Module 9

Biological Psychology and Neurotransmission


AP Photo/Frederik Meijer Gardens & Sculpture Park, Chuck Heiney

Module Learning Objectives

- **9-1** Explain why psychologists are concerned with human biology.
- **9-2** Describe the parts of a neuron, and explain how its impulses are generated.
- **9-3** Describe how nerve cells communicate with other nerve cells.
- **9-4** Describe how neurotransmitters influence behavior, and explain how drugs and other chemicals affect neurotransmission.

Biology, Behavior, and Mind

9-1 Why are psychologists concerned with human biology?

Your every idea, every mood, every urge is a biological happening. You love, laugh, and cry with your body. Without your body—your genes, your brain, your appearance—you would, indeed, be nobody. Although we find it convenient to talk separately of biological and psychological influences on behavior, we need to remember: To think, feel, or act without a body would be like running without legs.

Our understanding of how the brain gives birth to the mind has come a long way. The ancient Greek philosopher Plato correctly located the mind in the spherical head—his idea of the perfect form. His student, Aristotle, believed the mind was in the heart, which pumps warmth and vitality to the body. The heart remains our symbol for love, but science has long since overtaken philosophy on this issue. It's your brain, not your heart, that falls in love.

In the early 1800s, German physician Franz Gall proposed that *phrenology,* studying bumps on the skull, could reveal a person's mental abilities and character traits (**FIGURE 9.1**). At one point, Britain had 29 phrenological societies, and phrenologists traveled North America giving skull readings (Hunt, 1993).

ScienceCartoonsPlus.com

"Then it's agreed—you can't have a mind without a brain, but you can have a brain without a mind."

TEACH

TRM Discussion Starter

Use the Module 9 Fact or Falsehood? activity from the TRM to introduce the concepts from this module.

TEACH

Teaching Tip

Teaching this unit early in the course is important because it enables students to grasp foundational knowledge essential to mastering the remainder of the course. Helping students chunk this information will help them learn a large amount of very important material more easily.

TEACH

Teaching Tip

Point out the organization of this unit's content, from a micro level to a macro level. Helping students organize this material properly will help them keep it straight when they take the test.

TEACH

Interdisciplinary Connections

Frances Gall is credited with developing phrenology, the study of the surface of the skull as a way to identify mental abilities. In his autobiography, Gall related that he was exasperated by fellow students who, although less intelligent than himself, received higher grades because they were better memorizers. In reflecting on his rivals, he concluded that they all had one prominent physical characteristic in common: large and protruding eyeballs. Convinced that greater intelligence was associated with larger brains, he speculated that specific parts of the brain were the seats of specific faculties or traits. People with good verbal memories might have particularly well-developed "organs of verbal memory" somewhere in their brains. Gall further surmised that this was in the region of the frontal lobes directly behind the eyes, where the pressure of the enlarged brain caused the eyes to protrude.

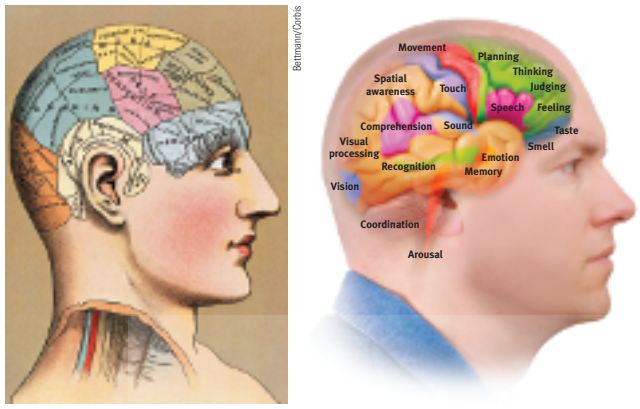


Figure 9.1
A wrongheaded theory Despite initial acceptance of Franz Gall's speculations, bumps on the skull tell us nothing about the brain's underlying functions. Nevertheless, some of his assumptions have held true. Though they are not the functions Gall proposed, different parts of the brain do control different aspects of behavior, as suggested here (from *The Human Brain Book*) and as you will see throughout this unit.

Using a false name, humorist Mark Twain put one famous phrenologist to the test. "He found a cavity [and] startled me by saying that that cavity represented the total absence of the sense of humor!" Three months later, Twain sat for a second reading, this time identifying himself. Now "the cavity was gone, and in its place was . . . the loftiest bump of humor he had ever encountered in his life-long experience!" (Lopez, 2002). Although its initial popularity faded, phrenology succeeded in focusing attention on the *localization of function*—the idea that various brain regions have particular functions.

You and I are living in a time Gall could only dream about. By studying the links between biological activity and psychological events, **biological psychologists** are announcing discoveries about the interplay of our biology and our behavior and mind at an exhilarating pace. Within little more than the past century, researchers seeking to understand the biology of the mind have discovered that

- the body is composed of cells.
- among these are nerve cells that conduct electricity and "talk" to one another by sending chemical messages across a tiny gap that separates them.
- specific brain systems serve specific functions (though not the functions Gall supposed).
- we integrate information processed in these different brain systems to construct our experience of sights and sounds, meanings and memories, pain and passion.
- our adaptive brain is wired by our experience.

We have also realized that we are each a system composed of subsystems that are in turn composed of even smaller subsystems. Tiny cells organize to form body organs. These organs form larger systems for digestion, circulation, and information processing. And those systems are part of an even larger system—the individual, who in turn is a part of a family, culture, and community. Thus, we are *biopsychosocial* systems. To understand our behavior, we need to study how these biological, psychological, and social systems work and interact.

In this unit we start small and build from the bottom up—from nerve cells up to the brain, and then to the environmental influences that interact with our biology. We will also work from the top down, as we consider how our thinking and emotions influence our brain and our health.

AP® Exam Tip

There is a ton of vocabulary in this unit. However, learning vocabulary is really not so hard: The secret is to work on it every day. Try flash cards. Work with a study buddy. Impress your non-psych friends with your new vocabulary. Just don't leave it until the night before the test. If you rehearse the vocabulary throughout the unit, you will do better on the unit test. The big bonus is that you will also retain far more information for the AP® exam.

"If I were a college student today, I don't think I could resist going into neuroscience."
-Novelist Tom Wolfe, 2004

biological psychology
the scientific study of the links between biological (genetic, neural, hormonal) and psychological processes. (Some biological psychologists call themselves *behavioral neuroscientists, neuropsychologists, behavior geneticists, physiological psychologists,* or *biopsychologists.*)

TEACH

Teaching Tip

One key study that students may want to be familiar with in order to appreciate the science of behavior and mental processes was conducted in 1972. Rosenzweig, Bennett, and Diamond conducted research with rats that showed that enriched environments contributed to more complex neural connections in the cortex. This study shows that neural complexity could be influenced by environmental factors, showing how nature and nurture interact.

Renner, M. J., & Rosenzweig, M. R. (1987). *Enriched and impoverished environments: Effects on brain and behavior*. New York: Springer.

TEACH

Common Pitfalls

Students often assume that all research discussed in this unit was done on humans. In fact, most of the research done in this unit was done on animals. Help students appreciate how similarities in biology contribute to our understanding not only of ourselves but also of nonhuman animals.

TEACH

Common Pitfalls

While studying neural communication, students often fail to appreciate the complexity of the neural network in the nervous system. The neural chain presented in the text is the simplest way neurons communicate. For the vast majority of the nervous system, multiple neurons connect with each other, creating a complex network capable of almost endless combinations of neurons communicating. Help students understand that this simple presentation does not capture the true complexity of neural communication.

TEACH

Teaching Tip

Neuroglia (or *glial cells*, discussed in Module 12) are another category of neural cells that provide the support network of cells surrounding the neurons and blood vessels of the brain and nervous system.

They are thought to outnumber typical neurons 10 to 1. There are 3 types of neuroglia in the body:

- *Oligodendroglia* (o-lig-o-dendro-glia) are cells found in the central nervous system (CNS) that produce myelin, a protective covering of axons that speeds neural transmissions.
- *Schwann cells* perform the same function as oligodendroglia, but are found in the peripheral nervous system (PNS). Aside from location, the main difference between Schwann cells and oligodendroglia is that only Schwann cells can help axons regenerate.
- *Astrocytes* are star-shaped and form most of the matrix in which neural cells are embedded and envelop blood vessels in the brain. They also absorb dead neural cells.

Neural Communication

For scientists, it is a happy fact of nature that the information systems of humans and other animals operate similarly—so similarly that you could not distinguish between small samples of brain tissue from a human and a monkey. This similarity allows researchers to study relatively simple animals, such as squids and sea slugs, to discover how our neural systems operate. It allows them to study other mammals' brains to understand the organization of our own. Cars differ, but all have engines, accelerators, steering wheels, and brakes. An alien could study any one of them and grasp the operating principles. Likewise, animals differ, yet their nervous systems operate similarly. Though the human brain is more complex than a rat's, both follow the same principles.

neuron a nerve cell; the basic building block of the nervous system.

dendrites a neuron's bushy, branching extensions that receive messages and conduct impulses toward the cell body.

axon the neuron extension that passes messages through its branches to other neurons or to muscles or glands.

myelin [MY-uh-lin] **sheath** a fatty tissue layer segmentally encasing the axons of some neurons; enables vastly greater transmission speed as neural impulses hop from one sausage-like node to the next.

action potential a neural impulse; a brief electrical charge that travels down an axon.

"I sing the body electric." -Walt Whitman, "Children of Adam" (1855)

Neurons

9-2 What are the parts of a neuron, and how are neural impulses generated?

Our body's neural information system is complexity built from simplicity. Its building blocks are **neurons,** or nerve cells. To fathom our thoughts and actions, memories and moods, we must first understand how neurons work and communicate.

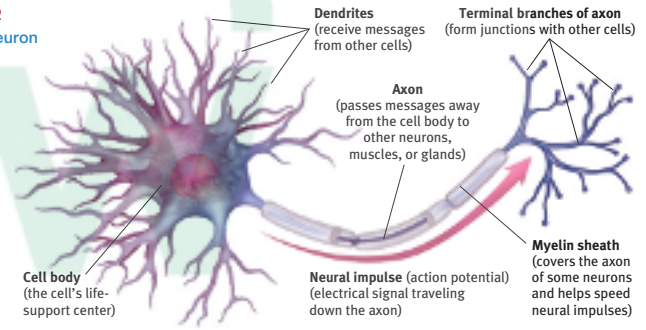
Neurons differ, but all are variations on the same theme (**FIGURE 9.2**). Each consists of a *cell body* and its branching fibers. The bushy **dendrite** fibers receive information and conduct it toward the cell body. From there, the cell's lengthy **axon** fiber passes the message through its terminal branches to other neurons or to muscles or glands. Dendrites listen. Axons speak.

Unlike the short dendrites, axons may be very long, projecting several feet through the body. A neuron carrying orders to a leg muscle, for example, has a cell body and axon roughly on the scale of a basketball attached to a rope 4 miles long. Much as home electrical wire is insulated, some axons are encased in a **myelin sheath,** a layer of fatty tissue that insulates them and speeds their impulses. As myelin is laid down up to about age 25, neural efficiency, judgment, and self-control grow (Fields, 2008). If the myelin sheath degenerates, *multiple sclerosis* results: Communication to muscles slows, with eventual loss of muscle control.

Neurons transmit messages when stimulated by signals from our senses or when triggered by chemical signals from neighboring neurons. In response, a neuron fires an impulse, called the **action potential**—a brief electrical charge that travels down its axon.

Depending on the type of fiber, a neural impulse travels at speeds ranging from a sluggish 2 miles per hour to a breakneck 180 miles per hour. But even this top speed is 3 million times slower than that of electricity through a wire. We measure brain activity in

Figure 9.2
A motor neuron



TEACH

Common Pitfalls

The importance of the myelin sheath cannot be emphasized enough. Myelin, produced by glial cells, helps make neural communication more efficient. Without myelin, neurons would not communicate as quickly, making behavior and mental processes occur more slowly or perhaps not occur at all. Multiple sclerosis is a disorder in which myelin is attacked by the body's immune system, and people who have this disorder find movement increasingly difficult.

ENGAGE

Active Learning

Two major disorders, multiple sclerosis and Guillain–Barré syndrome, are related to issues with myelin. Have students research the symptoms, causes, and treatments of these disorders. They may also contact doctors who treat these conditions to interview them or their patients for more insight into how the destruction of myelin in the nervous system affects daily life.

milliseconds (thousandths of a second) and computer activity in nanoseconds (billionths of a second). Thus, unlike the nearly instantaneous reactions of a high-speed computer, your reaction to a sudden event, such as a book slipping off your desk during class, may take a quarter-second or more. Your brain is vastly more complex than a computer, but slower at executing simple responses. And if you are an elephant—whose round-trip message travel time from a yank on the tail to the brain and back to the tail is 100 times longer than for a tiny shrew—reflexes are slower yet (More et al., 2010).

Like batteries, neurons generate electricity from chemical events. In the neuron's chemistry-to-electricity process, *ions* (electrically charged atoms) are exchanged. The fluid outside an axon's membrane has mostly positively charged ions; a resting axon's fluid interior has mostly negatively charged ions. This positive-outside/negative-inside state is called the *resting potential.* Like a tightly guarded facility, the axon's surface is very selective about what it allows through its gates. We say the axon's surface is *selectively permeable.*

When a neuron fires, however, the security parameters change: The first section of the axon opens its gates, rather like sewer covers flipping open, and positively charged sodium ions flood through the cell membrane (**FIGURE 9.3**). This *depolarizes* that axon section, causing another axon channel to open, and then another, like a line of falling dominos, each tripping the next.

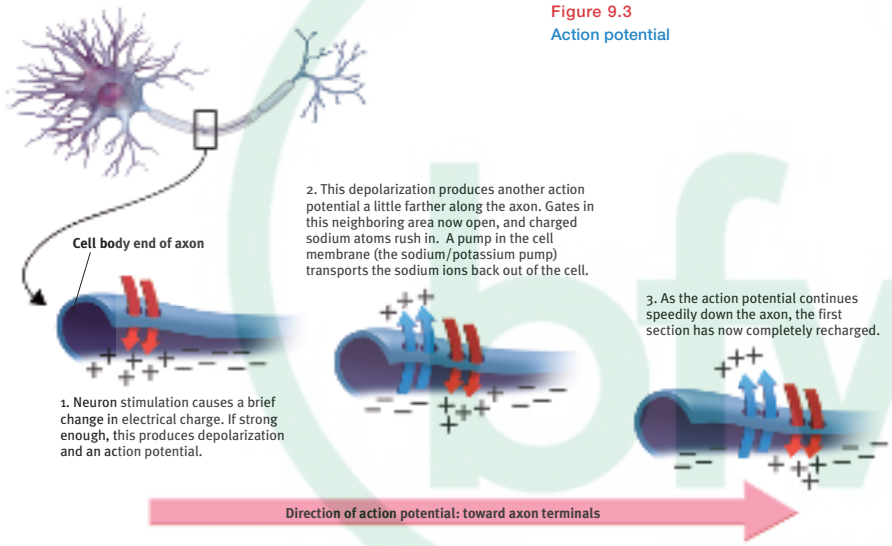
During a resting pause called the **refractory period,** rather like a web page pausing to refresh, the neuron pumps the positively charged sodium ions back outside. Then it can fire again. (In myelinated neurons, as in Figure 9.2, the action potential speeds up by hopping from the end of one myelin "sausage" to the next.) The mind boggles when imagining this electrochemical process repeating up to 100 or even 1000 times a second. But this is just the first of many astonishments.

refractory period a period of inactivity after a neuron has fired.

Each neuron is itself a miniature decision-making device performing complex calculations as it receives signals from hundreds, even thousands, of other neurons. Most signals are *excitatory,* somewhat like pushing a neuron's accelerator. Some are *inhibitory,* more like

"What one neuron tells another neuron is simply how much it is excited." -Francis Crick, *The Astonishing Hypothesis*, 1994

Figure 9.3
Action potential



TEACH

Teaching Tip

The **sodium–potassium pump** is the mechanism by which ions are allowed to pass through the membrane of the neural cell. Named for the 2 primary elements present in the ion exchange, this pump brings positively charged ions into the cell and then pumps them back out when the action potential is over. This term may show up on the AP® exam.

TEACH

Teaching Tip

The Nodes of Ranvier are the spaces in between the myelin sheaths that encircle the axon. These spaces are important to keep the charge going through the relatively long axon. Without these spaces, the charge might lose its intensity before reaching the end of the cell.

TEACH

TRM Common Pitfalls

An explanation of the following terms may help students better understand the concept of the action potential:

- *Ions* have a charge, either positive or negative. When these particles move, they create electricity, which is what the action potential is.
- The natural tendency for matter is to move from a more crowded situation to a less crowded situation. The neuron is packed with negatively charged ions, with the positively charged ions positioned on the outside of the cell.
- The neuron's membrane is normally impermeable, but neurotransmitters weaken it, allowing the ions to move according to the principle above.

Use the Teacher Demonstration: Modeling a Neuron and Using Dominoes to Illustrate the Action Potential from the TRM.

TEACH

TRM Common Pitfalls

The action potential is one of the most complicated processes discussed in AP® Psychology. Be sure to have several ways to explain this concept so all students can have the opportunity to learn it. By understanding this process, students will better grasp neurotransmitters, myelin, excitation, and inhibition.

Use this activity from the TRM to provide an alternate explanation for this concept: Student Activity: Neural Transmission.

threshold the level of stimulation required to trigger a neural impulse.

all-or-none response a neuron's reaction of either firing (with a full-strength response) or not firing.

pushing its brake. If excitatory signals exceed inhibitory signals by a minimum intensity, or **threshold,** the combined signals trigger an action potential. (Think of it as a class vote: If the excitatory people with their hands up outvote the inhibitory people with their hands down, then the vote passes.) The action potential then travels down the axon, which branches into junctions with hundreds or thousands of other neurons or with the body's muscles and glands.

Increasing the level of stimulation above the threshold will not increase the neural impulse's intensity. The neuron's reaction is an **all-or-none response:** Like guns, neurons either fire or they don't. How, then, do we detect the intensity of a stimulus? How do we distinguish a gentle touch from a big hug? A strong stimulus can trigger *more* neurons to fire, and to fire more often. But it does not affect the action potential's strength or speed. Squeezing a trigger harder won't make a bullet go faster.

AP® Exam Tip

Note the important shift here. So far, you have been learning about how just one neuron operates. The action potential is the mechanism for communication *within* a single neuron. Now you are moving on to a discussion of two neurons and how communication occurs *between* them. Very different, but equally important.

"All information processing in the brain involves neurons 'talking to' each other at synapses."
-Neuroscientist Solomon H. Snyder (1984)

How Neurons Communicate

9-3 How do nerve cells communicate with other nerve cells?

Neurons interweave so intricately that even with a microscope you would have trouble seeing where one neuron ends and another begins. Scientists once believed that the axon of one cell fused with the dendrites of another in an uninterrupted fabric. Then British physiologist Sir Charles Sherrington (1857–1952) noticed that neural impulses were taking an unexpectedly long time to travel a neural pathway. Inferring that there must be a brief interruption in the transmission, Sherrington called the meeting point between neurons a **synapse.**

We now know that the axon terminal of one neuron is in fact separated from the receiving neuron by a *synaptic gap* (or *synaptic cleft*) less than 1 millionth of an inch wide. Spanish anatomist Santiago Ramón y Cajal (1852–1934) marveled at these near-unions of neurons, calling them "protoplasmic kisses." "Like elegant ladies air-kissing so as not to muss their makeup, dendrites and axons don't quite touch," notes poet Diane Ackerman (2004, p. 37). How do the neurons execute this protoplasmic kiss, sending information across the tiny synaptic gap? The answer is one of the important scientific discoveries of our age.

When an action potential reaches the knob-like terminals at an axon's end, it triggers the release of chemical messengers, called **neurotransmitters** (**FIGURE 9.4**). Within 1/10,000th of a second, the neurotransmitter molecules cross the synaptic gap and bind to receptor sites on the receiving neuron—as precisely as a key fits a lock. For an instant, the neurotransmitter unlocks tiny channels at the receiving site, and ions flow in, exciting or inhibiting the receiving neuron's readiness to fire. Then, in a process called **reuptake,** the sending neuron reabsorbs the excess neurotransmitters.

synapse [SIN-aps] the junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron. The tiny gap at this junction is called the *synaptic gap* or *synaptic cleft.*

neurotransmitters chemical messengers that cross the synaptic gaps between neurons. When released by the sending neuron, neurotransmitters travel across the synapse and bind to receptor sites on the receiving neuron, thereby influencing whether that neuron will generate a neural impulse.

reuptake a neurotransmitter's reabsorption by the sending neuron.

How Neurotransmitters Influence Us

9-4 How do neurotransmitters influence behavior, and how do drugs and other chemicals affect neurotransmission?

In their quest to understand neural communication, researchers have discovered dozens of different neurotransmitters and almost as many new questions: Are certain neurotransmitters found only in specific places? How do they affect our moods, memories, and mental abilities? Can we boost or diminish these effects through drugs or diet?

Later modules explore neurotransmitter influences on hunger and thinking, depression and euphoria, addictions and therapy. For now, let's glimpse how neurotransmitters influence our motions and our emotions. A particular brain pathway may use only one or two neurotransmitters (**FIGURE 9.5**), and particular neurotransmitters may affect specific

ENGAGE

Active Learning

An interesting way to demonstrate how the action potential works is to compare the process to a flushing toilet. Here are some concepts to highlight:

- All-or-none response is similar to the strength of each flush. When you depress the lever, the flush is the same each time.
- Threshold: A softer push of the lever will not create a flush because it does not reach threshold.
- Refractory period: In order to flush, the tank must be full. Two flushes in a row cannot occur if the tank has not had time to fill.

TEACH

Concept Connections

Neurotransmitters (NTs) are the key component for all behavior and mental processes. The NTs carry the messages for all that we do and send messages for us to be happy or sad, to move or stay still. NTs can function differently depending on where they are located in the nervous system. Scientists are still discovering how these chemicals work, so students should be aware that the information in this unit is in no way comprehensive or definitive, only the tip of the iceberg.

TEACH

Flip It

Have students watch the Flip It Video: Action Potential so they can have a working knowledge of this concept before coming to class. You can then focus on more active demonstrations of the neural communication in class.

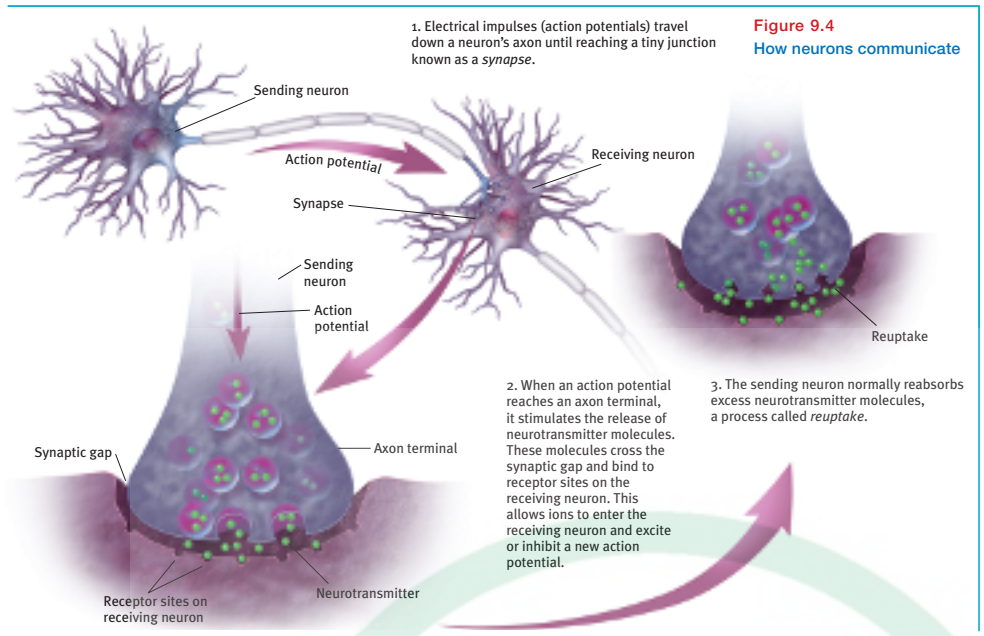


Figure 9.4
How neurons communicate

behaviors and emotions (**TABLE 9.1** on the next page). But neurotransmitter systems don't operate in isolation; they interact, and their effects vary with the receptors they stimulate. *Acetylcholine (ACh),* which is one of the best-understood neurotransmitters, plays a role in learning and memory. In addition, it is the messenger at every junction between motor neurons (which carry information from the brain and spinal cord to the body's tissues) and skeletal muscles. When ACh is released to our muscle cell receptors, the muscle contracts. If ACh transmission is blocked, as happens during some kinds of anesthesia, the muscles cannot contract and we are paralyzed.

"When it comes to the brain, if you want to see the action, follow the neurotransmitters."
-Neuroscientist Floyd Bloom (1993)

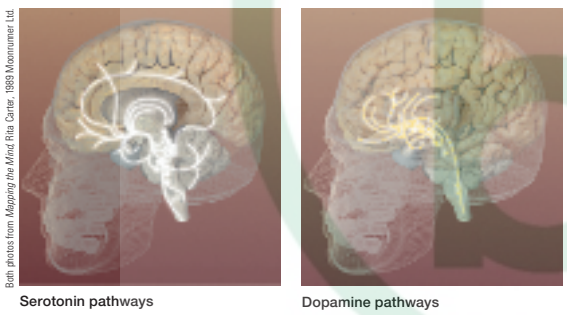


Figure 9.5
Neurotransmitter pathways Each of the brain's differing chemical messengers has designated pathways where it operates, as shown here for serotonin and dopamine (Carter, 1998).

TEACH

Common Pitfalls

From the diagram, it may seem to students that only 1 neuron and 1 neurotransmitter act on each synapse. However, some neurons can house more than 1 NT, and usually more than one neuron is present at any given synapse. Help students to realize that Figure 9. 4 is intentionally simplified to help communicate the basic idea of the process involved in neural communication, but that the reality is amazingly complex.

ENGAGE

Active Learning

Have students research myasthenia gravis, a neurological disorder resulting from the depletion of acetylcholine to help students understand how important acetylcholine is. Without ACh, the muscles do not move properly. People with this disorder experience extreme fatigue because it takes enormous effort to move muscles at all.

TEACH

Teaching Tip

Figure 9. 5 shows serotonin and dopamine pathways throughout the brain. Point out that the function of the neurotransmitter depends on which part of the brain it acts upon.

- If the NT is acting in the brainstem, it affects basic functions like breathing and heartbeat.
- If it acts on areas in the midbrain, it affects functions like memory and emotion.
- Finally, if it acts on areas in the cortex, higher functions like memory integration, problem solving, and perception are affected.

Helping students see this hierarchical organization of the brain and how NTs play a role in that will give them a better understanding of neuroanatomy.

LiquidLibrary/Jupiterimages

AP® Exam Tip

As the text indicates, there are dozens of different neurotransmitters. Though there's no way to predict exactly which ones you'll see on the AP® exam, it's quite possible that the ones in Table 9.1 are ones you'll be asked about.

Table 9.1 Some Neurotransmitters and Their Functions

Neurotransmitter	Function	Examples of Malfunctions
Acetylcholine (ACh)	Enables muscle action, learning, and memory.	With Alzheimer's disease, ACh-producing neurons deteriorate.
Dopamine	Influences movement, learning, attention, and emotion.	Oversupply linked to schizophrenia. Undersupply linked to tremors and decreased mobility in Parkinson's disease.
Serotonin	Affects mood, hunger, sleep, and arousal.	Undersupply linked to depression. Some antidepressant drugs raise serotonin levels.
Norepinephrine	Helps control alertness and arousal.	Undersupply can depress mood.
GABA (gamma-aminobutyric acid)	A major inhibitory neurotransmitter.	Undersupply linked to seizures, tremors, and insomnia.
Glutamate	A major excitatory neurotransmitter; involved in memory.	Oversupply can overstimulate the brain, producing migraines or seizures (which is why some people avoid MSG, monosodium glutamate, in food).

Researchers made an exciting discovery about neurotransmitters when they attached a radioactive tracer to morphine, showing where it was taken up in an animal's brain (Pert & Snyder, 1973). The morphine, an opiate drug that elevates mood and eases pain, bound to receptors in areas linked with mood and pain sensations. But why would the brain have these "opiate receptors"? Why would it have a chemical lock, unless it also had a natural key to open it?

Researchers soon confirmed that the brain does indeed produce its own naturally occurring opiates. Our body releases several types of neurotransmitter molecules similar to morphine in response to pain and vigorous exercise. These **endorphins** (short for *endo*genous [produced within] m*orphine*) help explain good feelings such as the "runner's high," the painkilling effects of acupuncture, and the indifference to pain in some severely injured people. But once again, new knowledge led to new questions.

Physician Lewis Thomas, on the endorphins: "There it is, a biologically universal act of mercy. I cannot explain it, except to say that I would have put it in had I been around at the very beginning, sitting as a member of a planning committee." -*The Youngest Science*, 1983

endorphins [en-DOR-fins] "morphine within"—natural, opiate-like neurotransmitters linked to pain control and to pleasure.

agonist a molecule that, by binding to a receptor site, stimulates a response.

HOW DRUGS AND OTHER CHEMICALS ALTER NEUROTRANSMISSION

If indeed the endorphins lessen pain and boost mood, why not flood the brain with artificial opiates, thereby intensifying the brain's own "feel-good" chemistry? One problem is that when flooded with opiate drugs such as heroin and morphine, the brain may stop producing its own natural opiates. When the drug is withdrawn, the brain may then be deprived of any form of opiate, causing intense discomfort. For suppressing the body's own neurotransmitter production, nature charges a price.

Drugs and other chemicals affect brain chemistry at synapses, often by either exciting or inhibiting neurons' firing. **Agonist** molecules may be similar enough to a neurotransmitter to bind to its receptor and mimic its effects. Some opiate drugs are agonists and produce a temporary "high" by amplifying normal sensations of arousal or pleasure.

Stephen VanHorn/Shutterstock

TEACH

Interdisciplinary Connections

Each of the neurotransmitters featured in Table 9. 1 is chemically similar to a drug or other chemical that affects behavior, cognition, and emotion. Here are similarities the chart does not point out:

- Dopamine is similar to cocaine.
- Serotonin is similar to LSD and Ecstasy.

Just as our body produces its own painkillers, so, too, does it produce the chemicals necessary for energy, euphoria, and even hallucinations. In healthy people, these chemicals are balanced to produce normal experiences. Taking illegal or nonprescribed drugs disrupts this balance, causing abnormal levels of energy, emotion, and sensory experience.

TEACH

Teaching Tip

Another neurotransmitter not described in Table 9. 1 is Substance P, the body's pain NT. This NT works in opposition with endorphins to regulate pain. Substance P signals that the body is in pain, and endorphins are triggered to inhibit the pain signal.

TEACH

Teaching Tip

Strenuous exercise triggers the release of endorphins. Studies of seasoned runners, for example, show that during a long, difficult workout the nervous system can dip into its endorphin reserve and not only block pain messages, but also produce the so-called runner's high. The endorphin system can be brought into action by neurostimulation therapy. In this pain-reducing technique, wires are pasted to the skin near an injury, and a slight electric current is delivered through electrodes. Low-frequency, high-intensity impulses stimulate endorphin release. Olympic athletes have used this method to ease various aches and pains. In February 2010, champion skier Lindsey Vonn competed in the Olympic downhill with an extremely painful shin injury. Despite the pain, she won a gold medal.

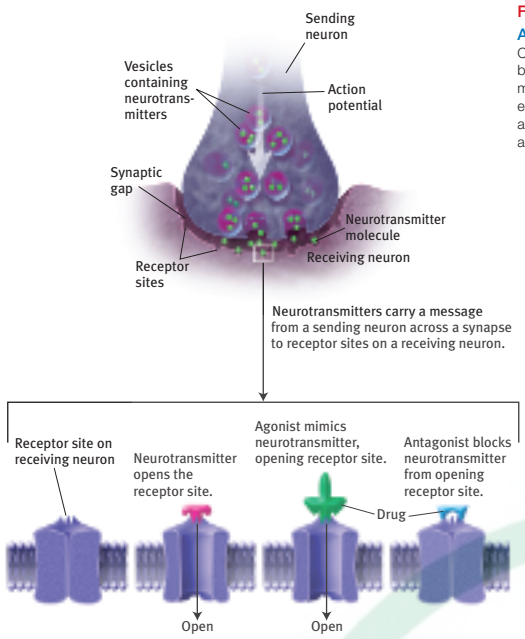


Figure 9.6
Agonists and antagonists
Curare poisoning paralyzes its victims by blocking ACh receptors involved in muscle movements. Morphine mimics endorphin actions. Which is an agonist, and which is an antagonist? (Art adapted from Higgins & George, 2007.)

ANSWER: Morphine is an agonist; curare is an antagonist.

Antagonists also bind to receptors but their effect is instead to block a neurotransmitter's functioning. Botulin, a poison that can form in improperly canned food, causes paralysis by blocking ACh release. (Small injections of botulin—Botox—smooth wrinkles by paralyzing the underlying facial muscles.) These antagonists are enough like the natural neurotransmitter to occupy its receptor site and block its effect, as in **FIGURE 9.6**, but are not similar enough to stimulate the receptor (rather like foreign coins that fit into, but won't operate, a candy machine). Curare, a poison some South American Indians have applied to hunting-dart tips, occupies and blocks ACh receptor sites on muscles, producing paralysis in animals struck by the darts.

antagonist a molecule that, by binding to a receptor site, inhibits or blocks a response.

Before You Move On

► ASK YOURSELF
Can you recall a time when the endorphin response may have protected you from feeling extreme pain?

► TEST YOURSELF
How do neurons communicate with one another?

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

AP® Exam Tip
Be very clear on this. Neurotransmitters are produced inside the body. They can excite and inhibit neural communication. Drugs and other chemicals come from outside the body. They can have an agonistic effect or an antagonistic effect on neurotransmission.

TEACH

Common Pitfalls

Be sure students understand the difference between agonist and antagonist when these terms pertain to drugs. These terms are often confused, so being able to distinguish between them will help students if these terms show up on the AP® exam.

TEACH

Teaching Tip

In order for drugs to have an effect on the body, there must be an accompanying receptor site on a neuron that matches the structure of that drug. Therefore, the body produces natural chemical substances that are similar to many of the drugs that affect the body. When we introduce drugs into our bodies, we are either increasing the amount of these substances in the body or blocking substances that are supposed to work in a specific way.

But not all substances can pass through the body's **blood–brain barrier,** which protects the brain from pathogens and harmful substances. For example, Parkinson's patients cannot simply take dopamine to alleviate their symptoms. They must take a precursor of dopamine called L-dopa that will metabolize into dopamine once it reaches the brain.

ENGAGE

Active Learning

Have students research how common prescription and recreational drugs are related to neurotransmitters. Discuss how our understanding of neurotransmitters can help people with neurological disorders and help us see how those who abuse drugs harm themselves.