CHAPTER 2

Biology, Culture, and Human Behavior

CHAPTER OUTLINE

- Neurons: Building Blocks of the Nervous System
- The Nervous System: Its Basic Structure and Functions
- The Brain: Where Consciousness . . . Is
- The Brain and Human Behavior: Where Biology and Consciousness Meet
- Heredity and Behavior: Genetics and Evolutionary Psychology
- Culture and Behavior

What do you do when you wake up in the morning? You probably check the time on the bed side clock, then decides to wake up or not. Once you see the time, the information is relayed back to the brain. Through a simple looking and quick analysis, you then decide if it is a good time to wake up. You wake up with your legs, arms and other parts of your body working in unison. This very simple act of getting up in the morning if looked carefully would suggest how biology underscores each action you take.

The basic theme of this chapter is that : *Everything we think, feel, or do has an important basis in biologica processes and events*—and primarily in activities occurring in our brains and other portions of the nervous sys tem. Do you understand these words? It is the result of activity in your brain. Do you feel hungry? It is th result of activity in your brain and other biological events. Can you remember what your psychology professo looks like? Again, it's the result of activity in several areas of your brain. We could go on, but by now we ar sure you get the point: *Everything psychological has a biological basis,* in the sense that it is associated or linke with biological processes or events. It does not mean that everything is reducible to biology. The cultural an environmental context also influence the pattern of behavior. In particular the cultural meanings and practic significantly shape human behavior.

This chapter begins by considering the biological processes that underlie our behavior. The goal is certain ly not to make you an expert on these processes: This is a course in psychology, not biology, and we promis not to forget it. But as you'll soon see, we really can't obtain full answers to many questions about behavi without attention to biological factors—especially activity in our brains. This is followed by an analysis cultural influences on behavior.

We shall begin by providing some basic information about the nervous system and, especially, the brai So let's turn now to neurons—the building blocks of which, ultimately, our consciousness is composed.

Neurons:
Building Blocks of the Nervous System

You are driving down the road when suddenly your friend, who is sitting in the seat next to you, shouts: "Watch out for that truck!" Immediately, you experience strong anxiety, step on the brake, and look around in every direction. The process seems automatic, but think about it for a moment: How did information from your ears get "inside" and trigger your emotions and behavior? The answer involves the activity of **neurons**: cells within our bodies that are specialized for the tasks of receiving, moving, and processing information.

Neurons: Cells specialized for communicating information, the basic building blocks of the nervous system.

Dendrites: The parts of neurons that conduct action potentials toward the cell body.

Axon: The part of the neuron that conducts the action potential away from the cell body.

Glial Cells: Cells in the nervous system that surround, support, and protect neurons.

Axon Terminals: Structures at the end of axons that contain transmitter substances.

Synapse: A region where the axon of one neuron closely approaches other neurons or the cell membrane of other types of cells such as muscle cells.

Neurons: Their Basic Structure

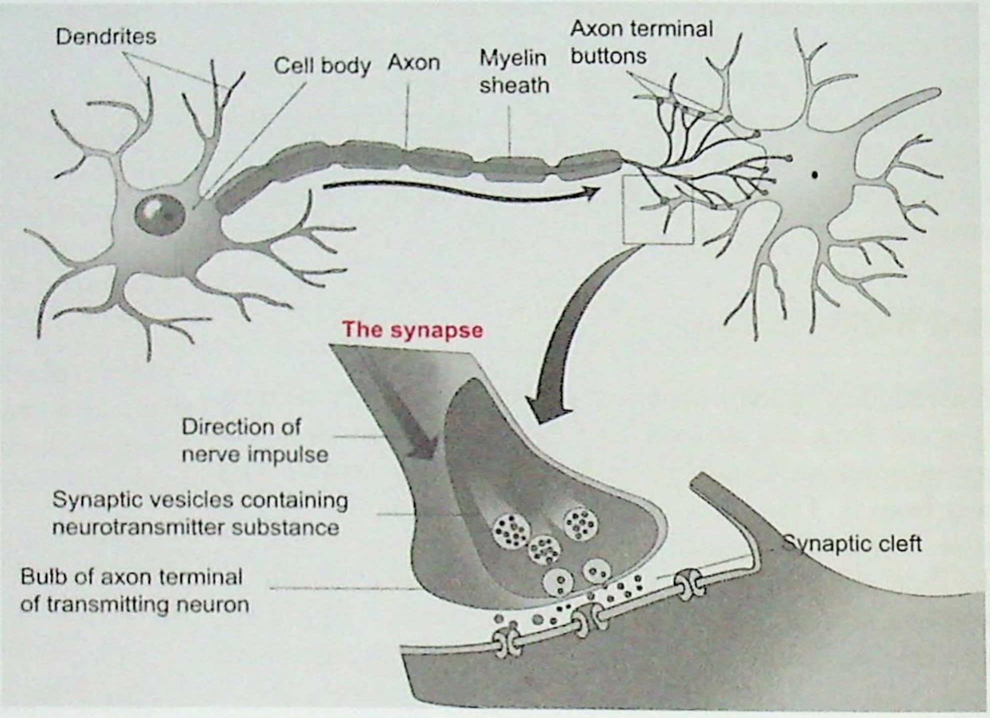
Neurons are tremendously varied in appearance. Yet most consist of three basic parts: (1) a *cell body*, (2) an *axon*, and (3) one or more *dendrites*. **Dendrites** carry information toward the cell body, whereas **axons** carry information away from it. Thus, in a sense, neurons are one-way channels of communication. Information usually moves from dendrites or the cell body toward the axon and then outward along this structure. A simplified diagram of a neuron and actual neurons are shown, magnified, in Figure 2.1. Scientists estimate that the human brain may contain more than 100 billion neurons.

In many neurons the axon is covered by a sheath of fatty material known as *myelin*. The myelin sheath (fatty wrapping) is interrupted by small gaps (places where it is absent). Both the sheath and the gaps in it play an important role in the neuron's ability to transmit information, a process we'll consider in detail shortly. Damage to the myelin sheath surrounding axons can seriously affect synaptic transmission. In diseases such as *multiple sclerosis* (MS), progressive deterioration of the myelin sheath leads to jerky, uncoordinated movement in the affected person.

The myelin sheath is actually produced by another basic set of building blocks within the nervous system, **glial cells**. Glial cells, which outnumber neurons by about ten to one, serve several functions in our nervous system; they form the myelin sheath around axons and perform basic housekeeping chores, such as cleaning up cellular debris. They also help form the *blood–brain barrier*—a barrier that prevents certain substances in the bloodstream from reaching the brain.

Near its end, the axon divides into several small branches. These, in turn, end in round structures known as **axon terminals** that closely approach, but do not actually touch other cells (other neurons, muscle cells, or gland cells). The region at which the axon terminals of a neuron closely approach other cells is known as the **synapse**. The manner in which neurons communicate with other cells across this tiny space is described next.

Figure 2.1
Neurons: Their Basic Structure
Neurons vary in form, but all possess the basic structures: a cell body, an axon (with axon terminals), and one or more dendrites.



Neurons: Their Basic Function

As we consider how neurons function, two questions arise: (1) How does information travel from point to point within a single neuron? And (2) how is information transmitted from one neuron to another or from neurons to other cells of the body?

Communication Within Neurons: Graded and Action Potentials

Graded Potential: A basic type of signal within neurons that results from external physical stimulation of the dendrite or cell body. In contrast to the all-or-nothing nature of action potentials, graded potentials vary in proportion to the size of the stimulus that produced them.

The answer to the first question is complex but can be summarized as follows: When a neuron is at rest, there is a tiny electrical charge (–70 millivolts) across the cell membrane. That is, the inside of the cell has a slight negative charge relative to the outside. This electrical charge is due to the fact that several types of ions (positively and negatively charged particles) exist in different concentrations outside and inside the cell. As a result, the interior of the cell membrane acquires a tiny negative charge relative to the outside. This resting potential does not occur by accident; the neuron works to maintain it by actively pumping positively charged ions back outside if they enter, while retaining negatively charged ions in greater concentrations than are present outside the cell.

Stimulation, either directly (by light, heat, or pressure) or by chemical messages from other neurons, produces **graded potentials**—a basic type of signal *within* neurons. An important feature of graded potentials i that their magnitude varies in proportion to the size of the stimulus that produced it. Thus, a loud sound or bright light produces graded potentials of greater magnitude than a softer sound or dim light. Because graded potentials tend to weaken quickly, they typically convey incoming information over short distances, usually along the dendrite toward the neuron's cell body. Please note that neurons receive information from many other cells—often from thousands of them.

If the overall pattern of graded potentials reaching the cell body is of sufficient magnitude—if it exceeds the *threshold* of the neuron in question—complex biochemical changes occur in the cell membrane, and an *action potential* is generated (please refer to Figure 2.2). During an **action potential**, some types of positively charged ions are briefly allowed to enter the cell membrane more readily than before. This influx of positive ions reduces, then totally eliminates the resting potential. Indeed, for a brief period of time, the interior of the cell actually attains a net positive charge relative to the outside. This change in electrical potential across the cell membrane moves rapidly along the neuron, and it is this moving disturbance, known as the action potential, is the basic signal within our nervous system—the signal that is ultimately the basis of everything we sense, think, or do.

After a very brief period (1 or 2 milliseconds), the neuron actively pumps the positive ions back outside and allows other ions, which flowed outside via their own ion channels, to reenter. As a result, the resting potential is gradually restored, and the cell becomes ready to "fire" once again. Unlike graded potentials, the action potential is an *all-or-none response*. Either it occurs at full strength or it does not occur at all; there is nothing in between. Also, the speed of conduction of an action potential is very rapid in neurons possessing a myelin sheath. In a sense, the action potential jumps from one small gap in the sheath to another—openings known as **nodes of Ranvier**. Speeds along myelinated axons can reach 270 miles per hour.

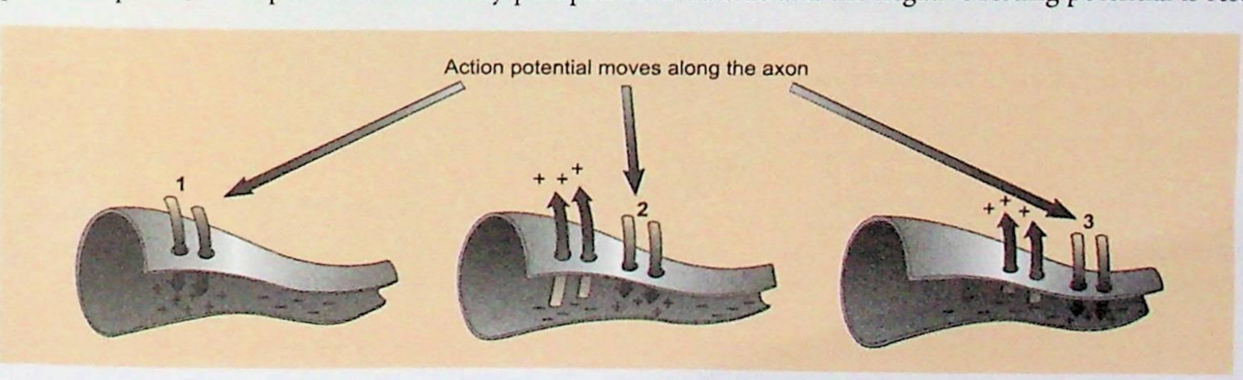
Action Potential: A rapidly moving wave of depolarization (shift in electrical potential) that travels along the cell membrane of a neuron. This disturbance along the membrane communicates information within the neuron.

Nodes of Ranvier: Small gaps in the myelin sheath surrounding the axons of many neurons.

Communication Between Neurons: Synaptic Transmission

We noted earlier that neurons closely approach, but do not actually touch other neurons (or other cells of the body). How, then, does the action potential cross the gap between them? Existing evidence points to the following answer.

Figure 2.2
The Action Potential
The action potential—the most basic signal in the nervous system—consists of a rapidly moving wave of depolarization that travels along the membrane of the individual neuron. As the action potential moves, the negative charge across the cell membrane briefly disappears—largely as a result of positively charged particles moving inside. After the action potential passes, these particles are actively pumped back outside and the negative resting potential is restored.



When a neuron "fires," the action potential that is produced travels along the membrane of the axon to the axon terminals. Within the axon terminals are many structures known as **synaptic vesicles**. Arrival of the action potential causes these vesicles to approach the cell membrane, where they fuse with the membrane and then empty their contents into the synapse (see Figure 2.3). The chemicals thus released—known as **neurotransmitters**—travel across the tiny synaptic gap until they reach specialized receptor sites in the membrane of the other cell.

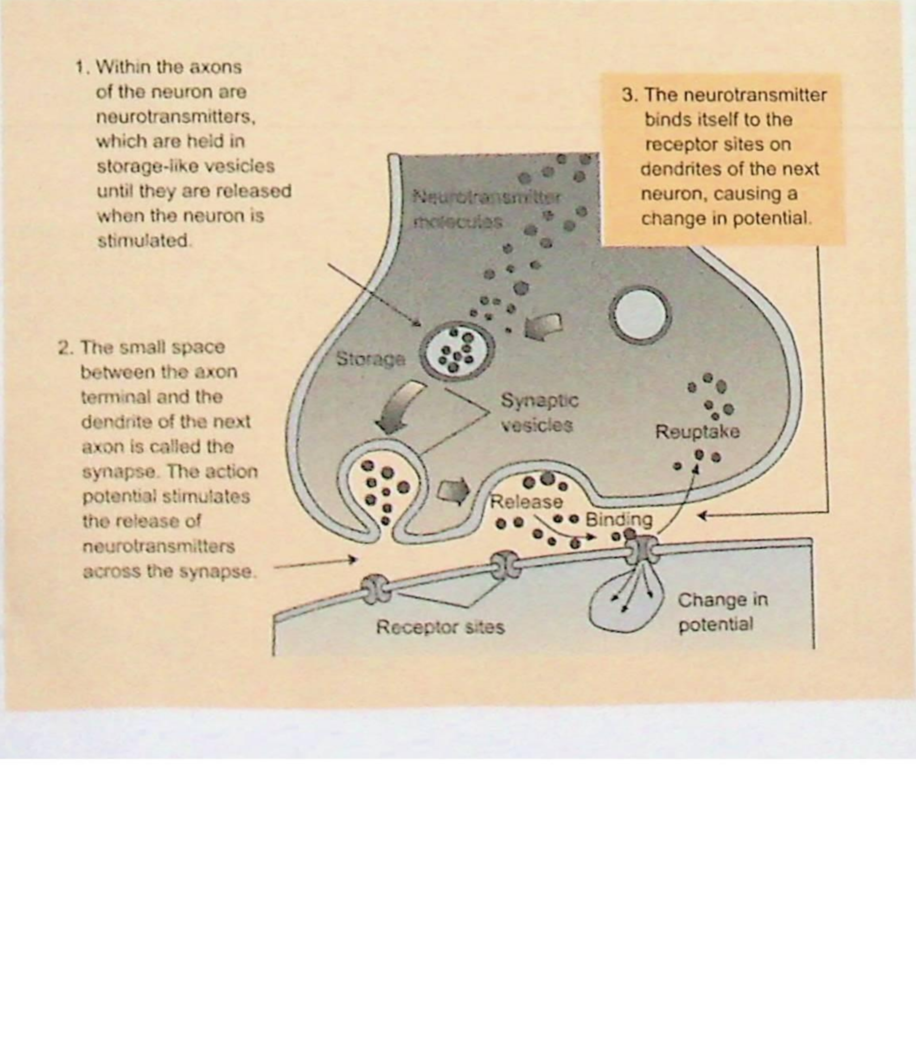
Synaptic Vesicles: Structures in the axon terminals that contain various neurotransmitters.

Neurotransmitters: Chemicals, released nu neurons, that carry information across synapses.

These receptors are complex protein molecules into whose structure neurotransmitter substances fit like chemical keys into a lock. Specific neurotransmitters can deliver signals only at certain locations on cell membranes, thereby introducing precision into the nervous system's complex communication system. Upon binding to their receptors, neurotransmitters either produce their effects directly, or function indirectly through the interaction of the neurotransmitter and its receptor with other substances.

Neurotransmitters produce one of two effects. If their effects are *excitatory* in nature, they make it more likely for the neuron they reach to fire. If, instead, their effects are *inhibitory*, they make it less likely that the neuron will fire. What happens to neurotransmitters *after* they cross the synapse from one neuron to another? Either they are taken back for reuse in the axon terminals of the neuron that released them, a process known as *reuptake*, or they are broken down by various enzymes present at the synapse—in a sense, chemically deactivated.

Figure 2.3
Synaptic Transmission
The axon terminals found on the ends of axons contain many synaptic vesicles. When an action potential reaches the axon terminal, these vesicles move toward the cell membrane. Once there, the vesicles fuse with the membrane and release their contents (neurotransmitters) into the synapse.



It is important to note that in our comments so far, we have greatly simplified reality by describing a situation in which one neuron contacts another across a single synapse. In fact, this is rarely, if ever, the case. Most neurons actually form synapses with many others—ten thousand or more in some cases. Thus, at any given moment, most neurons are receiving a complex pattern of excitatory and inhibitory influences from many neighbors.

Whether a neuron conducts an action potential or not, then, depends on the total pattern of this input; for example, whether excitatory or inhibitory input predominates. Further, the effects of excitatory and inhibitory input can be cumulative over time, in part because such effects do not dissipate instantaneously. Thus, if a neuron that has recently been stimulated, but not sufficiently to produce an action potential, is stimulated again soon afterwards, the two sources of excitation may combine so that an action potential is generated.

Neurotransmitters: Chemical Keys to the Nervous System

The fact that transmitter substances produce either excitatory or inhibitory effects might seem to suggest that there are only two types. In fact, there are many different neurotransmitters, and many more chemical substances that can mimic the effects of neurotransmitters; in fact, many drugs produce their effects in this way. Several known neurotransmitters and their functions are summarized in Table 2.1. Although the specific roles of many transmitter substances are still under study, we are now fairly certain about the functions of a few. Perhaps the one about which we know most is *acetylcholine*. It is the neurotransmitter at every junction between

Table 2.1

Neurotransmitters: An Overview

Neurons communicate with one another across the synapse through neurotransmitters. Several of these are listed and described here.

NEUROTRANSMITTER	LOCATION	EFFECTS
Acetylcholine	Found throughout the central nervous system, in the autonomic nervous system, and at all neuromuscular junctions.	Involved in muscle action, learning, and memory.
Norepinephrine	Found in neurons in the autonomic nervous system.	Primarily involved in control or alertness and wakefullness.
Dopamine	Produced by neurons located in a region of the brain called the substantia nigra.	Involved in movement, attention, and learning. Degeneration of dopamine-producing neurons has been linked to Parkinson's disease. Too much dopamine has been linked to schizophrenia.
Serotonin	Found in neurons in the brain and spinal cord.	Plays a role in the regulation of mood and in the control of eating, sleep, and arousal. Has also been implicated in the regulation of pain and in dreaming.
GABA (gamma-amino-butyric acid)	Found throughout the brain and spinal cord.	GABA is the major inhibitory neurotransmitter in the brain. Abnormal levels of GABA have been implicated in sleep and eating disorders.

motor neurons (neurons concerned with muscular movements) and muscle cells. Anything that interferes with the action of acetylcholine can produce paralysis. South American hunters have long used this fact to their advantage by dipping their arrow tips in *curare*—a poisonous substance that occupies acetylcholine receptors. As a result, paralysis is produced, and the unlucky animal dies quickly through suffocation. Some evidence suggests that the severe memory loss characteristic of persons suffering from *Alzheimer's disease* results from a degeneration of cells that produce acetylcholine. Examinations of the brains of persons who have died from this disease show unusually low levels of this substance (Coyle, Price, & DeLong, 1983).

The Endorphins

During the 1970s, researchers studying the effects of morphine and other opiates made a surprising discovery: There appeared to be special receptor sites for such drugs within the brain (Hughes et al., 1975). Why should such receptors exist? It was soon discovered that naturally occurring substances that closely resemble morphine in chemical structure are produced by the brain. These substances, known as endorphins, seemed to act as neurotransmitters, stimulating specialized receptor sites. Why should the brain produce such substances? Research suggests that endorphins are released by the body in response to pain or vigorous exercise and so help reduce sensations that might otherwise interfere with ongoing behavior (Fields & Basbaum, 1984). Additional evidence indicates that endorphins also serve to intensify positive sensations—for example, the "runner's high" many people experience after vigorous exercise. In short, it appears that the brain possesses an internal mechanism for moderating unpleasant sensations and magnifying positive ones, and that the effects of morphine and other opiates stem, at least in part, from the fact that these drugs act on this naturally existing system.

Drugs and Neurotransmitters

Now that we have considered the nature and function of neurotransmitters, we are in a better position to understand how the drug produces its effects. In many cases, drugs affect our feelings or behavior by altering the process of synaptic transmission. They do this because they are similar enough in chemical structure to neurotransmitters to occupy the receptor sites normally occupied by the neurotransmitters themselves (e.g., Kalivas & Samson, 1992). In this respect, drugs can produce two basic effects: They can mimic the effects of the neurotransmitter, in which case they are described as being **agonists**, or they can inhibit the effects normally produced by the neurotransmitter, in which case they are described as being **antagonists**. Many painkillers (analgesics) occupy receptor sites normally stimulated by endorphins; thus, they block pain and produce a temporary high. Addicting drugs such as opium, heroin, and crack cocaine also occupy these sites, and produce more intensely pleasurable sensations than endorphins. This seems to play a key role in their addicting properties.

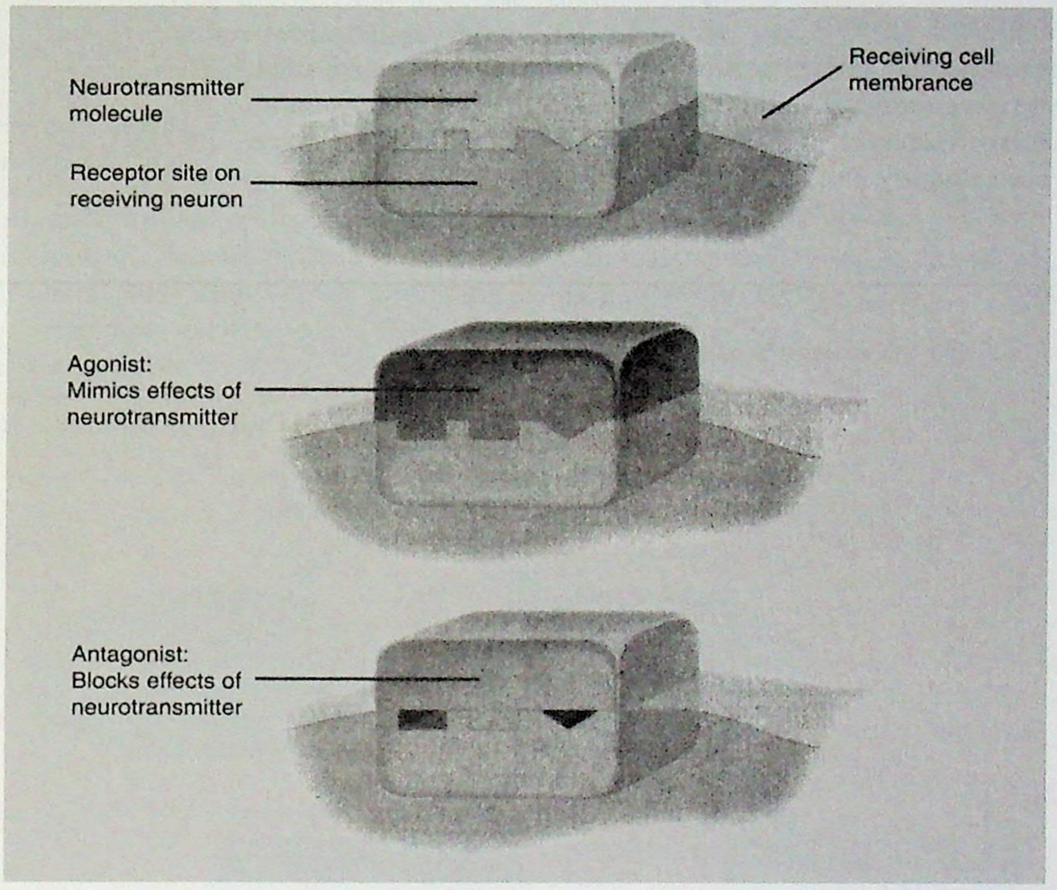
Agonist: A chemical substance that mimics the action of a neurotransmitter at a receptor site.

Antagonist: A chemical substance that inhibits the effect normally produced by a neurotransmitter at a receptor site.

REVIEW QUESTIONS

- What do neurons do, and what are their basic parts?
- What are action potentials and graded potentials? How do neurons communicate with one another?
- What are the effects of neurotransmitters?
- How do drugs produce their effects? What are agonists? Antagonists?

Figure 2.4
How Drugs Affect the Nervous System: Agonists and Antagonists
Naturally occurring neurotransmitters fit receptor sites on neurons like a key fitting into a lock. Some drugs are close enough in structure to these neurotransmitters to fit into the same receptor sites. Drugs that then mimic the effects of the neurotransmitter are said to act as *agonists*. Drugs that block the effects normally produced by the neurotransmitter are termed *antagonists*.



The Nervous System:
Its Basic Structure and Functions

If neurons are building blocks, then the **nervous system** is the structure that they, along with other types of cells, combine to erect. The nervous system is actually a complex network of neurons that regulates our bodily functions and permits us to react to the external world in countless ways, so it deserves very careful attention. But remember: This is not a course in biology, so the main reason for focusing on the nervous system is to provide a foundation for understanding its role in all aspects of our behavior.

Nervous System: The complex network of neurons that regulates bodily processes and is ultimately responsible for all aspects of conscious experience.

The Nervous System: Its Major Divisions

Central Nervous System: The brain and the spinal cord.

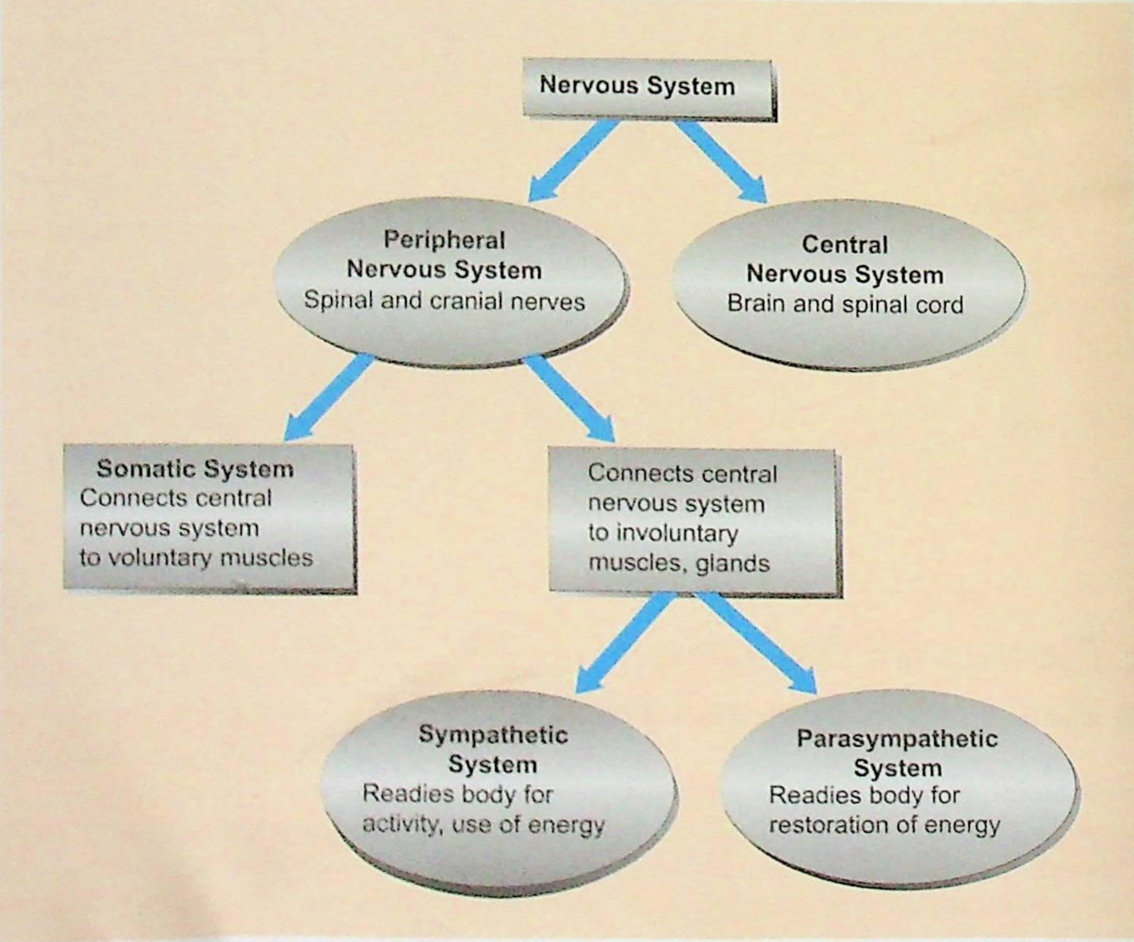
Peripheral Nervous System: The portion of the nervous system that connects internal organs, glands, and voluntary and involuntary muscles to the central nervous system.

Although the nervous system functions as an integrated whole, it is often viewed as having two major portions—the **central nervous system** and the **peripheral nervous system**. These and other divisions of the nervous system are presented in Figure 2.5.

The Central Nervous System

The central nervous system (CNS) consists of the brain and the spinal cord. The spinal cord runs through the middle of a bony column of hollow bones known as vertebrae. You can feel them by moving your hand up and down the middle of your back.

Figure 2.5
Major Divisions of the Nervous System



The spinal cord has two major functions. First, it carries sensory information via **afferent** (sensory) **nerve fibers** from receptors throughout the body to the brain and conducts information via **efferent** (motor) **nerve fibers** from the brain to muscles and glands. Second, it plays a key role in various reflexes. These are seemingly automatic actions evoked rapidly by particular stimuli. Withdrawing your hand from a hot object or blinking your eye in response to a rapidly approaching object are common examples of reflex actions. In their simplest form, reflexes involve neural circuits in which information from various receptors is carried to the spinal cord, where it stimulates other neurons known as interneurons. These then transmit information to muscle cells, thus producing reflex actions. In fact, reflexes are usually much more complex than this. Hundreds or even thousands of neurons may influence a reflex, and input from certain areas of the brain may be involved as well. Whatever their precise nature, though, spinal reflexes offer an obvious advantage: They permit us to react to potential dangers much more rapidly than we could if the information first had to travel all the way to the brain.

Afferent Nerve Fibers: Nerve fibers in the spinal cord that carry information from receptors throughout the body toward the brain.

Efferent Nerve Fibers: Nerve fibers in the spinal cord that carry information from the brain to muscles and glands through-out the body.

Somatic Nervous System: The portion of the peripheral nervous system that connects the brain and spinal cord to voluntary muscles.

Autonomic Nervous System: The part of the peripheral nervous system that connects internal organs, glands, and involuntary muscles to the central nervous system.

Sympathetic Nervous System: The portion of the autonomic nervous system that readies the body for expenditure of energy.

Parasympathetic Nervous System: The portion of the autonomic nervous system that readies the body for restoration of energy.

The Peripheral Nervous System

The peripheral nervous system consists primarily of nerves, bundles of axons from many neurons, which connect the central nervous system with sense organs and with muscles and glands throughout the body. Most of these nerves are attached to the spinal cord; these spinal nerves serve all of the body below the neck. Other nerves known as cranial nerves extend from the brain. They carry sensory information from receptors in the eyes and ears and other sense organs; they also carry information from the central nervous system to muscles in the head and neck.

As you can see in Figure 2.5, the peripheral nervous system has two subdivisions: the **somatic** and **autonomic nervous systems**. The somatic nervous system connects the central nervous system to voluntary muscles throughout the body. Thus, when you engage in almost any voluntary action, such as ordering a pizza or reading the rest of this chapter, portions of your somatic nervous system are involved. In contrast, the autonomic nervous system connects the central nervous system to internal organs and glands and to muscles over which we have little voluntary control—for instance, the muscles in our digestive system.

We can't stop dividing things here, because the autonomic nervous system, too, consists of two distinct parts. The first is known as the **sympathetic nervous system**. In general, this system prepares the body for using energy, as in vigorous physical actions. Thus, stimulation of this division increases heartbeat, raises blood pressure, releases sugar into the blood for energy, and increases the flow of blood to muscles used in physical activities. The second portion of the autonomic system, known as the **parasympathetic nervous system**, operates in the opposite manner. It stimulates processes that conserve the body's energy. Activation of this system slows heartbeat, lowers blood pressure, and diverts blood away from skeletal muscles (for example, muscles in the arms and legs) and to the digestive system. Figure 2.5 summarizes many of the functions of the sympathetic and parasympathetic divisions of the autonomic nervous system.