

# Module 10

## The Nervous and Endocrine Systems

### Module Learning Objectives

- 10-1** Describe the functions of the nervous system's main divisions, and identify the three main types of neurons.
- 10-2** Describe the nature and functions of the endocrine system and its interaction with the nervous system.



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

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

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

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

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

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

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

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

### The Nervous System

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

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

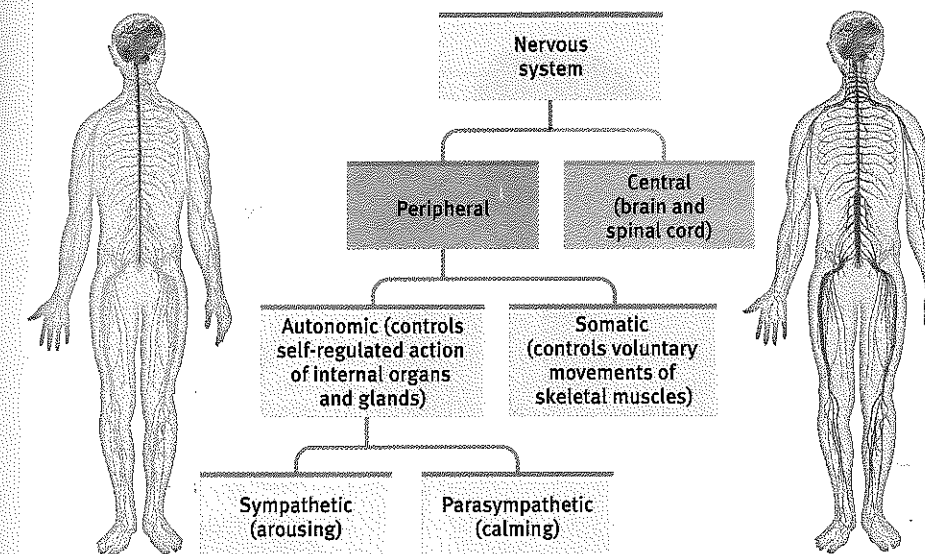
Information travels in the nervous system through three types of neurons. **Sensory neurons** carry messages from the body's tissues and sensory receptors inward to the brain and spinal cord for processing. **Motor neurons** carry instructions from the central

peripheral nervous system

Central nervous system

Figure 10.1

The functional divisions of the human nervous system



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

### The Peripheral Nervous System

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

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

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

### The Central Nervous System

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

### AP<sup>®</sup> Exam Tip

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

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

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

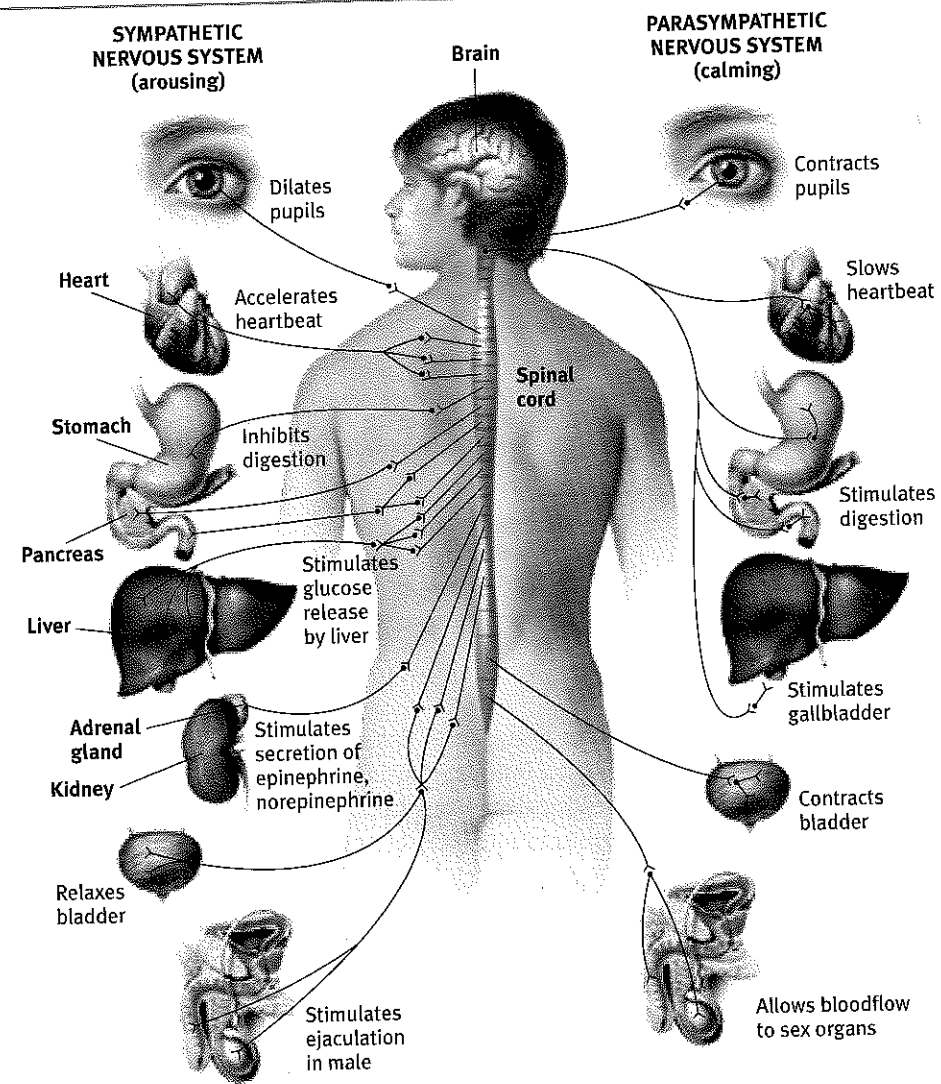
**autonomic** [aw-tuh-NAHM-ik] **nervous system (ANS)** the part of the peripheral nervous system that controls the glands and the muscles of the internal organs (such as the heart). Its sympathetic division arouses; its parasympathetic division calms.

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

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

Figure 10.2

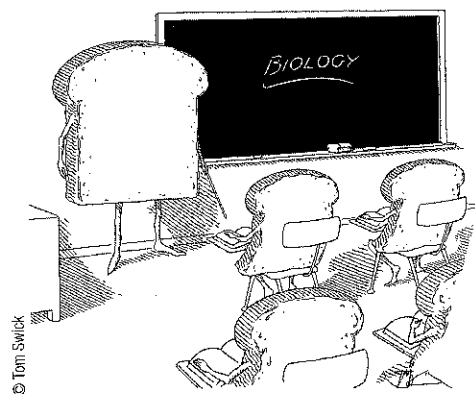
The dual functions of the autonomic nervous system. The autonomic nervous system controls the more autonomous (or self-regulating) internal functions. Its sympathetic division arouses and expends energy. Its parasympathetic division calms and conserves energy, allowing routine maintenance activity. For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



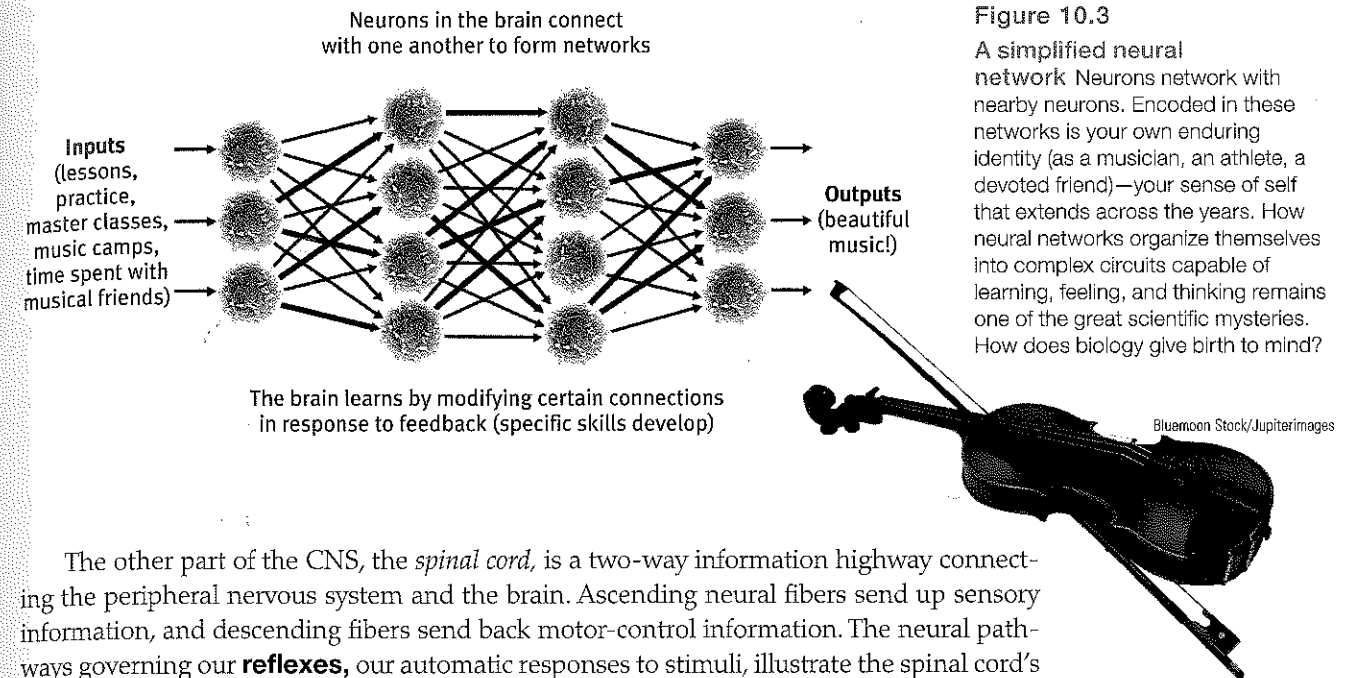
It is the brain that enables our humanity—our thinking, feeling, and acting. Tens of billions of neurons, each communicating with thousands of other neurons, yield an everchanging wiring diagram. With some 40 billion neurons, each connecting with roughly 10,000 other neurons, we end up with perhaps 400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

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

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



“The body is made up of millions and millions of crumbs.”

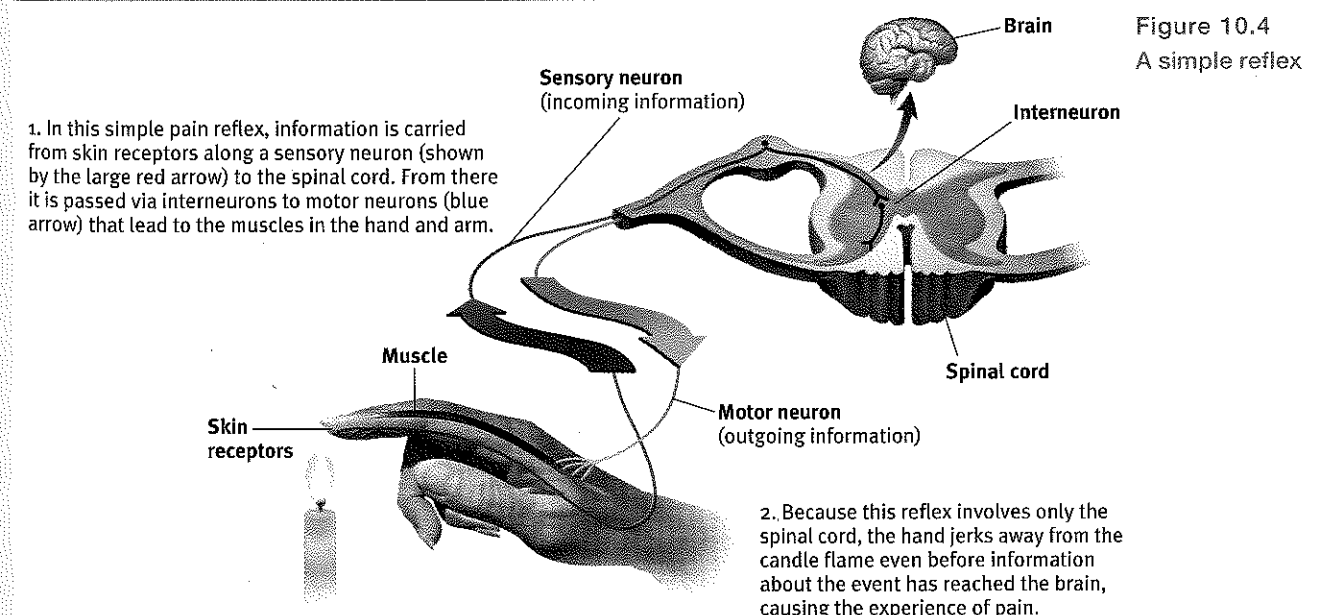


The other part of the CNS, the *spinal cord*, is a two-way information highway connecting the peripheral nervous system and the brain. Ascending neural fibers send up sensory information, and descending fibers send back motor-control information. The neural pathways governing our **reflexes**, our automatic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

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

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

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



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

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

## Before You Move On

### ▶ ASK YOURSELF

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

### ▶ TEST YOURSELF

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

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

## The Endocrine System

10-2

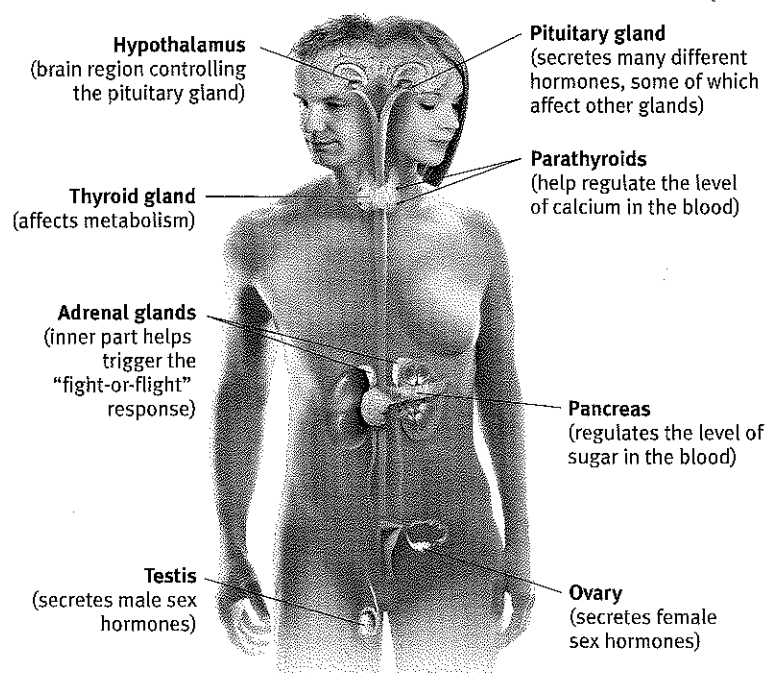
What is the nature and what are the functions of the endocrine system, and how does it interact with the nervous system?

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

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

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

Figure 10.5  
The endocrine system



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

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

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

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

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

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

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

## Before You Move On

### ▶ ASK YOURSELF

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

### ▶ TEST YOURSELF

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

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