

2

The Biological Perspective

THINKING CRITICALLY

What do you see as the brain's role in our behavior? How much do you think your behavior is influenced by hormones and chemicals in the nervous system?

After you have answered the question, watch the video to compare the answers of other students to yours.

- ▶ The response entered here will be saved to your notes and may be collected by your instructor if he/she requires it.



 Watch the Video

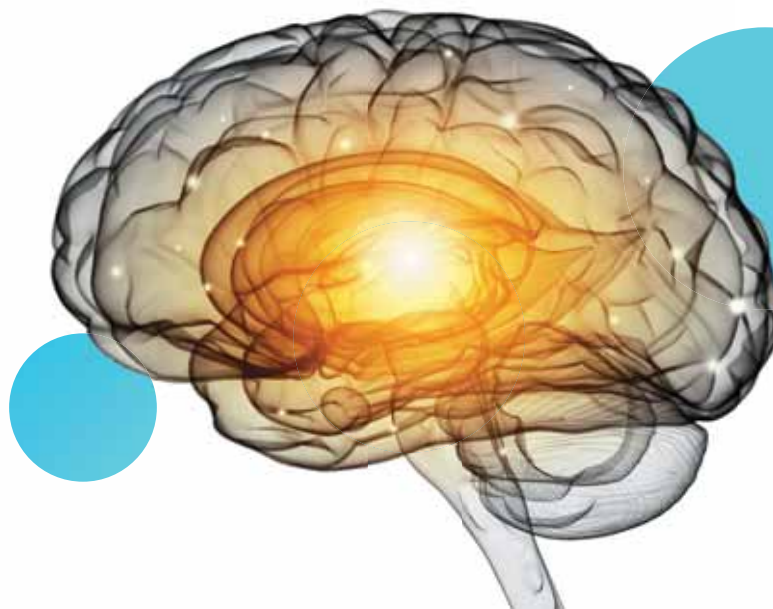
Why study **the nervous system and the glands?**

How could we possibly understand any of our behavior, thoughts, or actions without knowing something about the incredible organs that allow us to act, think, and react? If we can understand how the brain, the nerves, and the glands interact to control feelings, thoughts, and behavior, we can begin to truly understand the complex organism called a human being.



Learning Objectives

- 2.1** Identify the parts of a neuron and the function of each.
- 2.2** Explain the action potential.
- 2.3** Describe how neurons use neurotransmitters to communicate with each other and with the body.
- 2.4** Describe how the brain and spinal cord interact and respond to external experiences.
- 2.5** Differentiate the roles of the somatic and autonomic nervous systems.
- 2.6** Explain why the pituitary gland is known as the “master gland.”
- 2.7** Recall the role of various endocrine glands.
- 2.8** Describe how lesioning studies and brain stimulation are used to study the brain.
- 2.9** Compare and contrast neuroimaging techniques for mapping the structure and function of the brain.
- 2.10** Identify the different structures of the hindbrain and the function of each.
- 2.11** Identify the structures of the brain that are involved in emotion, learning, memory, and motivation.
- 2.12** Identify the parts of the cortex that process the different senses and those that control movement of the body.
- 2.13** Name the parts of the cortex that are responsible for higher forms of thought, such as language.
- 2.14** Explain how some brain functions differ between the left and right hemispheres.
- 2.15** Identify some potential causes of attention-deficit/hyperactivity disorder.



Neurons and Nerves: Building the Network

This chapter will explore a complex system of cells, chemicals, and organs that work together to produce behavior, thoughts, and actions. The first part of this complex arrangement is the **nervous system**, a network of cells that carries information to and from all parts of the body. The field of **neuroscience** is a branch of the life sciences that deals with the structure and functioning of the brain and the neurons, nerves, and nervous tissue that form the nervous system. **Biological psychology, or behavioral neuroscience**, is the branch of neuroscience that focuses on the biological bases of psychological processes, behavior, and learning, and it is the primary area associated with the biological perspective in psychology.

STRUCTURE OF THE NEURON: THE NERVOUS SYSTEM'S BUILDING BLOCK

2.1 Identify the parts of a neuron and the function of each.

In 1887, Santiago Ramón y Cajal, a doctor studying slides of brain tissue, first theorized that the nervous system was made up of individual cells (Ramón y Cajal, translation, 1995). Although the entire body is composed of cells, each type of cell has a special purpose and function and, therefore, a special structure. For example, skin cells are flat, but muscle cells are long and stretchy. Most cells have three things in common: a nucleus, a cell body, and a cell membrane holding it all together. The **neuron** is the specialized cell in the nervous system that receives and sends messages within that system. Neurons are one of the messengers of the body, and that means that they have a very special structure, which we will explore in **Figure 2.1**.

nervous system

an extensive network of specialized cells that carries information to and from all parts of the body.

neuroscience

a branch of the life sciences that deals with the structure and function of neurons, nerves, and nervous tissue.

biological psychology or behavioral neuroscience

branch of neuroscience that focuses on the biological bases of psychological processes, behavior, and learning.

neuron

the basic cell that makes up the nervous system and that receives and sends messages within that system.

dendrites

branchlike structures of a neuron that receive messages from other neurons.

soma

the cell body of the neuron responsible for maintaining the life of the cell.

axon

tubelike structure of neuron that carries the neural message from the cell body to the axon terminals, for communication with other cells.

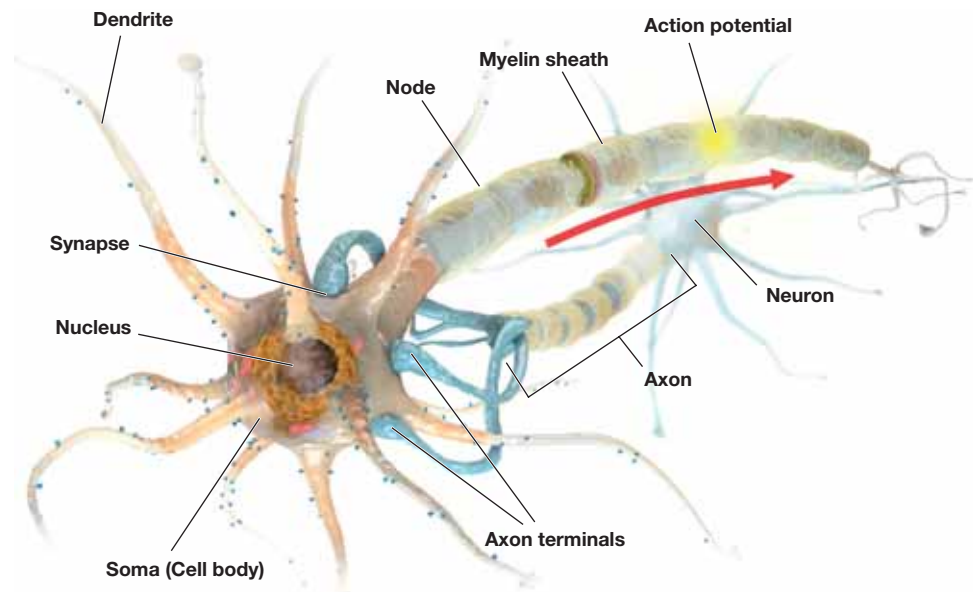


Figure 2.1 The Structure of the Neuron

The parts of the neuron that receive messages from other cells are called the **dendrites**. The name *dendrite* means “tree-like,” or “branch,” and this structure does indeed look like the branches of a tree. The dendrites are attached to the cell body, or **soma**, which is the part of the cell that contains the nucleus and keeps the entire cell alive and functioning. The word *soma* means “body.” The **axon** (from the Greek for “axis”) is a fiber attached to the soma, and its job is to carry messages out to other cells. The end of

the axon branches out into several shorter fibers that have swellings or little knobs on the ends called **axon terminals** (may also be called *presynaptic terminals*, *terminal buttons*, or *synaptic knobs*), which are responsible for communicating with other nerve cells.

Neurons make up a large part of the brain, but they are not the only cells that affect our thinking, learning, memory, perception, and all of the other facets of life that make us who we are. The other primary cells are called glia, or **glial cells**, which serve a variety of functions. While historically viewed as support cells for neurons, the expanded roles of glia are still being discovered. And while they help maintain a state of *homeostasis*, or sense of balance in the nervous system, they are increasingly being better understood as partner cells, not just support cells (Kettenmann & Ransom, 2013; Verkhratsky et al., 2014). Some glia serve as a sort of structure on which the neurons develop and work and that hold the neurons in place. For example, during early brain development, radial glial cells (extending from inner to outer areas like the spokes of a wheel) help guide migrating neurons to form the outer layers of the brain. Other glia are involved in getting nutrients to the neurons, cleaning up the remains of neurons that have died, communicating with neurons and other glial cells, and insulating the axons of some neurons.

Glial cells affect both the functioning and structure of neurons, and specific types also have properties similar to stem cells, which allow them to develop into new neurons, both during prenatal development and in adult mammals (Bullock et al., 2005; Gotz et al., 2015; Kriegstein & Alvarez-Buylla, 2009). Glial cells are also being investigated for their possible role in a variety of neurodevelopmental diseases like *autism spectrum disorder*, degenerative disorders such as Alzheimer’s disease, and psychiatric disorders including *major depressive disorder* and *schizophrenia* (Molofsky et al., 2012; Peng et al., 2015; Sahin & Sur, 2015; Verkhratsky et al., 2014; Yamamuro et al., 2015). [LINK](#) to [Learning Objectives 8.7, 14.9, and 14.14](#). Glial cells also play important roles in learning, behavior, and neuroplasticity by affecting synaptic connectivity and facilitating communication between neurons in specific neural networks (Hahn et al., 2015; Martín et al., 2015).

Two special types of glial cells, called *oligodendrocytes* and *Schwann cells*, generate a layer of fatty substances called **myelin**. Oligodendrocytes produce myelin for the neurons in the brain and spinal cord (the central nervous system); Schwann cells produce myelin for the neurons of the body (the peripheral nervous system). Myelin wraps around the shaft of the axons, forming an insulating and protective sheath. Bundles of myelin-coated axons travel together as “cables” in the central nervous system called *tracts*, and in the peripheral nervous system bundles of axons are called **nerves**. Myelin from Schwann cells has a unique feature that can serve as a tunnel through which damaged nerve fibers can reconnect and repair themselves. That’s why a severed toe might actually regain some function and feeling if sewn back on in time. Unfortunately, myelin from oligodendrocytes covering axons in the brain and spinal cord does not have this feature, and these axons are more likely to be permanently damaged.

The myelin sheath is a very important part of the neuron. It not only insulates and protects the neuron, it also speeds up the neural message traveling down the axon. As shown in Figure 2.1, sections of myelin bump up next to each other on the axon, similar to the way sausages are linked together. The places where the myelin seems to bump are actually small spaces on the axon called nodes, which are not covered in myelin. Myelinated and unmyelinated sections of axons have slightly different electrical properties. There are also far more ion channels at each node. Both of these features affect the speed at which the electrical signal is conducted down the axon. When the electrical impulse that is the neural message travels down an axon coated with myelin, the electrical impulse is regenerated at each node and appears to “jump” or skip rapidly from node to node down the axon (Koester & Siegelbaum, 2013; Schwartz et al., 2013). That makes the message go much faster down the coated axon than it would down an uncoated axon of a neuron in the brain. In the disease called *multiple sclerosis* (MS), the myelin sheath is destroyed (possibly by the individual’s own immune system), which leads to diminished

axon terminals

enlarged ends of axonal branches of the neuron, specialized for communication between cells.

glial cells

cells that provide support for the neurons to grow on and around, deliver nutrients to neurons, produce myelin to coat axons, clean up waste products and dead neurons, influence information processing, and, during prenatal development, influence the generation of new neurons.

myelin

fatty substances produced by certain glial cells that coat the axons of neurons to insulate, protect, and speed up the neural impulse.

nerves

bundles of axons coated in myelin that travel together through the body.

or complete loss of neural functioning in those damaged cells. Early symptoms of MS may include fatigue; changes in vision; balance problems; and numbness, tingling, or muscle weakness in the arms or legs. Just as we are learning more about the expanded roles of glial cells, our knowledge about the structure and function of myelin is also expanding far beyond myelin simply being an insulator of axons. Myelin thickness varies, and myelin distribution may vary along the length of an axon, likely affecting communication properties of those neurons and impacting larger neural networks (Fields, 2014; Tomassy et al., 2014).

GENERATING THE MESSAGE WITHIN THE NEURON: THE NEURAL IMPULSE

2.2 Explain the action potential.



Exactly how does this “electrical message” work inside the cell?

A neuron that’s at rest—not currently firing a neural impulse or message—is actually electrically charged. Inside and outside of the cell is a semiliquid (jelly-like) solution in which there are charged particles, or *ions*. Although both positive and negative ions are located inside and outside of the cell, the relative charge of ions inside the cell is mostly negative, and the relative charge of ions outside the cell is mostly positive due to both **diffusion**, the process of ions moving from areas of high concentration to areas of low concentration, and *electrostatic pressure*, the relative balance of electrical charges when the ions are at rest. The cell membrane itself is *semipermeable*, meaning that some molecules may freely pass through the membrane while others cannot. Some molecules that are outside the cell enter through tiny protein openings, or *channels*, in the membrane, while molecules inside the cell can pass through the same channels to the outside of the cell. Many of these channels are gated—they open or close based on the electrical potential of the membrane—more about that in a minute. Inside the cell is a concentration of both smaller positively charged potassium ions and larger negatively charged protein ions. The negatively charged protein ions, however, are so big that they can’t get out, which leaves the inside of the cell primarily negative when at rest. Outside the cell are lots of positively charged sodium ions and negatively charged chloride ions, but they are unable to enter the cell membrane when the cell is at rest because the ion channels that would allow them in are closed. But because the outside sodium ions are positive and the inside ions are negative, and because opposite electrical charges attract each other, the sodium ions will cluster around the membrane. This difference in charges creates an electrical potential.

Think of the ions inside the cell as a baseball game inside a stadium (the cell walls). The sodium ions outside the cell are all the fans in the area, and they want to get inside to see the game. When the cell is resting (the electrical potential is in a state called the **resting potential**, because the cell is at rest), the fans are stuck outside. The sodium ions cannot enter when the cell is at rest, because even though the cell membrane has all these channels, the *particular channels* for the big sodium ions aren’t open yet. But when the cell receives a strong enough stimulation from another cell (at the dendrites or soma), the cell membrane opens up those particular channels, one after the other, all down its surface, allowing the sodium ions (the “fans”) to rush into the cell. That causes the inside of the cell to become mostly positive and the outside of the cell to become mostly negative, because many of the positive sodium ions are now inside the cell—at the point where the first ion channel opened. This electrical charge reversal will start at the part of the axon closest to the soma, the *axon hillock*, and then proceed down the axon in a kind of chain reaction. (Picture a long hallway with many doors in which the first door opens, then the second, and so on all the way down the hall.) This electrical charge reversal is known as the **action potential** because the electrical potential is now in action rather than at rest.

diffusion

process of molecules moving from areas of high concentration to areas of low concentration.

resting potential

the state of the neuron when not firing a neural impulse.

action potential

the release of the neural impulse, consisting of a reversal of the electrical charge within the axon.

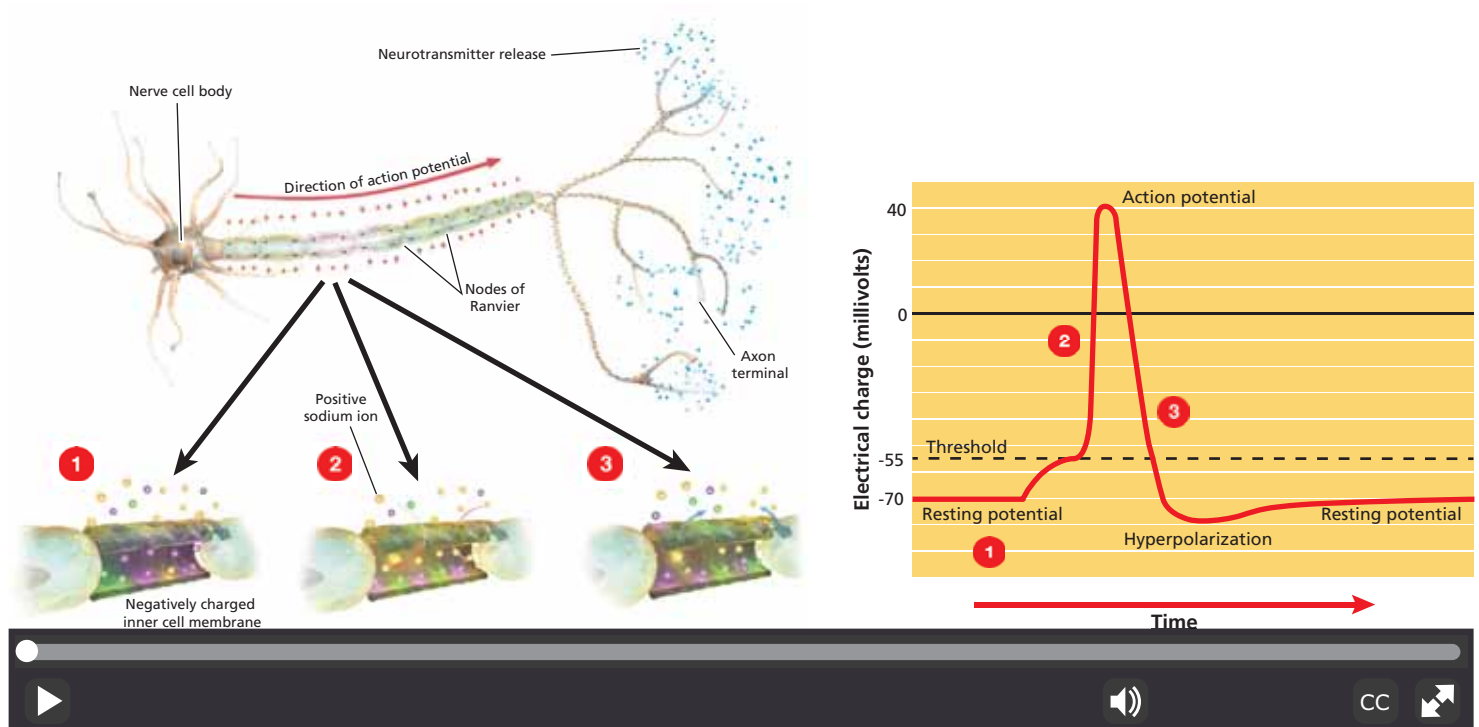


Figure 2.2 The Neural Impulse Action Potential

Voltage is graphed at a given axonal node over 2 to 3 milliseconds (thousandths of a second). From an initial resting state, enough stimulation is received that the threshold of excitation is reached and an action potential is triggered. The resulting rapid depolarization, repolarization, brief hyperpolarization, and return to resting potential coincide with movement of sodium and potassium ions across the cell membrane.

Each action potential sequence takes about one thousandth of a second, so the neural message travels very fast—from 2 miles per hour in the slowest, shortest neurons to 270 miles per hour in other neurons. (See **Figure 2.2**.)

Now the action potential is traveling down the axon. When it gets to the end of the axon, something else happens: the message will get transmitted to another cell (that step will be discussed momentarily). Meanwhile, what is happening to the parts of the cell that the action potential has already left behind? How does the cell get the “fans” back outside? Remember, the action potential means that the cell is now positive inside and negative outside at the point where the channel opened. Several things happen to return the cell to its resting state. First, the sodium ion channels close immediately after the action potential has passed, allowing no more “fans” (sodium ions) to enter. The cell membrane also literally pumps the positive sodium ions back outside the cell, kicking the “fans” out until the next action potential opens the ion channels again. This pumping process is a little slow, so another type of ion gets into the act. Small, positively charged potassium ions inside the neuron move rapidly out of the cell after the action potential passes, helping more quickly restore the inside of the cell to a negative charge. Now the cell becomes negative inside and positive outside, and the neuron is capable of “firing off” another message. Once the sodium pumps finish pumping out the sodium ions, the neuron can be said to have returned to its full resting potential, poised and ready to do it all again.

To sum all that up, when the cell is stimulated, the first ion channel opens and the electrical charge *at that ion channel* is reversed. Then the next channel opens and *that* charge is reversed, but in the meantime the *first* ion channel has been closed and the charge is returning to what it was when it was at rest. The action potential is the *sequence* of ion channels opening all down the length of the cell’s axon.

So if the stimulus that originally causes the neuron to fire is very strong, will the neuron fire more strongly than it would if the stimulus were weak?

Neurons actually have a threshold for firing, and all it takes is a stimulus that is just strong enough to get past that threshold to make the neuron fire. Here's a simple version of how this works: Each neuron is receiving many signals from other neurons. Some of these signals are meant to cause the neuron to fire, whereas others are meant to prevent the neuron from firing. The neuron constantly adds together the effects of the "fire" messages and subtracts the "don't fire" messages, and if the fire messages are great enough, the threshold is crossed and the neuron fires. When a neuron does fire, it fires in an **all-or-none** fashion. That is, neurons are either firing at full strength or not firing at all—there's no such thing as "partial" firing of a neuron. It would be like turning on a light switch—it's either on or it's off. Once the switch is turned to the on position, the light will come on. When it's turned to the off position, the light is off.

So, what's the difference between strong stimulation and weak stimulation? A strong message will cause the neuron to fire repeatedly (as if someone flicked the light switch on and off as quickly as possible), and it will also cause more neurons to fire (as if there were a lot of lights going on and off instead of just one).

all-or-none

referring to the fact that a neuron either fires completely or does not fire at all.

synaptic vesicles

sac-like structures found inside the synaptic knob containing chemicals.

neurotransmitters

chemical found in the synaptic vesicles that, when released, has an effect on the next cell.

NEUROTRANSMISSION

2.3 Describe how neurons use neurotransmitters to communicate with each other and with the body.

Now that we know how the message travels within the axon of the cell, what is that "something else" that happens when the action potential reaches the end of the axon?

Once a neural signal reaches the axon terminals of a neuron, several events take place to allow neurons to communicate with each other. These events are dependent upon key structures within a neuron and on the surface of adjacent neurons.

SENDING THE MESSAGE TO OTHER

CELLS: THE SYNAPSE Look once again at the axon terminals in Figure 2.1. Figure 2.3 shows an axon terminal enlarged to giant scale. Notice that the presynaptic terminal is not empty. It has a number of little sac-like structures in it called **synaptic vesicles**. The word *vesicle* is Latin and means a "little blister" or "fluid-filled sac."

Inside the synaptic vesicles are chemicals suspended in fluid, which are molecules of substances called **neurotransmitters**. The name is simple enough—they are inside a neuron and they are going to transmit a message. (Neurons have traditionally been viewed as containing a single type of neurotransmitter, but it is now accepted that neurons

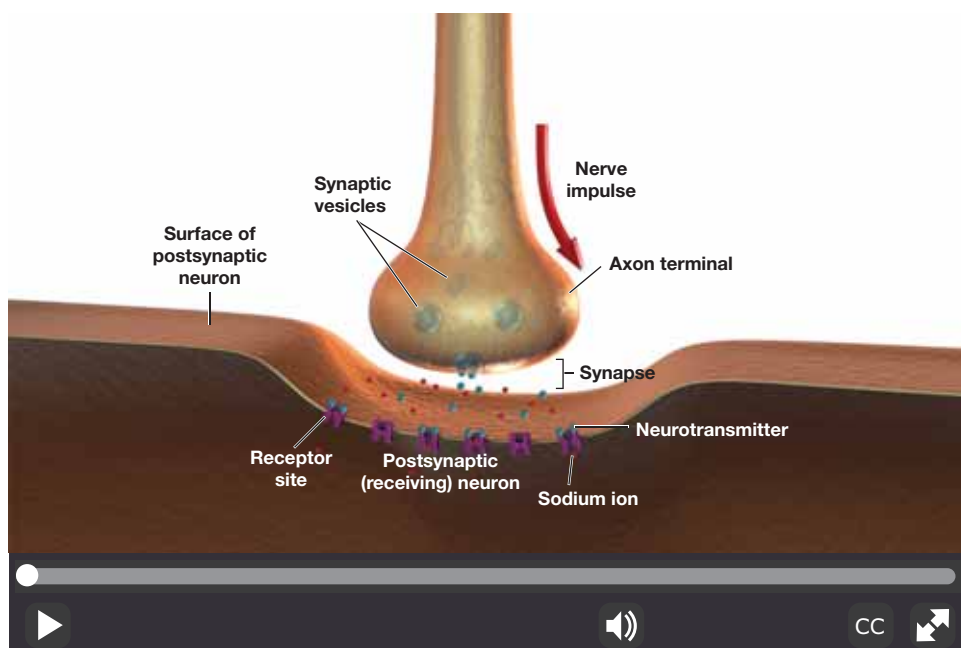


Figure 2.3 The Synapse

The nerve impulse reaches the axon terminal, triggering the release of neurotransmitters from the synaptic vesicles. The molecules of neurotransmitter cross the synaptic gap to fit into the receptor sites that fit the shape of the molecule, opening the ion channel and allowing sodium ions to rush in.

may release more than one neurotransmitter. For simplicity and unless otherwise specified, our discussion throughout the text will assume a single, predominant neurotransmitter is being released.) Next to the axon terminal is the dendrite of another neuron (see **Figure 2.3**). Between them is a fluid-filled space called the **synapse** or the **synaptic gap**. Instead of an electrical charge, the vesicles at the end of the axon (also called the presynaptic membrane) contain the molecules of neurotransmitters, and the surface of the dendrite next to the axon (the postsynaptic membrane) contains ion channels that have **receptor sites**, proteins that allow only particular molecules of a certain shape to fit into it, just as only a particular key will fit into a keyhole. Synapses can also occur on the soma of the postsynaptic cell, as the surface membrane of the soma also has receptor sites.

How do the neurotransmitters get across the gap? Recall the action potential making its way down the axon after the neuron has been stimulated. When that action potential, or electrical charge, reaches the synaptic vesicles, the synaptic vesicles release their neurotransmitters into the synaptic gap. The molecules then float across the synapse, and many of them fit themselves into the receptor sites, opening the ion channels and allowing sodium to rush in, activating the next cell. It is this very activation that stimulates, or releases, the action potential in that cell. It is important to understand that the “next cell” may be a neuron, but it may also be a cell on a muscle or a gland. Muscles and glands have special cells with receptor sites on them, just like on the dendrite or soma of a neuron.

So far, we’ve been talking about the synapse as if neurotransmitters always cause the next cell to fire its action potential (or, in the case of a muscle or gland, to contract or start secreting its chemicals). But the neurons must have a way to be turned *off* as well as on. Otherwise, when a person burns a finger, the pain signals from those neurons would not stop until the burn was completely healed. Muscles are told to contract or relax, and glands are told to secrete or stop secreting their chemicals. The neurotransmitters found at various synapses around the nervous system can either turn cells on (called an *excitatory* effect) or turn cells off (called an *inhibitory* effect), depending on exactly what synapse is being affected. Although some people refer to neurotransmitters that turn cells on as *excitatory* neurotransmitters and the ones that turn cells off as *inhibitory* neurotransmitters, it’s really more correct to refer to **excitatory synapses** and **inhibitory synapses**. In other words, it’s not the neurotransmitter itself that is excitatory or inhibitory, but rather it is the effect of that neurotransmitter that is either excitatory or inhibitory at the receptor sites of a particular synapse.

NEUROTRANSMITTERS: MESSENGERS OF THE NETWORK The first neurotransmitter to be identified was named *acetylcholine* (ACh). It is found at the synapses between neurons and muscle cells. Acetylcholine stimulates the skeletal muscles to contract but actually slows contractions in the heart muscle. If acetylcholine receptor sites on the muscle cells are blocked in some way, then the acetylcholine can’t get to the site and the muscle will be incapable of contracting—paralyzed, in other words. This is exactly what happens when *curare*, a drug used by South American Indians on their blow darts, gets into the nervous system. Curare’s molecules are just similar enough to fit into the receptor site without actually stimulating the cell, making curare an **antagonist** (a chemical substance that blocks or reduces the effects of a neurotransmitter) for ACh.

What would happen if the neurons released too much ACh? The bite of a black widow spider does just that. Its venom stimulates the release of excessive amounts of ACh and causes convulsions and possible death. Black widow spider venom is an **agonist** (a chemical substance that mimics or enhances the effects of a neurotransmitter) for ACh.

ACh also plays a key role in memory, arousal, and attention. For example, ACh is found in the hippocampus, an area of the brain that is responsible for forming new

synapse (synaptic gap)

microscopic fluid-filled space between the axon terminal of one cell and the dendrites or soma of the next cell.

receptor sites

three-dimensional proteins on the surface of the dendrites or certain cells of the muscles and glands, which are shaped to fit only certain neurotransmitters.

excitatory synapse

synapse at which a neurotransmitter causes the receiving cell to fire.

inhibitory synapse

synapse at which a neurotransmitter causes the receiving cell to stop firing.

antagonists

chemical substances that block or reduce a cell’s response to the action of other chemicals or neurotransmitters

agonists

chemical substances that mimic or enhance the effects of a neurotransmitter on the receptor sites of the next cell, increasing or decreasing the activity of that cell.



The venom of the black widow spider causes a flood of acetylcholine to be released into the body's muscle system, causing convulsions.

memories, and low levels of ACh have been associated with Alzheimer's disease, the most common type of dementia. [LINK](#) to [Learning Objective 6.13](#). We will focus more on agonists and antagonists later in the chapter.

Dopamine (DA) is a neurotransmitter found in the brain, and like some of the other neurotransmitters, it can have different effects depending on the exact location of its activity. For example, if too little DA is released in a certain area of the brain, the result is Parkinson's disease—the disease that is currently being battled by actor Michael J. Fox, and that affected the late former boxing champ Muhammad Ali (Almasay, 2016; Ahlskog, 2003). If too much DA is released in other areas, the result is a cluster of symptoms that may be part of schizophrenia (Akil et al., 2003). [LINK](#) to [Learning Objective 14.13](#).

Serotonin (5-HT) is a neurotransmitter originating in the lower part of the brain that can have either an excitatory or inhibitory effect, depending on the particular synapses being affected. It is associated with sleep, mood, anxiety, and appetite. For example, low levels of 5-HT activity have been linked to depression. [LINK](#) to [Learning Objective 14.9](#).

Although ACh was the first neurotransmitter found to have an excitatory effect at the synapse, the nervous system's major excitatory neurotransmitter is *glutamate*. Like ACh, glutamate plays an important role in learning and memory and may also be involved in the development of the nervous system and in synaptic plasticity (the ability of the brain to change connections among its neurons). However, an excess of glutamate results in overactivation and neuronal damage and may be associated with the cell death that occurs after stroke or head injury or in degenerative diseases like Alzheimer's disease and Huntington disease (Julien et al., 2011; Siegelbaum et al., 2013).

Another neurotransmitter is *gamma-aminobutyric acid* or GABA. Whereas glutamate is the major neurotransmitter with an excitatory effect, GABA is the most common neurotransmitter producing inhibition in the brain. GABA can help calm anxiety, for example, by binding to the same receptor sites that are affected by tranquilizing drugs and alcohol. In fact, the effect of alcohol is to enhance the effect of GABA, which causes the general inhibition of the nervous system associated with getting drunk. This makes alcohol an agonist for GABA. [LINK](#) to [Learning Objective 4.13](#). **Table 2.1** below lists some neurotransmitters and their functions.

A group of substances known as *neuropeptides* can serve as neurotransmitters or hormones or influence the action of other neurotransmitters (Schwartz & Javitch, 2013).

Table 2.1 Some Neurotransmitters and Their Functions

Neurotransmitters	Functions
Acetylcholine (ACh)	Excitatory or inhibitory; involved in arousal, attention, memory, and controls muscle contractions
Norepinephrine (NE)	Mainly excitatory; involved in arousal and mood
Dopamine (DA)	Excitatory or inhibitory; involved in control of movement and sensations of pleasure
Serotonin (5-HT)	Excitatory or inhibitory; involved in sleep, mood, anxiety, and appetite
Gamma-aminobutyric acid (GABA)	Major inhibitory neurotransmitter; involved in sleep and inhibits movement
Glutamate	Major excitatory neurotransmitter; involved in learning, memory formation, nervous system development, and synaptic plasticity
Endorphins	Inhibitory neural regulators; involved in pain relief

You may have heard of the set of neuropeptides called *endorphins*—pain-controlling chemicals in the body. When a person is hurt, a neurotransmitter that signals pain is released. When the brain gets this message, it triggers the release of endorphins. The endorphins bind to receptors that open the ion channels on the axon. This causes the cell to be unable to fire its pain signal, and the pain sensations eventually lessen. For example, you might bump your elbow and experience a lot of pain at first, but the pain will quickly subside to a much lower level. Athletes may injure themselves during an event and yet not feel the pain until after the competition is over, when the endorphin levels go down.

The name *endorphin* comes from the term *endogenous morphine*. (*Endogenous* means “native to the area”—in this case, native to the body.) Scientists studying the nervous system found receptor sites that fit morphine molecules perfectly and decided that there must be a natural substance in the body that has the same effect as morphine. Endorphins are one reason that heroin and the other drugs derived from opium are so addictive—when people take morphine or heroin, their bodies neglect to produce endorphins. When the drug wears off, they are left with no protection against pain at all, and *everything* hurts. This pain is one reason most people want more heroin, creating an addictive cycle of abuse. [LINK](#) to [Learning Objective 4.11](#).

💬 If the neurotransmitters are out there in the synaptic gap and in the receptor sites, what happens to them when they aren’t needed anymore?

CLEANING UP THE SYNAPSE: REUPTAKE AND ENZYMES The neurotransmitters have to get out of the receptor sites before the next stimulation can occur. Some just drift away through the process of diffusion, but most will end up back in the presynaptic neuron to be repackaged into the synaptic vesicles in a process called **reuptake**. (Think of a little suction tube, sucking the chemicals back into the vesicles.) That way, the synapse is cleared for the next release of neurotransmitters. Some drugs, like cocaine, affect the nervous system by blocking the reuptake process, as shown in [Figure 2.4](#).

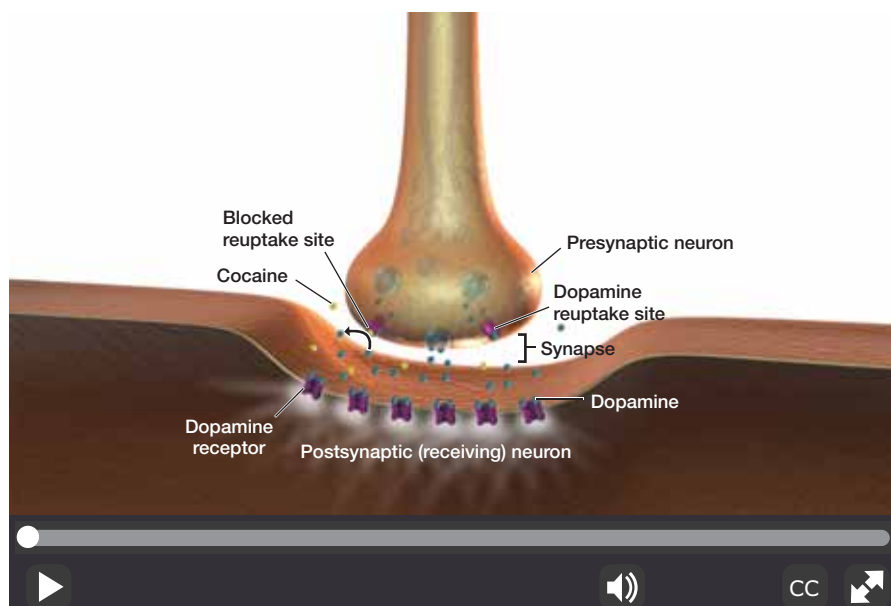


Figure 2.4 Neurotransmitters: Reuptake

reuptake

process by which neurotransmitters are taken back into the synaptic vesicles.

There is one neurotransmitter that is not taken back into the vesicles, however. Because ACh is responsible for muscle activity, and muscle activity needs to happen rapidly and continue happening, it's not possible to wait around for the "sucking up" process to occur. Instead, an enzyme* specifically designed to break apart ACh clears the synaptic gap very quickly (a process called **enzymatic degradation**.) There are enzymes that break down other neurotransmitters as well.

💬 I think I understand the synapse and neurotransmitters now, but how do I relate that to the real world?

Knowing how and why drugs affect us can help us understand why a doctor might prescribe a particular drug or why certain drugs are dangerous and should be avoided. Because the chemical molecules of various drugs, if similar enough in shape to the neurotransmitters, can fit into the receptor sites on the receiving neurons just like the neurotransmitters do, drugs can act as agonists or antagonists. Drugs acting as agonists, for example, can mimic or enhance the effects of neurotransmitters on the receptor sites of the next cell. This can result in an increase or decrease in the activity of the receiving cell, depending on what the effect of the original neurotransmitter (excitatory or inhibitory) was going to be. So if the original neurotransmitter was excitatory, the effect of the agonist will be to increase that excitation. If it was inhibitory, the effect of the agonist will be to increase that inhibition. Another deciding factor is the nervous system location of the neurons that use a specific neurotransmitter.

For example, some antianxiety medications, such as diazepam (Valium®), are classified as benzodiazepines (LINK to Learning Objective 15.10.) and are agonists for GABA, the primary inhibitory neurotransmitter in the brain. Areas of the brain that you will learn about later that play a role in controlling anxiety, agitation, and fear include the amygdala, orbitofrontal cortex, and the insula (LeDoux & Damasio, 2013; Zilles & Amunts, 2012). By increasing the inhibitory (calming) action of GABA, the benzodiazepines directly calm these specific brain areas (Julien et al., 2011; Preston et al., 2008).

Other drugs act as antagonists, blocking or reducing a cell's response to the action of other chemicals or neurotransmitters. Although an antagonist might sound like it has only an inhibitory effect, it is important to remember that if the neurotransmitter that the antagonist affects is inhibitory itself, the result will actually be an *increase* in the activity of the cell that would normally have been inhibited; the antagonist *blocks* the inhibitory effect.

Last, some drugs yield their agonistic or antagonistic effects by impacting the amount of neurotransmitter in the synapse. They do so by interfering with the regular reuptake or enzymatic degradation process. Remember that the neurotransmitter serotonin helps regulate and adjust people's moods, but in some people the normal process of adjustment is not working properly. Some of the drugs used to treat depression are called SSRIs (selective serotonin reuptake inhibitors). SSRIs block the reuptake of serotonin, leaving more serotonin available in the synapse to bind with receptor sites. Over several weeks, the individual's mood improves. Although the reason for this improvement is not as simple as once believed (i.e., low levels of serotonin = low levels of mood) or fully understood, SSRIs are effective for depression, anxiety, and obsessive-compulsive disorder (Hyman & Cohen, 2013; Julien et al., 2011; Stahl, 2013).

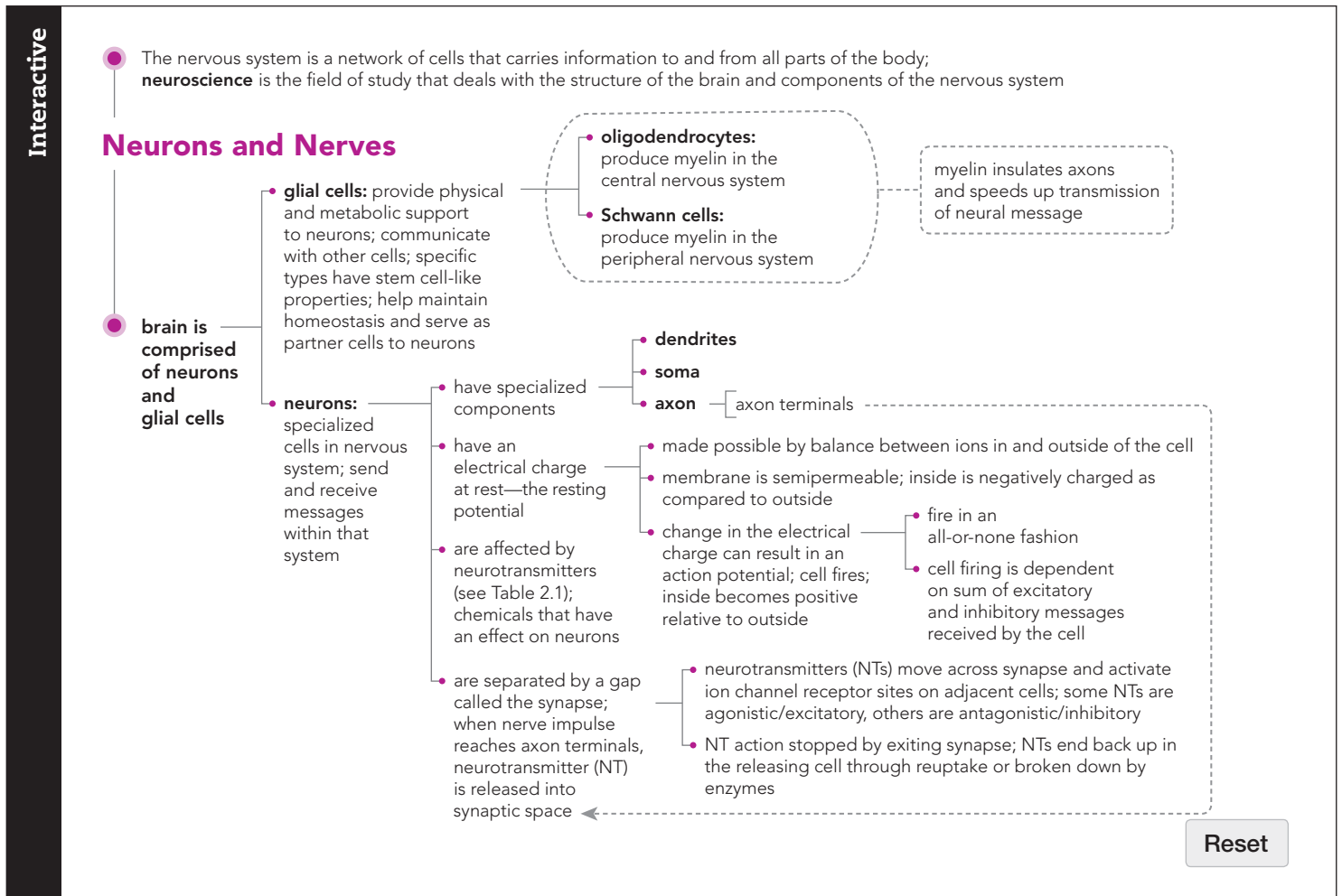
This section covered the neuron and how neurons communicate. The next section looks at the bigger picture—the nervous system itself.

enzymatic degradation

process by which the structure of a neurotransmitter is altered so it can no longer act on a receptor.

*enzyme: a complex protein that is manufactured by cells.

Concept Map LO. 2.1, 2.2, 2.3



Practice Quiz How much do you remember?

Pick the best answer.

- Which part of the neuron carries messages to other cells?
 - axon
 - dendrite
 - soma
 - myelin
- Which one of the following is NOT a function of glial cells?
 - getting nutrients to the neurons
 - generating action potentials
 - cleaning up the remains of dead neurons
 - generating myelin
- When a neuron's resting potential is occurring, the neuron is _____ charged on the inside.
 - positively
 - negatively
 - both positively and negatively
 - neutrally
- Neurotransmitters must pass from an axon terminal to the next dendrite by crossing a fluid-filled space called the _____.
 - synapse.
 - reuptake inhibitor.
 - neuron.
 - glial cell.
- The venom of a black widow spider acts as a(n) _____ by mimicking the effects of acetylcholine.
 - agonist
 - antagonist
 - protagonist
 - glial cell
- Which of the following is associated with pain relief?
 - acetylcholine
 - glutamate
 - serotonin
 - endorphins

An Overview of the Nervous System

Now that we have looked at the cells that make up the nervous system and ways in which they process and communicate information, take a look at **Figure 2.5**. This figure shows the organization of the various parts of the nervous system and will help in

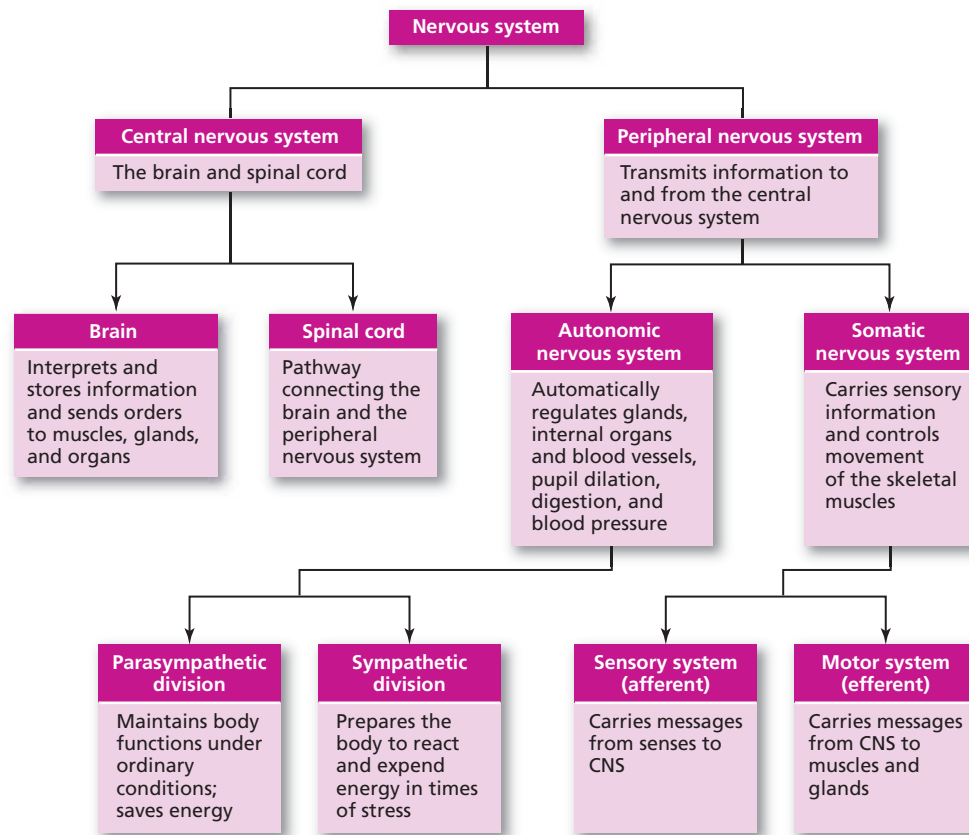


Figure 2.5 An Overview of the Nervous System

understanding how all the different parts work together in controlling the way people and animals think, act, and feel.

THE CENTRAL NERVOUS SYSTEM: THE “CENTRAL PROCESSING UNIT”

2.4 Describe how the brain and spinal cord interact and respond to external experiences.

The **central nervous system (CNS)** is composed of the brain and the spinal cord. Both the brain and the spinal cord are composed of neurons and glial cells that control the life-sustaining functions of the body as well as all thought, emotion, and behavior.

THE BRAIN The brain is the core of the nervous system, the part that makes sense of the information received from the senses, makes decisions, and sends commands out to the muscles and the rest of the body, if needed. Many different areas of the brain are involved in preparing us for an appropriate response to the information received, and the brain is responsible for cognition and thoughts, including learning, memory, and language. Later parts of this chapter will cover the brain in more detail, but for now, you should know the brain is organized into different regions, each with primary functions. While the neurons in each of the different areas work in much the same way, it is the groups of cells and the connections between them and other parts of the brain or components of the nervous system, and our experiences, that influence the various functions found in specific brain areas (Amaral & Strick, 2013; Heimer, 1995; Squire & Kandel, 2009).

THE SPINAL CORD The **spinal cord** is a long bundle of neurons that serves two vital functions for the nervous system. Look at the cross-section of the spinal cord in **Figure 2.6**. Notice that it seems to be divided into two areas, a lighter outer section and a darker inner section. If it were a real spinal cord, the outer section would appear to be white and the inner section

central nervous system (CNS)

part of the nervous system consisting of the brain and spinal cord.

spinal cord

a long bundle of neurons that carries messages between the body and the brain and is responsible for very fast, lifesaving reflexes.

would seem gray. That's because the outer section is composed mainly of myelinated axons and nerves, which appear white, whereas the inner section is mainly composed of cell bodies of neurons, which appear gray. The purpose of the outer section is to carry messages from the body up to the brain and from the brain down to the body. It is simply a message "pipeline."

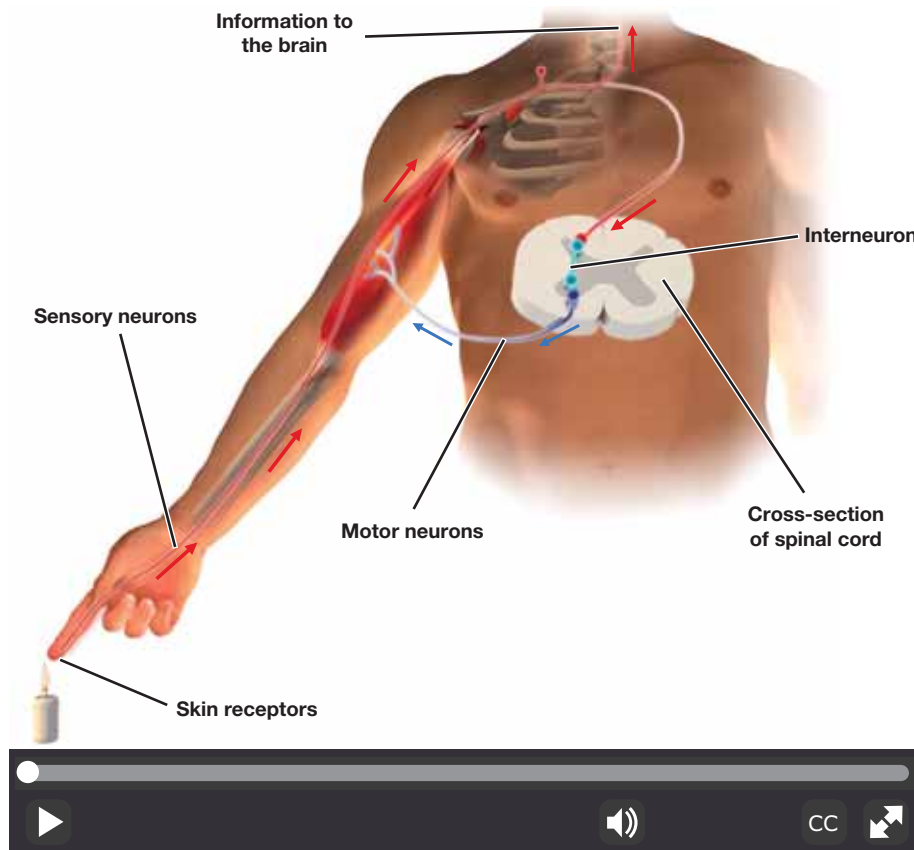


Figure 2.6 The Spinal Cord Reflex

The pain from the burning heat of the candle flame stimulates the afferent nerve fibers, which carry the message up to the interneurons in the middle of the spinal cord. The interneurons then send a message out by means of the efferent nerve fibers, causing the hand to jerk away from the flame.

The inside section, which is made up of cell bodies separated by glial cells, is actually a primitive sort of "brain." This part of the spinal cord is responsible for certain reflexes—very fast, lifesaving reflexes. To understand how the spinal cord reflexes work, it is important to know there are three basic types of neurons: **afferent (sensory) neurons** that carry messages from the senses to the spinal cord, **efferent (motor) neurons** that carry messages from the spinal cord to the muscles and glands, and **interneurons** that connect the afferent neurons to the efferent neurons (and make up the inside of the spinal cord and much of the brain itself). (See Figure 2.6.) Touch a flame or a hot stove with your finger, for example, and an afferent neuron will send the pain message up to the spinal column, where it enters into the central area of the spinal cord. The interneuron in that central area will then receive the message and send out a response along an efferent neuron, causing your finger to pull back. This all happens very quickly. If the pain message had to go all the way up to the brain before a response could be made, the response time would be greatly increased and more damage would be done to your finger. So having this kind of **reflex arc** controlled by the spinal cord alone allows for very fast response times. (A good way to avoid mixing up the terms *afferent* and *efferent* is to remember "afferent neurons access the spinal cord, efferent neurons exit." The pain message does eventually get to the brain, where other motor responses may be triggered, like saying "Ouch!" and putting the finger in your mouth.

afferent (sensory) neuron

a neuron that carries information from the senses to the central nervous system.

efferent (motor) neuron

a neuron that carries messages from the central nervous system to the muscles of the body.

interneuron

a neuron found in the center of the spinal cord that receives information from the afferent neurons and sends commands to the muscles through the efferent neurons. Interneurons also make up the bulk of the neurons in the brain.

reflex

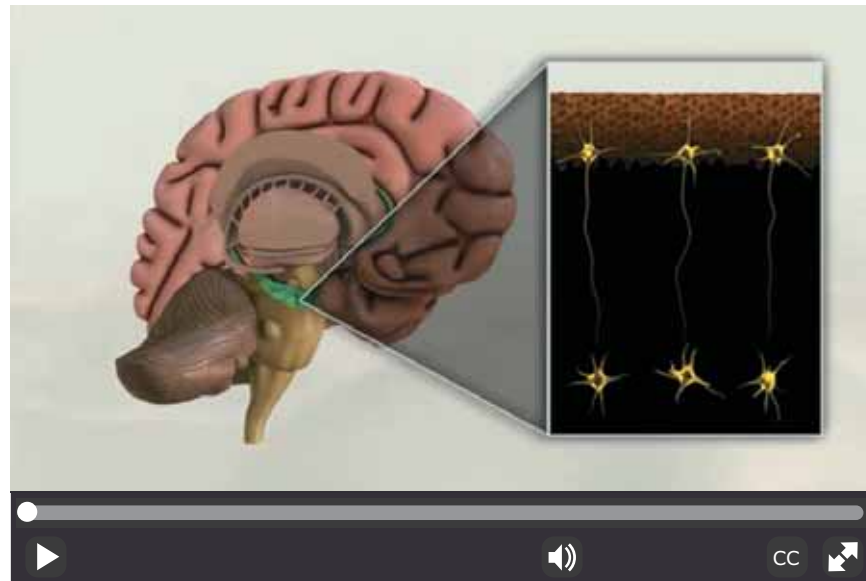
an involuntary response, one that is not under personal control or choice.



The look on this young woman's face clearly indicates that she has experienced pain in her shoulder. Pain is a warning signal that something is wrong. What might be some of the problems encountered by a person who could feel no pain at all?

DAMAGE TO THE CENTRAL NERVOUS SYSTEM, NEUROPLASTICITY, AND NEUROGENESIS

Damage to the central nervous system was once thought to be permanent. Neurons in the brain and spinal cord were not seen as capable of repairing themselves. When people recovered from a stroke, for example, it was assumed that it was primarily due to healthy brain cells taking over the functions of the damaged ones. Scientists have known for a while now that some forms of central nervous system damage can be repaired by the body's systems, and in recent years great strides have been made in repairing spinal cord damage. The brain actually exhibits a great deal of **neuroplasticity**, the ability to constantly change both the structure and function of many cells in the brain in response to trauma or experience (Neville & Bavelier, 2000; Rossini et al., 2007; Sanders et al., 2008). For example, dendrites grow and new synapses are formed in at least some areas of the brain as people learn new things throughout life (Sanes & Jessell, 2013a, 2013b). The video *Overview of Neuroplasticity* explains some aspects of neuroplasticity in more detail.



[Watch the Video](#) *Overview of Neuroplasticity*

neuroplasticity

the ability within the brain to constantly change both the structure and function of many cells in response to experience or trauma.

neurogenesis

the formation of new neurons; occurs primarily during prenatal development but may also occur at lesser levels in some brain areas during adulthood.

stem cells

special cells found in all the tissues of the body that are capable of becoming other cell types when those cells need to be replaced due to damage or wear and tear.

The brain may also change through **neurogenesis**, the formation of new neurons, and an important process during the development of our nervous system. The greatest period of neurogenesis takes place prior to birth, during the prenatal period. And while not at the same level as during early development, the brains of most mammals continue to produce neurons well into adulthood, primarily in the *hippocampus* and *olfactory bulb*. Humans are an exception. We do not appear to have any new neurons produced in our olfactory bulbs as we grow older (Bergmann et al., 2012). However, we do continue to generate new neurons in the hippocampus throughout adulthood, with only a slight decline as we get older (Spalding et al., 2013). And most recently, researchers have found strong but preliminary evidence of human adult neurogenesis in the *striatum* (Ernst et al., 2014; Ernst & Frisen, 2015), an important area of the brain related to motor control, voluntary movement, and other functions.

Scientists are exploring ways to facilitate both neurogenesis and neuroplasticity. In efforts to repair spinal cord damage, they are examining the application of special proteins that are typically involved in the development and survival of new neurons and in the maintenance of existing neurons (Harvey et al., 2015). Researchers are also examining the effects of implanting Schwann cells from the peripheral nervous system to the central nervous system to aid in treating spinal cord injuries (Deng et al., 2013).

Researchers are constantly looking for new ways to repair the brain. One avenue of research has involved scientists investigating the possibility of transplanting **stem cells** to

repair damaged or diseased brain tissue. Stem cells can become any cell in the body and may offer promise for addressing diseases such as Parkinson's and Alzheimer's or the repair of damaged spinal cords or brain tissue. If stem cells can be implanted into areas that have been damaged, the newly developed neurons may assume the roles that the original (now damaged) neurons can no longer perform. Besides transplantation, researchers are also examining the feasibility of activating stem cells through electrical stimulation (Huang et al., 2015).

Efforts to promote neurogenesis, neuroplasticity, or to aid in rehabilitation, have also examined a variety of other areas, including sleep, cognitive training, pharmacological intervention, and physical activity. Research with animals suggests sustained aerobic activity increases neurogenesis in the hippocampus, at least for some that are genetically inclined to benefit from aerobic exercise (Nokia et al., 2016). Physical exercise also appears to benefit neuroplasticity in humans (Mueller et al., 2015; Prakash et al., 2015). Sleep is another important factor. Brain wave activity changes have been recorded during sleep following specific learning experiences, and changes have been noted to coincide with symptoms observed in some psychological disorders (Tesler et al., 2016; Wilhelm et al., 2014).

While not a rehabilitative approach, ongoing research is investigating how neuroplasticity and functioning of the nervous system are influenced through **epigenetics**, or the interaction between genes and environmental factors that influence gene activity. Such factors include our physical environment, nutritional status, and life experiences. We cannot reverse time, but new life experiences can influence our brain, impact future behavior, and impact our resiliency and ability to cope with life's challenges (Caldji et al., 1998; Goossens et al., 2015; McEwen et al., 2015; Tammen et al., 2013).

THE PERIPHERAL NERVOUS SYSTEM: NERVES ON THE EDGE

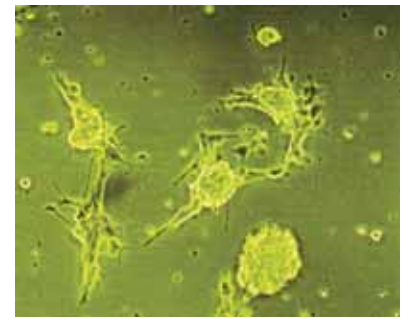
2.5 Differentiate the roles of the somatic and autonomic nervous systems.

🗨️ Okay, that takes care of the central nervous system, except for the detail on the brain. How does the central nervous system communicate with the rest of the body?

The term *peripheral* refers to things that are not in the center or that are on the edges of the center. The **peripheral nervous system** or **PNS** (see **Figure 2.7** and also refer to **Figure 2.5**) is made up of all the nerves and neurons that are not contained in the brain and spinal cord. It is this system that allows the brain and spinal cord to communicate with the sensory systems of the eyes, ears, skin, and mouth and allows the brain and spinal cord to control the muscles and glands of the body. The PNS can be divided into two major systems: the **somatic nervous system**, which consists of nerves that control the voluntary muscles of the body, and the **autonomic nervous system (ANS)**, which consists of nerves that control the involuntary muscles, organs, and glands.

THE SOMATIC NERVOUS SYSTEM One of the parts of a neuron is the soma, or cell body (remember that the word *soma* means “body”). The somatic nervous system is made up of the **sensory pathway**, which comprises all the nerves carrying messages from the senses to the central nervous system (those nerves containing afferent neurons), and the **motor pathway**, which is all of the nerves carrying messages from the central nervous system to the voluntary, or skeletal,* muscles of the body—muscles that allow people to move their bodies (those nerves composed of efferent neurons). When people are walking, raising their hands in class, lifting a flower to smell, or directing their gaze toward the person they are talking to or to look at a pretty picture, they are using the somatic nervous system. (As seen in the discussion of spinal cord reflexes, although these muscles are called the “voluntary muscles,” they can move involuntarily when a reflex response occurs.

*skeletal: having to do with the bones of the body, or skeleton.



This electron micrograph shows a stem cell in the process of becoming a neuron.

epigenetics

the interaction between genes and environmental factors that influence gene activity; environmental factors include diet, life experiences, and physical surroundings.

peripheral nervous system (PNS)

all nerves and neurons that are not contained in the brain and spinal cord but that run through the body itself.

somatic nervous system

division of the PNS consisting of nerves that carry information from the senses to the CNS and from the CNS to the voluntary muscles of the body.

autonomic nervous system (ANS)

division of the PNS consisting of nerves that control all of the involuntary muscles, organs, and glands.

sensory pathway

nerves coming from the sensory organs to the CNS consisting of afferent neurons.

motor pathway

nerves coming from the CNS to the voluntary muscles, consisting of efferent neurons.

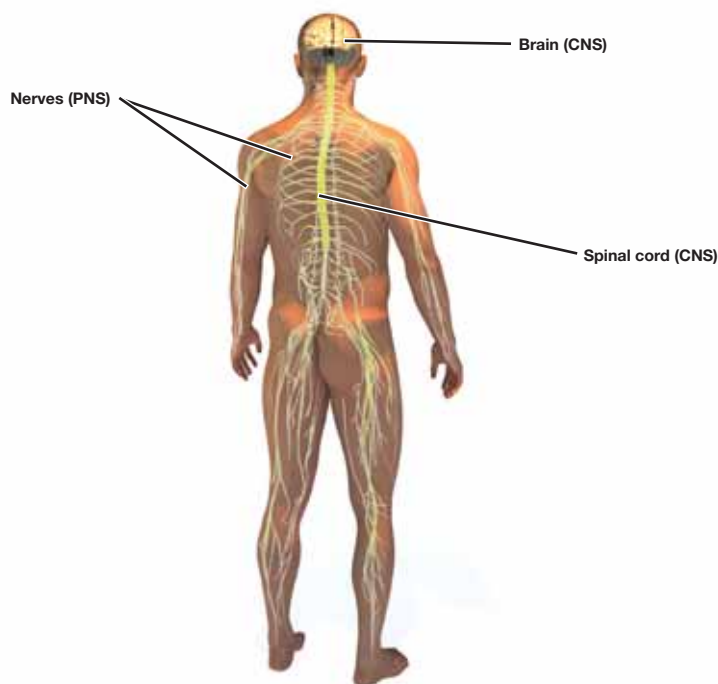


Figure 2.7 The Peripheral Nervous System

They are called “voluntary” because they *can* be moved at will but are not limited to only that kind of movement.)

Involuntary* muscles, such as the heart, stomach, and intestines, together with glands such as the adrenal glands and the pancreas, are all controlled by clumps of neurons located on or near the spinal column. (The words *on or near* are used quite deliberately here. The neurons *inside* the spinal column are part of the central nervous system, not the peripheral nervous system.) These large groups of neurons near the spinal column make up the *autonomic nervous system*.

THE AUTONOMIC NERVOUS SYSTEM The word *autonomic* suggests that the functions of this system are more or less automatic, which is basically correct. Whereas the somatic division of the peripheral nervous system controls the senses and voluntary muscles, the autonomic division controls everything else in the body—organs, glands, and involuntary muscles. The autonomic nervous system is divided into two systems, the *sympathetic division* and the *parasympathetic division*. (See **Figure 2.8**.) (For a schematic representation of how all the various sections of the nervous system are organized, look back at Figure 2.5.)

THE SYMPATHETIC DIVISION The **sympathetic division** of the autonomic nervous system is primarily located on the middle of the spinal column—running from near the top of the ribcage to the waist area. It may help to think of the name in these

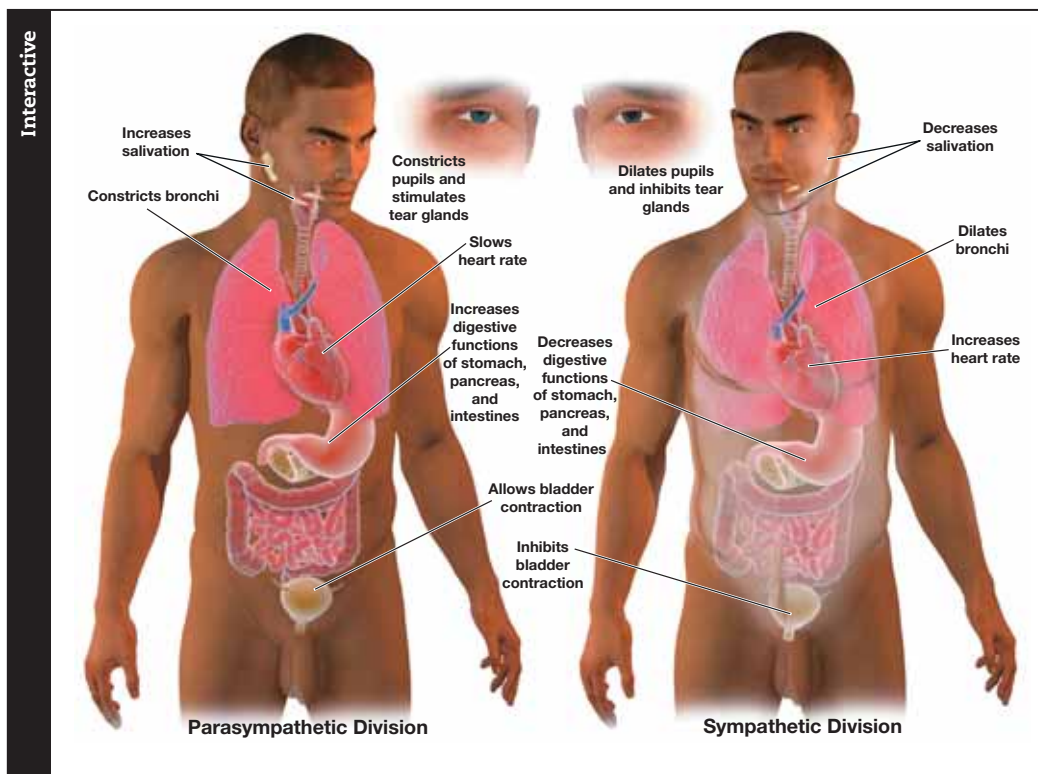


Figure 2.8 Functions of the Parasympathetic and Sympathetic Divisions of the Nervous System

sympathetic division

part of the ANS that is responsible for reacting to stressful events and bodily arousal; “fight-or-flight system.”

*involuntary: not under deliberate control.

terms: The *sympathetic* division is in *sympathy* with one's emotions. In fact, the sympathetic division is usually called the "fight-or-flight system" because it allows people and animals to deal with all kinds of stressful events. **LINK** to [Learning Objective 11.4](#). Emotions during these events might be anger (hence the term *fight*) or fear (that's the "flight" part, obviously) or even extreme joy or excitement. Yes, even joy can be stressful. The sympathetic division's job is to get the body ready to deal with the stress. Many of us have experienced a fight-or-flight moment at least once in our lives. Participate in the survey *Do You Fly or Fight?* to learn more about how your body responds.

Survey DO YOU FLY OR FIGHT?

Interactive

INTRODUCTION
SURVEY
RESULTS

This survey asks you about your experiences with and reactions towards stressful events, particularly those that stimulate your Autonomic Nervous System (ANS).

Click Next to begin the survey

"Fight or flight" is a catchphrase used to describe the way we react to stressful events, particularly fear. Some research suggests that there are actually four stages to the "fight or flight" response. Thinking of the "fight or flight" moments you have experienced, how often have you experienced each of these stages?

Fright/Tonic Immobility (frozen stiff, can't move, "deer in headlights" feeling)

- Never
- Seldom
- Sometimes
- Often
- Prefer not to state

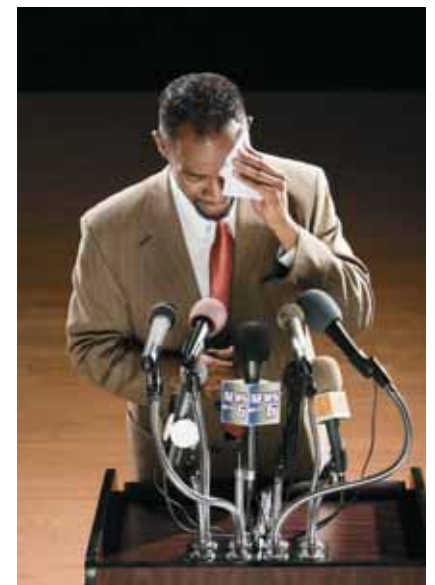
Previous
Next

 **Simulate** the **Experiment** *Do You Fly or Fight?*

What are the specific ways in which this division readies the body to react? (See Figure 2.8.) The pupils seem to get bigger, perhaps to let in more light and, therefore, more information. The heart starts pumping faster and harder, drawing blood away from nonessential organs such as the skin (so at first the person may turn pale) and sometimes even away from the brain itself (so the person might actually faint). Blood needs lots of oxygen before it goes to the muscles, so the lungs work overtime, too (the person may begin to breathe faster). One set of glands in particular receives special instructions. The adrenal glands will be stimulated to release certain stress-related chemicals (members of a class of chemicals released by glands called *hormones*) into the bloodstream. These stress hormones will travel to all parts of the body, but they will only affect certain target organs. Just as a neurotransmitter fits into a receptor site on a cell, the molecules of the stress hormones fit into receptor sites at the various target organs—notably, the heart, muscles, and lungs. This further stimulates these organs to work harder. But not every organ or system will be stimulated by the activation of the sympathetic division. Digestion of food and excretion* of waste are not necessary functions when dealing with stressful situations, so these systems tend to be shut down or inhibited. Saliva, which is part of digestion, dries right up (ever try whistling when you're scared?). Food that was in the stomach sits there like a lump. Usually, the urge to go to the bathroom will be suppressed, but if the person is really scared, the bladder or bowels may actually empty (this is why people who die under extreme stress, such as hanging or electrocution, will release their urine and waste). The sympathetic division is also going to demand that the body burn a tremendous amount of fuel, or blood sugar.

Now, all this bodily arousal is going on during a stressful situation. If the stress ends, the activity of the sympathetic division will be replaced by the activation of the parasympathetic division. If the stress goes on too long or is too intense, the person

*excretion: in this sense, the act of eliminating waste products from the body.



Speaking in public is something many people find to be particularly stressful. Which part of the speaker's autonomic nervous system is most likely to be working hard at this moment?

might actually collapse (as a deer might do when being chased by another animal). This collapse occurs because the parasympathetic division overresponds in its inhibition of the sympathetic activity. The heart slows, blood vessels open up, blood pressure in the brain drops, and fainting can be the result.

THE PARASYMPATHETIC DIVISION If the sympathetic division can be called the fight-or-flight system, the **parasympathetic division** might be called the “eat-drink-and-rest” system. The neurons of this division are located at the top and bottom of the spinal column, on either side of the sympathetic division neurons (*para* means “beyond” or “next to” and in this sense refers to the neurons located on either side of the sympathetic division neurons).

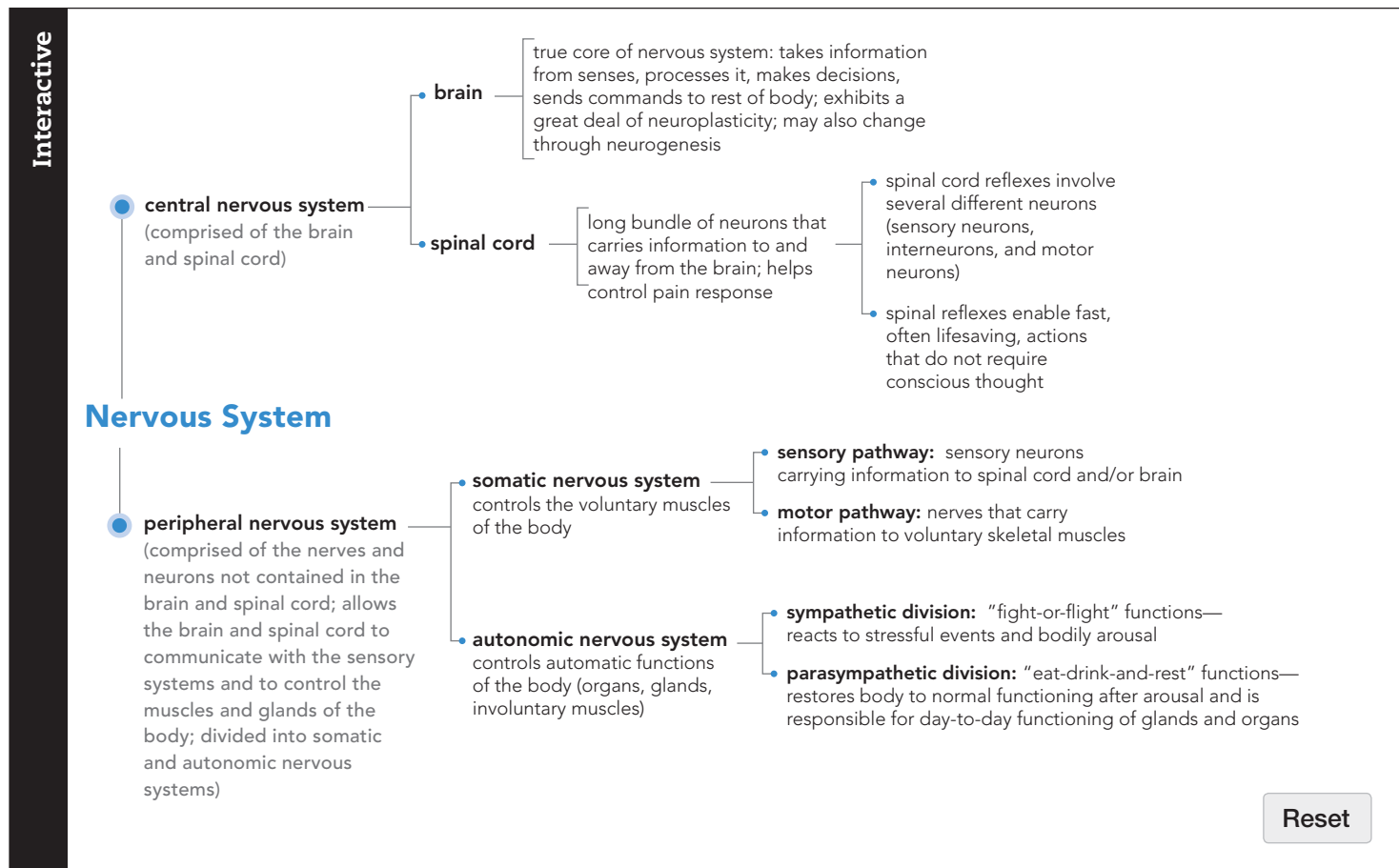
In looking at Figure 2.8, it might seem as if the parasympathetic division does pretty much the opposite of the sympathetic division, but it’s a little more complex than that. The parasympathetic division’s job is to return the body to normal functioning after a stressful situation ends. It slows the heart and breathing, constricts the pupils, and reactivates digestion and excretion. Signals to the adrenal glands stop because the parasympathetic division isn’t connected to the adrenal glands. In a sense, the parasympathetic division allows the body to restore all the energy it burned—which is why people are often very hungry *after* the stress is all over.

The parasympathetic division does more than just react to the activity of the sympathetic division. It is the parasympathetic division that is responsible for most of the ordinary, day-to-day bodily functioning, such as regular heartbeat and normal breathing and digestion. People spend the greater part of their 24-hour day eating, sleeping, digesting, and excreting. So it is the parasympathetic division that is typically active. At any given moment, then, one or the other of these divisions, sympathetic or parasympathetic, will determine whether people are aroused or relaxed.

parasympathetic division

part of the ANS that restores the body to normal functioning after arousal and is responsible for the day-to-day functioning of the organs and glands; “eat-drink-and-rest system.”

Concept Map LO. 2.4, 2.5



Practice Quiz How much do you remember?

Pick the best answer.

- If you touch a hot stove, your spinal cord can prompt you to withdraw your hand without having to send the message all the way to the brain. This is due to what scientists call
 - the reflex arc.
 - neuroplasticity.
 - the parasympathetic nervous system.
 - the sympathetic nervous system.
- What is the process whereby the structure and function of brain cells change in response to trauma, damage, or even learning?
 - shallow lesioning
 - deep lesioning
 - cell regeneration
 - neuroplasticity
- The neurons of the sensory pathway contain
 - efferent neurons.
 - afferent neurons.
 - both efferent and afferent neurons.
 - voluntary muscle fibers.
- Yvonne's ability to reach for and pick up her book is largely due to the functions of the _____ pathway of the _____ nervous system.
 - sensory; somatic
 - motor; somatic
 - autonomic; peripheral
 - parasympathetic; autonomic
- Which of the following would be active if you have just had an automobile accident?
 - sympathetic division
 - parasympathetic division
 - somatic division
 - motor division

Distant Connections: The Endocrine Glands



How do the glands fit into all of this? Aren't there more glands than just the adrenal glands? How do they affect our behavior?

Earlier we addressed neurons and the neurotransmitters and how they release into the synapse to communicate with postsynaptic neurons. This type of chemical communication is fairly specific, primarily affecting neurons in the immediate vicinity of the originating neuron, and also very fast (almost immediate). Other structures also use chemical communication but do so at a different rate and act in a more far-reaching manner. For example, glands are organs in the body that secrete chemicals. Some glands, such as salivary glands and sweat glands, secrete their chemicals directly onto the body's tissues through tiny tubes, or ducts. This kind of gland affects the functioning of the body but doesn't really affect behavior. Other glands, called **endocrine glands**, have no ducts and secrete their chemicals directly into the bloodstream (see **Figure 2.9**). The chemicals secreted by this type of gland are called **hormones**. As mentioned earlier in the chapter when talking about the sympathetic division of the autonomic nervous system, these hormones flow into the bloodstream, which carries them to their target organs. The molecules of these hormones then fit into receptor sites on those organs to fulfill their function, affecting behavior as they do so. As compared to synaptic communication, endocrine communication is generally slower due to the time it takes hormones to travel to target organs, and the behaviors and responses they affect may not occur until hours, weeks, or years later.

The hormones affect behavior and emotions by stimulating muscles, organs, or other glands of the body. Some theories of emotion state that the surge in certain hormones actually triggers the emotional reaction (Izard, 1988; Zajonc, 1980, 1984). [LINK](#) to **Learning Objective 9.9**. Some of the hormones produced by endocrine glands also influence the activity of the brain, producing excitatory or inhibitory effects (Schwartz & Javitch, 2013).

endocrine glands

glands that secrete chemicals called hormones directly into the bloodstream.

hormones

chemicals released into the bloodstream by endocrine glands.

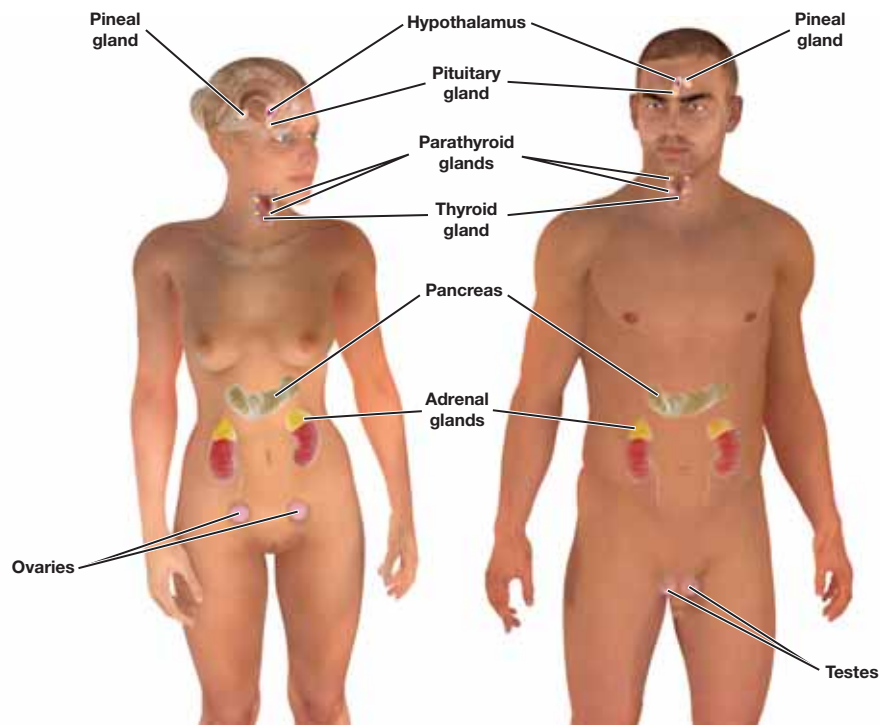


Figure 2.9 The Endocrine Glands

The endocrine glands secrete hormones directly into the bloodstream, which carries them to organs in the body, such as the heart, pancreas, and sex organs.

THE PITUITARY: MASTER OF THE HORMONAL UNIVERSE

2.6 Explain why the pituitary gland is known as the “master gland.”

The **pituitary gland** is located under the brain, just below the hypothalamus. The hypothalamus controls the glandular system by influencing the pituitary. That is because the pituitary gland is the *master gland*, the one that controls or influences all of the other endocrine glands.

Part of the pituitary secretes several hormones that influence the activity of the other glands. One of these hormones is a *growth hormone* that controls and regulates the increase in size as children grow from infancy to adulthood. There are also hormones that stimulate the gonads (ovaries and testes) to release female or male sex hormones, which in turn influence the development and functioning of the reproductive organs, development of secondary sex characteristics in puberty, and reproductive behavior in general. **LINK** to [Learning Objective 10.1](#). Male and female sex hormones have also been implicated in cognitive changes as we grow older. One study has found a correlation between lower levels of the male sex hormone androgen and cognitive decline in older men (Hsu et al., 2015), and for females, hormonal therapy during a limited postmenopausal time window may lower the risk of mild cognitive impairment later in their lives (Scott et al., 2012). Another part of the pituitary controls things associated with pregnancy and levels of water in the body.

THINKING CRITICALLY

Some people think that taking human growth hormone (HGH) supplements will help reverse the effects of aging. If this were true, what would you expect to see in the news media or medical journals? How would you expect HGH supplements to be marketed as a result?

- The response entered here will be saved to your notes and may be collected by your instructor if he/she requires it.

Submit

pituitary gland

gland located in the brain that secretes human growth hormone and influences all other hormone-secreting glands (also known as the master gland).

The hormone that controls aspects of pregnancy is called **oxytocin**, and it is involved in a variety of ways with both reproduction and parental behavior. It stimulates contractions of the uterus in childbirth. The word itself comes from the Greek word *oxys*, meaning “rapid,” and *tokos*, meaning “childbirth,” and injections of oxytocin are frequently used to induce or speed up labor and delivery. It is also responsible for the *milk letdown reflex*, which involves contraction of the mammary gland cells to release milk for the nursing infant. The hormone that controls levels of water in our body is called *vasopressin*, and it essentially acts as an antidiuretic, helping the body to conserve water.

You may have seen oxytocin covered in the news lately, as its role in human social behavior has been making headlines. Sometimes referred to in the media as the “love hormone” or the “trust hormone,” it is prompting a great deal of research. While the role of oxytocin and vasopressin has been demonstrated in the formation of social bonds in nonhuman animals such as prairie voles, the exact role of these hormones in human social behavior is still under investigation (Ferguson et al., 2001; Lim & Young, 2006; Miller, 2013; Stoesz et al., 2013; Winslow et al., 1993).

From investigations of receptor genes to direct impact on social behaviors, both of these hormones are gathering a lot of attention (Donaldson & Young, 2008; Poulin et al., 2012; Scheele et al., 2012). One study has suggested men in monogamous relationships were more likely to keep a greater distance between themselves and an attractive female during their first meeting after receiving oxytocin (Scheele et al., 2012). The result suggested may help men in heterosexual monogamous relationships remain faithful to their partners.

There is additional evidence that oxytocin may have different effects for different individuals under different conditions. Men less socially proficient at recognizing social cues performed better on a task of empathic accuracy after receiving nasal administration of oxytocin, whereas more socially proficient males did not (Bartz et al., 2010). Especially in light of growing interest in the potential role of oxytocin as a treatment for a variety of psychiatric behaviors where social behavior is impacted (e.g., autism, social anxiety), researchers need to be aware of the different impacts oxytocin may have on different individuals in different situations (Bartz et al., 2011). Oxytocin’s effects depend on what people believe about themselves in relation to other people and what they believe about achieving close social relationships (Bartz et al., 2015). Besides the prosocial affects most often studied, some researchers have suggested it may be tied more to increasing the importance of social stimuli. As such, administration of oxytocin has also been tied to increased aggressive responses (Ne’eman et al., 2016).

OTHER ENDOCRINE GLANDS

2.7 Recall the role of various endocrine glands.

As the master gland, the pituitary forms a very important part of a feedback system, one that includes the hypothalamus and the organs targeted by the various hormones. The balance of hormones in the entire endocrine system is maintained by feedback from each of these “players” to the others.

THE PINEAL GLAND The **pineal gland** is located in the brain, near the back, directly above the brain stem. It plays an important role in several biological rhythms. The pineal gland secretes a hormone called *melatonin*, which helps track day length (and seasons). In some animals, this influences seasonal behaviors such as breeding and molting. In humans, melatonin levels are more influential in regulating the sleep–wake cycle. **LINK** to [Learning Objective 4.3](#).

THE THYROID GLAND The **thyroid gland** is located inside the neck and secretes hormones that regulate growth and metabolism. One of these, a hormone called *thyroxin*,

oxytocin

hormone released by the posterior pituitary gland that is involved in reproductive and parental behaviors.

pineal gland

endocrine gland located near the base of the cerebrum; secretes melatonin.

thyroid gland

endocrine gland found in the neck; regulates metabolism.



When the pancreas does not excrete enough insulin, the result is diabetes. A person with diabetes must keep a close watch on blood sugar levels. Some people test more than once a day while others are able to test only a few times a week. Devices such as the one in use here make it much easier—and far less painful—to test blood sugar levels than in years past.

pancreas

endocrine gland; controls the levels of sugar in the blood.

gonads

sex glands; secrete hormones that regulate sexual development and behavior as well as reproduction.

ovaries

the female gonads or sex glands.

testes

the male gonads or sex glands.

adrenal glands

endocrine glands located on top of each kidney that secrete over 30 different hormones to deal with stress, regulate salt intake, and provide a secondary source of sex hormones affecting the sexual changes that occur during adolescence.

regulates metabolism (how fast the body burns its available energy). As related to growth, the thyroid plays a crucial role in body and brain development.

PANCREAS The **pancreas** controls the level of blood sugar in the body by secreting *insulin* and *glucagon*. If the pancreas secretes too little insulin, it results in *diabetes*. If it secretes too much insulin, it results in *hypoglycemia*, or low blood sugar, which causes a person to feel hungry all the time and often become overweight as a result. **LINK** to [Learning Objective 9.6](#).

THE GONADS The **gonads** are the sex glands, including the **ovaries** in the female and the **testes** in the male. They secrete hormones that regulate sexual behavior and reproduction. They do not control all sexual behavior, though. In a very real sense, the brain itself is the master of the sexual system—human sexual behavior is not controlled totally by instincts and the actions of the glands as in some parts of the animal world, but it is also affected by psychological factors such as attractiveness. **LINK** to [Learning Objective 10.1](#).

THE ADRENAL GLANDS Everyone has two **adrenal glands**, one on top of each kidney. The origin of the name is simple enough; *renal* comes from a Latin word meaning “kidney” and *ad* is Latin for “to,” so *adrenal* means “to or on the kidney.” Each adrenal gland is actually divided into two sections, the *adrenal medulla* and the *adrenal cortex*. It is the adrenal medulla that releases epinephrine and norepinephrine when people are under stress and aids in sympathetic arousal.

The adrenal cortex produces more than 30 different hormones called *corticoids* (also called steroids) that regulate salt intake, help initiate* and control stress reactions, and also provide a source of sex hormones in addition to those provided by the gonads. One of the most important of these adrenal hormones is *cortisol*, released when the body experiences stress, both physical stress (such as illness, surgery, or extreme heat or cold) and psychological stress (such as an emotional upset). Cortisol is important in the release of glucose into the bloodstream during stress, providing energy for the brain itself, and the release of fatty acids from the fat cells that provide the muscles with energy.

*initiate: begin or start.

Concept Map LO. 2.6, 2.7

Interactive

glands are organs in the body that secrete chemicals; some affect functioning of the body but not behavior; others have widespread influence on the body and behavior

Distant Connections: The Endocrine Glands

endocrine glands secrete chemicals called *hormones* into bloodstream; affect behavior and emotions by influencing the activity of the brain and by controlling muscles and organs such as the heart, pancreas, and sex organs

- pituitary gland
- pineal gland
- thyroid gland
- pancreas
- gonads
- adrenal glands

Reset

Practice Quiz How much do you remember?

Pick the best answer.

- Your friend Melissa has suffered from diabetes for her entire life. She regularly tests her blood to make sure her sugar levels are not too high or low. Which gland in her endocrine system is responsible for regulating her blood sugar?
 - pancreas
 - thyroid
 - pituitary
 - adrenal
- Andrew has always been thin. In fact, he often seems to be able to eat whatever he wants without gaining weight. The doctor told his parents that Andrew's _____ gland is the cause of his fast metabolism.
 - pituitary
 - adrenal
 - thyroid
 - pancreas
- Although oxytocin has been tied to a variety of prosocial behaviors such as “love” and “trust,” some researchers believe that in humans, it may actually work to increase _____.
 - heart rate and empathy
 - the importance of some social stimuli
 - negative pair bonding
 - social loafing
- Which gland(s) have the greatest influence over other components of the endocrine system?
 - gonads
 - pineal
 - pituitary
 - pancreas

Looking Inside the Living Brain

Scientists can't be sure what brain tissue really looks like when it's inside the skull of a living person—nor can they be certain that it looks identical to that of a brain sitting on a dissecting table. How can scientists find out if the brain is intact, if parts are missing or damaged, or what the various parts of the brain do?

METHODS FOR STUDYING SPECIFIC REGIONS OF THE BRAIN

2.8 Describe how lesioning studies and brain stimulation are used to study the brain.

Researchers are able to learn about the brain through accidental damage or through intentional manipulation of brain tissue. When appropriate, such manipulation can be accomplished through lesioning or stimulation methods.

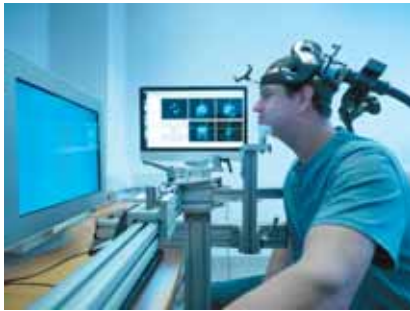
LESIONING STUDIES One way to get some idea of the functions that various areas of the brain control is to study animals or people with damage in those areas. In animals, that may mean researchers will deliberately damage a part of the brain, after which they test the animal to see what has happened to its abilities. In such an experiment, once the test animal is anesthetized and given medication for pain, an electrode, which is a thin wire or probe insulated everywhere but at its tip, is surgically inserted into the brain. An electrical current strong enough to kill off the target neurons is sent through the tip of the wire. This procedure is called **lesioning**.

It should be obvious that researchers cannot destroy areas of brains in living human beings. One method they can use is to study and test people who already have brain damage. However, this is not an ideal way to study the brain. No two case studies of humans are likely to present damage in exactly the same area of the brain, nor would the cases involve exactly the same amount of damage.

BRAIN STIMULATION In contrast to lesioning, a less harmful way to study the brain is to temporarily disrupt or enhance the normal functioning of specific brain areas through electrical stimulation and then study the resulting changes in behavior or cognition. The procedure of stimulating a specific area of the brain is much the same as in lesioning, but the much milder current in this research does no damage to the neurons. It does cause the neurons to react as if they had received a message. This is called *electrical stimulation of the brain*, or *ESB*. It has become an important technique in psychology, as its use in animals (and humans under very special circumstances such as testing before surgery to address seizure disorders) has informed us in many areas of investigation, including new directions for therapy.

lesioning

insertion of a thin, insulated electrode into the brain through which an electrical current is sent, destroying the brain cells at the tip of the wire.



This person is participating in a study that involves repetitive transcranial magnetic stimulation (rTMS). This procedure uses magnetic pulses to stimulate specific areas of the cortex. rTMS is being used in both studies of cognition, as seen here, and in the exploration of new potential treatments for a variety of psychological disorders.

INVASIVE TECHNIQUES: STIMULATING FROM THE INSIDE A specific type of ESB called *deep brain stimulation (DBS)* has been shown to be very helpful in some disorders in humans. In this procedure, neurosurgeons place electrodes in specific deep-brain areas and then route the electrode wires to a pacemaker-like device called an impulse generator that is surgically implanted under the collarbone. The impulse generator then sends impulses to the implanted electrodes, stimulating the specific brain areas of interest. DBS has been widely used as a treatment for Parkinson's disease and may play an important role in the treatment of seizure disorder, chronic pain, and possibly some psychiatric disorders (Fisher et al., 2010; Rabins et al., 2009; Weaver et al., 2009), among other areas. Also, using DBS for specific disorders allows researchers to learn about other effects DBS may have on the brain such as affecting an individual's mood or memory. It should be noted that invasive techniques such as DBS are typically only used after all other less intrusive treatments have been shown to be ineffective or whose side effects have been deemed undesirable. For example, DBS is being investigated for the treatment of anorexia nervosa in individuals for whom other treatments have not been effective (Lipsman et al., 2013).

One of the newest and fastest developing areas in brain stimulation is *optogenetics*, where neurons can be activated by light rather than electricity. While currently only used in animal models, it is being employed across a variety of areas to enhance our understanding of the brain, cognition, and behavior (Burguière et al., 2013; Miocinovic et al., 2013). Furthermore, the technique is not only being used to refine existing DBS methods, it is also being paired with other methods, such as *fMRI*, to further enhance our understanding of brain function in both normal and disordered behavior (Creed et al., 2015; Ferenczi et al., 2016).

NONINVASIVE TECHNIQUES: STIMULATING FROM THE OUTSIDE There are also noninvasive techniques for stimulating the brain that contribute to research and our knowledge of the brain in a variety of areas. In *transcranial magnetic stimulation (TMS)*, magnetic pulses are applied to the cortex using special copper wire coils that are positioned over the head. The resulting magnetic fields stimulate neurons in the targeted area of the cortex. Longer-lasting stimulation results when the pulses are administered in a repetitive fashion, which is referred to as *repetitive TMS (rTMS)*. Another procedure, called *transcranial direct current stimulation (tDCS)*, uses scalp electrodes to pass very low-amplitude direct current to the brain to change the excitability of cortical neurons directly below the electrodes. Both rTMS and tDCS are being evaluated as research tools in studies of cognition such as memory retrieval and decision making (Boggio et al., 2010; Boggio et al., 2009) and as possible treatment options for a variety of psychological disorders including post-traumatic stress disorder (PTSD) and depression and physical disorders due to suffering a stroke (Boggio, Rocha, et al., 2009; Nitsche et al., 2009; Williams et al., 2010).

Bear in mind that stimulating the cortex may facilitate specific functions or behaviors but impair others. For example, if someone is counting from 1 to 20 and the brain is stimulated in the correct location of the motor cortex, the person's speech would be disrupted, but perhaps stimulating in other areas of the frontal lobe may assist the person in attending to the counting task. Furthermore, the brain has widespread connections, so stimulation in one area is likely to affect other areas. In one study, inhibitory stimulation of the left prefrontal cortex resulted in reduced blood oxygenation on both the left and right sides of the prefrontal cortex (Tupak et al., 2013).

Note: tDCS is NOT the same as electroconvulsive therapy, which uses much higher levels of current through the entire brain, resulting in a grand mal seizure and changes in the brain chemistry associated with depression. **LINK** to [Learning Objective 15.11](#).

NEUROIMAGING TECHNIQUES

2.9 Compare and contrast neuroimaging techniques for mapping the structure and function of the brain.

All of these methods of stimulation yield important information about the brain and behavior, but they do not allow us to see what is going on with the brain as a whole.



Figure 2.10 Mapping Brain Structure

Fig 2.10a: CT scan from a 5-year-old girl with a head injury and skull fracture, depicting the brain and swelling associated with the injury. Fig 2.10b: Same CT scan highlighting the skull fracture (indicated by the red arrow). Contrast the brain detail of Fig 2.10a with the MRI scan in Fig 2.10c (different, adult individual). Note the scans are in the horizontal plane, separating the brain into upper and lower portions. Fig 2.10d: Different type of MRI image from an older adult, with cortical cell loss (atrophy) and white matter changes. Notice the enlarged ventricles and widening of the grooves (sulci) in the outer cortex as compared to 2.10c. Figs 2.10a, b, c, and d images created with OsiriX software; CT and MRI data courtesy of N. White.

Instead, various neuroimaging techniques can do this, either by directly imaging the brain's structure (the different parts) or its function (how the parts work). These methods also vary in their degree of spatial resolution (ability to see fine detail) and temporal resolution (ability to time lock a recorded event).

MAPPING STRUCTURE As hinted at earlier, aside from observing the person's behavior, scientists had to wait until a person died to fully investigate if there were changes or damage to the individual's brain. Fortunately, modern neuroimaging allows us to image the brain's structure while the person is still alive.

COMPUTED TOMOGRAPHY (CT) Scientists have several ways to look inside the human brain without causing harm to the person. One way is to take a series of X-rays of the brain, aided by a computer. This is accomplished during a **CT scan (computed tomography)** involves mapping "slices" of the brain by computer). CT scans can show stroke damage, tumors, injuries, and abnormal brain structure. (See **Figure 2.10a**.) A CT scan is also the structural imaging method of choice when there is metal in the body (e.g., a bullet or surgical clips) and useful for imaging possible skull fractures. (See **Figure 2.10b**.)

MAGNETIC RESONANCE IMAGING (MRI) As useful as a CT scan can be for imaging the skull, it doesn't show very small details within the brain. The relatively newer technique of **magnetic resonance imaging, or MRI**, provides much more detail (see **Figure 2.10c** and **Figure 2.10d**), even allowing doctors to see the effects of very small strokes. The person getting an MRI scan is placed inside a machine that generates a powerful magnetic field to align hydrogen atoms in the brain tissues (these normally spin in a random fashion); then radio pulses are used to make the atoms spin at a particular frequency and direction. The time it takes for the atoms to return to their normal spin allows a computer to create a three-dimensional image of the brain and display "slices" of that image on a screen.

Using MRI as a basis, several techniques have been developed that allow us to study other aspects of the brain. *MRI spectroscopy* allows researchers to estimate the concentration of specific chemicals and neurotransmitters in the brain. Another fascinating technique is called *DTI, or diffusion tensor imaging*. The brain has two distinct color regions, *gray matter*, the outer areas consisting largely of neurons with unmyelinated axons, and *white matter*, the fiber tracts consisting of myelinated axons (the myelin is responsible for the lighter color). DTI uses MRI technology to provide a way to measure connectivity in the brain by imaging these white matter tracts. DTI has been used to investigate normal

computed tomography (CT) scan
brain-imaging method using computer-controlled X-rays of the brain.

magnetic resonance imaging (MRI)
brain-imaging method using radio waves and magnetic fields of the body to produce detailed images of the brain.

function, such as structural changes associated with different levels of memory performance, and various disorders and conditions including Alzheimer’s disease, MS, and traumatic brain injury (Hayes et al., 2016; Ly et al., 2016; Muthuraman et al., 2016; Wang et al., 2016).

MAPPING FUNCTION In addition to imaging the different parts of the brain to understand what may or may not be present, examining the function of the brain is also important in understanding behavior and mental processes.

THE ELECTROENCEPHALOGRAM (EEG) As important as imaging brain structure is, it is sometimes important to know how different brain areas function. A fairly harmless way to study the activity of the living brain is to record the electrical activity of the cortex just below the skull using a device called an **electroencephalograph**. The first **electroencephalogram (EEG)** recording in humans was accomplished in 1924 by Hans Berger (Niedermeyer, 2005). Recording the EEG involves using small metal disks or sponge-like electrodes placed directly on the scalp and a special solution to help conduct the electrical signals from the cortex just below. These electrodes are connected to an amplifier and then to a computer to view the information. The resulting electrical output forms waves that indicate many things, such as stages of sleep, seizures, and even the presence of tumors. The EEG can also be used to help determine which areas of the brain are active during various mental tasks that involve memory and attention. EEG activity can be classified according to appearance and frequency, and different waves are associated with different brain activity. For example, *alpha waves* in the back of the brain are one indication of relaxed wakefulness (seen in bottom two lines in **Figure 2.11a**). EEG waveforms are covered in more detail in Chapter Four. [LINK](#) to [Learning Objective 4.5](#).

Another common EEG-based technique focuses on *event-related potentials*, or *ERPs*. In ERP studies, multiple presentations of a stimulus are measured during an EEG and then averaged to remove variations in the ongoing brain activity that is normally recorded during the EEG. The result is a measurement of the response of the brain related to the stimulus event itself, or an event-related potential. ERPs allow the study of different stages of cognitive processing. For example, the use of ERPs has allowed researchers to investigate differences in brain processing associated with the recognition of facial expression of emotion in individuals with and without schizophrenia (Lee et al., 2010). In other studies, ERPs are being studied as a possible method of lie detection (Hu et al., 2013; Labkovsky & Rosenfeld, 2014; Rosenfeld et al., 2008).

electroencephalogram (EEG)

a recording of the electrical activity of large groups of cortical neurons just below the skull, most often using scalp electrodes.

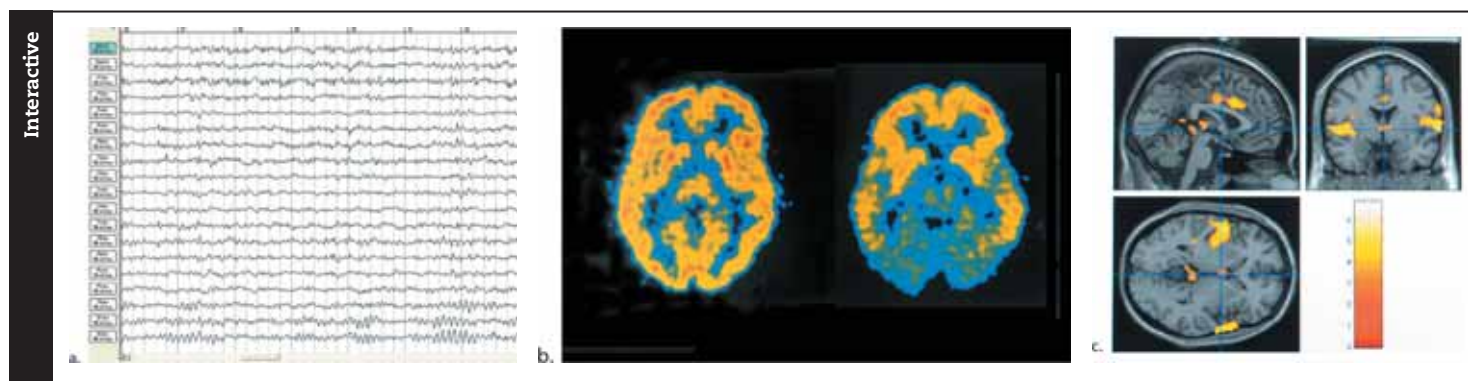


Figure 2.11 Mapping Brain Function

Various methods for mapping brain function. An EEG record is shown in 2.11a, a PET scan image in 2.11b, and an image from an fMRI study in 2.11c. Data and figure for 2.11a courtesy of N. White.

MAGNETOENCEPHALOGRAPHY (MEG) While the EEG alone does not allow for the direct identification of areas of brain activation, a closely related technique does. *Magnetoencephalography* (MEG) uses devices that are very sensitive to magnetic fields called superconducting quantum interference devices, which are contained in a helmet-like device that is placed over the individual's head. MEG has many applications and is being used to differentiate dementia disorders and to explore cognitive processes in autism (M. A. Williams & Sachdev, 2010).

POSITRON EMISSION TOMOGRAPHY (PET) The functional neuroimaging methods discussed so far rely on the electrical activity of the brain. Other techniques make use of other indicators of brain activity, including energy consumption or changes in blood oxygen levels (if areas of the brain are active, they are likely using fuel and oxygen). In **positron emission tomography (PET)**, the person is injected with a radioactive glucose (a kind of sugar). The computer detects the activity of the brain cells by looking at which cells are using up the radioactive glucose and projecting the image of that activity onto a monitor. The computer uses colors to indicate different levels of brain activity. For example, lighter colors may indicate greater activity. (See **Figure 2.11b**.) With this method, researchers can actually have the person perform different tasks while the computer shows what his or her brain is doing during the task. A related technique is *single photon emission computed tomography (SPECT)*, which measures brain blood flow and takes advantage of more easily obtainable radioactive tracers than those used for PET (Bremner, 2005).

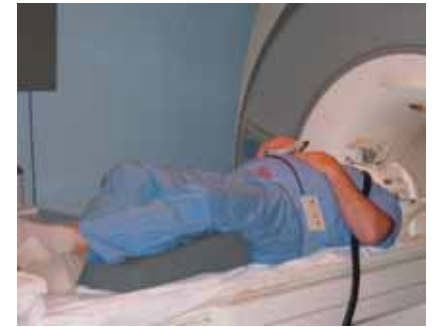
FUNCTIONAL MRI (fMRI) Although traditional MRI scans only show structure, **functional MRI (fMRI)**, in which the computer tracks changes in the oxygen levels of the blood (see **Figure 2.11c**), provides information on the brain's function as well. By superimposing information about where oxygen is being used in the brain over an image of the brain's structure, researchers can identify what areas of the brain are most active during specific tasks. By combining such images taken over a period of time, a sort of "movie" of the brain's functioning can be made (Lin et al., 2007). Functional MRIs can give more detail, tend to be clearer than PET scans, and are an incredibly useful tool for research into the workings of the brain. For example, fMRI has been used to demonstrate that older adults with a genetic risk for Alzheimer's disease show greater activation in brain areas associated with semantic knowledge and word retrieval when compared to older adults without that genetic risk. This finding may one day help clinicians and researchers identify individuals at risk for Alzheimer's much earlier in the disease process (Wierenga et al., 2010). There is also exciting research suggesting individuals can use fMRI to learn how to regulate their own brain processes. Individuals with schizophrenia were able to use real-time fMRI (rtfMRI) to learn how to control a portion of their brain that assists in recognition of facial emotions, which is a common deficit in schizophrenia (Ruiz et al., 2013). Functional neuroimaging is also helping researchers understand how various types of treatment and therapy affect the brain in a variety of disorders (Ball et al., 2014; Fournier & Price, 2014; Miller et al., 2015).

THINKING CRITICALLY

You may see a lot of brain imaging studies in the news or on the Internet. Thinking back to the research methods discussed in Chapter One (Learning Objectives 1.6 through 1.11), what kinds of questions should you ask about these studies before accepting the findings as valid?

- The response entered here will be saved to your notes and may be collected by your instructor if he/she requires it.

Submit



As part of an fMRI study on attention, one of your authors is fitted with headphones, an angled mirror, and a hand response pad. During the study, the headphones will allow him to hear audio instructions and stimuli, and the mirror will allow him to view task items projected on a rear screen placed outside of the scanner. The response pad is used to indicate answers for the various tasks.

positron emission tomography (PET)

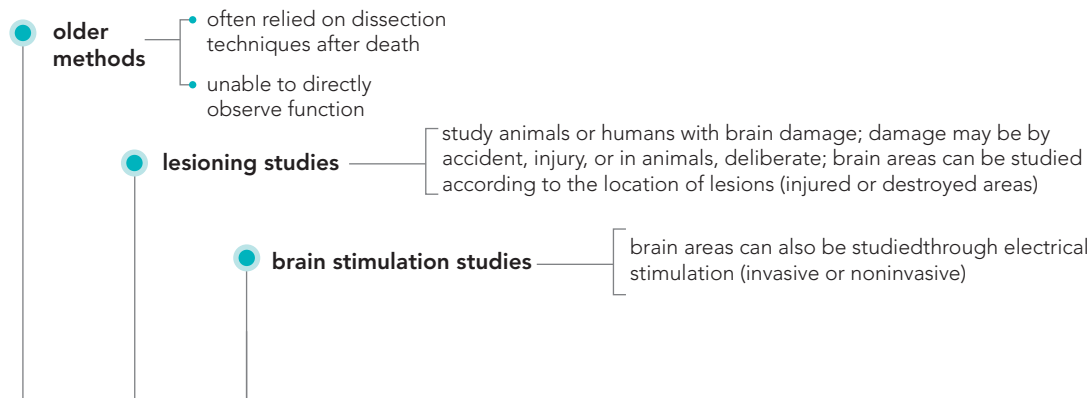
brain-imaging method in which a radioactive sugar is injected into the subject and a computer compiles a color-coded image of the activity of the brain.

functional magnetic resonance imaging (fMRI)

MRI-based brain-imaging method that allows for functional examination of brain areas through changes in brain oxygenation.

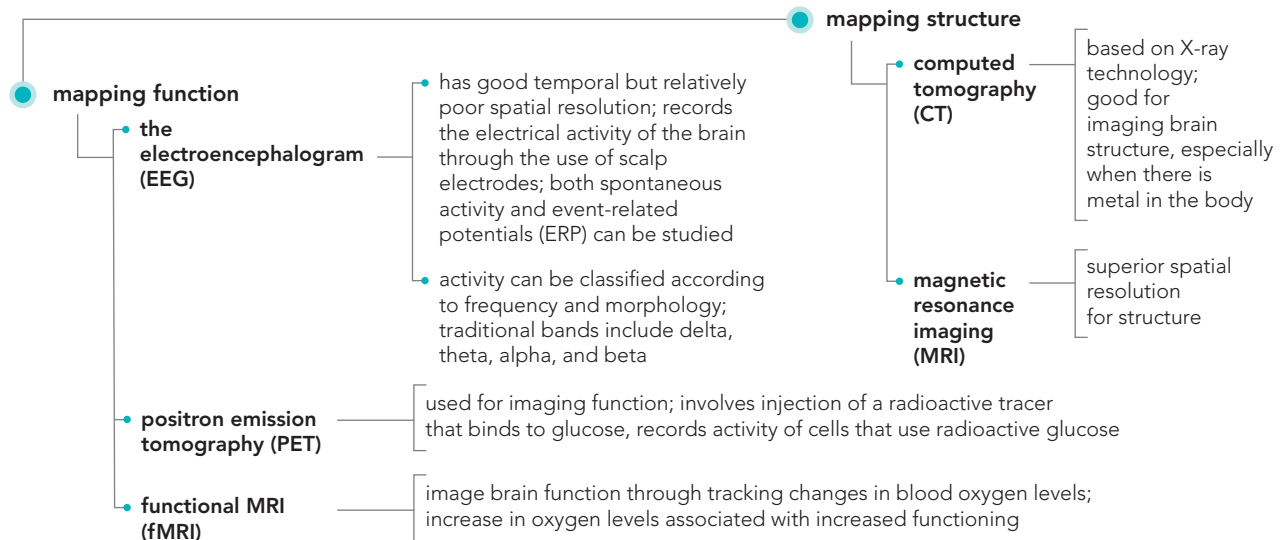
Concept Map LO. 2.8, 2.9

Interactive



Looking Inside the Living Brain

(methods for studying the structures and/or activity of the living brain)



Reset

Practice Quiz How much do you remember?

Pick the best answer.

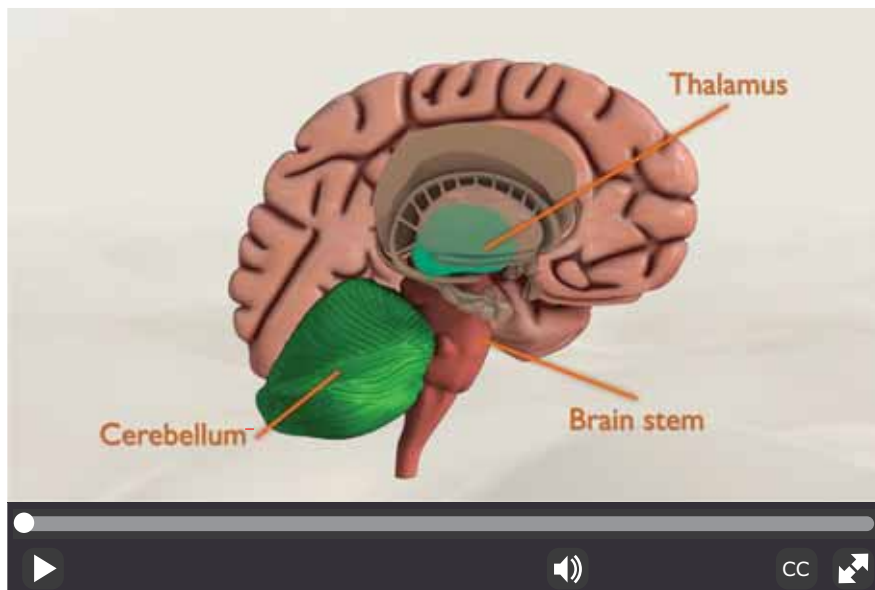
- Which of the following techniques involves passing a mild current through the brain to activate certain structures without damaging them?
 - electroconvulsive tomography (ECT)
 - magnetic resonance imaging (MRI)
 - deep brain lesioning
 - electrical stimulation of the brain (ESB)
- Which of the following techniques analyzes blood oxygen levels to look at the functioning of the brain?
 - EEG
 - CT
 - fMRI
 - PET
- Dr. Roll is conducting a research study. She wants to measure the physical connectivity in the research participants' brains by imaging their white matter. Which of the following methods will she use?
 - diffusion tensor imaging (DTI)
 - MRI spectroscopy
 - functional magnetic resonance imaging (fMRI)
 - computed tomography (CT)
- If you were suffering from neurological problems and your neurologist wanted to have a study done of your brain and its electrical functioning, which of the following techniques would be most appropriate?
 - PTI
 - EEG
 - PET
 - DTI

From the Bottom Up: The Structures of the Brain



Okay, now I understand a little more about how we look inside the brain. What exactly IS inside the brain?

Now it's time to look at the various structures of the brain, starting from the bottom and working up to the top. The video *Parts of the Brain* describes the major parts of the brain and their functions. This text won't be discussing every single part of the brain, only major areas of interest to psychologists as explorers of behavior. Many areas also have multiple roles, but a full understanding of the brain is not possible within one chapter of an introductory psychology text. Furthermore, while there may be brain and behavior differences according to sex or gender, despite what you may have read in the popular press, there is little evidence of people having a "female" versus a "male" brain (Joel et al., 2015). Human brains can simply not be categorized that way.



[Watch the Video](#) *Parts of the Brain*

THE HINDBRAIN

2.10 Identify the different structures of the hindbrain and the function of each.

The brain can be divided into three main divisions early in our development that later subdivide into smaller divisions. The three primary divisions are the forebrain, the midbrain, and the hindbrain. The forebrain includes the cortex, the basal ganglia, and the limbic system. The midbrain is important for both sensory and motor functions. The hindbrain includes the medulla, pons, and cerebellum.

MEDULLA The **medulla** is located at the top of the spinal column. In **Figure 2.12**, it is the first "swelling" at the top of the spinal cord, just at the very bottom of the brain. This is the part of the brain that a person would least want to have damaged, as it controls life-sustaining functions such as heartbeat, breathing, and swallowing. It is in the medulla that the sensory nerves coming from the left and right sides of the body cross over, so that sensory information from the left side of the body goes to the right side of the brain and vice versa.

medulla

the first large swelling at the top of the spinal cord, forming the lowest part of the brain, which is responsible for life-sustaining functions such as breathing, swallowing, and heart rate.

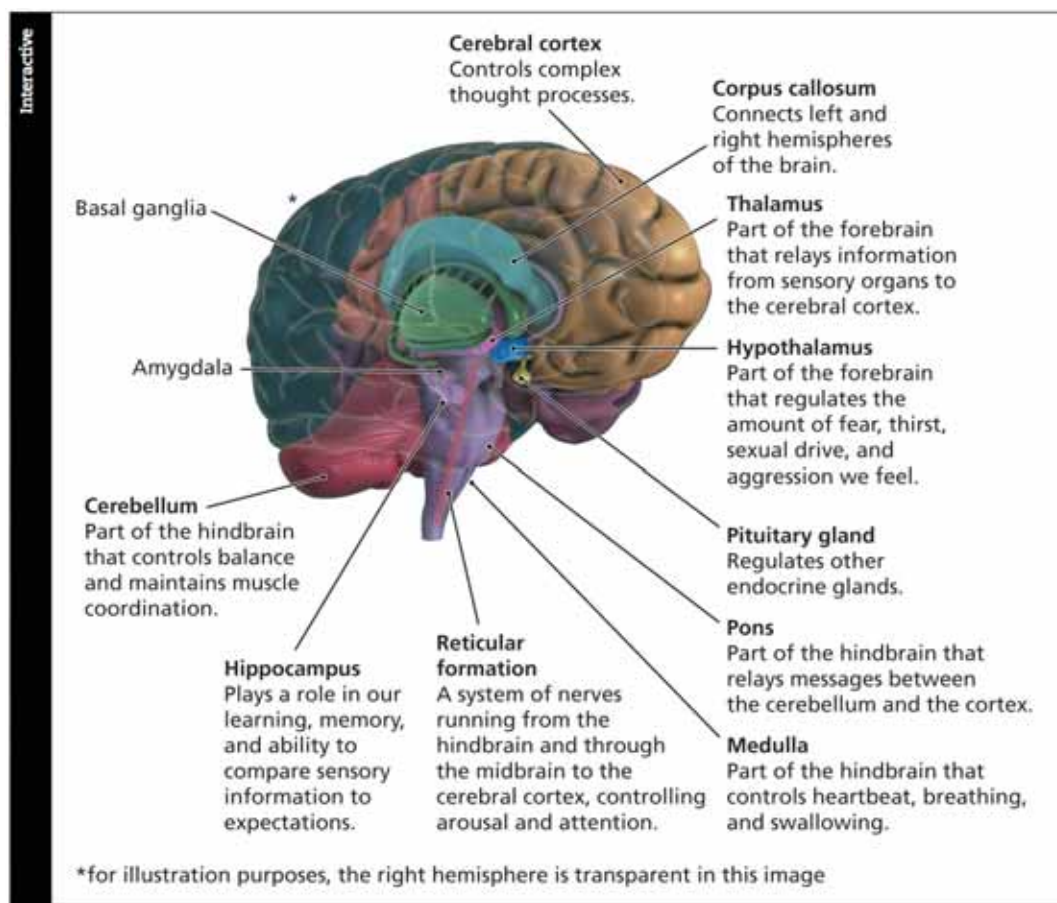


Figure 2.12 Major Structures of the Human Brain

PONS The **pons** is the larger “swelling” just above the medulla. This term means “bridge,” and the pons is indeed the bridge between the cerebellum and the upper sections of the brain. As in the medulla, there is a crossover of nerves, but in this case it is the motor nerves carrying messages from the brain to the body. This allows the pons to coordinate the movements of the left and right sides of the body. (It will be useful to remember these nerve crossovers when reading about the functions of the left and right sides of the brain in a later part of this chapter.) The pons also influences sleep, dreaming, and arousal. The role that the pons plays in sleep and dreams will be discussed in more detail in Chapter Four. **LINK** to [Learning Objective 4.7](#).

THE RETICULAR FORMATION The **reticular formation (RF)** is a network of neurons running through the middle of the medulla and the pons and slightly beyond. These neurons are responsible for people’s ability to generally attend to certain kinds of information in their surroundings. Basically, the RF allows people to ignore constant, unchanging information (such as the noise of an air conditioner) and become alert to changes in information (for example, if the air conditioner stopped, most people would notice immediately).

The reticular formation is also the part of the brain that helps keep people alert and aroused. One part of the RF is called the *reticular activating system (RAS)*, and it stimulates the upper part of the brain, keeping people awake and alert. When a person is driving and someone suddenly pulls out in front of the vehicle, it is the RAS that brings that driver to full attention. It is also the system that lets a mother hear her baby cry in the night, even though she might sleep through other noises. The RAS has also been suggested by brain-scanning studies as a possible area involved in attention-deficit/hyperactivity

pons

the larger swelling above the medulla that relays information from the cortex to the cerebellum, and that plays a part in sleep, dreaming, left-right body coordination, and arousal.

reticular formation (RF)

an area of neurons running through the middle of the medulla and the pons and slightly beyond that is responsible for general attention, alertness, and arousal.

disorder, in which children or adults have difficulty maintaining attention to a single task (Durstun, 2003).

Studies have shown that when the RF of rats is electrically stimulated while they are sleeping, they immediately awaken. If the RF is destroyed (by deep lesioning, for example), they fall into a sleeplike coma from which they never awaken (Moruzzi & Magoun, 1949; Steriade & McCarley, 1990). The RF is also implicated in comas in humans (Plum & Posner, 1985).

CEREBELLUM At the base of the skull, behind the pons and below the main part of the brain, is a structure that looks like a small brain. This is the **cerebellum** (meaning “little brain”). The cerebellum is the part of the lower brain that controls all involuntary, rapid, fine motor movement. People can sit upright because the cerebellum controls all the little muscles needed to keep them from falling out of their chair. It also coordinates voluntary movements that have to happen in rapid succession, such as walking, skating, dancing, playing a musical instrument, and even the movements of speech. Learned reflexes, skills, and habits are also stored here, which allows them to become more or less automatic. Because of the cerebellum, people don’t have to consciously think about their posture, muscle tone, and balance.

So if your cerebellum is damaged, you might be very uncoordinated?

Yes. In fact, this happens in a disease called *spinocerebellar degeneration*, where the first symptoms of cerebellum deterioration are tremors, an unsteady walk, slurred speech, dizziness, and muscle weakness. The person suffering from this disease will eventually be unable to walk, stand, or even get a spoon to his or her own mouth (Schöls et al., 1998). These symptoms are similar to what one might see in a person who is suffering from alcohol intoxication.

Just like we are starting to better understand the various roles of glial cells, researchers and scientists are still working to better understand other functions of the cerebellum. Research suggests the cerebellum is involved in much more than motor control and may be involved with a variety of higher functions, with parts of the cerebellum activated during sensorimotor tasks and other parts involved in cognitive or emotional tasks (Stoodley & Schmahmann, 2009). Research continues to investigate the role of the cerebellum in these and other tasks once believed to be the domain of other lobes of the brain, in a large part by examining the connections between the cerebellum and other functional areas and patterns of brain activation during specific tasks (Strick et al., 2009; Voogd & Ruigrok, 2012). Studies using fMRI have investigated such higher-level cognitive functions as language and working memory and the timing of perceptual tasks like visual attention (Kellermann et al., 2012; Stoodley et al., 2012). While much is still to be learned, evidence exists that the cerebellum is involved in both perceptual processes and disorders that are characterized by perceptual disturbances such as schizophrenia and autism spectrum disorder (Baumann et al., 2015).

STRUCTURES UNDER THE CORTEX: THE LIMBIC SYSTEM

2.11 Identify the structures of the brain that are involved in emotion, learning, memory, and motivation.

The forebrain includes the two cerebral hemispheres of the brain, including the cortex, which is discussed in detail later in this chapter, and a number of important structures located under the cortex in each hemisphere. These subcortical structures (the prefix *sub* means “under” or “below”) play a part in our thinking and behavior. While there are subcortical structures that influence motor control and the learning of motor skills, the *basal ganglia*, and white matter fiber pathways that connect the cortex to other parts of the



This gymnast must count on her cerebellum to help her balance and coordinate the many fine motor commands that allow her to balance on this narrow beam. What other kinds of professions depend heavily on the activity of the cerebellum?

cerebellum

part of the lower brain located behind the pons that controls and coordinates involuntary, rapid, fine motor movement, and may have some cognitive functions.

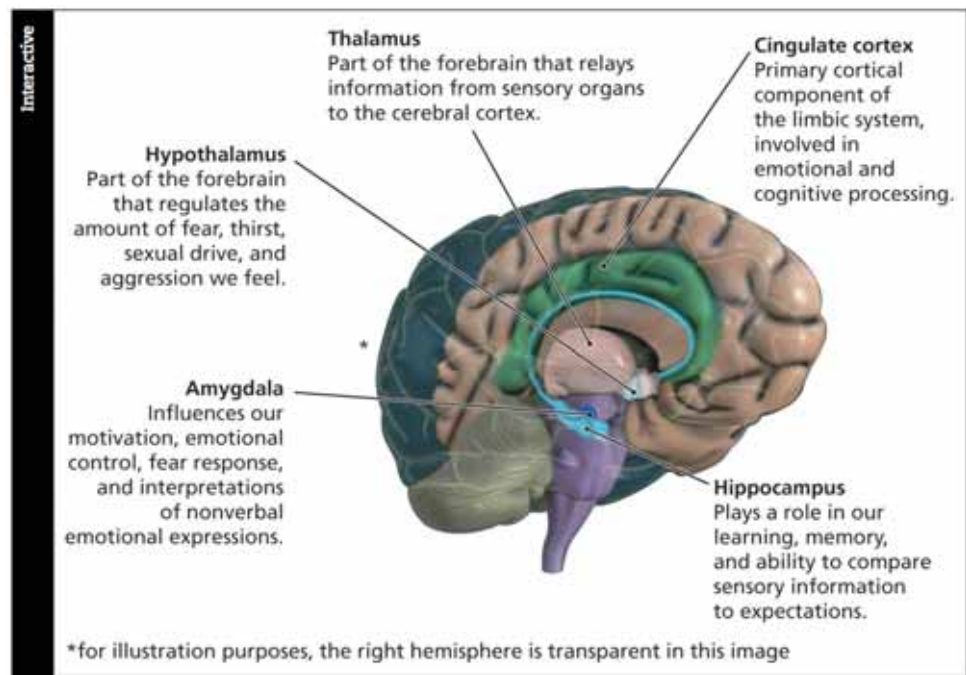


Figure 2.13 The Limbic System

limbic system

a group of several brain structures located primarily under the cortex and involved in learning, emotion, memory, and motivation.

thalamus

part of the limbic system located in the center of the brain, this structure relays sensory information from the lower part of the brain to the proper areas of the cortex and processes some sensory information before sending it to its proper area.

olfactory bulbs

two bulb-like projections of the brain located just above the sinus cavity and just below the frontal lobes that receive information from the olfactory receptor cells.

hypothalamus

small structure in the brain located below the thalamus and directly above the pituitary gland, responsible for motivational behavior such as sleep, hunger, thirst, and sex.

hippocampus

curved structure located within each temporal lobe, responsible for the formation of long-term declarative memories.

brain and spinal cord, we will focus on the subcortical structures that have been collectively referred to as the *limbic system*. (See **Figure 2.13**.)

The **limbic system** (the word *limbic* means *limbus* or “margin,” referring to a border around something, and these structures are found between the upper brain and brain stem) includes the thalamus, hypothalamus, hippocampus, amygdala, and the cingulate cortex. In general, the limbic system is involved in emotions, motivation, memory, and learning.

THALAMUS The **thalamus** (“inner chamber”) is in some ways similar to a triage* nurse. This somewhat round structure in the center of the brain acts as a kind of relay station for incoming sensory information. Like a nurse, the thalamus might perform some processing of that sensory information before sending it on to the part of the cortex that deals with that kind of sensation—hearing, sight, touch, or taste. Damage to the thalamus might result in the loss or partial loss of any or all of those sensations. Recent research has also suggested the thalamus may affect the functioning of task-specific regions of the cortex. For example, a study of children with dyslexia found abnormal connections between the thalamus and brain areas associated with reading behavior (Fan et al., 2014).

The sense of smell is unique in that signals from the neurons in the sinus cavity go directly into special parts of the brain called **olfactory bulbs**, just under the front part of the brain. Smell is the only sense that does not have to first pass through the thalamus.

HYPOTHALAMUS A very small but extremely powerful part of the brain is located just below and in front of the thalamus (see **Figure 2.13**). The **hypothalamus** (“below the inner chamber”) regulates body temperature, thirst, hunger, sleeping and waking, sexual activity, and emotions. It sits right above the pituitary gland. The hypothalamus controls the pituitary, so the ultimate regulation of hormones lies with the hypothalamus.

HIPPOCAMPUS Like many structures in the brain, the **hippocampus** was named based on its appearance. Hippocampus is the Greek word for “seahorse,” and it was

*triage: a process for sorting injured people into groups based on their need for, or likely benefit from, immediate medical treatment.

given to this brain structure because the first scientists who dissected the brain thought it looked like a seahorse. The hippocampus is located within the medial temporal lobe on each side of the brain (medial means “toward the middle”). Research has shown that the hippocampus is instrumental in forming long-term (permanent) declarative memories that are then stored elsewhere in the brain (Squire & Kandel, 2009). [LINK](#) to [Learning Objective 6.12](#). As mentioned earlier, ACh, the neurotransmitter involved in muscle control, is also involved in the memory function of the hippocampus. People who have Alzheimer’s disease, for example, have much lower levels of ACh in that structure than is normal, and the drugs given to these people boost the levels of ACh.

AMYGDALA The **amygdala** (“almond”) is another area of the brain named for its shape and appearance. It is located near the hippocampus. The amygdala is involved in fear responses and memory of fear. Information from the senses goes to the amygdala before the upper part of the brain is even involved, so that people can respond to danger very quickly, sometimes before they are consciously aware of what is happening. In 1939 researchers found that monkeys with large amounts of their temporal lobes removed—including the amygdala—were completely unafraid of snakes and humans, both normally fear-provoking stimuli (Klüver & Bucy, 1939). This effect came to be known as the *Klüver-Bucy syndrome*. Rats that have damaged amygdala structures will also show no fear when placed next to a cat (Maren & Fanselow, 1996). Case studies of humans with damage to the amygdala also show a link to decreased fear response (Adolphs et al., 2005). Although the amygdala plays a vital role in forming emotional memories, it is still unclear if the memories are stored in the amygdala (Squire & Kandel, 2009). One study has suggested activity in the amygdala impacts hippocampal neuroplasticity by facilitating structural changes in the hippocampus, possibly underlying the influence of stress on fear memories (Giachero et al., 2015).

CINGULATE CORTEX The *cingulate cortex* is the limbic structure that is actually found in the cortex. It is found right above the corpus callosum in the frontal and parietal lobes and plays an important role in both emotional and cognitive processing. The cingulate cortex can be divided into up to four regions that play different roles in processing emotional, cognitive, and autonomic information (Vogt & Palomero-Gallagher, 2012). It has been shown to be active during a variety of cognitive tasks such as selective attention, written word recognition, and working memory (Cabeza & Nyberg, 2000) and has been implicated in a variety of psychological and mental disorders including attention-deficit/hyperactivity disorder (Bush et al., 1999; Bush et al., 2008), schizophrenia, major depressive disorder, and bipolar disorder (Fornito et al., 2009; Maletic et al., 2007). The next section further explores the cortex and its functions.

THE CORTEX

2.12 Identify the parts of the cortex that process the different senses and those that control movement of the body.

As stated earlier, the **cortex** (“rind” or outer covering) is the outermost part of the brain, which is the part of the brain most people picture when they think of what the brain looks like. It is made up of tightly packed neurons and actually is only about one tenth of an inch thick on average (Fischl et al., 2001; MacDonald et al., 2000; Zilles, 1990). The cortex is very recognizable surface anatomy because it is full of wrinkles.

● Why is the cortex so wrinkled?

The wrinkling of the cortex allows a much larger area of cortical cells to exist in the small space inside the skull. If the cortex were to be taken out, ironed flat, and measured, it would be about 2 to 3 square feet. (The owner of the cortex would also be dead, but that’s fairly obvious, right?) As the brain develops before birth, it forms a smooth outer



This young woman’s thirst is regulated by her hypothalamus.

amygdala

brain structure located near the hippocampus, responsible for fear responses and memory of fear.

cortex

outermost covering of the brain consisting of densely packed neurons, responsible for higher thought processes and interpretation of sensory input.



From top to bottom, a rat brain, sheep brain, and human brain (not to scale!). Note the differences in the amount of corticalization, or wrinkling, of the cortex between these three brains. Greater amounts of corticalization are associated with increases in size and complexity.

covering on all the other brain structures. This will be the cortex, which will get more and more wrinkled as the brain increases in size and complexity. This increase in wrinkling is called “corticalization.”

CEREBRAL HEMISPHERES The cortex is divided into two sections called the **cerebral hemispheres**, which are connected by a thick, tough band of neural fibers (axons) called the **corpus callosum** (literally meaning “hard body,” as calluses on the feet are hard). (Refer to Figure 2.12.) The corpus callosum allows the left and right hemispheres to communicate with each other. Each hemisphere can be roughly divided into four sections or lobes by looking at the deeper wrinkles, or fissures, in its surface. The lobes are named for the skull bones that cover them (see Figure 2.14).

Another organizational feature of the cortex is that for specific regions, each hemisphere is responsible for the opposite side of the body, either for control or for receiving information. For example, the motor cortex controls the muscles on the opposite side of the body. If we are writing with our right hand, the motor cortex in the left hemisphere is responsible for controlling those movements. This feature, referred to as *contralateral organization*, plays a role in information coming from many of the sense organs to the brain and in the motor commands originating in the brain going to the rest of the body.

Information from our body can also be transmitted to both sides of the brain, or *bilaterally* (as in hearing and vision), or to only one side of the brain, or *ipsilaterally* (as in taste and olfaction). These aspects are also important in the study of *brain lateralization*, which we will come back to later in the chapter. Why do we have this arrangement for some functions and not for others? No one really knows, but at least for some information, it assists with identifying where information from the environment is coming from. For auditory information from the ears, having sensory information projected to both hemispheres allows us to localize sounds by comparing the slightly different information coming from each ear.

OCCIPITAL LOBES At the base of the cortex, toward the back of the brain, is an area called the **occipital lobe**. This area processes visual information from the eyes in the *primary visual cortex*. The *visual association cortex*, also in this lobe and in parts of the

cerebral hemispheres

the two sections of the cortex on the left and right sides of the brain.

corpus callosum

thick band of neurons that connects the right and left cerebral hemispheres.

occipital lobe

section of the brain located at the rear and bottom of each cerebral hemisphere containing the primary visual centers of the brain.

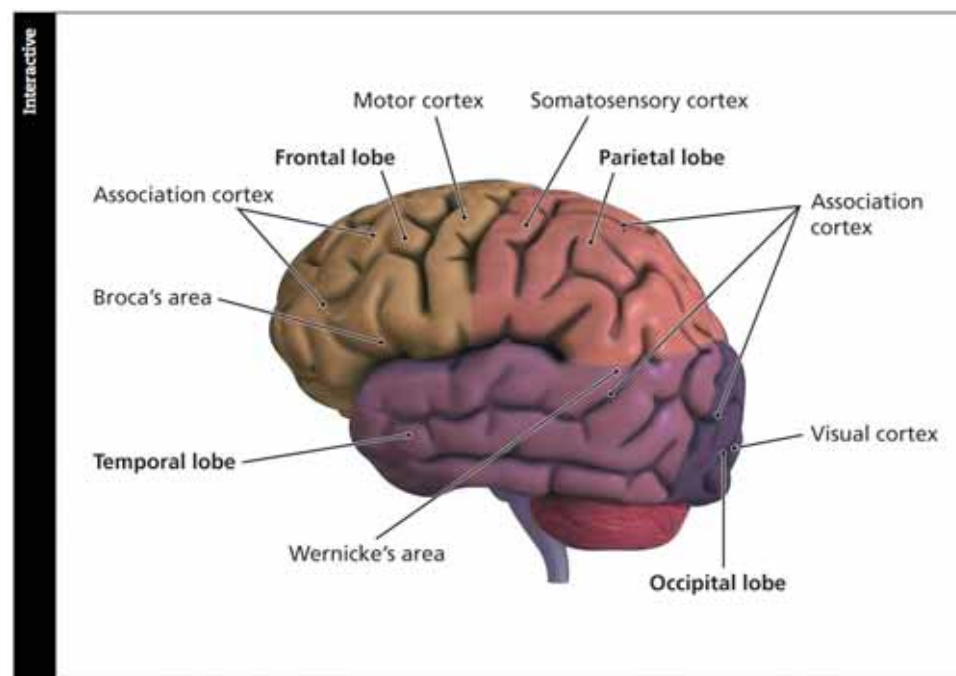


Figure 2.14 Lobes and Cortical Areas of the Brain

temporal and parietal lobes, helps identify and make sense of the visual information from the eyes. The famed neurologist Oliver Sacks once had a patient who had a tumor in his right occipital lobe area. He could still see objects and even describe them in physical terms, but he could not identify them by sight alone. When given a rose, the man began to describe it as a “red inflorescence” of some type with a green tubular projection. Only when he held it under his nose (stimulating the sense of smell) did he recognize it as a rose (Sacks, 1990). Each area of the cortex has these association areas that help people make sense of sensory information.

PARIETAL LOBES The **parietal lobes** are at the top and back of the brain, just under the parietal bone in the skull. This area contains the **somatosensory cortex**, an area of neurons (see **Figure 2.15**) at the front of the parietal lobes on either side of the brain. This area processes information from the skin and internal body receptors for touch, temperature, and body position. The somatosensory cortex is laid out in a rather interesting way—the cells at the top of the brain receive information from the bottom of the body, and as one moves down the area, the signals come from higher and higher in the body. It’s almost as if a little upside-down person were laid out along this area of cells.

TEMPORAL LOBES The beginnings of the **temporal lobes** are found just behind the temples of the head. These lobes contain the *primary auditory cortex* and the *auditory association area*. Also found in the left temporal lobe is an area that in most people is particularly involved with language. We have already discussed some of the medial structures of the temporal lobe, the amygdala and hippocampus, that are involved in aspects of learning and memory. There are also parts of the temporal lobe that help us process visual information.

FRONTAL LOBES These lobes are at the front of the brain, hence, the name **frontal lobes**. (It doesn’t often get this easy in psychology; feel free to take a moment to appreciate it.) Here are found all the higher mental functions of the brain—planning, personality, memory storage, complex decision making, and (again in the left hemisphere in most people) areas devoted to language. The frontal lobe also helps in controlling emotions by means of its connection to the limbic system. The most forward part of the frontal lobes is called the prefrontal cortex. The middle area toward the center (medial prefrontal cortex) and bottom surface above the eyes (orbitofrontal prefrontal cortex—right above the orbits of the eye) have strong connections to the limbic system. Phineas Gage, who was mentioned in Chapter One, suffered damage to his left frontal lobe (Ratiu et al., 2004). He lacked emotional control for some time immediately after the accident because of the damage to his prefrontal and orbitofrontal cortex, and the connections with limbic system structures. Overall, he had connections damaged from the left frontal cortex to many other parts of the brain (Van Horn et al., 2012). People with damage to the frontal lobe may also experience problems with performing mental or motor tasks, such as getting stuck on one step in a process or on one wrong answer in a test and repeating it over and over again, or making the same movement over and over, a phenomenon called *perseveration* (Asp & Tranel, 2013; Luria, 1965).

The frontal lobes also contain the **motor cortex**, a band of neurons located at the back of each lobe. (See **Figure 2.15**.) These cells control the movements of the body’s voluntary muscles by sending commands out to the somatic division of the peripheral nervous system. The motor cortex is laid out just like the somatosensory cortex, which is right next door in the parietal lobes.

This area of the brain has been the focus of a great deal of research, specifically as related to the role of a special type of neuron. These neurons are called **mirror neurons**, which fire when an animal performs an action—but they also fire when an animal observes that same action being performed by another. Previous brain-imaging studies in humans suggested that we, too, have mirror neurons in this area of the brain (Buccino et al., 2001;



This boxer must rely on his parietal lobes to sense where his body is in relation to the floor of the ring and the other boxer, his occipital lobes to see his target, and his frontal lobes to guide his hand and arm into the punch.

parietal lobes

sections of the brain located at the top and back of each cerebral hemisphere containing the centers for touch, temperature, and body position.

somatosensory cortex

area of cortex at the front of the parietal lobes responsible for processing information from the skin and internal body receptors for touch, temperature, and body position.

temporal lobes

areas of the cortex located along the side of the brain, starting just behind the temples, containing the neurons responsible for the sense of hearing and meaningful speech.

frontal lobes

areas of the brain located in the front and top, responsible for higher mental processes and decision making as well as the production of fluent speech.

motor cortex

rear section of the frontal lobe, responsible for sending motor commands to the muscles of the somatic nervous system.

mirror neurons

neurons that fire when an animal or person performs an action and also when an animal or person observes that same action being performed by another.

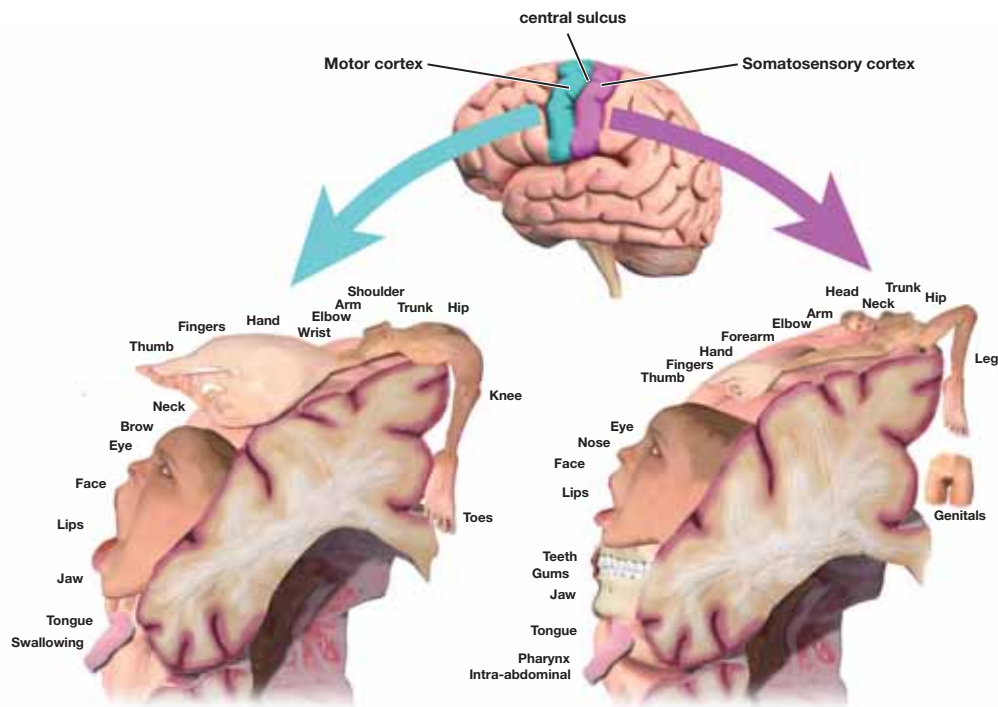


Figure 2.15 The Motor and Somatosensory Cortex

The motor cortex in the frontal lobe controls the voluntary muscles of the body. Cells at the top of the motor cortex control muscles at the bottom of the body, whereas cells at the bottom of the motor cortex control muscles at the top of the body. Body parts are drawn larger or smaller according to the number of cortical cells devoted to that body part. For example, the hand has many small muscles and requires a larger area of cortical cells to control it. The somatosensory cortex, located in the parietal lobe just behind the motor cortex, is organized in much the same manner and receives information about the sense of touch and body position.



As this boy imitates the motions his father goes through while shaving, certain areas of his brain are more active than others, areas that control the motions of shaving. But even if the boy were only *watching* his father, those same neural areas would be active—the neurons in the boy's brain would *mirror* the actions of the father he is observing.

association areas

areas within each lobe of the cortex responsible for the coordination and interpretation of information, as well as higher mental processing.

Buccino et al., 2004; Iacoboni et al., 1999). However, single-cell and multicell recordings in humans have demonstrated that neurons with mirroring functions are found not only in motor regions but also in parts of the brain involved in vision and memory, suggesting such neurons provide much more information than previously thought about our own actions as compared to the actions of others (Mukamel et al., 2010). These findings may have particular relevance for better understanding or treating specific clinical conditions that are believed to involve a faulty mirror system in the brain, such as autism (Oberman & Ramachandran, 2007; Rizzolatti et al., 2009). [LINK](#) to Learning Objective 8.7.

THE ASSOCIATION AREAS OF THE CORTEX



2.13 Name the parts of the cortex that are responsible for higher forms of thought, such as language.

☛ You've mentioned association cortex a few times. Do the other lobes of the brain contain association cortex as well?

Association areas are made up of neurons in the cortex that are devoted to making connections between the sensory information coming into the brain and stored memories, images, and knowledge. In other words, association areas help people make sense of the incoming sensory input. Although association areas in the occipital and temporal lobes

have already been mentioned, much of the brain's association cortex is in the frontal lobes. Furthermore, some special association areas are worth talking about in more detail.

BROCA'S AREA In the left frontal lobe of most people is an area of the brain associated with the production of speech. (In a small portion of the population, this area is in the right frontal lobe.) More specifically, this area allows a person to speak smoothly and fluently. It is called *Broca's area* after nineteenth-century neurologist Paul Broca, who first provided widely accepted clinical evidence that deficits in fluent and articulate speech result from damage to this area (Finger, 1994). However, it appears that Broca's area is not responsible for the production of speech itself but rather for the interaction between frontal, temporal, and motor areas responsible for speech production (Flinker et al., 2015). Damage to Broca's area causes a person to be unable to get words out in a smooth, connected fashion. People with this condition may know exactly what they want to say and understand what they hear others say, but they cannot control the actual production of their own words. Speech is halting and words are often mispronounced, such as saying "cot" instead of "clock" or "non" instead of "nine." Some words may be left out entirely, such as "the" or "for." This is called **Broca's aphasia**. *Aphasia* refers to an inability to use or understand either written or spoken language (Goodglass et al., 2001). (Stuttering is a somewhat different problem in getting words *started* rather than mispronouncing them or leaving them out, but it may also be related to Broca's area.)

WERNICKE'S AREA In the left temporal lobe (again, in most people) is an area called *Wernicke's area*, named after the physiologist and Broca's contemporary, Carl Wernicke, who first studied problems arising from damage in this location. This area of the brain appears to be involved in understanding the meaning of words (Goodglass et al., 2001). A person with **Wernicke's aphasia** would be able to speak fluently and pronounce words correctly, but the words would be the wrong ones entirely. For example, Elsie suffered a stroke to the temporal lobe, damaging this area of the brain. As the ER nurse inflated a blood pressure cuff, Elsie said, "Oh, that's so Saturday hard." Elsie *thought* she was making sense. She also had trouble understanding what the people around her were saying to her. In another instance, Ernest suffered a stroke at the age of 80 and also showed signs of Wernicke's aphasia. For example, he asked his wife to get him some milk out of the air conditioner. Right idea, wrong word. To hear audio examples of aphasia,  **Listen** to the **Audio File** Broca's Aphasia, and  **Listen** to the **Audio File** Wernicke's Aphasia.

Broca's aphasia

condition resulting from damage to Broca's area, causing the affected person to be unable to speak fluently, to mispronounce words, and to speak haltingly.

Wernicke's aphasia

condition resulting from damage to Wernicke's area, causing the affected person to be unable to understand or produce meaningful language.

Classic Studies in Psychology

Through the Looking Glass—Spatial Neglect

Dr. V. S. Ramachandran reported in his fascinating book, *Phantoms in the Brain* (Ramachandran & Blakeslee, 1998), the case of a woman with an odd set of symptoms. When Ellen's son came to visit her, he was shocked and puzzled by his formerly neat and fastidious* mother's appearance. The woman who had always taken pride in her looks, who always had her hair perfectly done and her nails perfectly manicured, looked messy and totally odd. Her hair was uncombed on the left side. Her green shawl was hanging neatly over her right shoulder but hanging onto the floor on the left. Her lipstick was neatly applied to the right side of her lips, and *only to the right side—the left side of her face was completely bare of makeup!* Yet her eyeliner, mascara, and blush were all neatly applied to the right side of her face.

What was wrong? The son called the doctor and was told that his mother's stroke had left her with a condition called **spatial neglect**, or unilateral neglect, in which a person with damage to the right parietal and occipital lobes of the cortex will ignore

*fastidious: having demanding standards, difficult to please.



As this woman applies make-up to the right side of her face, is she really "seeing" the left side? If she has spatial neglect, the answer is "no." While her eyes work just fine, her damaged right hemisphere refuses to notice the left side of her visual field.

everything in the left visual field. Damage to areas of the frontal and temporal lobes may also play a part along with the parietal damage. Spatial neglect can affect the left hemisphere, but this condition occurs less frequently and in a much milder form than right-hemisphere neglect (Corbetta et al., 2005; Heilman et al., 1993; Springer & Deutsch, 1998).

When the doctor examined this woman, he tried to get her to notice her left side by holding up a mirror (remember, she was not blind—she just would not notice anything on her left side unless her attention was specifically called to it). She responded correctly when asked what the mirror was and she was able to describe her appearance correctly, but when an assistant held a pen just within the woman’s reach, reflected in the mirror on her left side, she tried to reach *through the mirror* to get the pen with her good right hand. When the doctor told her that he wanted her to grab the real object and not the image of it in the mirror, she told him that the pen was *behind* the mirror and even tried to reach around to get it.

Clearly, persons suffering from spatial neglect can no longer perceive the world in the same way as other people do. For these people, the left sides of objects, bodies, and spaces are somewhere “through the looking glass.”


Questions for Further Discussion

1. If a person with spatial neglect only eats the food on the right side of the plate, what could caregivers do to help that person get enough to eat?
2. What other odd things might a person with spatial neglect do that a person with normal functioning would not? What other things might a person with spatial neglect fail to do?

THE CEREBRAL HEMISPHERES: ARE YOU IN YOUR RIGHT MIND?

2.14 Explain how some brain functions differ between the left and right hemispheres.

🗣️ I’ve heard that some people are right brained and some are left brained. Are the two sides of the brain really that different?

Most people tend to think of the two cerebral hemispheres as identical twins. Both sides have the same four lobes and are arranged in much the same way. But language seems to be confined to only the left hemisphere in about 90 percent of the population (Toga & Thompson, 2003). What other special tasks do the two halves of the **cerebrum** (the upper part of the brain consisting of the two hemispheres and the structures connecting them) engage in, and how do researchers know about such functions? Participate in the experiment simulation *Hemispheric Specialization* to test the language abilities of the two hemispheres  **Simulate the Experiment**, *Hemispheric Specialization*.

SPLIT-BRAIN RESEARCH Roger Sperry was a pioneer in the field of hemisphere specialization. He won a Nobel Prize for his work in demonstrating that the left and right hemispheres of the brain specialize in different activities and functions (Sperry, 1968). In looking for a way to cure epilepsy (severe muscle spasms or seizures resulting from brain damage), Sperry cut through the corpus callosum, the thick band of neural fibers that joins the two hemispheres. In early research with animals, this technique worked and seemed to have no side effects. The first people to have this procedure done also experienced relief from their severe epileptic symptoms, but testing found that (in a sense) they now had two brains in one body.

The special testing involves sending messages to only one side of the brain, which is now possible because the connecting tissue, the corpus callosum, has been cut. Remember that each hemisphere is largely responsible for controlling, or receiving information from, the opposite side of the body. **Figure 2.16** shows what happens with a typical split-brain patient.

spatial neglect

condition produced most often by damage to the parietal lobe association areas of the right hemisphere, resulting in an inability to recognize objects or body parts in the left visual field.

cerebrum

the upper part of the brain consisting of the two hemispheres and the structures that connect them.

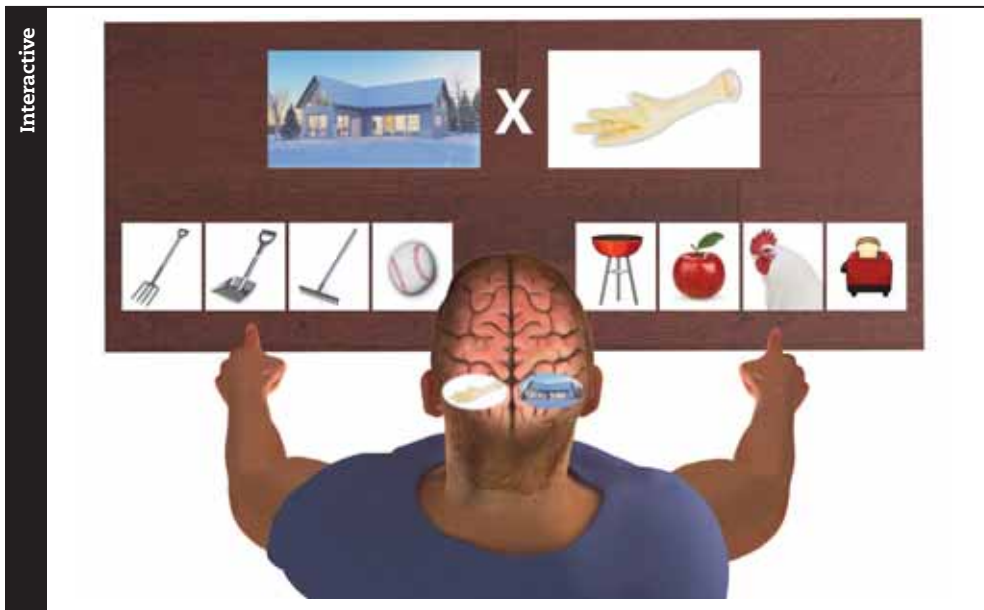


Figure 2.16 The Split-Brain Experiment

Building off methods developed by Roger Sperry, Michael Gazzaniga and Joseph LeDoux used this simultaneous concept test to further investigate functions of the left and right hemispheres of the brain

In a split-brain patient, if a picture of a ball is flashed to the right side of the screen, the image of the ball will be sent to the left occipital lobe. The person will be able to say that he or she sees a ball. If a picture of a hammer is flashed to the left side of the screen, the person will not be able to *verbally* identify the object or be able to state with any certainty that something was seen. But if the left *hand* (controlled by the right hemisphere) is used, the person can point to the hammer he or she “didn’t see.” The right occipital lobe clearly saw the hammer, but the person could not *verbalize* that fact (Sperry, 1968). By doing studies such as these, researchers have found that the left hemisphere specializes in language, speech, handwriting, calculation (math), sense of time and rhythm (which is mathematical in nature), and basically any kind of thought requiring analysis. The right hemisphere appears to specialize in more global (widespread) processing involving perception, visualization, spatial perception, recognition of patterns, faces, emotions, melodies, and expression of emotions. It also comprehends simple language but does not produce speech. (See **Table 2.2.**)

In general, the left hemisphere processes information in a sequence and is good at breaking things down into smaller parts, or performing analysis (Springer & Deutsch, 1998). The right hemisphere, by contrast, processes information all at once and simultaneously, a more global or holistic* style of processing. Remember the discussion in Chapter One of the early days of psychology, the structuralists, and the Gestalt psychologists? One could almost say that the left hemisphere of the brain is a structuralist who wants to break everything down into its smallest parts, and the right side of the brain is a Gestaltist, who wants to study only the whole.

💬 So there really are left-brained and right-brained people?

Actually, unless one is a split-brain patient, the two sides of the brain are always working together as an integrated whole. For example, the right side might recognize someone’s face, while the left side struggles to recall the person’s name. People aren’t really left- or right-brained, they are “whole-brained.” Michael Gazzaniga was one of Roger Sperry’s students, his collaborator, and is a long-time researcher in the area of brain asymmetry and cognitive neuroscience. Gazzaniga’s continuing work in brain lateralization has led to insights

*holistic: relating to or concerned with complete systems or wholes.

Table 2.2 Specialization of the Two Hemispheres

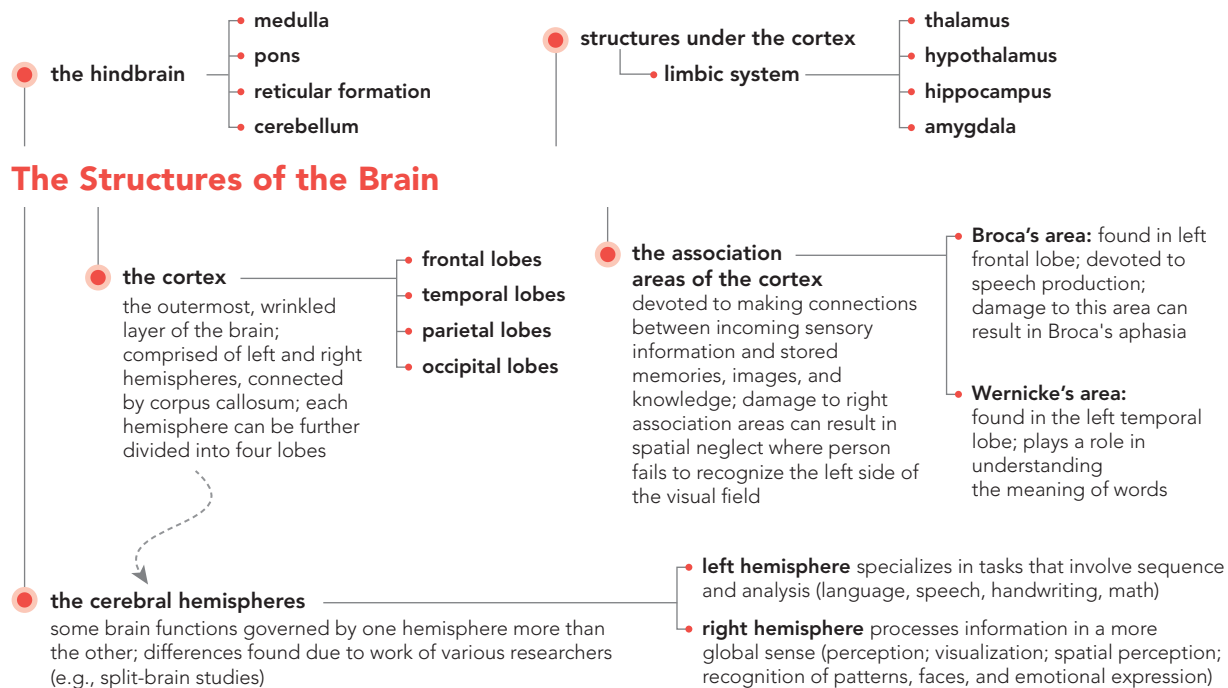
Left Hemisphere	Right Hemisphere
Controls the right hand	Controls the left hand
Spoken language	Nonverbal
Written language	Visual-spatial perception
Mathematical calculations	Music and artistic processing
Logical thought processes	Emotional thought and recognition
Analysis of detail	Processes the whole
Reading	Pattern recognition
	Facial recognition

of the integrated mind, and he continues to work in related areas including human consciousness, perception, and neuroethics (Gazzaniga, 2006, 2009).

HANDEDNESS The separate functions of the left and right sides of the brain are often confused with handedness, or the tendency to use one hand for most fine motor skills. Roughly 90% of individuals are right handed, and handedness appears to be influenced largely through genetics (Corballis, 2009; Ocklenburg et al., 2013). While most right-handed people also have their left hemisphere in control of their other fine motor skills, such as speech, a few right-handers actually have their language functions in the right hemisphere, in spite of the dominance of the left hemisphere for controlling the right hand. Among left-handed people, there are also many who, although right-brain dominant for motor control, still have their language functions on the left side of the brain. One study suggests approximately 4% of right-handed, 15% of ambidextrous, and 27% of left-handed people have language functions in the right hemisphere (Knecht et al., 2000).

Concept Map LO. 2.10, 2.11, 2.12, 2.13, 2.14

Interactive



Reset

Practice Quiz How much do you remember?

Pick the best answer.

- Which brain structure allows us to pay attention to certain stimuli while ignoring others?
 - medulla
 - cerebellum
 - reticular formation
 - pons
- Which brain structure relays incoming sensory information?
 - thalamus
 - hypothalamus
 - reticular formation
 - pons
- If you were to develop a rare condition in which you were not able to remember to be afraid of certain situations, animals, or events, which part of the brain would most likely be damaged?
 - cingulate cortex
 - hypothalamus
 - thalamus
 - amygdala
- What part of the brain can sometimes be referred to as the “rind” or outer covering?
 - thalamus
 - medulla
 - corpus callosum
 - cortex
- In which of the following lobes of the cortex would you find the primary visual cortex?
 - frontal
 - temporal
 - occipital
 - parietal
- You have a dream in which you wake up to find that people around you are using words that make no sense. What’s more, your friends don’t seem to understand you when you speak. At one point in your dream, your mom tells you that you almost forgot your tree limb today. When you give her a puzzled look, she holds up your lunchbox and repeats, “You know, your tree limb.” Your predicament in your dream is most like which of the following disorders?
 - Wernicke’s aphasia
 - Broca’s aphasia
 - apraxia
 - spatial neglect

APA Goal 2: Scientific Reasoning and Critical Thinking

Phineas Gage and Neuroplasticity

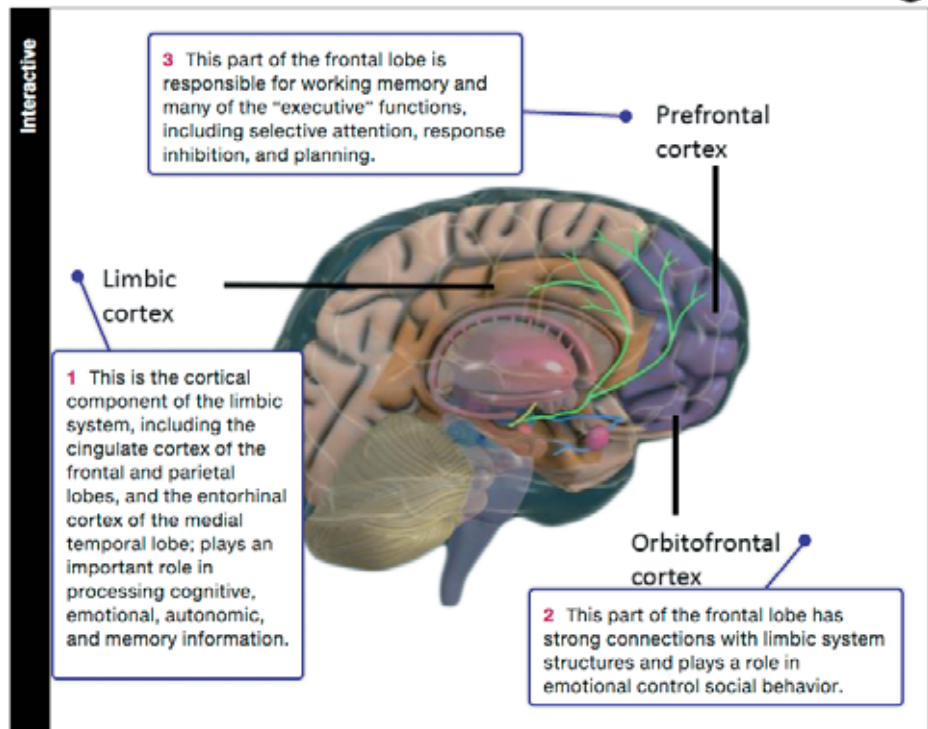
Addresses APA LO 2.2: Demonstrate psychology information literacy.

Earlier in the chapter you read about neuroplasticity as well as the role of the frontal lobes in the case of Phineas Gage. There is little question about the significant changes that likely occurred in Phineas’s behavior and personality immediately following the accident and trauma to his brain. However, based on what you know about the brain, his injury, and neuroplasticity and recovery, what questions might you have regarding his behavior and personality immediately before and after the injury and later in his life?

With regard to initial changes, it was reported that Gage went from being well balanced, energetic, and a smart business man to being fitful, irreverent, and impatient to the point that those who knew him said he was “no longer Gage” (Harlow, 1848). In turn, many reports in psychology (including many psychology textbooks!) have previously suggested Gage’s behavior and personality were permanently altered (Griggs, 2015; Macmillan, 2000; Macmillan & Lena, 2010). It is also important to note that at the time of Gage’s accident, not as much was known about specific aspects of brain function and injury, much less recovery from brain injury.

As you have read, the actual amount of brain damage was not as well understood until relatively recently. Recent investigations using reconstructions of his skull and other methods have identified the most likely areas of brain damage. These studies have revealed damage to the left frontal lobe, primarily the prefrontal and orbitofrontal areas, and the white matter connections between the left frontal lobe and other parts of the brain (Ratiu et al., 2004; Van Horn et al., 2012). Given these brain areas’ involvement in goal-directed behavior, planning, personality, emotional control, and the connections to other brain areas, it is easy to imagine the profound changes initially reported in Gage’s behavior.



APA Goal 2 Relevant Brain Areas - Phineas Gage's Accident


Phineas Gage experienced behavioral and personality changes immediately following his accident. Explore some of the brain areas that were either injured or affected by his injury.

But what about his behavior later in life? Although he has historically been portrayed as being permanently altered, there has been some evidence to suggest he experienced a fair amount of recovery. After a period of time in which he exhibited himself and the tamping iron at least twice, there has not been any confirmation that he was actually in a "freak show" and in contrast, he traveled throughout the New England area of the United States, found employment in a horse stable, and later traveled to Chile for work to drive a horse-drawn coach (Harlow, 1868; Macmillan & Lena, 2010). This was not a single horse-and-buggy setup, but rather a six-horse stagecoach that was loaded with passengers and luggage. Although some may consider the work menial, it certainly had to provide some challenges as he had to take care of the horses, tend to the needs of his passengers, and most likely learn something about local customs (Macmillan & Lena, 2010; Van Horn et al., 2012).

There has also been an image of Phineas discovered although the date is not known. What does the portrait below suggest with regard to Phineas's confidence, demeanor, etc.?

From this information and what you know in your study of psychology thus far, can you answer the following questions?

THINKING CRITICALLY

1. What type of questions should you ask yourself when referring to case studies? Do the questions differ based on the case studies being modern or historical?
2. What kind of supports and structure might have been provided to Phineas through his postaccident jobs that would have possibly helped him with his recovery?
3. How might the modern study of psychology help us better understand other historical case studies?

Submit

Applying Psychology to Everyday Life

Paying Attention to Attention-Deficit/ Hyperactivity Disorder

2.15 Identify some potential causes of attention-deficit/hyperactivity disorder.

Attention-deficit/hyperactivity disorder (ADHD) is a developmental disorder involving behavioral and cognitive aspects of inattention, impulsivity, and hyperactivity. Despite what many people have been told over the years, it is not due to bad parenting, too much junk food, or certain types of food coloring, and while symptoms may change somewhat, people do not outgrow the disorder. ADHD is a biological disorder that is related to genetics, environmental influences, and variations in brain structure and function.

Previously referred to as attention deficit disorder (ADD), there are currently three diagnostic categories for this disorder in the *Diagnostic and Statistical Manual of Mental Disorders (DSM-5)*. These include ADHD predominantly hyperactive/impulsive presentation, ADHD predominantly inattentive presentation, and ADHD combined presentation (American Psychiatric Association, 2013). Although ADHD is most commonly diagnosed in children, the disorder tends to persist into adolescence and adulthood. Inattention and impulsivity are often reported in adults, whereas symptoms of hyperactivity tend to decline with age. The ADHD-related problems in adults can range from strained relations with family, friends, or a significant other to problems with substance abuse, traffic accidents, or job stability (Barkley et al., 2008). A longitudinal study found a group of males diagnosed with ADHD in childhood were more likely to have issues across a variety of domains when followed up with as adults. At a mean age of 41, the men with ADHD had significantly worse educational, occupational, economic, and social outcomes and more divorces than non-ADHD comparisons (Klein et al., 2012).

There are not only ongoing issues from the disorder itself but also with the medications used to treat it. In the United States there is a growing concern over the misuse of prescription drugs on college campuses, for example, by students without ADHD in the attempt to improve their attention or concentration when studying. And for some students, the most common source of the medication is a friend with a prescription (Garnier-Dykstra et al., 2012). Furthermore, an ongoing increase in the number of ADHD diagnoses and prescriptions for stimulant medications appears to coincide with the use of ADHD medications as “neuroenhancers” in otherwise healthy children and adolescents and has prompted the American Academy of Neurology to publish a position paper against such practices (Graf et al., 2013).

The brain areas involved in the behavioral and cognitive characteristics of ADHD are typically divided into those responsible for regulating attention and cognitive control and those responsible for alertness and motivation (Nigg, 2010). Cortical and subcortical brain areas involved and found to be smaller in neuroimaging studies of ADHD are the prefrontal cortex (primarily on the right side), basal ganglia (subcortical structures involved in response control), cerebellum, and corpus callosum (Giedd et al., 2015; Nigg, 2006).

Since ADHD involves a variety of behaviors and cognitive aspects, research has often looked for specific markers that may lead to the actual causes of the disorder. These markers may be biological, cognitive, or behavioral measures (Nigg, 2010). To assess individual markers, researchers may combine neuroimaging and electrophysiological studies of individuals with ADHD while at rest or while they perform specific cognitive tasks (like various tests of attention). Some studies use EEG or ERPs (Clarke et al., 2007; Loo et al., 2009; Missonnier et al., 2013; van der Stelt et al., 2010; White et al., 2005), whereas others use MRI, fMRI, or PET (Bush et al., 2008; Mostert et al., 2016; Volkow et al., 2007).

Some research suggests that some aspects of attention are actually normal in individuals with ADHD. The aspect of attention with which individuals with ADHD do have problems is vigilance (being able to “watch out” for something important). Another cognitive area that appears to be impaired is being able to effectively control one’s own cognitive processes such as staying on task, maintaining effort, or engaging in self-control (Nigg, 2010).

These findings have prompted researchers to reexamine the causes of ADHD and have highlighted the likelihood of more than one cause and more than one brain route to ADHD. Research is looking at a variety of areas including environmental factors such as low-level lead exposure, genetic influences, the role of heredity and familial factors, and personality factors (Forster & Lavie, 2016; Nigg, 2010; Nigg et al., 2016). Furthermore, causes for the prevalence of ADHD continue to be examined, with variables ranging from the impact of sleep, circadian rhythms, and environmental light exposure (Arns et al., 2013) to the manner in which ADHD symptoms are characterized and diagnosed. While some of these areas of investigation are not completely new and have been examined before, the possibility of multiple causes and interactions between these causes has not been examined as closely as it is being examined in current ADHD research.

Questions for Further Discussion

1. How might a psychology professional help parents or teachers understand the neuroimaging techniques and brain areas associated with ADHD?
2. If a college student has ADHD, what aspects of their school or personal lives might be impacted by problems with vigilance or cognitive control?
3. What kinds of problems may arise in individuals taking ADHD medications when they do not have the actual symptoms of the disorder?

Chapter Summary

Neurons and Nerves: Building the Network

2.1 Identify the parts of a neuron and the function of each.

- The nervous system is a complex network of cells that carries information to and from all parts of the body.
- The brain is made up of two types of cells, neurons and glial cells.
- Neurons have four primary components: dendrites that receive input, a soma or cell body, axons that carry the neural message to other cells, and axon terminals that are the site of neurotransmitter release.
- Glial cells separate, support, and insulate the axons of some neurons; they influence thinking, memory, and other forms of cognition.
- Myelin insulates and protects the axons of some neurons. Some axons bundle together in “cables” called nerves. Myelin also speeds up the neural message.
- A neuron contains charged particles called ions. When at rest, the neuron is negatively charged on the inside and positively charged on the outside. When stimulated, this reverses the

charge by allowing positive sodium ions to enter the cell. This is the action potential.

- Neurons fire in an all-or-nothing manner. It is the speed and number of neurons firing that tell researchers the strength of the stimulus.

2.2 Explain the action potential.

- Synaptic vesicles in the end of the axon terminal release neurotransmitter chemicals into the synapse, or gap, between one cell and the next. The neurotransmitter molecules fit into receptor sites on the next cell, stimulating or inhibiting that cell’s firing. Neurotransmitters may be either excitatory or inhibitory.

2.3 Describe how neurons use neurotransmitters to communicate with each other and with the body.

- The first known neurotransmitter was acetylcholine (ACh). It stimulates muscles, helps in memory formation, and plays a role in arousal and attention.
- GABA is the major inhibitory neurotransmitter; high amounts of GABA are released when drinking alcohol.
- Serotonin (5-HT) is associated with sleep, mood, and appetite.

- Dopamine (DA) is associated with Parkinson's disease and schizophrenia.
- Endorphins are neural regulators that control our pain response.
- Most neurotransmitters are taken back into the synaptic vesicles in a process called reuptake.
- ACh is cleared out of the synapse by enzymes that break up the molecules.

An Overview of the Nervous System

2.4 Describe how the brain and spinal cord interact and respond to external experiences.

- The central nervous system consists of the brain and the spinal cord.
- The spinal cord serves two functions. The outer part of the cord transmits messages to and from the brain, whereas the inner part controls lifesaving reflexes such as the pain response.
- Spinal cord reflexes involve afferent neurons, interneurons, and efferent neurons, forming a simple reflex arc.
- Neuroplasticity refers to the brain's ability to modify its structure and function as the result of experience or injury; researchers are examining ways to capitalize on this feature to assist individuals with brain injury or disease.

2.5 Differentiate the roles of the somatic and autonomic nervous systems.

- The peripheral nervous system is all the neurons and nerves that are not part of the brain and spinal cord and that extend throughout the body.
- There are two systems within the peripheral nervous system, the somatic nervous system and the autonomic nervous system.
- The somatic nervous system contains the sensory pathway, or neurons carrying messages to the central nervous system, and the motor pathway, or neurons carrying messages from the central nervous system to the voluntary muscles.
- The autonomic nervous system consists of the parasympathetic division and the sympathetic division. The sympathetic division is our fight-or-flight system, reacting to stress, whereas the parasympathetic division is our eat-drink-and-rest system that restores and maintains normal day-to-day functioning of the organs.

Distant Connections: The Endocrine Glands

2.6 Explain why the pituitary gland is known as the "master gland."

- Endocrine glands secrete chemicals called hormones directly into the bloodstream, influencing the activity of the muscles and organs.
- The pituitary gland is found in the brain just below the hypothalamus. Among its many functions, it helps us conserve water and controls oxytocin, a hormone involved in the onset of labor and lactation. The pituitary also regulates growth hormone and influences the activity of the other glands.

2.7 Recall the role of various endocrine glands.

- The pineal gland is also located in the brain. It secretes melatonin, a hormone that regulates the sleep-wake cycle, in response to changes in light.
- The thyroid gland is located inside the neck. It controls metabolism (the burning of energy) by secreting thyroxin.
- The pancreas controls the level of sugar in the blood by secreting insulin and glucagons. Too much insulin produces hypoglycemia, whereas too little causes diabetes.
- The gonads are the ovaries in women and testes in men. They secrete hormones to regulate sexual growth, activity, and reproduction.
- The adrenal glands, one on top of each kidney, control the stress reaction through the adrenal medulla's secretion of epinephrine and norepinephrine. The adrenal cortex secretes more than 30 different corticoids (hormones), controlling salt intake, stress, and sexual development.

Looking Inside the Living Brain

2.8 Describe how lesioning studies and brain stimulation are used to study the brain.

- We can study the brain by using lesioning techniques to destroy certain areas of the brain in laboratory animals or by electrically stimulating those areas (ESB).
- We can use case studies of human brain damage to learn about the brain's functions but cannot easily generalize from one case to another.
- rTMS and tDCS are noninvasive methods for stimulating the brain.

2.9 Compare and contrast neuroimaging techniques for mapping the structure and function of the brain.

- Different neuroimaging methods allow scientists to investigate the structure or the function of the living brain.
- The electroencephalograph allows researchers to look at the electroencephalogram (EEG), or electrical activity of the surface of the brain, through the use of electrodes placed on the scalp that are then amplified and viewed using a computer. ERPs allow researchers to look at the timing and progression of cognitive processes.
- CT scans are computer-aided X-rays of the brain and show the skull and brain structure.
- MRI scans use a magnetic field, radio pulses, and a computer to give researchers an even more detailed look at the structure of the brain.
- fMRI allows researchers to look at the activity of the brain over a time period.
- PET scans use a radioactive sugar injected into the bloodstream to track the activity of brain cells, which is enhanced and color-coded by a computer. SPECT allows for the imaging of brain blood flow.

From the Bottom Up: The Structures of the Brain

2.10 Identify the different structures of the hindbrain and the function of each.

- The medulla is at the very bottom of the brain and at the top of the spinal column. It controls life-sustaining functions such as breathing and swallowing. The nerves from each side of the body also cross over in this structure to opposite sides.
- The pons is above the medulla and acts as a bridge between the cerebellum and the cerebrum. It influences sleep, dreaming, arousal, and coordination of movement on the left and right sides of the body.
- The reticular formation runs through the medulla and the pons and controls our general level of attention and arousal.
- The cerebellum is found at the base and back of the brain and coordinates fine, rapid motor movement, learned reflexes, posture, and muscle tone. It may also be involved in some cognitive and emotional functions.

2.11 Identify the structures of the brain that are involved in emotion, learning, memory, and motivation.

- The limbic system consists of the thalamus, hypothalamus, hippocampus, and amygdala.
- The thalamus is the relay station that sends sensory information to the proper areas of the cortex.
- The hypothalamus controls hunger, thirst, sexual behavior, sleeping and waking, and emotions. It also controls the pituitary gland.
- The hippocampus is the part of the brain responsible for the formation of long-term declarative memories.
- The amygdala controls our fear responses and memory of fearful stimuli.

2.12 Identify the parts of the cortex that process the different senses and those that control movement of the body.

- The cortex is the outer covering of the cerebrum and consists of a tightly packed layer of neurons about one tenth of an inch in thickness. Its wrinkles, or corticalization, allow for greater cortical area and are associated with greater brain complexity.
- The cortex is divided into two cerebral hemispheres connected by a thick band of neural fibers called the corpus callosum.
- The occipital lobes at the back and base of each hemisphere process vision and contain the primary visual cortex.
- The parietal lobes at the top and back of the cortex contain the somatosensory area, which processes our sense of touch, temperature, and body position.

- The temporal lobes contain the primary auditory area and are also involved in understanding language.
- The frontal lobes contain the motor cortex, which controls the voluntary muscles, and are also where all the higher mental functions occur, such as planning, language, and complex decision making.

2.13 Name the parts of the cortex that are responsible for higher forms of thought, such as language.

- Association areas of the cortex are found in all the lobes but particularly in the frontal lobes. These areas help people make sense of the information they receive from primary sensory areas and the lower areas of the brain.
- A region called Broca's area in the left frontal lobe is critical in the production of fluent, understandable speech. If damaged, the person has Broca's aphasia, in which words will be halting and pronounced incorrectly.
- An area called Wernicke's area in the left temporal lobe is important for the understanding of language. If damaged, the person has Wernicke's aphasia, in which speech is fluent but nonsensical. The wrong words are used.

2.14 Explain how some brain functions differ between the left and right hemispheres.

- Studies with split-brain patients, in which the corpus callosum has been severed to correct epilepsy, reveal that the left side of the brain seems to control language, writing, logical thought, analysis, and mathematical abilities. The left side also processes information sequentially.
- The right side of the brain processes information globally and controls emotional expression, spatial perception, recognition of faces, patterns, melodies, and emotions. Information presented only to the left hemisphere can be verbalized, but information only sent to the right cannot.

Applying Psychology to Everyday Life: Paying Attention to Attention-Deficit/Hyperactivity Disorder

2.15 Identify some potential causes of attention-deficit/hyperactivity disorder.

- ADHD is often diagnosed in children but may persist into adulthood. Multiple causes are possible, including genetic and environmental factors and several differences in brain structure and function.

Test Yourself

Pick the best answer.

- In the structure of the neuron, the _____ receives messages from other cells.
 - axon
 - dendrite
 - soma
 - myelin
- Oligodendrocytes and Schwann cells generate a fatty substance known as
 - glial.
 - soma.
 - myelin.
 - neurilemma.
- Which of the following insulates and protects a neuron's axon, as well as helps speed along electrical impulses?
 - synaptic knobs
 - receptor sites
 - myelin sheath
 - neuromodulators
- When a neuron is in the resting potential state, the neuron is negatively charged on the _____ and positively charged on the _____.
 - inside; outside
 - outside; inside
 - top; bottom
 - bottom; top
- Which neurotransmitter stimulates muscle cells to contract but slows contractions in the heart?
 - acetylcholine
 - GABA
 - serotonin
 - endorphin
- Heroin mimics the actions of endorphins, inhibiting pain signals and creating a "high" feeling. Heroin is an example of a(n):
 - antagonist.
 - agonist.
 - glial cell.
 - agonist.
- Involuntary muscles are controlled by the _____ nervous system.
 - somatic
 - autonomic
 - sympathetic
 - parasympathetic
- As you take notes, your heart beats at a normal rate. Your breathing is normal and your stomach slowly digests your earlier meal. What division of the peripheral nervous system is currently in action?
 - sympathetic
 - parasympathetic
 - autonomic
 - somatic
- Robert has had difficulty sleeping for the past 6 months, and his body seemingly no longer differentiates between night and day. His doctor believes the problem lies with Robert's endocrine system. What gland will Robert's physician focus on?
 - pituitary
 - adrenal
 - thyroid
 - pineal
- Which gland(s) is/are known to influence all other glands within the endocrine system?
 - pineal gland
 - pituitary gland
 - thyroid gland
 - adrenal glands
- Danielle is a subject in a study on memory and problem solving. The researcher is applying magnetic pulses to her brain through copper wire coils positioned directly above her scalp. Danielle study would best be described as a(n)
 - invasive stimulation technique.
 - noninvasive stimulation technique.
 - EEG technique.
 - PET technique.
- Which technique of studying the brain involves injecting the patient with radioactive glucose?
 - EEG
 - CT
 - MRI
 - PET
- Maria often sleeps soundly and rarely awakens to any outside noise. However, the cries of Maria's baby can awaken her immediately. What part of the brain is responsible for this reaction?
 - medulla
 - pons
 - reticular formation
 - cerebellum
- Nicole and Camille are synchronized swimmers for their college swim team. They often work long hours to ensure the movements in their routine are perfectly timed. What part of their brains must Camille and Nicole rely most upon?
 - medulla
 - pons
 - reticular formation
 - cerebellum
- Your psychology professor refers to this as the great relay station of the brain. What part is he or she referring to?
 - thalamus
 - hypothalamus
 - hippocampus
 - amygdala
- Which part of the brain is involved in the creation of memories and is often linked to Alzheimer's disease?
 - hippocampus
 - thalamus
 - hypothalamus
 - amygdala
- Madison suffered a severe blow to the back of her head when she was thrown to the mat during a judo match. Subsequently, her occipital lobe has been injured. Which of her senses has the highest chance of being affected?
 - hearing
 - touch
 - taste and smell
 - vision
- Jaime's grandfather recently suffered a stroke and has had difficulty with language production ever since. Most likely, he has experienced damage to the _____ area of his brain.
 - right rear
 - left frontal
 - left rear
 - right frontal
- Felicia is recovering from a brain injury. She is able to speak fluently but often uses incorrect words in a sentence. In one instance at a friend's birthday party, she said, "I would like something to drink. Can I have some battery?" Felicia's problem is known as
 - spatial neglect.
 - visual agnosia.
 - Broca's aphasia.
 - Wernicke's aphasia.
- Although the brain works largely as a whole, which of the following is *not* a correct pairing of hemisphere and function?
 - left; control of right-handed motor functions
 - right; control of right-handed motor functions
 - right; recognition of faces
 - left; reading