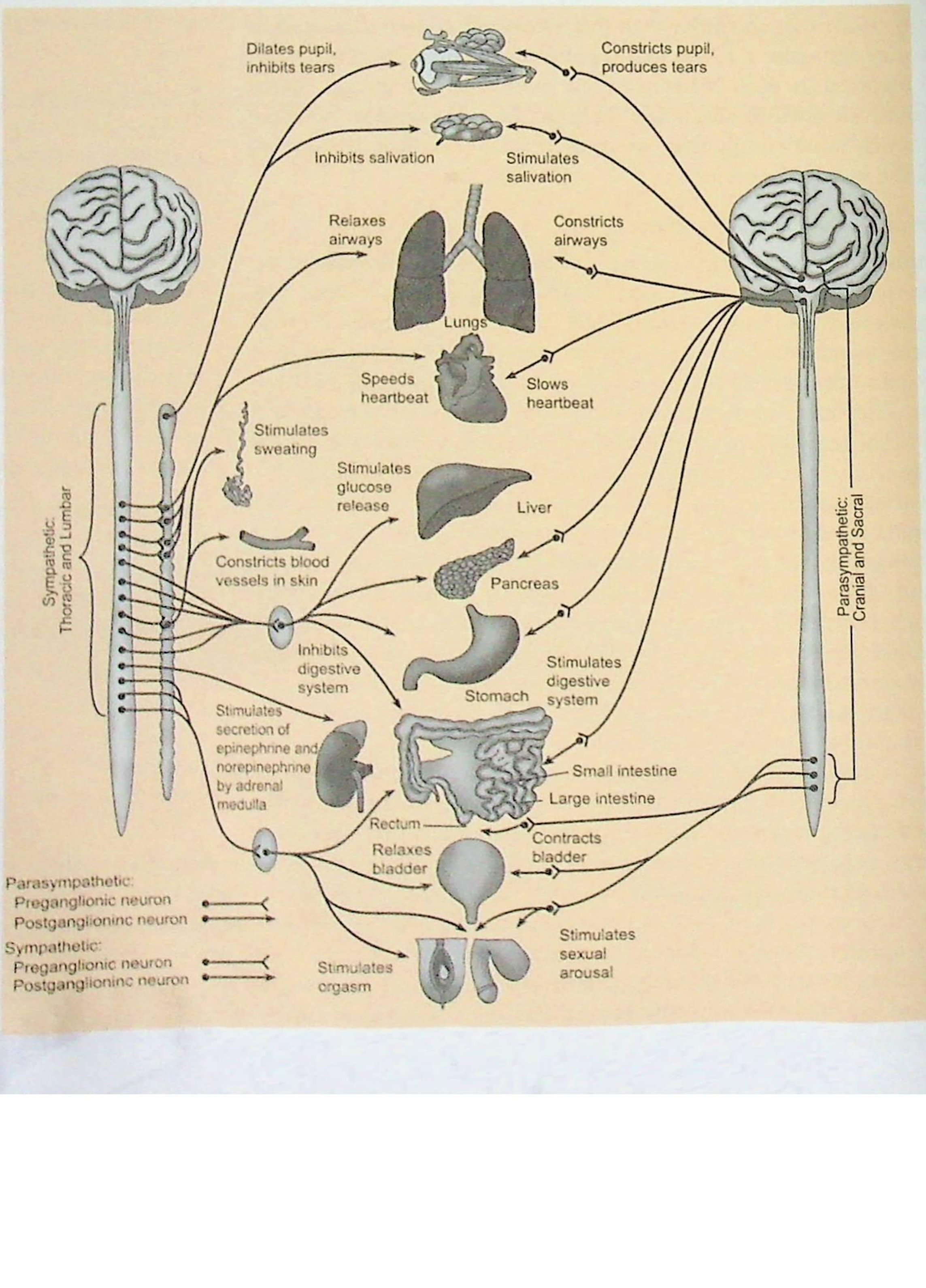
Before concluding, we should emphasize that while the autonomic nervous system plays an important role in the regulation of bodily processes, it does so mainly by transmitting information to and from the central nervous system. Thus, it is the central nervous system that ultimately runs the show.

Figure 2.6
The Autonomic Nervous System: An Overview
The autonomic nervous system consists of two major parts, the sympathetic and parasympathetic nervous systems. Some of the functions of each are shown here.

(*Source*: Carlson, 1999.)



REVIEW QUESTIONS

- What structures make up the central nervous system? What is the function of the spinal cord?
- What two systems make up the peripheral nervous system? What are the roles of these two systems?
- What are the functions of the sympathetic and parasympathetic nervous systems?

The Endocrine System: Chemical Regulators of Bodily Processes

The nervous system is our primary system for moving and processing information—for responding to the world around us and to our own internal states. Another system exists as well, however: the **endocrine system**, which consists of a variety of *glands*. Endocrine glands release chemicals called **hormones** directly into the bloodstream. These hormones exert profound effects on a wide range of processes related to basic bodily functions. Of special interest to psychologists are *neurohormones*—hormones that interact with and affect the nervous system. Neurohormones, like neurotransmitters, influence neural activity. Because they are released into the circulatory system rather than into synapses, however, they exert their effects more slowly, at a greater distance, and often for longer periods of time than neurotransmitters.

One major part of the endocrine system is the **pituitary gland**. It is sometimes described as the master gland of the body, for the hormones it releases control and regulate the actions of other endocrine glands. This gland is also closely connected to important regions of the brain that play a role in emotion—areas we'll discuss in the next section.

The pituitary is really two glands in one, the *posterior pituitary* and the *anterior pituitary*. The posterior pituitary releases hormones that regulate reabsorption of water by the kidneys and, in females, the production and release of milk. It is the anterior pituitary that releases the hormones that regulate the activity of other endocrine glands. One such hormone, ACTH, stimulates the outer layer of the adrenal gland, the *adrenal cortex*, causing it to secrete cortisone. Cortisone, in turn, affects cells in many parts of the body. The pituitary also secretes hormones that influence sexual development, govern the functioning of the sexual glands (regulating the amount of hormones they release), and help control basic bodily functions relating to metabolism and excretion.

Another important part of the endocrine system is the **adrenal glands**, which sit on top of the kidneys. In response to messages from the autonomic nervous system, the adrenal glands release *epinephrine* and *norepinephrine* (also known as *adrenaline* and *noradrenaline*). These hormones help the body handle emergencies—increasing heart rate, blood pressure, and sugar in the blood. The location and function of these and other parts of the endocrine system (e.g., the thyroid gland, which plays a role in the regulation of metabolism) are shown in Figure 2.6.

Endocrine System: A system for communication within our bodies. It consists of several glands that secrete hormones directly into the bloodstream.

Hormones: Substances secreted by endocrine glands that regulate a wide range of bodily processes.

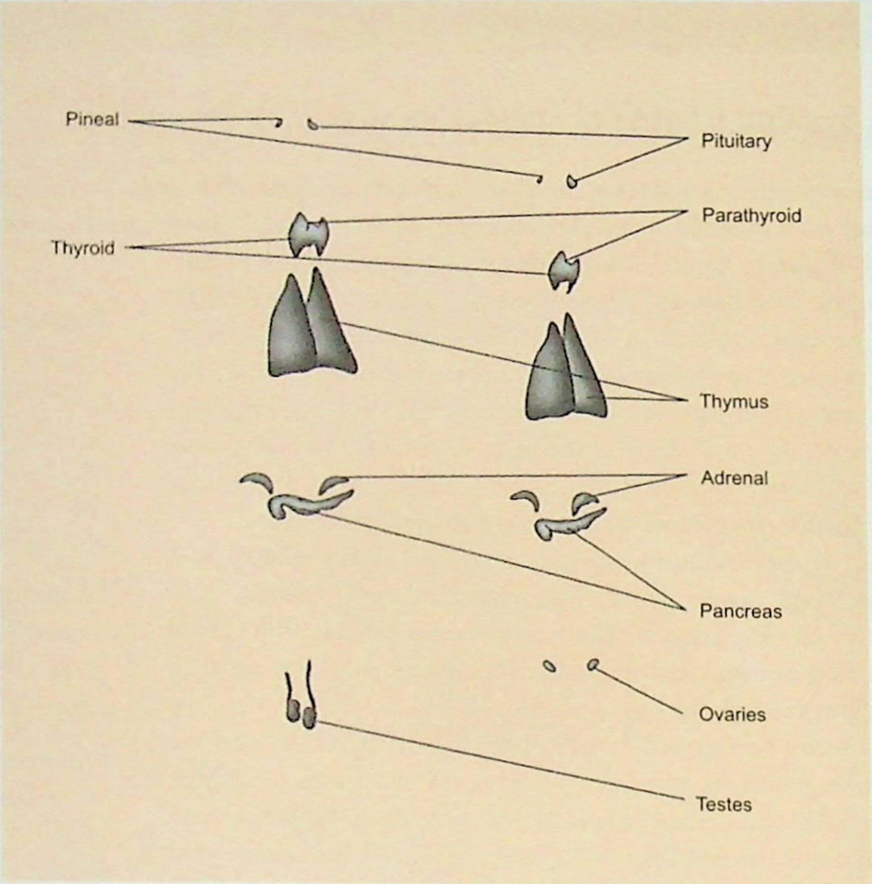
Pituitary Gland: An endocrine gland that releases hormones to regulate other glands and several basic biological processes.

Adrenal Glands: Glands that release hormones to help the body handle emergencies by, for example, increasing heart rate, blood pressure, and blood sugar levels.

REVIEW QUESTIONS

- What is the endocrine system?
- What are some of its major parts?

Figure 2.7
The Endocrine System
The endocrine system consists of several glands. The location of key glands are shown here.



The Brain
Where Consciousness . . . Is

Modern computers are impressive, but none can match the amazing abilities packed within the three pounds o the human brain. And even if we could build a computer as brilliant as deep thought, it could not, as far as w can tell, have the emotional experiences, imagery, insights, desires, motives, and creativity of the human brain Our brain is a marvelous organ indeed!

The Brain Stem: Survival Basics

Let's begin with the basics: the structures in the brain that regulate the bodily processes we share with man other life forms on earth. These structures are located in the *brain stem*, the portion of the brain that begins jus above the spinal cord and continues into the center of this complex organ (refer to Figure 2.7).

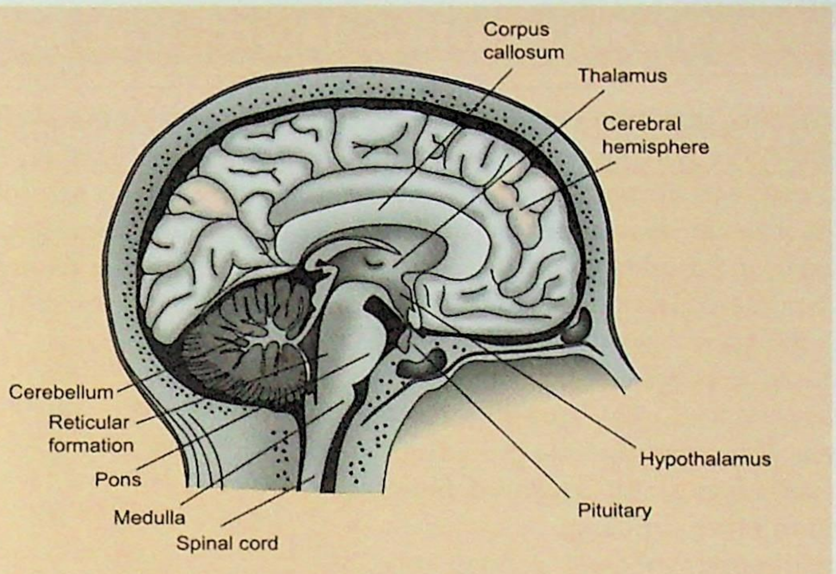


Figure 2.8
Basic Structure of the Human Brain
In this simplified drawing, the brain has been split down the middle to reveal its inner structure, the way you would cut an apple in half through its core.

Medulla: A structure in the brain concerned with the regulation of vital bodily functions such as breathing and heartbeat.

Pons: A portion of the brain through which sensory and motor information passes and which contains structures relating to sleep, arousal, and the regulation of muscle tone and cardiac reflexes.

Reticular Activating System: A structure within the brain concerned with sleep, arousal, and the regulation of muscle tone and cardiac reflexes.

Cerebellum: A part of the brain concerned with the regulation of basic motor activities.

Midbrain: A part of the brain containing primitive centers for vision and hearing. It also plays a role in the regulation of visual reflexes.

Two of these structures, the **medulla** and the **pons**, are located just above the point where the spinal cord enters the brain. Major sensory and motor pathways pass through both of these structures on their way to higher brain centers or down to effectors (muscles or glands) in other parts of the body. In addition, both the medulla and the pons contain a central core consisting of a dense network of interconnected neurons. This is the **reticular activating system**, and it has long been viewed as a part of the brain that plays a key role in sleep and arousal—a topic we'll discuss in greater detail in Chapter 4. Recent evidence, however, indicates that the reticular activating system is also concerned with many other functions, such as muscle tone, cardiac and circulatory reflexes, and attention (Pinel, 1993). Thus, referring to it as a single "system" is somewhat misleading. The medulla contains several *nuclei*—collections of neuron cell bodies—that control vital functions such as breathing, heart rate, and blood pressure, as well as coughing and sneezing.

Behind the medulla and pons is the **cerebellum** (refer again to Figure 2.8). It is primarily concerned with the regulation of motor activities, serving to orchestrate muscular activities so that they occur in a synchronized fashion. Damage to the cerebellum results in jerky, poorly coordinated muscle functioning. If such damage is severe, it may be impossible for a person to stand, let alone to walk or run. In addition, the cerebellum may also play a role in certain cognitive processes, such as learning (e.g., Daum et al., 1993).

Above the medulla and pons, near the end of the brain stem, is a structure known as the **midbrain**. It contains an extension of the reticular activating system as well as primitive centers concerned with vision and hearing: the *superior colliculi* (vision) and the *inferior colliculi* (hearing). The midbrain also contains structures that play a role in such varied functions as the pain-relieving effects of opiates and the guidance and control of motor movements by sensory input.

The Hypothalamus, Thalamus, and Limbic System: Motivation and Emotion

Although the **hypothalamus** is less than one cubic centimeter in size, this tiny structure exerts profound effects on our behavior. First, it regulates the autonomic nervous system, thus influencing reactions ranging from sweating and salivating to the shedding of tears and changes in blood pressure. Second, it plays a key role in *homeostasis*—the maintenance of the body's internal environment at optimal levels. Third, the hypothalamus seems to play a role in the regulation of eating and drinking. Initial studies seemed to indicate that damage to the *ventromedial* portion of the hypothalamus caused laboratory animals (usually rats) to overeat—to the point of obesity, in fact. In contrast, damage to the *lateral hypothalamus* resulted in reduced food intake and a generally reduced responsiveness to all sensory input. In short, the role of the hypothalamus seemed clear. However, these results were called into question when it was discovered that the procedures used to damage structures within the hypothalamus also destroyed fibers passing through the hypothalamus en route to other structures.

The results of additional studies reveal a more sharply defined role for the lateral hypothalamus: It co-ordinates communication between the parts of the brain that monitor and regulate aspects of the body's internal state (including thirst and hunger) and the frontal cortex—the structure responsible for planning and executing behavior. Thus, when damage is confined strictly to cells of the lateral hypothalamus, the brain continues its monitoring function, thereby detecting the need to eat or drink. However, this information does not reach the frontal cortex. As a result, this information is not converted into action—eating. (Please see Chapter 10 for further discussion of the regulation of eating and of several eating disorders.)

The hypothalamus also plays a role in other forms of motivated behavior, such as mating and aggression. It exerts this influence, at least in part, by regulating the release of hormones from the *pituitary gland*.

Above the hypothalamus, quite close to the center of the brain, is another important structure, the **thalamus**. This structure consists of two football-shaped parts, one in each hemisphere. This has sometimes been called the great relay station of the brain, and with good reason. The thalamus receives input from all of our senses except olfaction (smell), performs some preliminary analyses, and then transmits the information to other parts of the brain.

Finally, we should consider a set of structures that together are known as the **limbic system**. The structures that make up the limbic system play an important role in emotion and in motivated behavior, such as feeding, fleeing from danger, fighting, and sex. The largest of these structures, the **hippocampus**, plays a key role in the formation of memories, a topic we'll consider in Chapter 6. The **amygdala**, also part of the limbic system, is involved in aspects of emotional control and in the formation of emotional memories. In animals, damage to this structure can produce striking differences in behavior; for example, a typically docile cat may become uncontrollably violent. Much more disturbing, recent findings indicate that dysfunctions in the limbic system—or in other parts of the brain that influence it—may play a role in human violence.

Hypothalamus: A small structure deep within the brain that plays a key role in the regulation of the autonomic nervous system and of several forms of motivated behavior such as eating and aggression.

Thalamus: A structure deep within the brain that receives sensory input from other portions of the nervous system and then transmits this information to the cerebral hemispheres and other parts of the brain.

Limbic System: Several structures deep within the brain that play a role in emotional reaction and behavior.

Hippocampus: A structure of the limbic system that plays role in the formation of certain types of memories.

Amygadala: A limbic stytem structure involved in aspects of emotional control and formation of emotional memories.

Beyond The Headlines: As Psychologists See It

Is Violence the Result of Faulty Neural Brakes?

WASHINGTON POST (APRIL 14, 1998)–An engineer described as friendly and outgoing flies into a rage during a family argument and beats his wife and 13-month-old daughter to death with a champagne bottle. . . . A young man who has a "quick temper" goes back to the auto parts store from which he'd been fired and kills three of his former coworkers. . . . Sociologists, psychiatrists, criminologists and others have long struggled to understand what makes some people turn violent. Childhood abuse clearly can be a factor, bur researchers have wondered whether some people are born with the tendency–and a new report suggests some are.

In the first study of its kind, neuroscientists used high-tech imaging technology to peer inside the minds of killers to try to determine whether their brains differ in some fundamental way. The researchers found evidence that some people are born with brains that any make them prone to violence ... specifically, the part of their brains involved in creating a sense of "conscience" may be dysfunctional. . . . The researchers found that 26 murderers from comparatively benign backgrounds, who has not suffered child abuse, showed 14.2% less activity in a part of the medial prefrontal cortex known as the orbitofrontal cortex on the right hemisphere. The medial prefrontal cortex, located just behind the forehead, has been shown in animal research to be involved in inhibiting the limbic system, a region ... that produces aggressive behavior. Animal research also has shown that the right orbitofrontal cortex is involved in fear conditioning–the association between antisocial behavior a punishment that in humans is thought to be key to developing a conscience. "When you train a dog, you punish it every time it does something wrong. A conscience is really just a set of conditioned responses," Andrian Raine, leader of the research team, noted. "There are a lot of factors involved in crime," Raine added, "and brain function is just one of those. But by understanding the brain function, we will be in a much better position to understand the complete causes of violent behavior."

A neural basis for conscience and for violent behavior? Wow! And the results do sound convincing: Among a group of murderers, a region of the brain that acts as a neural brake on another region (the limbic system) known to be involved in aggression showed reduced activity.

But there are some potential problems in this interpretation. First, we can't tell whether this reduced activity is the cause of the violent behavior shown by these people or the result of it. Other research indicates that after committing aggressive crimes, or perhaps simply after repeated exposure to films or television shows containing violence, many persons demonstrate reduced arousal in response to the pain and suffering of other (e.g, Baron, 1993a). Thus, it is possible that the murderers studied in this research showed reduced activity in their neural "braking" systems as a result of having engaged in violence rather than the reverse. Second, murderers–especially ones who commit the kind of unpremeditated violent actions shown by these persons–are a special group; they may differ from other people in many ways, and it may be *these* differences, not reductions in neural activity in a specific part of their brains, that are responsible for their behavior. Third, the size of this sample is very small–only twenty-six persons; moreover, we don't know if they are representative of all persons who