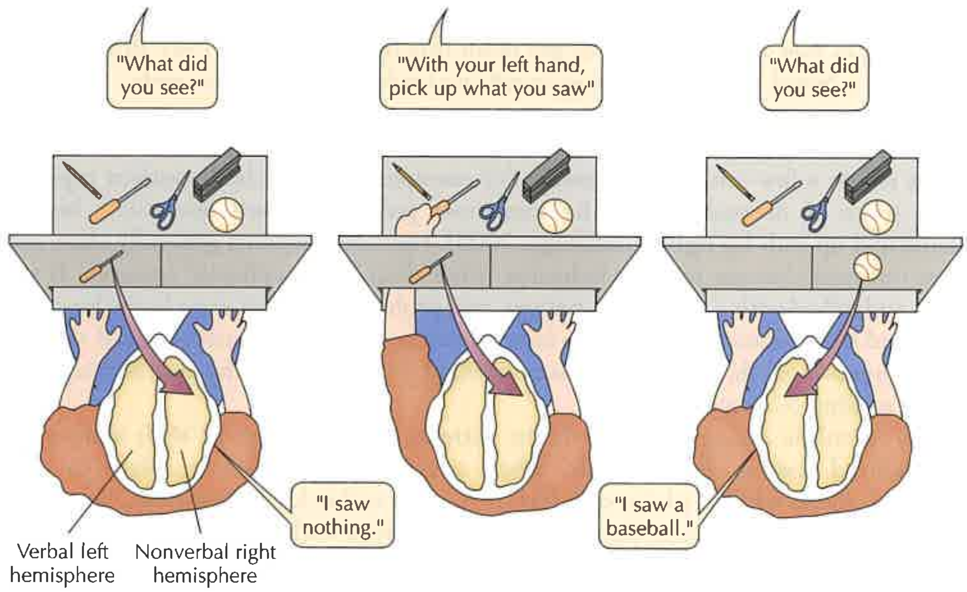


Figure 2.15 ***Split-brain research.*** When a split-brain patient stares straight ahead and a picture of a screw driver is flashed only to the left visual field, the information goes only to the nonverbal right hemisphere, and he cannot name what he saw. However, when asked to "pick up what you saw," his left hand can touch the items hidden behind the screen and easily identify the screwdriver. This shows that the right hemisphere received the photo image of the screwdriver, but the patient could not name it because the information did not travel across the severed corpus callosum to the left hemisphere where language is stored. Note when the image of a baseball is presented to the left hemisphere, the patient easily names it. Can you see why split-brain research is so important to brain researchers interested in studying the various functions of the two hemispheres?

strate the functional specialization of each hemisphere (Schiffer, Zaidel, Bogen, & Chasan-Taber, 1998).

Hemispheric Specialization

Dozens of studies on split-brain patients, and newer research on people whose brains are intact, have documented several differences between the two brain hemispheres (summarized in Figure 2.16) (Franz, Waldie, & Smith, 2000; Gazzaniga, 1970, 1995, 2000; Robertson et al., 2000; Zaidel, 1985, 1998). In general, for roughly 95 percent of all adults, the left hemisphere is specialized not only for language functions (speaking, reading, writing, and understanding language) but also for analytical functions, such as mathematics (Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999). In contrast, the right hemisphere is specialized primarily for nonverbal abilities, including art and musical abilities and perceptual and spatiomanipulative skills, such as maneuvering through space, drawing or building geometric designs, working jigsaw puzzles, building model cars, painting pictures, and recognizing faces (Springer & Deutsch, 1998). However, recent research with fMRI imaging suggests that the right hemisphere may also contribute to complex language comprehension (Robertson et al., 2000).

In another study, a team of researchers led by Fredric Schiffer (1998) at McLean Hospital in Massachusetts reported that different aspects of personality appear in the different hemispheres. In one patient, the right hemisphere seemed more disturbed by childhood memories of being bullied than did the left. In another patient, the right hemisphere seemed to regard the patient more positively, while also feeling more negative emotions such as loneliness and sadness (Schiffer, Zaidel, Bogen, & Chasan-Taber, 1998).

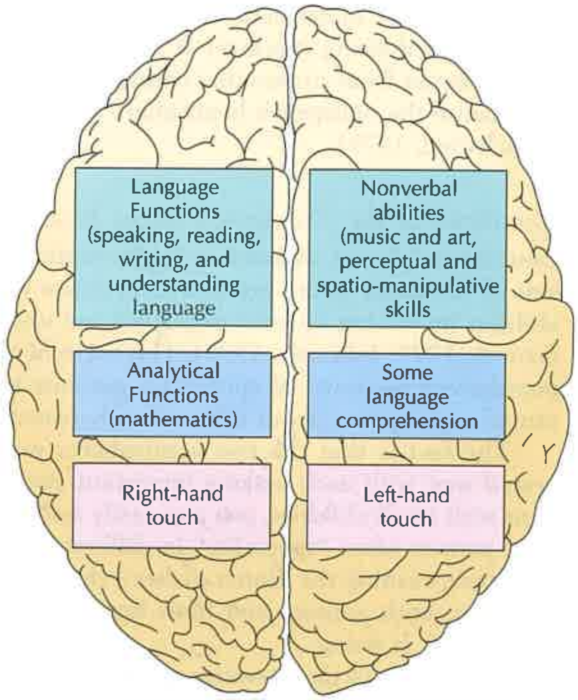


Figure 2.16 ***Functions of the left and right hemispheres.*** The left hemisphere specializes in verbal and analytical functions, whereas the right hemisphere focuses on nonverbal abilities, such as spatiomanipulative skills, art and musical abilities, and visual recognition tasks.

Is this left and right brain specialization reversed in left-handed people? Not necessarily. About 68 percent of left-handers (people who use their left hands to write, hammer a nail, and throw a ball) and 97 percent of right-handers have their language areas on the left hemisphere. This suggests that even though the right side of the brain is dominant for movement in left-handers, other types of skills are often localized in the same brain areas as for right-handers.

Although lefthanders are generally penalized for living in a right-handed world, there may be some benefits to being left-handed. For example, history shows that a disproportionate number of lefties have achieved greatness in art, music, sports, mathematics, and architecture, including Leonardo da Vinci, Michelangelo, Picasso, and M. C. Escher. Because the right hemisphere is superior at imagery and

TRY THIS *Yourself*

Would you like a demonstration of the specialized functions of your own two hemispheres? Some research suggests that the eyes tend to move to the right when a mental task involves the left hemisphere and to the left when the task involves the right hemisphere (see Kinsbourne, 1972). Read the following questions to a friend and record whether his or her eyes move to the right or to the left as he or she ponders the answers. Try to keep the monitoring of your friend's eye movements as natural as possible.

1. Define the word *neuroscience*.
2. What is a function of the corpus callosum?
3. What structure of the brain is located right above pituitary gland?
4. If you are on top of the brain and traveling straight down, what is directly below the parietal lobes?

The first two questions involve language skills and the left hemisphere, which should produce more eye movement to the right. Questions 3 and 4 require spatial reasoning and the right hemisphere, which should elicit more eye movement to the left.

Try the same test on at least four other friends or family members. You'll note two major points: (1) cerebral lateralization is a matter of degree — not all or nothing, and (2) individual differences do exist, especially among left-handers.

visualizing three-dimensional objects, it may help to use the left hand for drawing, painting, or drafting (Springer & Deutsch, 1998). Moreover, left-handers tend to recover better from strokes that damage the language areas in the brain, which may be because the nonspeech hemisphere in left-handers is better able to compensate (Geschwind, 1979).

The Myth of the "Neglected Right Brain"

Courses and books directed at "right-brain thinking" and "drawing on the right side of the brain" often promise to increase your intuition, creativity, and artistic abilities by waking up your neglected and underused right brain (e.g. Bragdon & Gamon, 1999; Edwards, 1999). This myth of the neglected right brain arose from popularized accounts of split-brain patients and exaggerated claims and unwarranted conclusions about differences between the left and right hemispheres.

The fact is that the two hemispheres work together in a coordinated, integrated way, with each making important contributions. If you are a married student with small children, you can easily understand this principle. Just as you and your partner often "specialize" in different jobs (one giving the kids their baths, the other washing the dinner dishes), the hemispheres also divide their workload. However, both parents and both hemispheres are generally aware of what the other "half" is doing.

In our tour of the nervous system, the principles of *localization of function* and *specialization* are common — dendrites receive information, the occipital lobe specializes in vision, and so on. However, it's important to remember that all parts of the brain and nervous system play overlapping and synchronized roles.

Check & Review

THE CEREBRAL CORTEX AND HEMISPHERIC SPECIALIZATION

The left and right cerebral hemispheres of the brain take up most of the room inside the skull. The outer covering of the hemispheres, the **cerebral cortex**, is divided into four lobes. The **frontal lobes** control movement and speech and are involved with self-awareness and planning ahead. The **parietal lobes** are the receiving area for sensory information. The **temporal lobes** are concerned with hearing and language. The occipital lobes are dedicated to vision and visual information processing.

The two hemispheres of the brain are linked by the **corpus callosum**, through which they communicate and coordinate. However, **split-brain** research shows that each hemisphere does perform somewhat separate functions. In most people, the left hemisphere is dominant in verbal skills, such as speaking and writing, and also for analytical tasks. The right hemisphere appears to excel at nonverbal tasks, such as spatio-manipulative skills, art and music, and visual recognition.

Recent research shows the brain can reorganize and change its structure and function throughout the lifespan **(neuroplasticity)**, and create new nerve cells **(neurogenesis)** from **stem cells.**

Questions

1. The bumpy, convoluted area making up the outside surface of the brain is the ________.
2. You are giving a speech. Name the cortical lobes involved in the following behaviors:
   a. Identifying faces in the audience
   b. Hearing questions from the audience
   c. Remembering where your car is parked when you're ready to go home
   d. Noticing that your new shoes are too tight and hurting your feet
3. The case of Phineas Gage suggests that the ________ lobes regulate our personality and are largely responsible for much of what makes us uniquely human. (a) frontal; (b) temporal; (c) parietal; (d) occipital
4. Although the left and right hemispheres of the brain are specialized, they are normally in close communication through the ________. (a) reciprocating circuits; (b) thalamus; (c) corpus callosum; (d) cerebellum

Answers to Questions can be found in Appendix B.

critical thinking — Active Learning

Understanding Central Nervous System Anatomy and Function

Being able to define a term or concept doesn't necessarily mean you fully comprehend it. The following exercise will help clarify your understanding of brain terminology and function. It also provides a model for the types of questions that lead to critical thinking.

Situation #1
A neurosurgeon is about to perform brain surgery. The surgeon stimulates (touches with an electrode) a tiny portion of the patient's brain, and the patient's right finger moves. After noting the reaction, the surgeon stimulates a portion of the brain a short distance away and the patient's right thumb moves.

Questions to Answer

1. What section of the brain has been stimulated? In which lobe of the brain is this section found?
2. Which hemisphere of the brain is being stimulated?
3. During this stimulation, would the patient experience pain? Why or why not?

Situation #2
The scene: An emergency room in a hospital. Two doctors are talking about a car crash victim who has just been wheeled in.

First Doctor: "Good grief! The whole cerebral cortex is severely damaged; we'll have to remove the entire area."

Second Doctor: "We can't do that. If we remove all that tissue, the patient will die in a matter of minutes."

First Doctor: "Where did you get your medical training — watching *General Hospital*? The patient won't die if we remove his whole cerebral cortex."

Second Doctor: "I resent your tone and insinuation. I went to one of the finest medical schools, and I'm telling you the patient will die if we remove his whole cerebral cortex."

Questions to Answer

1. If the whole cerebral cortex is removed, will the patient die? Explain your answer.
2. If the patient is kept alive without a cerebral cortex, what kinds of behaviors or responses would be possible? What changes would you expect in personality, memories, and emotions?
3. What behaviors could be expected with only the subcortex, medulla, and spinal cord intact? What if only the medulla and spinal cord were functioning? Only the spinal cord?
4. If a patient could be kept alive without a cerebral cortex, would life be worth living? How much of your brain would have to be removed before you would rather die?

RESEARCH HIGHLIGHT

Rewiring, Repairing, and Transplanting Brains and Spinal Cords

In 1989, President George Bush signed a resolution declaring the 1990s the "Decade of the Brain." The decade is over. What did we learn during those 10 years? Was it worth the thousands of research hours and millions of research dollars? You be the judge.

Imagine being completely paralyzed and unable to speak. Each year, thousands of people suffer serious brain and spinal cord injuries, and until recently, these injuries were considered permanent and beyond medical help. Scientists have long believed that after the first 2 or 3 years of life humans and most animals lack the capacity to repair or replace damaged neurons in the brain or spinal cord. Though nerves in the peripheral nervous system sometimes repair and regenerate themselves, it was accepted doctrine that this could not occur in the central nervous system.

Thanks in part to the "Decade of the Brain," this dogma has been overturned — the human brain is capable of lifelong *neuroplasticity* and *neurogenesis*. Let's begin with neuroplasticity. Rather than being a solid fixed organ, your brain is capable of changing its structure and function in response to changing environmental conditions (Beatty, 2001; Hata & Stryker, 1994; Tierney, Varga, Hosey, Grafman, & Braun, 2001). This process is termed **neuroplasticity**. Although the basic brain organization (cerebellum, cortex, and so on) is irreversibly established well before birth, the details are subject to revision. As you're learning a new sport or foreign language, for example, your brain changes and "rewires" itself. New synapses form and others disappear. Some dendrites grow longer and sprout new branches, whereas others are "pruned" away. This is what makes our brains so wonderfully adaptive (Begley, 2000; Hyman, 1999).

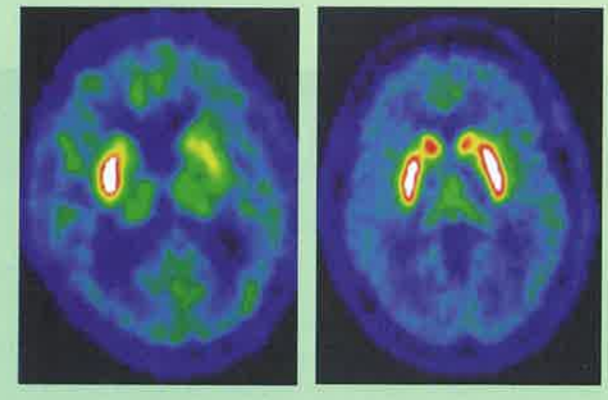
Remarkably, this rewiring has even helped "remodel" the brain following

Neuroplasticity *The brain's ability to reorganize and change its structure and function throughout the life span* strokes. For example, psychologist Edward Taub and his colleagues (1998, 2000) have had success with constraint-induced (CI) movement therapy in stroke patients. Immobilizing the unaffected ("good") arm (or leg) of the patient has restored function in some patients as long as 21 years after their strokes. Rather than coddling the affected arm, Taub requires rigorous and repetitive exercise, which he believes causes intact parts of the brain to take over for the stroke-damaged areas. In effect, Taub "recruits" intact brain cells.

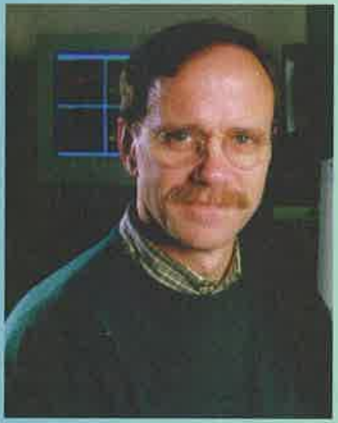
Other scientists researching Alzheimer's disease suggest "rerouting" neurons around damaged areas of the brain (Begley, 2000). This treatment would be analogous to an electrician's wiring a shunt around the damaged part of an electrical circuit. Obviously, there are limits to neuroplasticity. Even with the best "rewiring," most of us will never become another Tiger Woods or Albert Einstein. However, the fact that our brains continually reorganize themselves throughout our lives has enormous implications.

Perhaps the most dazzling find of the Decade of the Brain is **neurogenesis** — the production of nerve cells. Until very recently, it was believed that we are born with all the neurons we'll ever have. Life was a slow process of dying neurons and increasing loss of brain tissue. Today, however, we know that 80-year-olds have just as many neurons as 20-year-olds. Although we do lose hundreds of cells each day, our brains also replenish themselves with *new* cells that originate deep within the brain and migrate to become part of the brain's circuitry (Fuchs & Segre, 2000; Gage, 2000; Gould, Reeves, Graziano, & Gross, 1999; Kempermann & Gage, 1999; Vogel, 2000).

Even more exciting is the fact that the source of these newly created cells is neural **stem cells** — rare, precursor ("immature") cells that can grow and develop into any type of cell depending on the chemical signals they receive as they grow. Until now, physicians have used stem cells for bone marrow transplants, but many more clinical applications have already begun. For example, clinical trials using stem cells to repopulate or replace cells devastated by injury or disease have helped patients suffering from strokes, Alzheimer's, Parkinson's, epilepsy, stress, and depression (Diederich & Goetz, 2000; Park, 2000; Travis, 2000).



Stem cell research and Parkinson's disease. A fetal graft implanted in the brain of a Parkinson's patient ten years ago still produces significant levels of dopamine (the brain scan on the left). Note, however, that the activity of this area of the brain is still below that of the normal brain on the right.



Can adult brains grow new neurons? Neuroscientists once believed that each of us was born with all the brain cells we would ever have, but Fred Gage and others have shown that neurons are renewed throughout our life span.

Does this mean that people paralyzed from spinal cord injuries might be able to walk again? At this point, neurogenesis in the brain and spinal cord is minimal, but one possible bridge might be *transplanting* embryonic stem cells in the damaged area of the spinal cord. In research with rats, researchers have transplanted mouse embryonic stem cells into a damaged rat spinal cord (McDonald et al., 1999). When the damaged spinal cord was viewed several weeks later, the implanted cells had survived and spread throughout the injured spinal cord area. More importantly, the transplant-rats also showed some movement in previously paralyzed parts of their bodies. Medical researchers have also begun human trials using nerve grafts to repair damaged spinal cords (Barker & Dunnett, 1999; Saltus, 2000).

Although it is unwise to raise false hopes, we are making remarkable breakthroughs in neuroscience. The rewiring, repairing, and transplanting we discussed in this section are just a small part of what was discovered in the last 10 years. It has been said the Decade of the Brain represents the human brain's first big step toward understanding itself. Can you imagine what the next step (or the next decade) might bring?

Is paralysis permanent? Findings from the "Decade of the Brain" may provide hope for actor Christopher Reeve who was paralyzed in a horse riding accident and for people with other serious medical conditions.

Neurogenesis [nue-roh-JEN-uh-sis] *The division of nonneuronal cells to produce neurons*

Stem Cell *Precursor (immature) cells that give birth to new specialized cells; a stem cell holds all the information it needs to make bone, blood, brain — any part of a human body — and can also copy itself to maintain a stock of stem cells*

GENETICS AND EVOLUTION

How are heredity and evolution linked to human behavior?

We began this chapter with a look at the smallest part of the nervous system — the neuron — and then toured the structures of the brain. Now, we go backward in time to the moment of your own conception to see how *behavioral genetics* helps to explain your present adult being. Then we close this section and chapter by going even further back in history to look at the role of *evolution*.

Behavioral Genetics *A new field that combines genetics and psychology to study genetic and environmental influences on behavior*

Behavioral Genetics: How Much Can We Blame Our Parents?

A relatively new field called **behavioral genetics** has greatly increased our understanding of the relative contributions of genetic and environmental influences on behavior. As we discussed in Chapter 1, one of the oldest debates in psychology is the nature–nurture controversy. Throughout this text, you will find numerous examples of how both nature and nurture contribute to various behaviors and mental processes, such as intelligence (Chapter 8), prenatal development (Chapter 9), and mental disorders (Chapter 14). To provide a foundation for these upcoming discussions, we will explore a few basic principles of genetics and the methods used to study behavioral genetics.

Chromosome *Threadlike strands of DNA (deoxyribonucleic acid) molecules that carry genetic information*

Gene *A segment of DNA (deoxyribonucleic acid) that occupies a specific place on a particular chromosome and carries the code for hereditary transmission*

Basic Principles of Genetics

Every cell in your body contains lifelong *messages* from your parents — and you thought it was just their phone calls that bothered you! At the moment of your conception, your mother contributed one set of 23 **chromosomes** and another set of 23 came from your father. Each of these 46 chromosomes is composed of double-stranded molecules of *DNA (deoxyribonucleic acid)*, which, in turn, are made up of thousands of **genes** (Figure 2.17). Genes, the basic units of heredity, are themselves composed of small segments of DNA. We share many of the same genes with other animals and even insects and plants. But it's the genes we share with other humans that set us apart from gorillas, spiders, and tomatoes.

Have you ever wondered why some children have blond hair if both parents have brown hair? It depends on the particular combinations of gene types inherited by the child. For most characteristics, the child inherits two genes, one from each parent. If the inherited gene is *dominant*, the trait encoded in the gene will always be expressed. If the gene is *recessive*, the trait for that gene will be expressed only if the other gene in the pair is also a recessive gene. Because many people have single recessive genes that are not expressed, two brown-eyed parents, who both have recessive genes for blond hair, could produce a blond haired child.

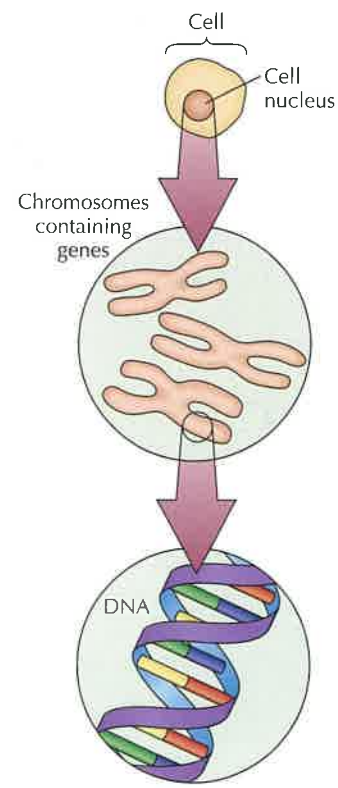


Figure 2.17 ***DNA, genes, chromosomes, cell.***

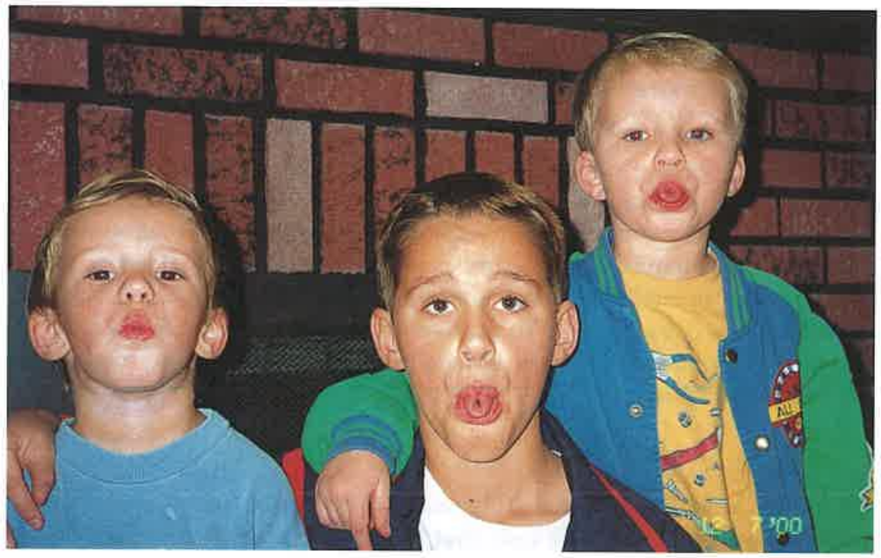
Methods for Studying Behavioral Genetics

Beyond hair and eye color or vision, how much are you shaped by your genetic inheritance? Or by your environment? To answer these questions, researchers generally rely on four methods:

1. ***Twin studies.*** Because each of us receives a different combination of genes, each person is truly biologically unique. The only exception to this genetic uniqueness occurs with *identical* (*monozygotic*) *twins*, which result when a fertilized ovum divides and forms two identical separate cells. These cells go on to produce two complete individuals with identical genetic information. *Fraternal* (*dizygotic*) *twins*, on the other hand, result from the fertilization of two separate eggs by different

TRY THIS *Yourself*

Can you curl your tongue lengthwise? This "ability" is one of the few traits that depends on only one dominant gene. You can increase your understanding of dominant versus recessive genes by doing a simple observation. If you can curl your tongue, one or both of your biological parents must also be able to curl his or her tongue — because this is a dominant trait. Conversely, if you cannot curl your tongue, both of your biological parents cannot curl their tongues.



sperm. These two "womb mates" are genetically no more alike than brothers and sisters born at different times.

The study of identical and fraternal twins offers a unique opportunity to evaluate the relative contributions of genetic and environmental forces in development (Segal & Bouchard, 2000). Identical twins who are separated at birth and reared apart are particularly important because they provide a limited form of control for the relative contributions of nature and nurture.

2. ***Adoption studies.*** Aside from studies of identical twins who may be adopted and reared apart, adoption studies compare two groups of relatives — biological parents and siblings ("blood relatives") and adoptive parents and siblings. If adopted children resemble their biological parents (and siblings), even though they were not raised in that family, then genetic factors probably had the greatest influence. On the other hand, if adopted children resemble their adoptive family, even though they do not share similar genes, then environmental factors may predominate.

3. ***Family studies.*** Researchers can also limit their studies to only blood relatives to see how much heredity has an influence. In these studies, the family history is explored in great detail. If a specific trait is inherited, there should be trait similarity among biological/blood relatives. Moreover, relatives who share more genes, like siblings, should exhibit more similarity than cousins. However, correlation

does not prove causation! Remember that families share not only genes but also environments. Family studies can provide useful insights about the *possible* impact of heredity, but they can't be used to establish cause-and-effect relationships.

4. ***Genetic abnormalities.*** One type of research that can provide definitive evidence is the study of genetic abnormalities. For example, an extra twenty-first chromosome fragment almost always causes a condition called Down syndrome. People with Down syndrome often have distinctive round faces, with small folds of skin across the inner edge of the eyes, and impaired psychomotor and physical development, as well as mental retardation. Other disorders like Alzheimer's disease, involving brain deterioration and memory loss, and schizophrenia, a severe mental disorder characterized by loss of contact with reality, are suspected to be caused by abnormalities in several genes or chromosomes (Bailer et al., 2000; Berretini, 2000). We will discuss these disorders in detail in upcoming chapters.

Findings from these four methods have allowed behavior geneticists to estimate the **heritability** of various traits. That is, the extent to which differences among individuals on psychological dimensions, such as intelligence and personality, are determined by genetic factors, as opposed to differences in environment. If genetics contributed *nothing* to the trait, it would have a heritability estimate of zero percent. If a trait were *completely* due to genetics, we would say it had a heritability estimate of 100 percent.

There are two important points to remember about heritability:

1. ***Heritability estimates do not apply to individuals.*** When people hear media reports that intelligence, musical abilities, or athletic talents are 30 to 50 percent inherited, they often mistakenly assume that this applies to them as individuals. Thus, if intelligence is 50 percent inherited, they believe that 50 percent is due to their parents and 50 percent to the environment. However, estimates of *heritability* are mathematical computations of the proportion of total variance in a trait that is explained by genetic variation within a *group*. In other words, these statistics *describe groups, not individuals*. Height, for example, has one of the highest heritability estimates — around 90 percent (Plomin, 1990). However, any one individual's personal height may be very different from his or her parents' or other blood relatives' height. We each inherit a unique combination of genes (unless we are identical twins). It is impossible to predict your individual height from a heritability estimate. You can estimate only for the group as a whole.

2. ***Genes and environment are inseparable.*** As first discussed in Chapter 1 (and throughout upcoming chapters), nature and nurture interact — they play off each other and are inseparable (Casti, 2000; Gottlieb, 2000; Maccoby, 2000). Imagine your inherited genes as analogous to water, sugar, salt, flour, eggs, baking powder, and oil. When you mix these ingredients and pour them on a hot griddle (one environment), you get pancakes. Add more oil (a different combination of genes) and a waffle iron (a different environment), and you get waffles. With another set of ingredients and environments (different pans and an oven), you can have crepes, muffins, or cakes. How can you separate the effects of ingredients and cooking methods? You can't. Nature and nurture interact.

> With a good heredity, nature deals you a fine hand at cards; and with a good environment, you learn to play the hand well.
>
> Walter C. Alvarez

"Virtual Twins" Julie (left) and Sara. Traditionally, biological twins have been "the gold standard" for genetic studies, but psychologist Nancy Segal has recently studied "virtual twins" (pairs of unrelated siblings of the same age, one or both adopted, who have been raised together since infancy). Segal suggests these twins provide unique information because they share a common family environment but no common genes.

Heritability *The proportion of observed variance in a particular trait (such as intelligence) that can be attributed to inherited genetic factors in contrast to environmental ones*

RESEARCH HIGHLIGHT

Breakthrough — The Human Genome is Mapped!

Since the 1980s, an exciting, ambitious, multibillion dollar international scientific effort called the *Human Genome Project (HGP)*, led by Francis Collins, and the *International Human Genome Sequencing Consortium (IHGSC)*, led by Craig Venter, have been creating "the human book of life." Working with new, high-tech methods, these two research teams set out to map all of the estimated 100,000 genes on the human chromosome. (The full set of genes for any organism is known as the *genome*—the total DNA blueprint of heritable traits contained in every cell of the body.)

On February 12, 2001, the journals *Science* and *Nature* published the breakthrough news that the mapping was complete, and that humans have only about 30,000 genes, which compares to around 19,000 for the roundworm and 13,000 for the fruit fly (International Human Genome, 2001; Venter et al., 2001). Although humans seem to have fewer genes than originally thought, their genes appear to be far more complex, and the completion of the analyses of the human genome is considered one of the most significant landmarks of all time, comparable to landing a man on the moon or splitting the atom. Francis Collins, leader of the HGP, described the genome as a "book of life" with three volumes:

> "It's a history book—a narrative of the journey of our species through time. It's a shop manual, with an incredibly detailed blueprint for building every human cell. And it's a transformational textbook of medicine, with insights that will give healthcare providers immense new powers to treat, prevent, and cure disease" (cited in Sherrid, p. 48).

Cracking the genetic code. J. Craig Venter and Francis Collins, lead researchers for the Human Genome Project, received joint credit for mapping the human genome. Their work is considered a monumental milestone in genetic research. Can you explain why?

This enormous research venture has already produced important findings on genetic contributors to disease (Jegalian & Lahn, 2001; Lemonick, 2000; Seppa, 2000).

Evolutionary Psychology: Darwin Explains Behavior and Mental Processes

Evolutionary Psychology *A branch of psychology that studies evolutionary principles, like natural selection and genetic mutations, which affect adaptation to the environment and help explain commonalities in behavior*

Natural Selection *The driving mechanism behind evolution that allows individuals with genetically influenced traits that are adaptive in a particular environment to stay alive and produce offspring*

If you've traveled in many countries or taken courses in anthropology, your initial focus may have been on all the strange and unusual practices of other cultures. But over time, you also undoubtedly noted that people the world over seem to eat, work, play with their friends, care for their children, and fight with their enemies in remarkably similar ways. How do we explain this?

Evolutionary psychology suggests that many behavioral commonalities, from eating to fighting with our enemies, emerged and remain in human populations because they helped our ancestors (and ourselves) survive. This perspective is based on the writings of Charles Darwin (1859) who suggested that natural forces select traits that are adaptive to the organism's survival. This process of **natural selection** occurs when one particular genetic trait gives a person a reproductive advantage over others. Although some people mistakenly believe that natural selection means "survival of the fittest," what really matters is *reproduction* — the survival of the genome. Because of natural selection, the fastest or otherwise most fit organisms will be more likely than the less fit to live long enough to mate and thus pass on their genes to the next generation.

Imagine that you are camping alone in a remote area and see a large grizzly bear approaching. According to the principles of *natural selection*, your chances for survival depend on how quickly and smartly you respond to the threat. But what if your child and a group of strangers and their children are also camping in the same spot? Whom do you protect? Most parents would "naturally" choose to help their own child. Why? Why does this feel so "natural" and automatic? According to evolutionary psychologists, natural selection favors animals whose concern for kin is proportional to their degree of biological relatedness. Thus, most people will devote more resources, protection, love and concern to close relatives. This helps ensure their "genetic survival."

In addition to natural selection, *genetic mutations* also help explain behavior. Given that each of us inherits over 100,000 genes, the probability is quite high that everyone carries at least one gene that has *mutated*, or changed from the original. The vast majority of mutated genes have no effect on behavior whatsoever. But, on occasion, a mutated gene will change an individual's behavior. It might cause someone to be more social, more risk taking, more shy, more careful. If the gene gives the person reproductive advantage, he or she will be more likely to pass on the gene to future generations. Another common misunderstanding is that evolution translates into continuing, long-term improvement. A genetic mutation can produce a population that is perfectly adapted to a current environment, but which may later perish if the environment changes.

Social and cultural factors can also affect evolution, as evidenced when the social or cultural factors influence the mating behavior of the people in a population (Segerstrale, 2000). For example, as explained in Chapter 16, the concept of beauty is culturally influenced. Therefore, those who best fit their culture's concept of beauty may find it easier to acquire mates and have more offspring, to whom they pass on their physical and behavioral traits. Similarly, in cultures that arrange marriages according to social class or religious factors, different traits may be selected and passed along to succeeding generations.

Evolutionary psychology is one of the seven major perspectives in modern psychology (Chapter 1, Introduction and Research Methods), and we will revisit this field many times throughout this text. For example, in Chapter 3 (Stress and Health Psychology), we examine the role of stress over the course of evolution, and Chapter 9 (Life Span Development I) explores the role of evolution in infant reflexes, language development, and attachment. In Chapter 11 (Gender and Human Sexuality), we look at modern controversies surrounding evolution and gender role development and supposed differences in sexual behavior. Chapter 12 (Motivation and Emotion) discusses the role of evolution in drives toward novelty and exploration and the universal recognition of facial expressions of emotion. Evidence of evolution in our helping and aggressive behaviors is discussed in Chapter 16 (Social Psychology).

In the following section, we explore biological differences between women and men that may have evolved from different gender-related adaptations.

***Evolution in Action?** Similar behaviors in humans and other animals may suggest common evolutionary influences.*

GENDER & CULTURAL DIVERSITY

The Evolution of Sex Differences

Because of the way our species evolved, modern men and women have many abilities that helped our ancestors adapt to their environment and hence to survive and reproduce. For example, Figures 2.18 and 2.19 show that men tend to score higher on tests of mathematical reasoning and spatial relationships, whereas women score higher on tests involving mathematical calculation and tasks requiring perceptual speed. Men also tend to be more accurate in target-directed motor skills, whereas women tend to be more efficient in skills requiring fine motor coordination. What accounts for these differences?

One possible answer from evolutionary psychologists is that ancient societies typically assigned men the task of "hunters" and women as "gatherers." The man's superiority on many spatial tasks and target-directed motor skills, for example, may have evolved from the adaptive demands of hunting. Similarly, activities such as gathering, child-rearing, and domestic tool construction and manipulation may have contributed to the woman's language superiority (Farber, 2000; Joseph, 2000; Silverman & Phillips, 1998). Some critics, however, suggest that evolution progresses much too slowly to account for this type of behavioral adaptation. Furthermore, evolutionary

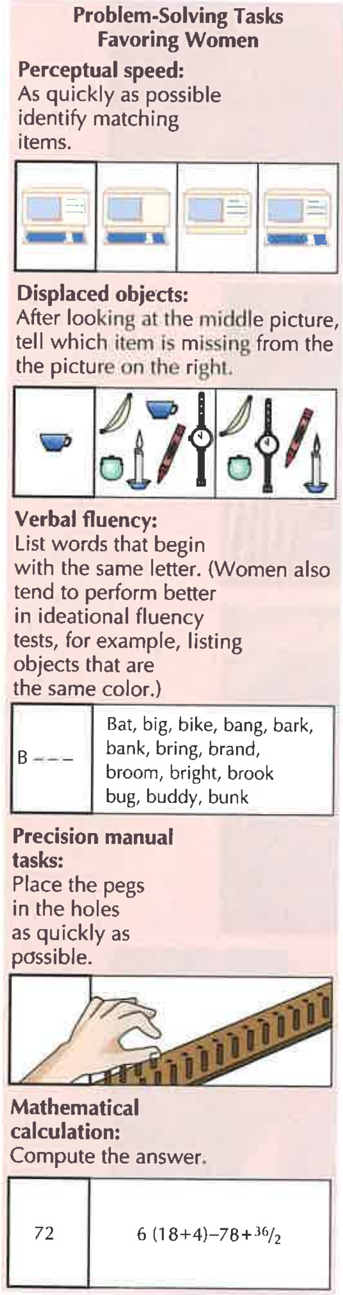


Figure 2.18 *Problem solving tasks favoring women.*

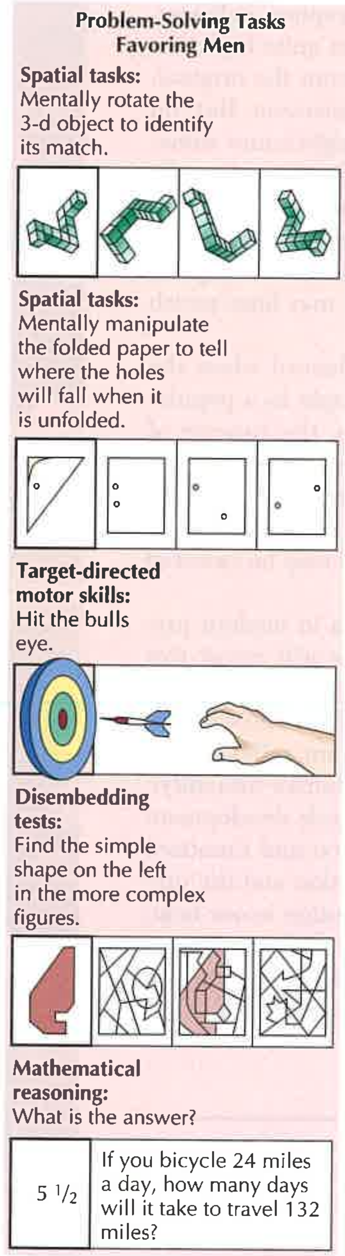


Figure 2.19 *Problem solving tasks favoring men.*

explanations of sex differences are highly speculative and obviously difficult to test scientifically (Eagly & Wood, 1999).

A less controversial explanation of sex differences comes from well-established knowledge of hormonal effects. All women and men produce both estrogens and androgens (the principal classes of female and male hormones). It is the relative proportion of these hormones that accounts for sex differences. Even before birth, development of genital anatomy is largely due to the presence or absence of *testosterone* (one of the androgens secreted by the testes). Although genetic sex is determined at the moment of conception — an XX pairing produces a female zygote and an XY pairing produces a male — during the first 6 to 8 weeks after conception, the genital areas of both male and female embryos are essentially the same. Once the sex glands begin to produce differing levels of hormonal secretions (androgens and estrogens), their genital organs *differentiate*.

In some cases, however, endocrine disorders can lead to overproduction or underproduction of these hormones during prenatal development. In general, males exposed prenatally to abnormally low levels of androgens exhibit more femalelike behavior than other males. Conversely, females exposed prenatally to abnormally high levels of androgens tend to show more malelike behavior compared with other females.

For example, studies of girls with *congenital adrenal hyperplasia* (CAH), a rare genetic disorder with an excess amount of *androgens*, grow up to be more "tomboyish" and aggressive than nonaffected girls (Leveroni & Berenbaum, 1998). Moreover, girls with CAH tend to outperform nonaffected girls on cognitive tests of spatial ability on which males are known to excel, such as the mental rotation task shown in Figure 2.19 (Hampson, Rouet, & Altman, 1998; Nass & Baker, 1991). Although physiological effects resulting from CAH — the development of male genitals and the overproduction of androgens — can be surgically or medically corrected, the hormonal influence on brain development appears irreversible.

In addition to possible sex differences due to prental hormonal influences, there also may be differences in the anatomical structure of men and women's brains (Boone, 2000; Castle, 2000; Dorion et al., 2000; Amunts, Jaencke, Mohlberg, Steinmetz, & Zilles, 2000). For example, Mark Lumley and Kevin Sielky (2000) found an interesting gender difference in a disorder known as *alexithymia*, which involves difficulty identifying and describing feelings. The disorder seems to reflect deficiencies in right hemisphere function or interhemispheric transfer, but only for men. For women, poorer short-term memory is a better predictor. In another study, Ruben Gur and his colleagues (1999) found that women have a greater percentage of their brains dedicated to gray matter (neuron cell bodies) than do men. Considering that there is very little or no difference between men and women in overall intelligence, the increased percentage of gray matter might just be an evolutionary adaptation to the smaller cranial size in women. Most women (and their brains) tend to be smaller than most men. Thus, some of the structural differences between male and female brains might reflect adaptations to differences in skull size (De Vries & Boyle, 1998).

Evolutionary psychology research emphasizes heredity and early biological processes in determining gender differences in cognitive behavior, but keep in mind that almost all sex differences are *correlational*. The mechanisms involved in the actual *cause* of certain human behaviors have yet to be determined. Furthermore, it is important to remember that all known variations *between* the two sexes are much smaller than differences *within* each sex. Finally, to repeat a theme discussed throughout this text, it is extremely difficult to separate the effects of biology (nature) from those of the environment (nurture) (Gottlieb, 2000; Maccoby, 2000).

Check & Review

GENETICS AND EVOLUTIONARY PSYCHOLOGY

Genes are strings of chemicals that hold the code for certain traits that are passed on from parent to child, and they can be dominant or recessive. Genes are found on long strands of DNA molecules called **chromosomes. Behavioral geneticists** use twin studies, adoption studies, family studies, and genetic abnormalities to explore genetic contributions to behavior and make estimates of **heritability.**

Evolutionary psychology is the branch of psychology that looks at evolutionary changes related to behavior. Several different processes, including **natural selection**, mutations, and social and cultural factors can affect evolution.

Questions

1. Evolutionary psychology is the branch of psychology that looks at
   a. How fossil discoveries affect behavior
   b. The relationship between genes and the environment
   c. The relationship between evolutionary changes and behavior
   d. The effect of culture change on behavior
2. What are the four chief methods used to study behavioral genetics?
3. According to evolutionary theorists, why are people more likely to help their family members than strangers?
4. How would evolutionary psychology explain why men tend to score higher on mathematical reasoning, spatial relationships, and target directed motor skills, whereas women score higher on mathematical calculation, tasks requiring perceptual speed, and fine motor coordination?

Answers to Questions can be found in Appendix B.

KEY TERMS

neuroscience (p. 46)
Biological Foundations
action potential (p. 52)
autonomic nervous system (ANS) (p. 48)
axon (p. 51)
cell body (p. 51)
central nervous system (CNS) (p. 46)
dendrites (p. 51)
endocrine [EN-dohe-krin] system (p. 57)
endorphins [en-DOR-fins] (p. 57)
glial cells (p. 51)
hormones (p. 57)
myelin [MY-uh-lin] sheath (p. 51)
neuron (p. 50)
neurotransmitter (p. 53)
parasympathetic nervous system (p. 48)
peripheral nervous system (PNS) (p. 48)
somatic nervous system (SNS) (p. 48)
sympathetic nervous system (p. 48)
synapse [SIN-aps] (p. 53)
A Tour Through the Brain
amygdala [uh-MIG-dull-uh] (p. 65)
association areas (p. 70)
brainstem (p. 63)
cerebellum [sehr-uh-BELL-um] (p. 63)
cerebral cortex (p. 66)
corpus callosum [CORE-puss] [cah-LOH-suhm] (p. 70)
frontal lobes (p. 66)
hypothalamus [hi-poh-THAL-uh-muss] (p. 64)
lateralization (p. 70)
limbic system (p. 64)
localization of function (p. 62)
medulla [muh-DUL-uh] (p. 63)
neurogenesis [nue-roe-JEN-uh-sis] (p. 76)
neuroplasticity (p. 76)
occipital [ahk-SIP-uh-tuhl] lobes (p. 68)
parietal [puh-RYE-uh-tuhl] lobes (p. 67)
pons (p. 63)
reticular formation (RF) (p. 63)
split brain (p. 70)
stem cell (p. 76)
temporal lobes (p. 68)
thalamus [THAL-uh-muss] (p. 64)
Genetics and Evolution
behavioral genetics (p. 77)
chromosome (p. 77)
evolutionary psychology (p. 80)
gene (p. 77)
heritability (p. 79)
natural selection (p. 80)

Visual Summary for Chapter 2

Biological Foundations

An Overview of the Nervous System

Central Nervous System (CNS)
- Brain
- Spinal Cord

Peripheral Nervous System (PNS)
- Somatic Nervous System (SNS)
- Autonomic Nervous System (ANS)
  - Parasympathetic
  - Sympathetic

Neurons as the Basic Building Blocks

Neurons: Individual nerve cells that transmit information throughout the body.
Glial cells: Provide structural, nutritional, and other support for neurons.

Key Features of a Neuron

- **Dendrites**: Receive information and send impulses to cell body.
- **Cell body**: Integrates incoming information and nourishes neuron.
- **Axon**: Carries information from cell body to other neurons.

(**Myelin Sheath**: Fatty insulation around some axons that speeds up action potential.)

How Neurons Communicate

- Communication *within the neuron* is through the **action potential**, a neural impulse that carries information along the axon.
- Communication *between neurons* occurs when an action potential reaches the axon terminal and stimulates the release of **neurotransmitters** into the **synapse**.

Chemical Messengers in the Nervous System

Three key chemical messengers:

1) **Neurotransmitters**: Chemicals manufactured and released by neurons that alter activity in other neurons, which thereby affects behavior and mental processes.
2) **Endorphins**: Chemicals that produce effects similar to those of opium based drugs like morphine.
3) **Hormones**: Chemicals released from the endocrine system into the bloodstream, which affect the nervous system.

A Tour Through the Brain

Tools for Exploration

Methods include brain dissection, ablation, lesioning, clinical observation, case studies, electrical recordings, electrical stimulation of the brain (ESB), brain imaging (such as CT, PET, MRI, fMRI).