

MODULE 6

The Nervous System and the Endocrine System: Communicating Within the Body

Key Concepts

How are the structures of the nervous system linked?

How does the endocrine system affect behavior?

In light of the complexity of individual neurons and the neurotransmission process, it should come as no surprise that the connections and structures formed by the neurons are complicated. Because each neuron can be connected to 80,000 other neurons, the total number of possible connections is astonishing. For instance, estimates of the number of neural connections within the brain fall in the neighborhood of 10 quadrillion—a 1 followed by 16 zeros—and some experts put the number even higher. However, connections among neurons are not the only means of communication within the body; as we'll see, the endocrine system, which secretes chemical messages that circulate through the blood, also communicates messages that influence behavior and many aspects of biological functioning (Kandel, Schwartz, & Jessell, 2000; Forlenza & Baum, 2004; Boahen, 2005).

The Nervous System: Linking Neurons

Whatever the actual number of neural connections, the human nervous system has both logic and elegance. We turn now to a discussion of its basic structures.

CENTRAL AND PERIPHERAL NERVOUS SYSTEMS

As you can see from the schematic representation in Figure 1, the nervous system is divided into two main parts: the central nervous system and the peripheral nervous system. The **central nervous system (CNS)** is composed of the brain and spinal cord. The **spinal cord**, which is about the thickness of a pencil, contains a bundle of neurons that leaves the brain and runs down the length of the back (see Figure 2). As you can see in Figure 1, the spinal cord is the primary means for transmitting messages between the brain and the rest of the body.

However, the spinal cord is not just a communication channel. It also controls some simple behaviors on its own, without any help from the brain. An example is the way the knee jerks forward when it is tapped with a rubber hammer. This behavior is a type of **reflex**, an automatic, involuntary response to an incoming stimulus. A reflex is also at work when you touch a hot stove and immediately withdraw your hand. Although the brain eventually analyzes and reacts to the situation ("Ouch—hot stove—pull away!"), the initial withdrawal is directed only by neurons in the spinal cord.

central nervous system (CNS)

The part of the nervous system that includes the brain and spinal cord.

spinal cord

A bundle of neurons that leaves the brain and runs down the length of the back and is the main means for transmitting messages between the brain and the body.

reflex An automatic, involuntary response to an incoming stimulus.

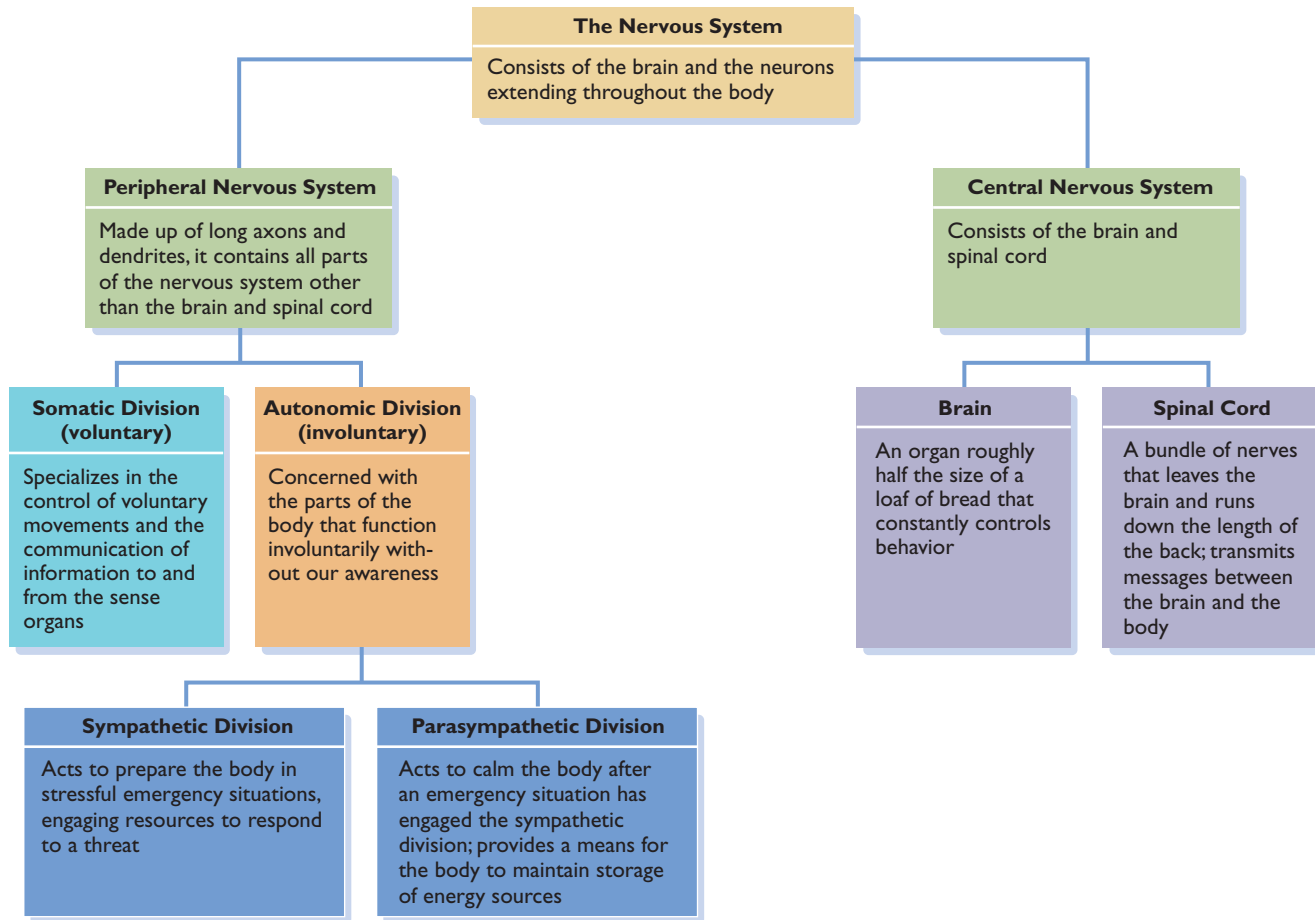


FIGURE 1 A schematic diagram of the relationship of the parts of the nervous system.

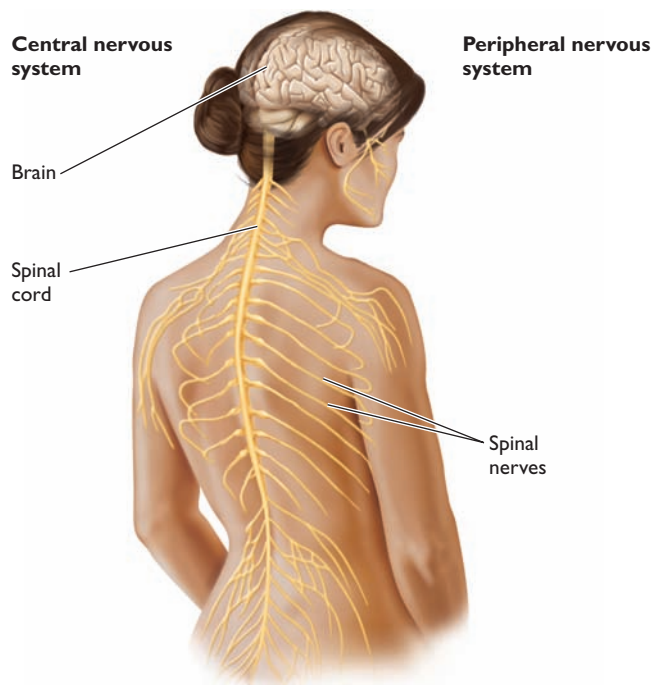


FIGURE 2 The central nervous system consists of the brain and spinal cord, and the peripheral nervous system encompasses the network of nerves connecting the brain and spinal cord to other parts of the body.

Study Alert
 Use Figures 1 and 2 to learn the components of the central and peripheral nervous systems.

sensory (afferent) neurons Neurons that transmit information from the perimeter of the body to the central nervous system.

motor (efferent) neurons Neurons that communicate information from the nervous system to muscles and glands.

interneurons Neurons that connect sensory and motor neurons, carrying messages between the two.

peripheral nervous system The part of the nervous system that includes the autonomic and somatic subdivisions; made up of neurons with long axons and dendrites, it branches out from the spinal cord and brain and reaches the extremities of the body.

somatic division The part of the peripheral nervous system that specializes in the control of voluntary movements and the communication of information to and from the sense organs.

autonomic division The part of the peripheral nervous system that controls involuntary movement of the heart, glands, lungs, and other organs.

sympathetic division The part of the autonomic division of the nervous system that acts to prepare the body for action in stressful situations, engaging all the organism's resources to respond to a threat.

parasympathetic division The part of the autonomic division of the nervous system that acts to calm the body after an emergency has ended.

Three kinds of neurons are involved in reflexes. **Sensory (afferent) neurons** transmit information from the perimeter of the body to the central nervous system. **Motor (efferent) neurons** communicate information from the nervous system to muscles and glands. **Interneurons** connect sensory and motor neurons, carrying messages between the two.

The importance of the spinal cord and reflexes is illustrated by the outcome of accidents in which the cord is injured or severed. In some cases, injury results in *quadriplegia*, a condition in which voluntary muscle movement below the neck is lost. In a less severe but still debilitating condition, *paraplegia*, people are unable to voluntarily move any muscles in the lower half of the body.

As suggested by its name, the **peripheral nervous system** branches out from the spinal cord and brain and reaches the extremities of the body. Made up of neurons with long axons and dendrites, the peripheral nervous system encompasses all the parts of the nervous system other than the brain and spinal cord. There are two major divisions—the somatic division and the autonomic division—both of which connect the central nervous system with the sense organs, muscles, glands, and other organs. The **somatic division** specializes in the control of voluntary movements—such as the motion of the eyes to read this sentence or those of the hand to turn this page—and the communication of information to and from the sense organs. The **autonomic division** controls the parts of the body that keep us alive—the heart, blood vessels, glands, lungs, and other organs that function involuntarily without our awareness. As you are reading at this moment, the autonomic division of the peripheral nervous system is pumping blood through your body, pushing your lungs in and out, and overseeing the digestion of your last meal.

ACTIVATING THE DIVISIONS OF THE AUTONOMIC NERVOUS SYSTEM

The autonomic division plays a particularly crucial role during emergencies. Suppose that as you are reading you suddenly sense that a stranger is watching you through the window. As you look up, you see the glint of something that might be a knife. As confusion clouds your mind and fear overcomes your attempts to think rationally, what happens to your body? If you are like most people, you react immediately on a physiological level. Your heart rate increases, you begin to sweat, and you develop goose bumps all over your body.

The physiological changes that occur during a crisis result from the activation of one of the two parts of the autonomic nervous system: the **sympathetic division**. The sympathetic division acts to prepare the body for action in stressful situations by engaging all of the organism's resources to run away or to confront the threat. This is often called the “fight or flight” response.

In contrast, the **parasympathetic division** acts to calm the body after the emergency has ended. When you find, for instance, that the stranger at the window is actually your roommate, who has lost his keys and is climbing in the window to avoid waking you, your parasympathetic division begins to take over, lowering your heart rate, stopping your sweating, and returning your body to the state it was in before you became alarmed. The parasympathetic division also directs the body to store energy for use in emergencies.

The sympathetic and parasympathetic divisions work together to regulate many functions of the body (see Figure 3). For instance, sexual arousal is controlled by the parasympathetic division, but sexual orgasm is a function of the sympathetic division. The sympathetic and parasympathetic divisions also are involved in a number of disorders. For example, one explanation of documented examples of “voodoo death”—in which a person is literally scared to death resulting from a voodoo curse—may be produced by overstimulation of the sympathetic division due to extreme fear (Sternberg, 2002).

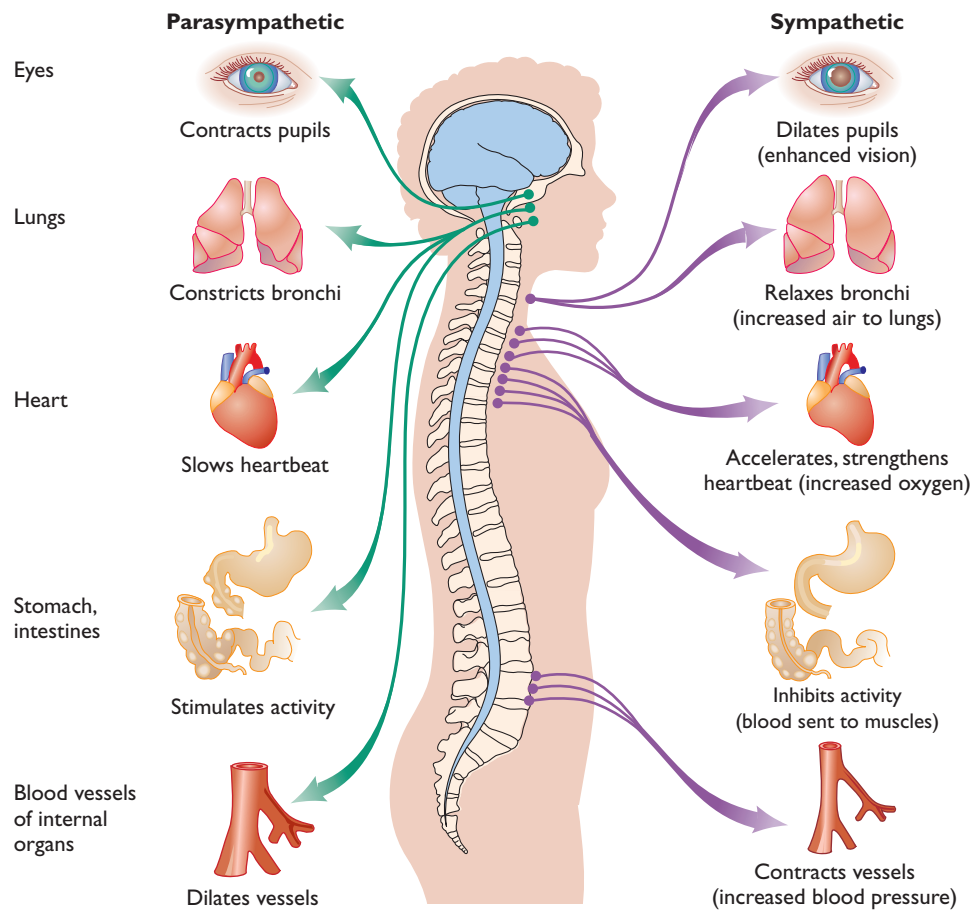


FIGURE 3 The major functions of the autonomic nervous system. The sympathetic division acts to prepare certain organs of the body for stressful situations, and the parasympathetic division acts to calm the body after the emergency has been passed. Can you explain why each response of the sympathetic division might be useful in an emergency?

The Evolutionary Foundations of the Nervous System

The complexities of the nervous system can be better understood if we take the course of evolution into consideration. The forerunner of the human nervous system is found in the earliest simple organisms to have a spinal cord. Basically, those organisms were simple input-output devices: When the upper side of the spinal cord was stimulated by, for instance, being touched, the organism reacted with a simple response, such as jerking away. Such responses were completely a consequence of the organism's genetic makeup.

Over millions of years, the spinal cord became more specialized, and organisms became capable of distinguishing between different kinds of stimuli and responding appropriately to them. Ultimately, a portion of the spinal cord evolved into what we would consider a primitive brain.

Today, the nervous system is *hierarchically organized*, meaning that relatively newer (from an evolutionary point of view) and more sophisticated regions of the brain regulate the older, and more primitive, parts of the nervous system. As we move up along the spinal cord and continue upward into the brain, then, the functions controlled by the various regions become progressively more advanced.

Why should we care about the evolutionary background of the human nervous system? The answer comes from researchers working in the area of **evolutionary psychology**, the branch of psychology that seeks to identify how behavior is influenced and produced by our genetic inheritance from our ancestors.

evolutionary psychology The branch of psychology that seeks to identify behavior patterns that are a result of our genetic inheritance from our ancestors.

Evolutionary psychologists argue that the course of evolution is reflected in the structure and functioning of the nervous system and that evolutionary factors consequently have a significant influence on our everyday behavior. Their work, in conjunction with the research of scientists studying genetics, biochemistry, and medicine, has led to an understanding of how our behavior is affected by heredity, our genetically determined heritage. In fact, evolutionary psychologists have spawned a new and increasingly influential field: behavioral genetics.

BEHAVIORAL GENETICS

behavioral genetics The study of the effects of heredity on behavior.

Our evolutionary heritage manifests itself not only through the structure and functioning of the nervous system but through our behavior as well. In the view of a growing area of study, people's personality and behavioral habits are affected in part by their genetic heritage. **Behavioral genetics** is the study of the effects of heredity on behavior. Behavioral genetics researchers are finding increasing evidence that cognitive abilities, personality traits, sexual orientation, and psychological disorders are determined to some extent by genetic factors (Ilies, Arvey, & Bouchard, 2006; Livesley & Jang, 2008; Vernon et al., 2008).

Behavioral genetics lies at the heart of the nature-nurture question, one of the key issues in the study of psychology. Although no one would argue that our behavior is determined *solely* by inherited factors, evidence collected by behavioral geneticists does suggest that our genetic inheritance predisposes us to respond in particular ways to our environment, and even to seek out particular kinds of environments. For instance, research indicates that genetic factors may be related to such diverse behaviors as level of family conflict, schizophrenia, learning disabilities, and general sociability (Ball et al., 2008; Davis, Haworth, & Plomin, 2009; Lakhan & Vieira, 2009).

Furthermore, important human characteristics and behaviors are related to the presence (or absence) of particular *genes*, the inherited material that controls the transmission of traits. For example, researchers have found evidence that novelty-seeking behavior is determined, at least in part, by a certain gene (Golimbet et al., 2007).

As we consider later in the book when we discuss human development, researchers have identified some 25,000 individual genes, each of which appears in a specific sequence on a particular *chromosome*, a rod-shaped structure that transmits genetic information across generations. In 2003, after a decade of effort, researchers identified the sequence of the 3 billion chemical pairs that make up human *DNA*, the basic component of genes. Understanding the basic structure of the human *genome*—the “map” of humans' total genetic makeup—brings scientists a giant step closer to understanding the contributions of individual genes to specific human structures and functioning (Andreasen, 2005; Dale & von Schantz, 2007; Plomin & Davis, 2009).

Molecular Genetics and Psychological Disorders Despite its relative infancy, the field of behavioral genetics has already made substantial contributions to our understanding of behavior. One branch of behavioral genetics, *molecular genetics*, seeks to identify specific genes that are associated with behavior and, in particular, psychological disorders. Genes that are physically close to one another on a particular chromosome tend to be linked and inherited together. By finding *genetic markers*—genes with a known location—that are linked to a disorder, scientists are beginning to learn how disorders such as schizophrenia and depression develop and can potentially be treated.

Molecular geneticists have already found that the risk of developing autism (a disorder that influences the development of language and effective social functioning) is increased in the presence of a gene related to early brain development. Children with this gene, a variation of the gene called *HOXA1*, are twice as likely to develop the disorder as children who do not have this variant (Hyman, 2003; Gregg et al., 2007).

Yet having the variant gene does not always lead to autism. More than 99.5% of people with the variant do not develop the disorder, and 60% of those with autism do not have the variant. It is probable that autism, like other disorders with a genetic

basis, is not triggered by the presence or absence of a single, particular gene. More likely, it is produced by several genes in combination, as well as perhaps requiring the presence of certain environmental influences, such as infection or brain injury. The challenge for behavior geneticists, then, is not only to determine what genes are responsible for particular behaviors but also to identify the environmental triggers that activate those genes (Sen et al., 2007).

In examining the genetic roots of various behaviors, the study of behavior genetics has stirred controversy. For instance, questions about the existence of genetic influences on criminality, intelligence, and homosexuality raise considerable emotion. Furthermore, it is unclear what the social and political consequences of discoveries in behavioral genetics would be. Would finding a strong genetic basis for criminal behavior lead to genetic screening and restricted civil rights for individuals having “criminal” genes? Clearly, behavioral genetic discoveries could have an impact on a number of important social issues (Wensley & King, 2008).

Behavioral Genetics, Gene Therapy, and Genetic Counseling Behavioral genetics also holds the promise of developing new diagnostic and treatment techniques for genetic deficiencies that can lead to physical and psychological difficulties. In *gene therapy*, scientists inject into a patient’s bloodstream genes meant to cure a particular disease. When the genes arrive at the site of defective genes that are producing the illness, they trigger the production of chemicals that can treat the disease (Jaffé, Prasad, & Larcher, 2006; Eberling et al., 2008; Isacson & Kordower, 2008).

The number of diseases that can be treated through gene therapy is growing, as we will see when we discuss human development. For example, gene therapy is now being used in experimental trials involving people with certain forms of cancer and blindness (Hirschler, 2007; Nakamura, 2004; Wagner et al., 2004).

Advances in behavioral genetics also have led to the development of a profession that did not exist several decades ago: genetic counseling. Genetic counselors help people deal with issues related to inherited disorders. For example, genetic counselors provide advice to prospective parents about the potential risks in a future pregnancy, based on their family history of birth defects and hereditary illnesses. In addition, the counselor considers the parents’ age and problems with children they already have. They also can take blood, skin, and urine samples to examine specific chromosomes.

Scientists have already developed genetic tests to determine whether someone is susceptible to certain types of cancer or heart disease, and it may not be long before analysis of a drop of blood can indicate whether a child—or potentially an unborn fetus—is susceptible to certain psychological disorders. How such knowledge will be used is a source of considerable speculation and controversy, controversy that is certain to grow as genetic testing becomes more common (Etchegary, 2004; Malpas, 2008).

The Endocrine System: Of Chemicals and Glands

Another of the body’s communication systems, the **endocrine system** is a chemical communication network that sends messages throughout the body via the bloodstream. Its job is to secrete **hormones**, chemicals that circulate through the blood and regulate the functioning or growth of the body. It also influences—and is influenced by—the functioning of the nervous system. Although the endocrine system is not part of the brain, it is closely linked to the hypothalamus.

As chemical messengers, hormones are like neurotransmitters, although their speed and mode of transmission are quite different. Whereas neural messages are measured in thousandths of a second, hormonal communications may take minutes to reach their destination. Furthermore, neural messages move through neurons in

endocrine system A chemical communication network that sends messages throughout the body via the bloodstream.

hormones Chemicals that circulate through the blood and regulate the functioning or growth of the body.

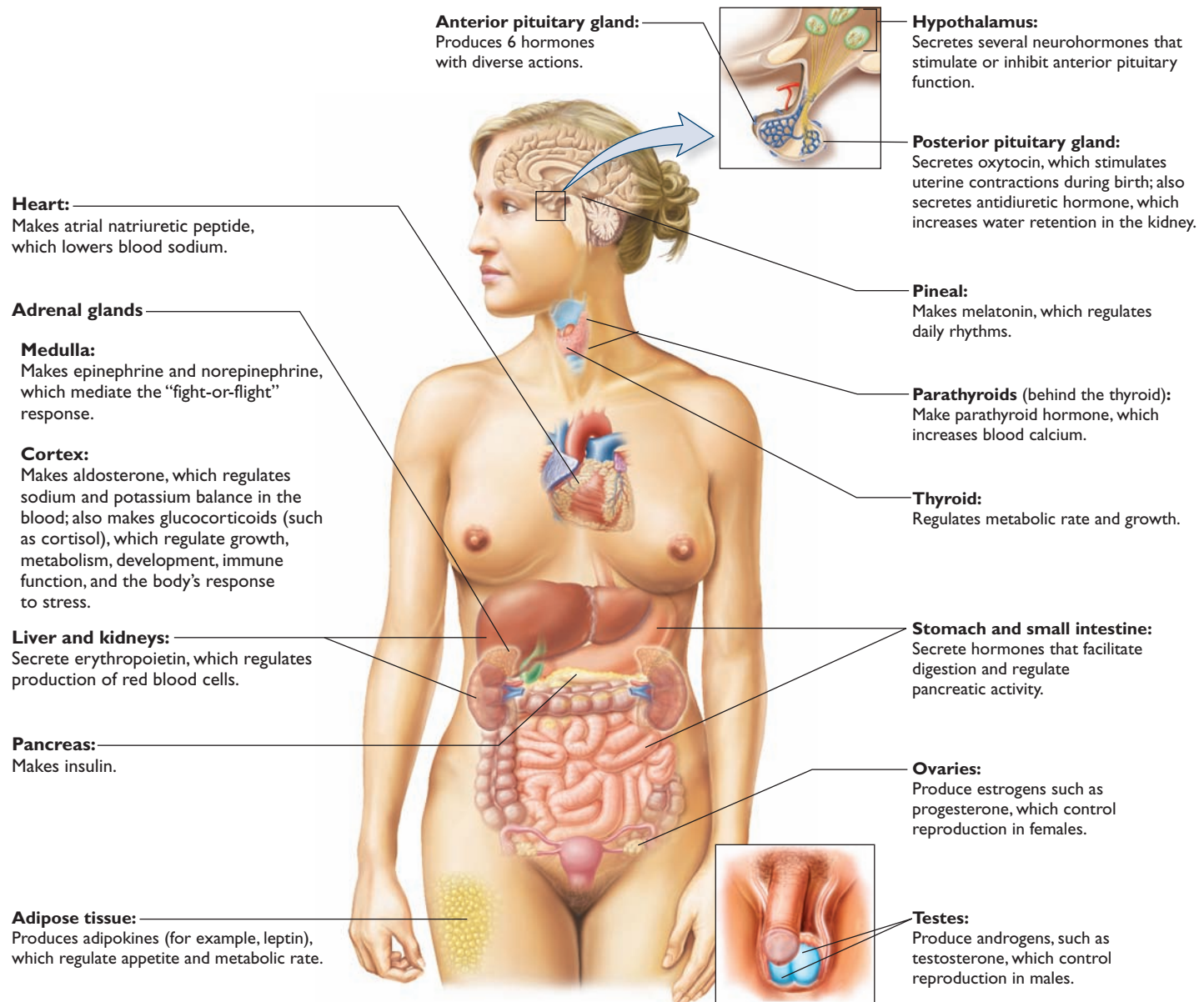


FIGURE 4 Location and function of the major endocrine glands. The pituitary gland controls the functioning of the other endocrine glands and, in turn, is regulated by the hypothalamus.

specific lines (like a signal carried by wires strung along telephone poles), whereas hormones travel throughout the body, similar to the way radio waves are transmitted across the entire landscape. Just as radio waves evoke a response only when a radio is tuned to the correct station, hormones flowing through the bloodstream activate only those cells that are receptive and “tuned” to the appropriate hormonal message.

pituitary gland The major component of the endocrine system, or “master gland,” which secretes hormones that control growth and other parts of the endocrine system.

A key component of the endocrine system is the tiny **pituitary gland**, which is found near—and regulated by—the hypothalamus. The pituitary gland has sometimes been called the “master gland” because it controls the functioning of the rest of the endocrine system. But the pituitary gland is more than just the taskmaster of other glands; it has important functions in its own right. For instance, hormones secreted by the pituitary gland control growth. Extremely short people and unusually tall ones usually have pituitary gland abnormalities. Other endocrine glands, shown in Figure 4, affect emotional reactions, sexual urges, and energy levels.



Steroids can provide added muscle and strength, but they have dangerous side effects. A number of well-known athletes in a variety of sports have been accused of using the drugs illegally.

Despite its designation as the “master gland,” the pituitary is actually a servant of the brain, because the brain is ultimately responsible for the endocrine system’s functioning. The brain maintains the internal balance of the body through the hypothalamus.

Individual hormones can wear many hats, depending on circumstances. For example, the hormone oxytocin is at the root of many of life’s satisfactions and pleasures. In new mothers, oxytocin produces an urge to nurse newborn offspring. The same hormone also seems to stimulate cuddling between species members. And—at least in rats—it encourages sexually active males to seek out females more passionately, and females to be more receptive to males’ sexual advances. There’s even evidence that oxytocin is related to the development of trust in others, helping to grease the wheels of effective social interaction (Kosfeld et al., 2005; Meinschmidt & Heim, 2007; Guastella, Mitchell, & Dadds, 2008).

Although hormones are produced naturally by the endocrine system, the ingestion of artificial hormones has proved to be both beneficial and potentially dangerous. For example, before the early 2000s, physicians frequently prescribed hormone replacement therapy (HRT) to treat symptoms of menopause in older women. However, because recent research suggests that the treatment has potentially dangerous side effects, health experts now warn that the dangers outweigh the benefits (Herrington & Howard, 2003).

The use of testosterone, a male hormone, and drugs known as *steroids*, which act like testosterone, is increasingly common. For athletes and others who want to bulk up their appearance, steroids provide a way to add muscle weight and increase strength. However, these drugs can lead to heart attacks, strokes, cancer, and even violent behavior, making them extremely dangerous. For example, in one infamous case, professional wrestler Chris Benoit strangled his wife, suffocated his son, and later hanged himself—acts that were attributed to his use of steroids (Klötz, 2006; Pagonis, Angelopoulos, & Koukoulis, 2006; Sandomir, 2007).

Study Alert

The endocrine system produces hormones, chemicals that circulate through the body via the bloodstream.

RECAP/EVALUATE/RETHINK

RECAP

How are the structures of the nervous system linked?

- The nervous system is made up of the central nervous system (the brain and spinal cord) and the peripheral nervous system. The peripheral nervous system is made up of the somatic division, which controls voluntary movements and the communication of information to and from the sense organs, and the autonomic division, which controls involuntary functions such as those of the heart, blood vessels, and lungs. (p. 60)
- The autonomic division of the peripheral nervous system is further subdivided into the sympathetic and parasympathetic divisions. The sympathetic division prepares the body in emergency situations, and the parasympathetic division helps the body return to its typical resting state. (p. 62)
- Evolutionary psychology, the branch of psychology that seeks to identify behavior patterns that are a result of our genetic inheritance, has led to increased understanding of the evolutionary basis of the structure and organization of the human nervous system. Behavioral genetics extends this study to include the evolutionary and hereditary basis of human personality traits and behavior. (p. 63)

How does the endocrine system affect behavior?

- The endocrine system secretes hormones, chemicals that regulate the functioning of the body, via the bloodstream. The pituitary gland secretes growth hormones and influences the release of hormones by other endocrine glands, and in turn is regulated by the hypothalamus. (p. 65)

EVALUATE

1. If you put your hand on a red-hot piece of metal, the immediate response of pulling it away would be an example of a(n) _____.
2. The central nervous system is composed of the _____ and the _____.
3. In the peripheral nervous system, the _____ division controls voluntary movements, whereas the _____ division controls organs that keep us alive and function without our awareness.
4. Maria saw a young boy run into the street and get hit by a car. When she got to the fallen child, she was in a state of panic. She was sweating, and her heart was racing. Her biological state resulted from the activation of what division of the nervous system?
 - a. parasympathetic
 - b. central
 - c. sympathetic
5. The emerging field of _____ studies ways in which our genetic inheritance predisposes us to behave in certain ways.

RETHINK

1. In what ways is the “fight-or-flight” response helpful to humans in emergency situations?
2. *From the perspective of a genetic counselor:* How would you explain the pros and cons of genetic counseling to someone who was interested in receiving genetic screening for various diseases and disorders?

Answers to Evaluate Questions

1. reflex; 2. brain, spinal cord; 3. somatic, autonomic; 4. c. sympathetic; 5. behavioral genetics

KEY TERMS

central nervous system (CNS) p. 60
 spinal cord p. 60
 reflex p. 60
 sensory (afferent) neurons p. 62

motor (efferent) neurons p. 62
 interneurons p. 62
 peripheral nervous system p. 62
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