# Unit III

## Biological Bases of Behavior

### Unit Overview

Biology and psychology are inextricably linked. For centuries, people have debated the relative importance of the mind and the body. Are the body and mind dependent on each other to exist? Or are the mind and body separate, coexisting to create a unified whole? Psychological science addresses questions about the mind and body, and their interaction with each other and with the environment. Without a doubt, an understanding of how the body works is critical to understanding ourselves.

Unit III presents an overview of the biology of the nervous system, the main system involved in behavior and mental processes. The nervous system is incredibly complex, and what students read in this book is only the beginning of what we know about how it all works to produce even the most basic of behaviors and cognitions. Unit III also examines the role of genetics and evolution in our understanding of ourselves. After learning about the concepts in this unit, students should be able to:

- Evaluate the importance of studying biology in a psychology course
- Describe the basic parts, mechanisms, and processes that make up the nervous systems
- Explain how the endocrine system and nervous systems interact
- Describe techniques used to study the brain and nervous systems
- Identify subfields in psychology devoted to studying the interaction of biology and environment
- Discuss how the brain adapts to change through reorganization and neurogenesis
- Explain the processes and findings of split-brain research
- Explain how the brain utilizes dual processing
- Describe the mechanisms and processes of behavior genetics
- Analyze the ways principles of behavior and molecular genetics explain the interaction of heredity and environment
- Explain heritability and how it relates to explain individual and group differences
- Describe and evaluate the principles of evolution as they relate to behavior tendencies and gender differences
- Summarize key points in the debate about the usefulness of evolutionary psychology
- Describe the biopsychosocial approach to development

### Alignment to AP® Course Description

**Topic 3: Biological Bases of Behavior (8–10% of AP® Examination)**

<table>
<thead>
<tr>
<th>Module</th>
<th>Topic</th>
<th>Essential Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 9</td>
<td>Biology, Behavior, and Mind</td>
<td>• Why is studying biology important to understanding psychology?</td>
</tr>
<tr>
<td></td>
<td>Neural Communication</td>
<td>• Why is knowing about neural communication important?</td>
</tr>
<tr>
<td>Module 10</td>
<td>The Nervous System</td>
<td>• Why is knowing about the nervous system important?</td>
</tr>
<tr>
<td></td>
<td>The Endocrine System</td>
<td>• How do the endocrine system and nervous system interact?</td>
</tr>
<tr>
<td>Module 11</td>
<td>The Tools of Discovery: Having our Heads Examined</td>
<td>• How have modern techniques of studying the brain helped our understanding of behavior and mental processes?</td>
</tr>
<tr>
<td></td>
<td>Older Brain Structures</td>
<td>• Why are the parts of the brain that control more basic function called &quot;older&quot;?</td>
</tr>
<tr>
<td>Module 12</td>
<td>Structure of the Cortex</td>
<td>• What qualities of the cortex differentiate humans from other animals?</td>
</tr>
<tr>
<td></td>
<td>Functions of the Cortex</td>
<td>• How are the functions of the cortex different and similar to other animals?</td>
</tr>
<tr>
<td></td>
<td>The Brain’s Plasticity</td>
<td>• Why is it important for the brain to be plastic and regenerative?</td>
</tr>
<tr>
<td>Module 13</td>
<td>Our Divided Brain</td>
<td>• What can research of split brain tell us, or not tell us, about how the brain works?</td>
</tr>
<tr>
<td></td>
<td>Right–Left Differences in the Intact Brain</td>
<td>• How do intact brains work differently from split brains?</td>
</tr>
<tr>
<td></td>
<td>The Biology of Consciousness</td>
<td>• What are the benefits and drawbacks of dual processing?</td>
</tr>
<tr>
<td>Module 14</td>
<td>Genes: Our Codes for Life</td>
<td>• How important are your genes to your daily behavior and mental processes?</td>
</tr>
</tbody>
</table>
### Module 14 (cont.)

- **Twin and Adoption Studies**
  - How do studies of twins and adoptees inform us about the nature–nurture issue?

- **The New Frontier: Molecular Genetics**
  - What is the promise of molecular genetics research?

- **Heritability**
  - How does knowing the heritability of a trait help inform an individual about behavior and mental processes?

- **Gene–Environment Interaction**
  - How do heredity and environment work together?

### Module 15

- **Natural Selection and Adaptation**
  - How much do natural selection and adaptation influence daily life?

- **Evolutionary Success Helps Explain Similarities**
  - How is being genetically similar important?

- **An Evolutionary Explanation of Human Sexuality**
  - What is the value of evolutionary explanations for gender differences?

- **Reflections on Nature and Nurture**
  - How would you explain the nature–nurture issue to someone who has not studied psychology?

## Unit Resources

### Module 9

- **STUDENT ACTIVITIES**
  - Fact or Falsehood?
  - Neural Transmission

- **TEACHER DEMONSTRATIONS**
  - Modeling a Neuron and Using Dominoes to Illustrate the Action Potential

- **FLIP IT VIDEOS**
  - Action Potential

### Module 10

- **STUDENT ACTIVITIES**
  - Fact or Falsehood?
  - Reaction-Time Measure of Neural Transmission and Mental Processes

- **FLIP IT VIDEOS**
  - Structure of the Nervous System
  - Reflex Arc

### Module 11

- **STUDENT ACTIVITIES**
  - Fact or Falsehood?
  - A Portable Brain Model
  - Case Studies in Neuroanatomy

- **FLIP IT VIDEOS**
  - Limbic System

### Module 12

- **STUDENT ACTIVITY**
  - Fact or Falsehood?

- **TEACHER DEMONSTRATIONS**
  - Neuroscience and Moral Judgments

- **FLIP IT VIDEOS**
  - Structure and Function of the Cortex

### Module 13

- **STUDENT ACTIVITY**
  - Fact or Falsehood?
  - The Wagner Preference Inventory

- **TEACHER DEMONSTRATIONS**
  - Behavioral Effects of the Split-Brain Operation
  - Hemispheric Specialization

- **FLIP IT VIDEOS**
  - Split-Brain Research

### Module 14

- **STUDENT ACTIVITY**
  - Fact or Falsehood?
  - Striking Similarities

- **FLIP IT VIDEOS**
  - Heritability

### Module 15

- **STUDENT ACTIVITY**
  - Fact or Falsehood?
  - Mate Preferences
Imagine that just moments before your death, someone removed your brain from your body and kept it alive by floating it in a tank of fluid while feeding it enriched blood. Would you still be in there? Further imagine that your still-living brain was transplanted into the body of a person whose own brain had been severely damaged. To whose home should the recovered patient return? If you say the patient should return to your home, you illustrate what most of us believe—that we reside in our head. An acquaintance of mine received a new heart from a woman who had received a heart-lung transplant. When the two chanced to meet in their hospital ward, she introduced herself: “I think you have my heart.” But only her heart; her self, she assumed, still resided inside her skull. We rightly presume that our brain enables our mind. Indeed, no principle is more central to today’s psychology, or to this book, than this: Everything psychological is simultaneously biological.
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.
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.

### 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.


### 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.
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.

Neurons

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 enclosed in a myelin sheath, a fatty tissue layer segmentally encasing the axons of some neurons, that enables vastly greater transmission speed as neural impulses hop from one sausage-like node to the next.

Neural impulses are brief electrical charges that travel down an axon. They pass from one to another at the nodes of myelination—the resulting “jumping” produces the neural impulse, or action potential. In an axon, the action potential may travel as quickly as 400 miles per hour. Conservation of energy makes the axon’s insulation worthwhile. Without it, the brain activity in the body’s electrical system would resemble the current drawn by a home electrical system. Axons must transmit impulses quickly or the body would be paralyzed.

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.

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.
millions (thousands 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 your 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.

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 brakes.

**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.

**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.
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**

**Concept Connections**

How do nerve cells communicate with other nerve cells?

Neurons interweave so intimately that even with a microscope you would have trouble seeing where one neuron ends and another begins. Scientists once believed that the axons 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-uncrossed 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 neurosynapses 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.

How Neurotransmitters Influence Us

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 chapters explore neurotransmitter influences on hunger and thinking, depression and euphoria, addictions and therapy. For now, let’s glimpse how neurotransmitters influence our moods and our emotions. A particular brain pathway may use only one neurotransmitter (FIGURE 9.5), and particular neurotransmitters may affect specific...
Please provide the content of the document so I can assist you better.
triggered to inhibit the pain signal.

The body is in pain, and endorphins are late pain. Substance P signals that the body’s pain NT. This NT works in opposition with endorphins to regulate pain. As the text indicates, there are dozens of 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.

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 (Port & 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 endogenous opiates, thereby intensifying the brain’s own “feel-good” chemistry) 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.

**Table 9.1 Some Neurotransmitters and Their Functions**

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

In areas linked with mood and pain sensations. 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 endogenous opiates, thereby intensifying the brain’s own “feel-good” chemistry) 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.

**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 charged 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 bond 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.
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.
Module 9 Review

9-1 Why are psychologists concerned with human biology?
- Psychologists working from a biological perspective study the links between biology and behavior.
- We are biopsychosocial systems, in which biological, psychological, and social-cultural factors interact to influence behavior.

9-2 What are the parts of a neuron, and how are neural impulses generated?
- Neurons are the elementary components of the nervous system, the body's speedy electrochemical information system.
- A neuron receives signals through its branching dendrites, and sends signals through its axons.
- Some axons are encased in a myelin sheath, which enables faster transmission.
- If the combined received signals exceed a minimum threshold, the neuron fires, transmitting an electrical impulse (the action potential) down its axon by means of a chemistry-to-electricity process. The neuron's reaction is an all-or-none process.

9-3 How do nerve cells communicate with other nerve cells?
- When action potentials reach the end of an axon (the axon terminals), they stimulate the release of neurotransmitters.
- These chemical messengers carry a message from the sending neuron across a synapse to receptor sites on a receiving neuron.
- The sending neuron, in a process called reuptake, then reabsorbs the excess neurotransmitter molecules in the synaptic gap.
- If incoming signals are strong enough, the receiving neuron generates its own action potential and relays the message to other cells.

9-4 How do neurotransmitters influence behavior, and how do drugs and other chemicals affect neurotransmission?
- Neurotransmitters travel designated pathways in the brain and may influence specific behaviors and emotions.
- Acetylcholine (ACh) affects muscle action, learning, and memory.
- Endorphins are natural opiates released in response to pain and exercise.
- Drugs and other chemicals affect brain chemistry at synapses.
- Agonists excite by mimicking particular neurotransmitters or by blocking their reuptake.
- Antagonists inhibit a particular neurotransmitter's release or block its effect.

Multiple-Choice Questions

1. Multiple sclerosis is a result of degeneration in the
   a. dendrite.
   b. axon.
   c. myelin sheath.
   d. terminal button.
   e. neuron.

2. Junita does not feel like getting out of bed, has lost her appetite, and feels tired most of the day. Which of the following neurotransmitters is in short supply for Junita?
   a. Dopamine
   b. Serotonin
   c. Acetylcholine
   d. Glutamate
   e. Norepinephrine

3. Which neurotransmitter inhibits CNS activity in order to calm a person down during stressful situations?
   a. GABA
   b. Norepinephrine
   c. Serotonin

4. Phrenology has been discredited, but which of the following ideas has its origins in phrenology?
   a. Brain lateralization
   b. Brain cavities contributing to sense of humor
   c. Bumps in the left hemisphere leading to emotional responses
   d. Brain function localization
   e. Belief that the mind pumps warmth and vitality into the body
5. When there is a negative charge inside an axon and a positive charge outside it, the neuron is
   a. in the process of reuptake.
   b. not in the refractory period.
   c. said to have a resting potential.
   d. said to have an action potential.
   e. depolarizing.
6. Morphine elevates mood and eases pain, and is most similar to which of the following?
   a. Dopamine
   b. Serotonin
   c. Endorphins
   d. Acetylcholine
   e. GABA

Practice FRQs

1. While hiking, Ken stumbled and fell down a 10-foot drop-off. Upon landing, he sprained his ankle badly. Ken was surprised that he felt very little pain for the first half hour. Explain how the following helped Ken feel little pain in the moments after the injury.
   • Endorphins
   • The synapse

Answer
1 point: Endorphins are natural, opiate-like neurotransmitters linked to controlling pain.
1 point: The synapse is the space between neurons where neurotransmitters like the endorphins carry information that influences how Ken feels.

2. Explain the role each of the following plays in sending a message through a neuron.
   • Dendrites
   • Axon
   • Myelin sheath

7. Neurotransmitters cross the ________ to carry information to the next neuron.
   a. synaptic gap
   b. axon
   c. myelin sheath
   d. dendrites
   e. cell body

8. What neurotransmitters are most likely in undersupply in someone who is depressed?
   a. Dopamine and GABA
   b. ACh and norepinephrine
   c. Dopamine and norepinephrine
   d. Serotonin and norepinephrine
   e. Serotonin and glutamate

Answer to Practice FRQ 2

1 point: Dendrites receive messages from other neurons.
1 point: The axon is an extension that makes it possible for the neuron to carry information over greater distances.
1 point: The myelin sheath covers the axon of some neurons and serves to speed up the action potential.
Module 10

The Nervous and Endocrine Systems

Module Learning Objectives

10-1 Describe the functions of the nervous system’s main divisions, and identify the three main types of neurons.

10-2 Describe the nature and functions of the endocrine system and its interaction with the nervous system.

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

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

The Nervous System

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

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

Information travels in the nervous system through three types of neurons. Sensory neurons carry messages from the body’s tissues and sensory receptors inward to the brain and spinal cord for processing. Motor neurons carry instructions from the central nervous system (CNS) to the rest of the body. Nerve bundles that form neural “cables” connecting the central nervous system (CNS) to the rest of the body.

Common Pitfalls

Students may have trouble understanding that the nervous system is an integrated network. The divisions discussed in this unit were created to recognize the executive function of the brain and spinal cord and the delivery function of the peripheral nerves. These 2 systems work seamlessly together, even though we separate them to understand them better.
nervous system out to the body's muscles and glands. Between the sensory input and motor output, information is processed in the brain's internal communication system via interneurons. Our complexity resides mostly in our interneuronal systems. Our nervous system has a few million sensory neurons, a few million motor neurons, and billions and billions of interneurons.

**The Peripheral Nervous System**

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

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

The autonomic nervous system serves two important, basic functions (FIGURE 10.2 on the next page). The sympathetic nervous system arouses and expends energy. If something alarms or challenges you (such as taking the AP® Psychology exam, or being stuffed in an MRI machine), your sympathetic nervous system will accelerate your heartbeat, raise your blood pressure, slow your digestion, raise your blood sugar, and cool you with perspiration. The parasympathetic nervous system calms. Its division of the autonomic nervous system controls the body's internal organs (such as the heart). Its automatic division arouses, its parasympathetic division calms.

**The Central Nervous System**

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

**TEACH**

**Common Pitfalls**

Remember what the sympathetic nervous system does by thinking about what we do when we feel sympathy—we try to help actively by comforting and consoling others. We have to act to help others, so the sympathetic nervous system will kick in, giving us the energy we need to accomplish our goals.

**TEACH**

**Teaching Tip**

Help students remember the differences among the nervous systems with these mnemonics:

- **Central nervous system**: The brain and spinal cord are located in the center of the body.
- **Peripheral nervous system**: Fingers and toes lie in the outermost areas of the body from the center, or the periphery of the body.
- **Somatic nervous system**: Volunteer work is done by choice, so the body's (or somatic) voluntary actions are controlled by this nervous system.
- **Autonomic nervous system**: Autonomic sounds similar to the word automatic, and the body's automatic actions (breathing, heartbeat, etc.) are controlled by this nervous system.

**TEACH**

**Concept Connections**

The sympathetic and parasympathetic nervous systems together make an opponent process system. Opponent processes work in opposition of each other, with one system performing one role and the other system performing the exact opposite role. In this case, the sympathetic nervous system causes the body to rise to the challenge it faces and the parasympathetic nervous system causes the body to calm after the challenge has been addressed. This opposition creates homeostasis, or balance, in the body.
Teaching Tip
Sensory neurons connect to the spinal cord dorsally, or in your back. Motor neurons connect in the anterior of the spinal cord, or in the front. Therefore, it is possible to lose feeling in lower portions of the body in a spinal cord injury but retain the ability to move if the spinal cord is not completely severed.

Teaching Tip
The dendrites of neurons contribute significantly to the complexity of the neural network. The more dendrites a neuron has, the greater the number of connections that 1 neuron can make with other neurons, increasing the likelihood that its message will get passed along the chain.

Common Pitfalls
The neural chain, also known as the reflex arc, can be described graphically.

Teaching Tip
Have you ever jerked away from a hot surface only to feel the burn after a delay? Interneurons make reflexes happen. These cells in the spinal cord process motor responses quickly to protect the body from harm. Without interneurons, you would experience severe burns if you left your hand on that hot surface long enough to process both the heat and the pain before jerking away!
The other part of the CNS, the spinal cord, is a two-way information highway connecting the peripheral nervous system and the brain. Ascending neural fibers send up sensory information, and descending fibers send back motor-control information. The neural pathways governing our reflexes, our automatic responses to stimuli, illustrate the spinal cord’s work. A simple spinal reflex pathway is composed of a single sensory neuron and a single motor neuron. These often communicate through an interneuron. The knee-jerk response, for example, involves one such simple pathway. A headless warm body could do it.

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

Information travels to and from the brain by way of the spinal cord. Were the top of your spinal cord severed, you would not feel pain from your paralyzed body below. Nor would you feel your hands jerking away not by your choice, but on its own.

1. In this simple pain reflex, information is carried from skin receptors along a sensory neuron (shown by the large red arrow) to the spinal cord. From there it is passed via interneurons to motor neurons (blue arrows) that lead to the muscles in the hand and arm.

2. Because this reflex involves only the spinal cord, the hand jerks away from the candle flame even before information about the event has reached the brain, causing the experience of pain.
ENGAGE
Active Learning
Have students research disorders of the endocrine system, including diabetes, abnormal growth, and hypo- and hyperthyroidism. Focus on the following questions:
- What physical problems do these disorders cause?
- What emotional problems do these disorders cause?
- What treatments are available for these disorders?

TEACH
Teaching Tip
Students may need to know some major endocrine glands for the AP® exam. Some important endocrine glands and the hormones they secrete are listed below:
- **Anterior pituitary gland** secretes growth hormone. Too little produces dwarfism; too much results in gigantism.
- **Posterior pituitary gland** secretes vasopressin (in addition to oxytocin), constricting blood vessels and raising blood pressure. Oxytocin in women sparks labor during pregnancy.
- **Thyroid** releases thyroxine and triiodothyronine, increasing metabolic rate, growth, and maturation.
- **Parathyroids** release parathyroid hormone, increasing blood calcium and decreasing potassium.
- **Pancreas** secretes insulin, regulating the level of sugar in the bloodstream.
- **Ovaries** secrete estrogen, promoting ovulation and female sex characteristics.
- **Testes** release androgens, promoting sperm production and male sex characteristics.

The Endocrine System
10-2
What is the nature and what are the functions of the endocrine system, and how does it interact with the nervous system?

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

Before You Move On
- **ASK YOURSELF**
  Does our nervous system’s design—with its synaptic gaps that chemical messenger molecules cross in an imperceptibly brief instant—surprise you? Would you have designed yourself differently?
- **TEST YOURSELF**
  How does information flow through your nervous system as you pick up a fork? Can you summarize this process?

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

The Endocrine System

**Figure 10.5**
**The endocrine system**

- **Hypothalamus** (brain region controlling the pituitary gland)
- **Pituitary gland** (controls many different hormones, some of which affect other glands)
- **Thyroid gland** (affects metabolism)
- **Thyroid gland** (affects metabolism)
- **Adrenal glands** (inner part helps trigger the “fight-or-flight” response)
- **Pancreas** (regulates the level of sugar in the blood)
- **Testes** (secretes male sex hormones)
- **Ovary** (secretes female sex hormones)
Some hormones are chemically identical to neurotransmitters (the chemical messengers that diffuse across a synapse and excite or inhibit an adjacent neuron). The endocrine system and nervous system are therefore close relatives. Both produce molecules that act on receptors elsewhere. Like many relatives, they also differ. The speedy nervous system zips messages from eyes to brain to hand in a fraction of a second. Endocrine messages trudge along in the bloodstream, taking several seconds or more to travel from the gland to the target tissue. If the nervous system’s communication delivers messages with the speed of a text message, the endocrine system is more like sending a letter through the mail.

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

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

Pituitary secretions also influence the release of hormones by other endocrine glands. The pituitary, then, is a sort of master gland (whose own master is the hypothalamus). For example, under the brain’s influence, the pituitary triggers your sex glands to release sex hormones. These in turn influence your brain and behavior. So, too, with stress. A stressful event triggers your hypothalamus to instruct your pituitary to release a hormone that causes your adrenal glands to flood your body with cortisol, a stress hormone that increases blood sugar. This feedback system (brain → pituitary → other glands → hormones → body and brain) reveals the intimate connection of the nervous and endocrine systems. The nervous system directs endocrine secretions, which then affect the nervous system. Conducting and coordinating this whole electrochemical orchestra is that maestro we call the brain.
Module 10 Review

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

- The central nervous system (CNS)—the brain and the spinal cord—is the nervous system's decision maker.
- The peripheral nervous system (PNS), which connects the CNS to the rest of the body by means of nerves, gathers information and transmits CNS decisions to the rest of the body.
- The two main PNS divisions are the somatic nervous system (which enables voluntary control of the skeletal muscles) and the autonomic nervous system (which controls involuntary muscles and glands by means of its sympathetic and parasympathetic divisions).
- Neurons cluster into working networks.
- There are three types of neurons:
  1. Sensory neurons carry incoming information from sense receptors to the brain and spinal cord.
  2. Motor neurons carry information from the brain and spinal cord out to the muscles and glands.
  3. Interneurons communicate within the brain and spinal cord and between sensory and motor neurons.

10-2 What is the nature and what are the functions of the endocrine system, and how does it interact with the nervous system?

- The endocrine system is a set of glands that secrete hormones into the bloodstream, where they travel through the body and affect other tissues, including the brain. The adrenal glands, for example, release the hormones that trigger the fight-or-flight response.
- The endocrine system’s master gland, the pituitary, influences hormone release by other glands. In an intricate feedback system, the brain’s hypothalamus influences the pituitary gland, which influences other glands, which release hormones, which in turn influence the brain.

Multiple-Choice Questions

1. Which of the following carries the information necessary to activate withdrawal of the hand from a hot object?
   a. Sensory neuron
   b. Motor neuron
   c. Interneuron
   d. Receptor neuron
   e. Reflex

2. Hormones are ______ released into the _______
   a. neurons; neurotransmitters
   b. chemical messengers; bloodstream
   c. electrical messengers; bloodstream
   d. electrical messengers; synapse
   e. chemical messengers; synapse

3. Which division of the nervous system produces the startle response?
   a. Parasympathetic
   b. Central
   c. Somatic
   d. Sympathetic
   e. Autonomic

4. Which of the following endocrine glands may explain unusually tall height in a 12-year-old?
   a. Pituitary
   b. Adrenal
   c. Pancreas
   d. Parathyroid
   e. Testes

5. Which of the following communicates with the pituitary, which in turn controls the endocrine system?
   a. Brachyroidis
   b. Autonomic nervous system
   c. Hypothalamus
   d. Spinal cord
   e. Pancreas

6. Which branch of the nervous system calms a person?
   a. Central nervous system
   b. Sympathetic
   c. Parasympathetic
   d. Somatic
   e. Endocrine

Answers to Multiple-Choice Questions

1. b  3. d  5. c
2. b  4. a  6. c
7. Epinephrine and norepinephrine increase energy and are released by the
   a. thyroid glands.
   b. pituitary gland.
   c. hypothalamus.
   d. thalamus.
   e. adrenal glands.

8. Interneurons are said to
   a. send messages from specific body parts to the brain.
   b. transmit and process information within the brain and spinal cord.
   c. act as connectors, supporting other neurons in the brain.
   d. send messages from the brain to body parts.
   e. influence the pituitary gland.

Practice FRQs
1. While walking barefoot, you step on a piece of glass. Before you have a chance to consciously process what has happened, you draw your foot away from the glass. Identify and explain the three types of neurons that deal with information regarding this painful stimulus.

   Answer
   1 point: Sensory neurons carry information from the point of the injury to the central nervous system.
   1 point: Interneurons are neurons within the brain and spinal cord. Interneurons would help you interpret the pain and enable your brain to send out marching orders.
   1 point: Motor neurons carry the instruction from the central nervous system to activate the muscles in your leg and foot.

2. Name and describe the components and subcomponents of the peripheral nervous system.

   (4 points)

   a. Peripheral nervous system
   b. Sensory neurons
   c. Motor neurons
   d. Autonomic nervous system
   e. Somatic nervous system

   a. Cervical ganglia
   b. Sympathetic ganglia
   c. Parasympathetic ganglia

   a. Spinal nerves
   b. Cranial nerves
   c. Spinal cord

   a. Somatic nervous system
   b. Autonomic nervous system
   c. Somatic nerves
   d. Autonomic nerves

   a. Spinal nerves
   b. Cranial nerves
   c. Spinal cord

Answer to Practice FRQ 2
1 point: Somatic nervous system. The somatic nervous system controls voluntary movement of the body.

1 point: Autonomic nervous system. The autonomic nervous system controls the glands and the internal organs.

1 point: Sympathetic nervous system. The sympathetic nervous system is the division of the autonomic nervous system that arouses the body in times of emergency (fight or flight).

1 point: Parasympathetic nervous system. The parasympathetic nervous system is the division of the autonomic nervous system that calms the body when no emergency exists (rest and digest).
Discuss the concepts from this module.

Common Pitfalls

Many of the now-outdated ideas about the brain (the 10% myth, phrenology, brain size equaling intelligence, etc.) were debunked thanks to neuroimaging techniques. The ability to see the inner workings of the brain in action has revolutionized the way we think about psychology.

Active Learning

Many items are available for use in discussing brain structure and function:

- **A variety of brain models useful for lecturing on brain structure is available from Ward's Natural Science (https://wardsci.com). One of the simplest and least expensive is the Introductory Brain model. It is bisected to show major structures both internally and externally as well as painted and numbered to distinguish the various components. Larger and more detailed models (e.g., one that allows you to dissect the brain into 8 parts and shows the intricate details of the limbic system) are available.**

- **3B Scientific (www.3bs.com) has numerous brain models available for purchase. You can view detailed descriptions and pictures of the models at their website.**

- **For something simple and inexpensive, yet sure to capture students’ attention, consider “The Brain Gelatin Mold” that enables you to make and bring a brain to class. Gerald Peterson suggests implanting some fruit to represent certain brain structures, such as the limbic system. The plastic mold actually provides the left hemisphere of a jiggly brain. It is available from Archie McFee & Co. at www.mcphee.com/shop.**

See Student Activity: A Portable Brain Model from the TRM for students to build 3-D models of the human brain themselves.
Today’s neuroscientists can also electrically, chemically, or magnetically stimulate various parts of the brain and note the effect. Depending on the stimulated brain part, people may—to name a few examples—giggle, hear voices, turn their head, feel themselves falling, or have an out-of-body experience (Selimbeyoglu & Parvizi, 2010). Scientists can even snoop on the messages of individual neurons. With tips so small they can detect the electrical pulse in a single neuron, modern microelectrodes can, for example, now detect exactly where the information goes in a cat’s brain when someone strikes its whisker. Researchers can also eavesdrop on the chatter of billions of neurons and can see color representations of the brain’s energy-consuming activity.

Right now, your mental activity is emitting telltale electrical, metabolic, and magnetic signals that would enable neuroscientists to observe your brain at work. Electrical activity in your brain’s billions of neurons sweeps in regular waves across its surface. An electroencephalogram (EEG) is an amplified readout of such waves. Researchers record the brain waves through a shower-cap–like hat that is filled with electrodes covered with a conductive gel. Studying an EEG of the brain’s activity is like studying a car engine by listening to its hum. With no direct access to the brain, researchers present a stimulus repeatedly and have a computer filter out brain activity unrelated to the stimulus. What remains is the electrical wave evoked by the stimulus (FIGURE 11.1).

“You must look into people, as well as at them,” advised Lord Chesterfield in a 1746 letter to his son. Unlike EEGs, newer neuroimaging techniques give us that Superman-like ability to see inside the living brain. For example, the CT (computed tomography) scan examines the brain by taking X-ray photographs that can reveal brain damage. Even more dramatic is the PET (positron emission tomography) scan (FIGURE 11.2 on the next page), which depicts brain activity by showing each brain area’s consumption of its chemical fuel, the sugar glucose. Active neurons are glucose hogs, and after a person receives temporarily radioactive glucose, the PET scan can track the gamma rays released by this “fuel for thought” as the person performs a given task. Rather like weather radar showing rain activity, PET-scan “hot spots” show which brain areas are most active as the person does mathematical calculations, looks at images of faces, or daydreams.

In MRI (magnetic resonance imaging) brain scans, the person’s head is put in a strong magnetic field, which aligns the spinning atoms of brain molecules. Then, a radio-wave pulse momentarily disorients the atoms. When the atoms return to their normal spin, they emit signals that provide a detailed picture of soft tissues, including the brain. MRI scans have revealed a larger-than-average neural area in the left hemisphere of musicians who display perfect pitch (Schlaug et al., 1995). They have also revealed enlarged ventricles—fluid-filled brain areas

**Figure 11.1**

*An electroencephalogram providing amplified tracings of waves of electrical activity in the brain.* Here it is displaying the brain activity of this 4-year-old who has epilepsy.

---

**TEACH**

**Concept Connections**

The scans discussed here are used to gain knowledge about most of the theories discussed throughout the book:

- Diagnosing psychological disorders
- Determining how drugs affect the brain and body
- Assessing the usefulness of hypnosis
- Examining whether unconscious processes affect behavior
- Exploring the interaction of sensation and perception

These are just a few of the ways that brain scans help psychologists understand behavior and mental processes better.

**ENGAGE**

**Enrichment**

Researchers are quick to acknowledge the limits of their methodology. For example, Dartmouth’s Michael Gazzaniga notes that the fMRI traces brain activity by tracking blood flow, which rises whenever there is a surge in metabolism. Elements of some tasks, he suggests, “may be so automatic that they require no increase in metabolism,” thus allowing active brain regions to slip past the technique undetected. Eric Kandel of Columbia University College of Physicians and Surgeons adds, “If a number of areas show activation, we don’t know whether they are causally involved or going along for the ride.” Certainly, no one claims that research will identify a single brain area as the site of morality or consciousness. “Everything that happens in the brain is based on the work of systems, like music in an orchestra performed from a score,” says Antonio Damasio of University of Iowa. “It all sounds like one thing, but it’s coming from 100 or more individual parts. What we’re doing is finding out those little parts.”

dents debate the following questions:

- If humans and other mammals share so many parts of the brain, what makes humans different from other mammals?
- Does explaining the brain from an evolutionary standpoint make you feel more or less different from other animals? Why?

### Critical Questions

When Myers refers to “older” parts of the brain, he is highlighting the parts that are shared in common with other mammals and are therefore the earliest parts of the brain to evolve. Have students debate the following questions:

- What are the evolutionary advantages of the parts of the brain that are shared in common with other mammals?
- Does explaining the brain from an evolutionary standpoint make you feel more or less different from other animals? Why?

### TEACH

#### Concept Connections

Help students realize that the auditory hallucinations people with schizophrenia experience are triggered in the brain without external stimulation. People with schizophrenia are actually hearing voices, but those voices have no external basis; MRI scans show that there is a biological basis for their hallucinations.

#### ENGAGE

#### Critical Questions

When Myers refers to “older” parts of the brain, he is highlighting the parts that are shared in common with other mammals and are therefore the earliest parts of the brain to evolve. Have students debate the following questions:

- If humans and other mammals share so many parts of the brain, what makes humans different from other mammals?
- Does explaining the brain from an evolutionary standpoint make you feel more or less different from other animals? Why?

### TEACH

#### Teaching Tip

Have students practice what each part of the brain is responsible for. First, they should list the parts of the brain. Then, give them a scenario (for example, playing in a soccer game or riding a bike on a busy street), and ask them to note what each part of the brain does during the scenario.
This increasing complexity arises from new brain systems built on top of the old, much as the Earth's landscape covers the old with the new. Digging down, one discovers the fossil remnants of the past—brainstem components performing for us much as they did for our distant ancestors. Let's start with the brain's basement and work up to the newer systems.

**The Brainstem**

The brain's oldest and innermost region is the brainstem. It begins where the spinal cord swells slightly after entering the skull. This slight swelling is the medulla (FIGURE 11.4). Here lie the controls for your heartbeat and breathing. As some brain-damaged patients in a vegetative state illustrate, we need no higher brain or conscious mind to orchestrate our heart's pumping and lungs' breathing. The brainstem handles those tasks.

Just above the medulla sits the pons, which helps coordinate movements. If a cat's brainstem is severed from the rest of the brain above it, the animal will still breathe and live—and even run, climb, and groom (Klemm, 1990). But cut off from the brain's higher regions, it won't purposefully run or climb to get food.

The brainstem is a crossover point, where most nerves to and from each side of the brain connect with the body's opposite side (FIGURE 11.5). This peculiar cross-wiring is but one of the brain's many surprises.

**The Thalamus**

Sitting atop the brainstem is the thalamus, a pair of egg-shaped structures that act as the brain's sensory control center (FIGURE 11.4). The thalamus receives information from all the senses except smell and routes it to the higher brain regions that deal with seeing, hearing, tasting, and touching. The thalamus also receives some of the higher brain's replies, which it then directs to the medulla and to the cerebellum (see the next page). Think of the thalamus as being to sensory information what London is to England's trains: a hub through which traffic passes en route to various destinations.

**Common Pitfalls**

Discussing the brain as having "older" structures points to the influence of evolution on the ways we think about the brain. Some students may feel that discussing evolution runs counter to religious or cultural beliefs. Focus this discussion on the ideas of how mammals share common parts of the nervous system. This commonality has allowed us to understand better both nonhuman animals and ourselves.

**Teaching Tip**

Identifying and labeling diagrams are a type of question that often shows up on the AP® exam. Give your students the opportunity to practice this type of question by having them label diagrams like the one in Figure 11.4.

Use Student Activity: Case Studies in Neuroanatomy from the TRM for practice on labeling brain areas activated during certain situations.

**Common Pitfalls**

Make sure students know that the nerves from each side of the body cross over in the brainstem. The right side of the brain controls the left side of the body and vice versa. Students will need to know this later in the portion of the unit when they study hemisphere specialization.
The Reticular Formation

Inside the brainstem, between your ears, lies the reticular ("reticulate") formation, a neuron network that extends from the spinal cord right up through the thalamus. As the spinal cord’s sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli and relays important information to other brain areas.

In 1949, Giuseppe Moruzzi and Horace Magoun discovered that electrically stimulating the reticular formation of a sleeping cat almost instantly produced an awake, alert animal. When Magoun severed a cat’s reticular formation without damaging the nearby sensory pathways, the effect was equally dramatic: The cat lapse into a coma from which it never awakened. The conclusion? The reticular formation enables arousal.

The Cerebellum

Extending from the rear of the brainstem is the baseball-sized cerebellum, meaning “little brain,” which is what its two wrinkled halves resemble (FIGURE 11.6). As you will see in Module 32, the cerebellum enables nonverbal learning and memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures (Bower & Parsons, 2003). And it coordinates voluntary movement (with assistance from the pons). When a soccer player executes a perfect bicycle kick (above), give his cerebellum nerve credit. If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky and exaggerated. Gone would be any dreams of being a dancer or guitarist. Under alcohol’s influence on the cerebellum, coordination suffers, as many a driver has learned after being pulled over and given a roadside test.

Note: These older brain functions all occur without any conscious effort. This illustrates another of our recurring themes: Our brain processes most information outside of our awareness. We are aware of the results of our brain’s labor (say, our current visual experience) but not of how we construct the visual image. Likewise, whether we are asleep or awake, our brainstem manages its life-sustaining functions, freeing our newer brain regions to think, talk, dream, or savor a memory.

The Limbic System

What are the limbic system’s structures and functions?

We’ve considered the brain’s oldest parts, but we’ve not yet reached its newest and highest regions, the cerebral hemispheres (the two halves of the brain). Between the oldest and newest brain areas lies the limbic system (limes means “border”). This system contains the amygdala, the hypothalamus, and the hippocampus (FIGURE 11.7). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let’s look at the limbic system’s links to emotions such as fear and anger, and to basic motives such as those for food and sex.

11-3 | What are the limbic system’s structures and functions?

11-3 | What are the limbic system’s structures and functions?

We’ve considered the brain’s oldest parts, but we’ve not yet reached its newest and highest regions, the cerebral hemispheres (the two halves of the brain). Between the oldest and newest brain areas lies the limbic system (limes means “border”). This system contains the amygdala, the hypothalamus, and the hippocampus (FIGURE 11.7). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let’s look at the limbic system’s links to emotions such as fear and anger, and to basic motives such as those for food and sex.

The Reticular Formation

Inside the brainstem, between your ears, lies the reticular (“netlike”) formation, a neuron network that extends from the spinal cord right up through the thalamus. As the spinal cord’s sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli and relays important information to other brain areas.

In 1949, Giuseppe Moruzzi and Horace Magoun discovered that electrically stimulating the reticular formation of a sleeping cat almost instantly produced an awake, alert animal. When Magoun severed a cat’s reticular formation without damaging the nearby sensory pathways, the effect was equally dramatic: The cat lapse into a coma from which it never awakened. The conclusion? The reticular formation enables arousal.

The Cerebellum

Extending from the rear of the brainstem is the baseball-sized cerebellum, meaning “little brain,” which is what its two wrinkled halves resemble (FIGURE 11.6). As you will see in Module 32, the cerebellum enables nonverbal learning and memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures (Bower & Parsons, 2003). And it coordinates voluntary movement (with assistance from the pons). When a soccer player executes a perfect bicycle kick (above), give his cerebellum nerve credit. If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky and exaggerated. Gone would be any dreams of being a dancer or guitarist. Under alcohol’s influence on the cerebellum, coordination suffers, as many a driver has learned after being pulled over and given a roadside test.

Note: These older brain functions all occur without any conscious effort. This illustrates another of our recurring themes: Our brain processes most information outside of our awareness. We are aware of the results of our brain’s labor (say, our current visual experience) but not of how we construct the visual image. Likewise, whether we are asleep or awake, our brainstem manages its life-sustaining functions, freeing our newer brain regions to think, talk, dream, or savor a memory.

The Limbic System

What are the limbic system’s structures and functions?

We’ve considered the brain’s oldest parts, but we’ve not yet reached its newest and highest regions, the cerebral hemispheres (the two halves of the brain). Between the oldest and newest brain areas lies the limbic system (limes means “border”). This system contains the amygdala, the hypothalamus, and the hippocampus (FIGURE 11.7). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let’s look at the limbic system’s links to emotions such as fear and anger, and to basic motives such as those for food and sex.

The Reticular Formation

Inside the brainstem, between your ears, lies the reticular (“netlike”) formation, a neuron network that extends from the spinal cord right up through the thalamus. As the spinal cord’s sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli and relays important information to other brain areas.

In 1949, Giuseppe Moruzzi and Horace Magoun discovered that electrically stimulating the reticular formation of a sleeping cat almost instantly produced an awake, alert animal. When Magoun severed a cat’s reticular formation without damaging the nearby sensory pathways, the effect was equally dramatic: The cat lapse into a coma from which it never awakened. The conclusion? The reticular formation enables arousal.

The Cerebellum

Extending from the rear of the brainstem is the baseball-sized cerebellum, meaning “little brain,” which is what its two wrinkled halves resemble (FIGURE 11.6). As you will see in Module 32, the cerebellum enables nonverbal learning and memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures (Bower & Parsons, 2003). And it coordinates voluntary movement (with assistance from the pons). When a soccer player executes a perfect bicycle kick (above), give his cerebellum nerve credit. If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky and exaggerated. Gone would be any dreams of being a dancer or guitarist. Under alcohol’s influence on the cerebellum, coordination suffers, as many a driver has learned after being pulled over and given a roadside test.

Note: These older brain functions all occur without any conscious effort. This illustrates another of our recurring themes: Our brain processes most information outside of our awareness. We are aware of the results of our brain’s labor (say, our current visual experience) but not of how we construct the visual image. Likewise, whether we are asleep or awake, our brainstem manages its life-sustaining functions, freeing our newer brain regions to think, talk, dream, or savor a memory.

The Limbic System

What are the limbic system’s structures and functions?

We’ve considered the brain’s oldest parts, but we’ve not yet reached its newest and highest regions, the cerebral hemispheres (the two halves of the brain). Between the oldest and newest brain areas lies the limbic system (limes means “border”). This system contains the amygdala, the hypothalamus, and the hippocampus (FIGURE 11.7). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let’s look at the limbic system’s links to emotions such as fear and anger, and to basic motives such as those for food and sex.

The Reticular Formation

Inside the brainstem, between your ears, lies the reticular (“netlike”) formation, a neuron network that extends from the spinal cord right up through the thalamus. As the spinal cord’s sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli and relays important information to other brain areas.

In 1949, Giuseppe Moruzzi and Horace Magoun discovered that electrically stimulating the reticular formation of a sleeping cat almost instantly produced an awake, alert animal. When Magoun severed a cat’s reticular formation without damaging the nearby sensory pathways, the effect was equally dramatic: The cat lapse into a coma from which it never awakened. The conclusion? The reticular formation enables arousal.

The Cerebellum

Extending from the rear of the brainstem is the baseball-sized cerebellum, meaning “little brain,” which is what its two wrinkled halves resemble (FIGURE 11.6). As you will see in Module 32, the cerebellum enables nonverbal learning and memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures (Bower & Parsons, 2003). And it coordinates voluntary movement (with assistance from the pons). When a soccer player executes a perfect bicycle kick (above), give his cerebellum nerve credit. If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky and exaggerated. Gone would be any dreams of being a dancer or guitarist. Under alcohol’s influence on the cerebellum, coordination suffers, as many a driver has learned after being pulled over and given a roadside test.

Note: These older brain functions all occur without any conscious effort. This illustrates another of our recurring themes: Our brain processes most information outside of our awareness. We are aware of the results of our brain’s labor (say, our current visual experience) but not of how we construct the visual image. Likewise, whether we are asleep or awake, our brainstem manages its life-sustaining functions, freeing our newer brain regions to think, talk, dream, or savor a memory.

The Limbic System

What are the limbic system’s structures and functions?

We’ve considered the brain’s oldest parts, but we’ve not yet reached its newest and highest regions, the cerebral hemispheres (the two halves of the brain). Between the oldest and newest brain areas lies the limbic system (limes means “border”). This system contains the amygdala, the hypothalamus, and the hippocampus (FIGURE 11.7). The hippocampus processes conscious memories. Animals or humans who lose their hippocampus to surgery or injury also lose their ability to form new memories of facts and events. Module 31 explains how our two-track mind processes our memories. For now, let’s look at the limbic system’s links to emotions such as fear and anger, and to basic motives such as those for food and sex.
THE AMYGDALA

Research has linked the amygdala, two lima-bean-sized neural clusters, to aggression and fear. In 1999, psychologist Heinrich Klüver and neurosurgeon Paul Bucy surgically removed a rhesus monkey’s amygdala, turning the normally ill-tempered animal into the most meek of creatures. In studies with other wild animals, including the lynx, wolverine, and wild rat, researchers noted the same effect.

What then might happen if we electrically stimulated the amygdala of a normally placid domestic animal, such as a cat? Do so in one spot and the cat prepares to attack, hissing with its back arched, its pupils dilated, its hair on end. Move the electrode only slightly within the amygdala, cage the cat with a small mouse, and now it cowers in terror.

These and other experiments have confirmed the amygdala’s role in rage and fear, including the perception of these emotions and the processing of emotional memories (Anderson & Phelps, 2000; Poremba & Gabriel, 2001). But we must be careful. The brain is not neatly organized into structures that correspond to our behavior categories. When we feel or act in aggressive or fearful ways, there is neural activity in many levels of our brain. Even within the limbic system, stimulating structures other than the amygdala can evoke aggression or fear. If you charge your cell phone’s dead battery, you can activate the phone and make a call. Yet the battery is merely one link in an integrated system.

THE HYPOTHALAMUS

Just below (hypo) the thalamus is the hypothalamus (Figure 11.8 on the next page), an important link in the command chain governing bodily maintenance. Some neural clusters in the hypothalamus influence hunger; others regulate thirst, body temperature, and sexual behavior. Together, they help maintain a steady internal state.

As the hypothalamus monitors the state of your body, it tunes into your blood chemistry and any incoming orders from other brain parts. For example, picking up signals from your brain’s cerebral cortex that you are thinking about sex, your hypothalamus will secrete hormones. These hormones will in turn trigger the adjacent “master gland,” your pituitary (see Figure 11.9), to influence your sex glands to release their hormones. These will intensify the thoughts of sex in your cerebral cortex. (Once again, we see the interplay between the nervous and endocrine systems: The brain influences the endocrine system, which in turn influences the brain.)

TEACH

Concept Connections

Help students remember the functioning of the hypothalamus by reminding them that it controls the function of the pituitary gland, studied in Module 10. The pituitary gland (the “master gland”) directs the hormonal system in its functioning. If our hormones regulate everything from hunger to stress reactions to sex, then the hypothalamus really does control the body!
A remarkable discovery about the hypothalamus illustrates how progress in science often occurs—when curious, open-minded investigators make an unexpected observation. Two young McGill University neuropsychologists, James Olds and Peter Milner (1954), were trying to implant an electrode in a rat’s reticular formation when they made a magnificent mistake: They placed the electrode incorrectly (Olds, 1979). Curiously, as if seeking more stimulation, the rat kept returning to the location where it had been stimulated by this misplaced electrode. On discovering that they had actually placed the device in a region of the hypothalamus, Olds and Milner realized they had stumbled upon a brain center that provides pleasurable rewards (Olds, 1979).

In a meticulous series of experiments, Olds (1958) went on to locate other “pleasure centers,” as he called them. (What the rats actually experience only they know, and they aren’t telling. Rather than attribute human feelings to rats, today’s scientists refer to reward centers, not “pleasure centers.”) When allowed to press pedals to trigger their own stimulation in these areas, rats would sometimes do so at a feverish pace—up to 7000 times per hour—until they dropped from exhaustion. Moreover, to get this stimulation, they would even cross an electrified floor that a starving rat would not cross to reach food (Figure 11.9).

Other limbic system reward centers, such as the nucleus accumbens in front of the hypothalamus, were later discovered in many other species, including dolphins and monkeys. In fact, animal research has revealed both a general dopamine-related reward system and specific centers associated with the pleasures of eating, drinking, and sex. Animals, it seems, come equipped with built-in systems that reward activities essential to survival.

Contemporary researchers are experimenting with new ways of using limbic stimulation to control animals’ actions in future applications, such as search-and-rescue operations. By rewarding rats for turning left or right, one research team trained previously caged rats to navigate natural environments (Talwar et al., 2002; Figure 11.10). By pressing buttons on a laptop, the researchers were then able to direct the rats—which carried a receiver, power source, and video camera on a backpack—to turn on cue, climb trees, scurry along branches, and turn around and come back down.

Do humans have limbic centers for pleasure? Indeed we do. To calms violent patients, one neurosurgeon implanted electrodes in such areas. Stimulated patients reported mild pleasure; unlike Olds’ rats, however, they were not driven to a frenzy (Deutsch, 1972; Hooper & Teresi, 1986).

Experiments have also revealed the effects of a dopamine-related reward system in people. One research team had people rate the desirability of different vacation destinations. Then, after receiving either a dopamine-increasing drug or a sugar pill, they imagined themselves vacationing at half the locations. A day later, when presented with pairs of vacation spots they
had initially rated equally, only the dopamine takers preferred the places they had imagined under dopamine’s influence (Sharot et al., 2009). The participants, it seems, associated the imagined experiences with dopamine-induced pleasant feelings.

Some researchers believe that addictive disorders, such as substance use disorders and binge eating, may stem from malfunctions in natural brain systems for pleasure and well-being. People genetically predisposed to this reward deficiency syndrome may crave whatever provides that missing pleasure or relieves negative feelings (Blum et al., 1996).

**FIGURE 11.11** locates the brain areas we’ve discussed, as well as the cerebral cortex, our next topic.

### Before You Move On

**ASK YOURSELF**

If one day researchers discover how to stimulate human limbic centers to produce as strong a reaction as found in other animals, do you think this process could be used to reduce the incidence of substance use? Could such use have any negative consequences?

**TEST YOURSELF**

Within what brain region would damage be most likely to disrupt your ability to skip rope? Your ability to sense tastes or sounds? In what brain region would damage perhaps leave you in a coma? Without the very breath and heartbeat of life?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Module 11 Review

Answers to Multiple-Choice Questions
1. c  3. b  5. e
2. e  4. d  6. c

Multiple-Choice Questions
1. Computer-enhanced X-rays used to create brain images are known as
   a. positron emission tomography scans.
   b. functional magnetic resonance images.
   c. computed tomography scans.
   d. electroencephalograms.
   e. magnetic resonance images.

2. What part of the brain triggers the release of adrenaline to boost heart rate when you’re afraid?
   a. Amygdala
   b. Thalamus
   c. Medulla
   d. Hippocampus
   e. Hypothalamus

3. A gymnast falls and hits her head on the floor. She attempts to continue practicing, but has trouble maintaining balance. What part of her brain has probably been affected?
   a. Reticular formation
   b. Cerebellum
   c. Amygdala
   d. Frontal lobe
   e. Brainstem

4. Which of the following scanning techniques measures glucose consumption as an indicator of brain activity?
   a. CT
   b. MRI
   c. fMRI
   d. PET
   e. EEG

5. Which of the following is sometimes referred to as the brain’s train hub, because it directs incoming sensory messages (with the exception of smell) to their proper places in the brain?
   a. Hypothalamus
   b. Pituitary
   c. Cerebellum
   d. Limbic system
   e. Thalamus

6. Which of the following brain areas is responsible for regulating thirst?
   a. Reticular activating system
   b. Amygdala
   c. Hypothalamus
   d. Hippocampus
   e. Brainstem

How do neuroscientists study the brain’s connections to behavior and mind?
- Case studies and lesioning first revealed the general effects of brain damage.
- Modern electrical, chemical, or magnetic stimulation has also revealed aspects of information processing in the brain.
- CT and MRI scans show anatomy. EEG, PET, and fMRI (functional MRI) recordings reveal brain function.

What structures make up the brainstem, and what are the functions of the brainstem, thalamus, and cerebellum?
- The brainstem, the oldest part of the brain, is responsible for automatic survival functions. Its components are the medulla (which controls heartbeat and breathing), the pons (which helps coordinate movements), and the reticular formation (which affects arousal).
- The thalamus, sitting above the brainstem, acts as the brain’s sensory control center. The cerebellum, attached to the rear of the brainstem, coordinates muscle movement and balance and also helps process sensory information.

What are the limbic system’s structures and functions?
- The limbic system is linked to emotions, memory, and drives.
- Its neural centers include the hippocampus (which processes conscious memories), the amygdala (involved in responses of aggression and fear), and the hypothalamus (involved in various bodily maintenance functions, pleasurable rewards, and the control of the endocrine system).
- The pituitary (the “master gland”) controls the hypothalamus by stimulating it to trigger the release of hormones.

What structures make up the brainstem, and what are the functions of the brainstem, thalamus, and cerebellum?

What structures make up the brainstem, and what are the functions of the brainstem, thalamus, and cerebellum?

What are the limbic system’s structures and functions?

What are the limbic system’s structures and functions?
7. The hypothalamus is a(n) _______ center for the brain.
   a. positioning
   b. aggression
   c. balance
   d. memory
   e. reward

8. Which of the following's primary function is processing memories?
   a. Cerebral cortex
   b. Medulla
   c. Corpus callosum
   d. Hippocampus
   e. Hypothalamus

Practice FRQs

1. Following a brain injury, Mike struggles to control his emotions and has difficulty establishing new memories. What parts of Mike’s brain have most likely been affected by his injury?
   Answer
   1 point: Damage to the amygdala would make it difficult for Mike to control his emotions.
   1 point: Damage to the hippocampus would affect Mike’s ability to establish new memories.

2. Identify the role of each of the following in listening to and taking notes during a psychology lecture.
   •  Hippocampus
   •  Cerebellum
   •  Cerebral cortex
   (3 points)

Answer to Practice FRQ 2

1 point: The hippocampus would play a role in transferring information obtained during the lecture from short-term to long-term memory.

1 point: The cerebellum would help the student by providing the fine motor coordination necessary to take notes or type on a laptop during the lecture.

1 point: The cerebral cortex is responsible for the higher-order thinking necessary to understand a college lecture.
The Cerebral Cortex

Module Learning Objectives

12-1 Identify the various regions of the cerebral cortex, and describe their functions.

12-2 Discuss the brain’s ability to reorganize itself, and define neurogenesis.

12-1 What are the functions of the various cerebral cortex regions?

Older brain networks sustain basic life functions and enable memory, emotions, and basic drives. Never neural networks within the cerebellum—the hemispheres that contribute 85 percent of the brain’s weight—form specialized work teams that enable our perceiving, thinking, and speaking. Like other structures above the brainstem (including the thalamus, hippocampus, and amygdala), the cerebral hemispheres come as a pair. Covering those hemispheres, like bark on a tree, is the cerebral cortex, a thin surface layer of interconnected neural cells. It is your brain’s thinking crown, your body’s ultimate control and information-processing center.

As we move up the ladder of animal life, the cerebral cortex expands, tight genetic controls relax, and the organism’s adaptability increases. Frogs and other small-cortex amphibians operate extensively on preprogrammed genetic instructions. The larger cortex of mammals offers increased capacities for learning and thinking, enabling them to be more adaptable. What makes us distinctively human most likely arises from the complex functions of our cerebral cortex.

Structure of the Cortex

If you opened a human skull, exposing the brain, you would see a wrinkled organ, shaped somewhat like the meat of an oversized walnut. Without those wrinkles, a flattened cerebral cortex would require triple the area—roughly that of a large pizza. The brain’s left and right hemispheres; the body’s ultimate control and information-processing center, are connected by a network of neurons that support, nourish, and protect neurons, as well as play a role in learning and thinking.

Glial cells (glia) are the nervous system’s support network, and they may also play a role in learning and thinking. They provide nutrients and绝缘 myelin, guide neural connections, and mop up ions and neurotransmitters. Glia may also play a role in learning and thinking, by “chatting” with neurons they may participate in information transmission and memory.

When Albert Einstein died in 1955, Dr. Thomas Harvey, with the family’s consent, kept the brain for scientific study:

- Although the overall size of Einstein’s brain was average, the region called the inferior parietal lobe, where visual-spatial cognition, mathematical thought, and imagery of movement are controlled, was 15% wider than normal.
- Einstein’s insights were often the result of visual images that he translated into mathematics. For example, his special theory of relativity was based on what he thought it would be like to ride through space on a beam of light.
- A feature known as the Sylvian fissure (a groove that normally runs through the brain tissue) was shorter than average. This meant that the brain cells were packed more closely together, permitting more interconnections and cross-referencing of information.

Critics observe that although Einstein’s brain may well be different, the cause–effect relationship is uncertain. The differences may be the result of strenuous mental exercise, not the cause of genius.

In more complex animal brains, the proportion of glia to neurons increases. A postmortem analysis of Einstein’s brain did not find more or larger-than-usual neurons, but it did reveal a much greater concentration of glial cells than found in an average Albert’s head (Fields, 2004).

Each hemisphere’s cortex is subdivided into four lobes, separated by prominent fissures, or folds: **Figure 12.1**. Starting at the front of your brain and moving over the top, there are the **frontal lobes** (behind your forehead), the **parietal lobes** (at the top and to the rear), and the **occipital lobes** (at the back of your head). Reversing direction and moving forward, just above your ears, you find the **temporal lobes**. Each of the four lobes carries out many functions, and many functions require the interplay of several lobes.

**Functions of the Cortex**

More than a century ago, surgeons found damaged cortical areas during autopsies of people who had been partially paralyzed or speechless. This rather crude evidence did not prove that specific parts of the cortex control complex functions like movement or speech. After all, if the entire cortex controlled speech and movement, damage to almost any area might produce the same effect. A TV with its power cord cut would go dead, but we would be foolish if we thought we had “localized” the picture in the cord.

**Motor Functions**

Scientists had better luck in localizing simpler brain functions. For example, in 1870, German physicians Gustav Fritsch and Eduard Hitzig made an important discovery: Mild electrical stimulation to parts of an animal’s cortex made parts of its body move. The effects were selective: Stimulation caused movement only when applied to an arch-shaped region at the back of the motor cortex. The frontal lobes, running roughly ear-to-ear across the top of the brain, were the focus of this region in the left or right hemisphere caused movements of specific body parts on the side of the body. Fritsch and Hitzig had discovered what is now called the **motor cortex**.

**MAPPING THE MOTOR CORTEX**

Lucky for brain surgeons and their patients, the brain has no sensory receptors. Knowing this, Otfrid Foerster and Wilder Penfield were able to map the motor cortex in hundreds of wide-awake patients by stimulating different cortical areas and observing the body’s responses.

**Common Pitfalls**

Teach students that the *lobe* is plural—there are 2 of each lobe, 1 for each hemisphere. Often, students will talk about the “frontal lobe” and forget that there are actually 2 frontal, parietal, occipital, and temporal lobes each.

**Common Pitfalls**

Help students remember that the motor cortex is in the frontal lobe and the somatosensory cortex is in the parietal lobe. The frontal lobe’s decision-making function works with the motor cortex to create purposeful movement. The parietal lobe’s association areas work with the somatosensory cortex to process sensory signals for accurate perception.
**TEACH**

**Teaching Tip**

Figure 12.2 features the sensory homunculus, a diagram showing how the cortex is parsed out to different parts of the body according to function. These diagrams show dramatically how much cortex is devoted to complex areas of the body like the face and hands and how little is devoted to rather simple areas such as the calf and back.

**ENGAGE**

**Applying Science**

Wilder Penfield, a famous neurosurgeon, studied at Oxford on a Rhodes scholarship under Charles Sherrington, the discoverer of the synapse. Penfield, along with colleague Herbert Jasper, perfected a technique to treat epilepsy through surgery by selectively lesioning cells in the brain that triggered the seizures. By keeping patients conscious on the operating table, he was able to stimulate cells in the brain and map areas before destroying the offending cells.

The sensory homunculus, largely created by Wilder Penfield through his mapping surgeries to treat epilepsy, has been essentially unaltered since its creation in the 1950s. Have students research ways in which the sensory homunculus is used by researchers and practitioners today.

---

**Figure 12.2**

Left hemisphere tissue devoted to each body part in the motor cortex and the somatosensory cortex. As you can see from this classic though inexact representation, the amount of cortex devoted to a body part in the motor cortex (in the frontal lobes) or in the somatosensory cortex (in the parietal lobes) is not proportional to that body part’s size. Rather, the brain devotes more tissue to sensitive areas and to areas requiring precise control. Thus, the fingers have a greater representation in the cortex than does the upper arm.

They discovered that body areas requiring precise control, such as the fingers and mouth, occupy the greatest amount of cortical space (Figure 12.2).

In one of his many demonstrations of motor behavior mechanics, Spanish neuroscientist José Delgado stimulated a spot on a patient’s left motor cortex, triggering the right hand to make a fist. Asked to keep the fingers open during the next stimulation, the patient, whose fingers closed despite his best efforts, remarked, “I guess, Doctor, that your electricity is stronger than my will” (Delgado, 1969, p. 114).

More recently, scientists were able to predict a monkey’s arm motion a tenth of a second before it moved—by repeatedly measuring motor cortex activity preceding specific arm movements (Gibbs, 1996). Such findings have opened the door to research on brain-controlled computers.

**Brain-Computer Interfaces**

By eavesdropping on the brain, could we enable someone—perhaps a paralyzed person—to move a robotic limb? Could a brain-computer interface command a cursor to write an e-mail or search the Internet? To find out, Brown University brain researchers implanted 100 tiny recording electrodes in the motor cortices of three monkeys (Nicolodi & Chapin, 2002; Ser-ruya et al., 2002). As the monkeys used a joystick to move a cursor to follow a moving red target (to gain reward), the researchers matched the brain signals with the arm movements. Then they programmed a computer to monitor the signals and operate the joystick. When a monkey merely thought about a move, the mind-reading computer moved the cursor with nearly the same proficiency as had the reward-seeking monkey. In follow-up experiments, two monkeys were trained to control a robot arm that could grasp and deliver food (Velliste et al., 2008), and then a human did the same (Figure 12.3).
Clinical trials of such cognitive neural prosthetics are now under way with people who have suffered paralysis or amputation (Andersen et al., 2010; Nurmikko et al., 2010). The first patient, a paralyzed 25-year-old man, was able to mentally control a TV, draw shapes on a computer screen, and play video games—all thanks to an aspirin-sized chip with 100 microelectrodes recording activity in his motor cortex (Hochberg et al., 2006). If everything psychological is also biological—if, for example, every thought is also a neural event—then microelectrodes perhaps could detect thoughts well enough to enable people to control events, as suggested by Figure 12.4 on the next page.

**Sensory Functions**

If the motor cortex sends messages out to the body, where does the cortex receive the incoming messages? Wilder Penfield also identified the cortical area that specializes in receiving information from the skin senses and from the movement of body parts. This area at the front of the parietal lobes, parallel to and just behind the motor cortex, we now call the somatosensory cortex (Figure 12.2). Stimulate a point on the top of this band of tissue and a person may report being touched on the shoulder; stimulate some point on the side and the person may feel something on the face.

The more sensitive the body region, the larger the somatosensory cortex area devoted to it (Figure 12.2). Your supersensitive lips project to a larger brain area than do your toes, which is one reason we kiss with our lips rather than touch toes. Rats have a large area of the brain devoted to their whisker sensations, and owls to their hearing sensations.

Scientists have identified additional areas where the cortex receives input from senses other than touch. At this moment, you are receiving visual information in the visual cortex in your occipital lobes, at the very back of your brain (Figures 12.5 and 12.6 on the next page). A bad enough bash there would make you blind. Stimulated there, you might see flashes of light or dashes of color. (In a sense, we do have eyes in the back of our head!) From your occipital lobes, visual information goes to other areas that specialize in tasks such as identifying words, detecting emotions, and recognizing faces.

Any sound you now hear is processed by your auditory cortex in your temporal lobes (just above your ears; see Figure 12.6). Most of this auditory information travels
ENGAGE
Active Learning
To demonstrate how areas of greater sensitivity are assigned greater areas of cortex, ask for a volunteer to come to the front of the room. Have the volunteer close his or her eyes and report the number of fingers you press on their skin. Randomly press from 1–4 digits lightly on their back and on the hand, then inform the class of the correct number after the volunteer’s guess. Greater accuracy for touch to the hand will be obvious. Far more cortex is devoted to the hand than to the back and this explains the difference in sensitivity. You could also do this same exercise by having students work in pairs.


Figure 12.5
The brain in action
This fMRI (functional MRI) scan shows the visual cortex in the occipital lobes activated (color representation of increased bloodflow) as a research participant looks at a photo. When the person stops looking, the region instantly calms down.

Figure 12.6
The visual cortex and auditory cortex
The visual cortex of the occipital lobes at the rear of your brain receives input from your eyes. The auditory cortex, in your temporal lobes—above your ears—receives information from your ears.

ENGAGE
Active Learning
Ask a volunteer to remove his or her shoe and sock. After a blindfold is in place, touch the 2nd, 3rd, or 4th toes gently with a pen or stylus. It is most effective to touch slightly to the left or right midline of each toe. Chute and Schatz report that student accuracy in identifying the toe being touched is only 80 or 90%. Less cortex is devoted to the toes than to, say, the fingers. At the same time, with feedback on accuracy, participants are 98% correct after as few as 10 trials. Performance, however, returns to baseline in a few days. (If you use this demonstration in class, you will want to obtain informed consent from your student volunteers.)

Association Areas

So far, we have pointed out small cortical areas that either receive sensory input or direct muscular output. Together, these occupy about one-fourth of the human brain’s thin, wrinkled cover. What, then, goes on in the vast regions of the cortex? In these association areas (the peach-colored areas in Figure 12.7), neurons are busy with higher mental functions—many of the tasks that make us human.

Electrically probing an association area won’t trigger any observable response. So, unlike the sensory and motor areas, association area functions cannot be neatly mapped. Their silence has led to what Donald McBurney (1996, p. 44) has called “one of the hardest weeds in the garden of psychology” – the claim that we ordinarily use only 10 percent of our brains. (If true, wouldn’t this imply a 90 percent chance that a bullet to your brain would land in an unused area?) Surgically lesioned animals and brain-damaged humans bear witness that association areas are not dormant. Rather, these areas interpret, integrate, and act on sensory information and link it with stored memories—a very important part of thinking.

Association areas are found in all four lobes. The prefrontal cortex in the forward part of the frontal lobes enables judgment, planning, and processing of new memories. People do not, but those with damage to a brain area behind the eyes often do (Koenigs et al., 2007). With their frontal lobes ruptured, people’s moral compass seems to disconnect from their behavior. (If you advocate pushing someone in front of a runaway boxcar to save five others? Most people do not, but those with damage to a brain area behind the eyes often do.)

Frontal lobe damage also can alter personality and remove a person’s inhibitions. Consider the classic case of railroad worker Phineas Gage. One afternoon in 1848, Gage, then 25 years old, was packing gunpowder into a rock with a tamping iron. A spark ignited the gunpowder, shooting the rod up through his left cheek and out the top of his skull, leaving his frontal lobes massively damaged (Figure 12.8 on the next page). To everyone’s amazement, he was immediately able to sit up and speak, and after the wound healed he returned to work. But the affable, soft-spoken man was now irritable, profane, and dishonest. This person, said his friends, was “no longer Gage.” Although his mental abilities and memories were intact, his personality was not. (Although Gage lost his job, he did, over time, adapt to his injury and find work as a stagecoach driver [Macmillan & Lena, 2010].)

More recent studies of people with damaged frontal lobes have revealed similar impairments. Not only may they become less inhibited (without the frontal lobe brakes on their impulses), but their moral judgments may seem unrestrained by normal emotions. Would you advocate pushing someone in front of a runaway boxcar to save five others? Most people do not, but those with damage to a brain area behind the eyes often do (Koenigs et al., 2007). With their frontal lobes ruptured, people’s moral compass seems to disconnect from their behavior.

Common Pitfalls

The idea that we only use 10% of our brains is a myth that arose in the last century. As brain research techniques have evolved, scientists have found that most of the brain is active at any given moment. Those areas that were thought to be unused were probably the association areas described in the text.
The study of language is one of the most complex fields of study. Just studying the complexity of how language is processed in the brain provides a clue to how difficult it is to master an in-depth knowledge of how language works. Learn more about language in Unit VII.

**TEACH**

**Common Pitfalls**

Myers points out that we should be wary of thinking that the brain has “hot spots” of functioning, avoiding the idea that certain functions reside in one area of the brain or another. This is an important point to make with students just learning about biological bases of behavior. What we learn at this point in psychology is the most basic understanding of neuroscience. The whole picture of the field is much more complex because brain function is interconnected.

**TEACH**

**Concept Connections**

The study of language is one of the most complex fields of study. Just studying the complexity of how language is processed in the brain provides a clue to how difficult it is to master an in-depth knowledge of how language works. Learn more about language in Unit VII.

**Figure 12.8**

**A blast from the past**

If Gage’s skull was kept as a medical record, using measurements and modern neuroimaging techniques, researchers have reconstructed the probable path of the rod through Gage’s brain (Damasio et al., 1994). (b) This recently discovered photo shows Gage after his accident. The image has been reversed to show the features correctly. (Early photos, such as this one, were actually mirror images.)

Association areas also perform other mental functions. In the parietal lobes, parts of which were large and unusually shaped in Einstein’s normal-weight brain, they enable mathematical and spatial reasoning (Witelson et al., 1999). In patients undergoing brain surgery, stimulation of one parietal lobe area produced a feeling of wanting to move an upper limb, the lips, or the tongue (but without any actual movement). With increased stimulation, patients falsely believed they actually had moved. Curiously, when surgeons stimulated a different association area near the motor cortex in the frontal lobes, the patients did move but had no awareness of doing so (Desmurget et al., 2009). These head-scratching findings suggest that our perception of moving flows not from the movement itself, but rather from our intention and the results we expected.

Yet another association area, on the underside of the right temporal lobe, enables us to recognize faces. If a stroke or head injury destroyed this area of your brain, you would still be able to describe facial features and to recognize someone’s gender and approximate age, yet be strangely unable to identify the person as, say, Lady Gaga, or even your grandmother.

Nevertheless, we should be wary of using pictures of brain “hot spots” to create a new phonotator that locates complex functions in precise brain areas (Utal, 2003). Complex mental functions don’t reside in any one place. There is no one spot in a rat’s small association cortex that, when damaged, will obliterate its ability to learn or remember a maze. Similarly, the acquisition, development, and use of language depends on both specialized neural networks and their integration. Nineteenth-century research by French physician Paul Broca and German investigator Carl Wernicke led to the discovery of specialized language brain areas. Damage to Broca’s area disrupts speaking, while damage to Wernicke’s area disrupts understanding. Today’s neuroscience has shown that language functions are distributed across other brain areas as well.

Memory, language, and attention result from the synchronized activity among distinct brain areas (Knight, 2007). Ditto for religious experience. Reports of more than 40 distinct brain regions becoming active in different religious states, such as praying and meditating, indicate that there is no simple “God spot” (Fingelkurts & Fingelkurts, 2009). The big lesson: Our mental experiences arise from coordinated brain activity.

**The Brain’s Plasticity**

To what extent can a damaged brain reorganize itself, and what is neurogenesis? Our brains are sculpted not only by our genes but also by our experiences. MRI scans show that well-practiced pianists have a larger-than-usual auditory cortex area that encodes piano sounds (Bavelier et al., 2000; Pantev et al., 1998). In Unit IX, we’ll focus more on how...
experience molds the brain. For now, let’s turn to another aspect of the brain’s plasticity: its ability to modify itself after damage.

Some of the effects of brain damage described earlier can be traced to two hard facts: (1) Severed neurones, unlike cut skin, usually do not regenerate. (If your spinal cord were severed, you would probably be permanently paralyzed.) And (2) some brain functions seem preassigned to specific areas. One newborn who suffered damage to temporal lobe facial recognition areas later remained unable to recognize faces (Farah et al., 2000). But there is good news: Some of the brain’s neural tissue can reorganize in response to damage. Under the surface of our awareness, the brain is constantly changing, building new pathways as it adjusts to little mishaps and new experiences.

Plasticity may also occur after serious damage, especially in young children (Kolb, 1989; see also FIGURE 12.9). Constraint-induced therapy aims to rewire brains and improve the dexterity of a brain-damaged child or even an adult stroke victim (Taub, 2004). By restraining a fully functioning limb, therapists force patients to use the “bad” hand or leg, gradually reprogramming the brain. One stroke victim, a surgeon in his fifties, was put to work cleaning tables, with his good arm and hand restrained. Slowly, the bad arm recovered its skills. As damaged-brain functions migrated to other brain regions, he gradually learned to write again and even to play tennis (Doidge, 2007).

The brain’s plasticity is good news for those who are blind or deaf. Blindness or deafness makes unused brain areas available for other uses (Amedi et al., 2005). If a blind person uses one finger to read Braille, the brain area dedicated to that finger expands as the sense of touch invades the visual cortex that normally helps people see (Barnagava, 1992a; Sadato et al, 1996). Plasticity also helps explain why some studies find that deaf people have enhanced peripheral vision (Bosworth & Dobkins, 1999). In those people whose native language is sign, the temporal lobe area normally dedicated to hearing waits in vain for stimulation. Finally, it looks for other signals to process, such as those from the visual system. Similar reassignment may occur when disease or damage frees up other brain areas normally dedicated to specific functions. If a slow-growing tumor disrupts language (which resides mostly in the left hemisphere), the right hemisphere may compensate (Thiel et al., 2006). If a finger is amputated, the somatosensory cortex that received its input will begin to receive input from the adjacent fingers, which then become more sensitive (Fox, 1984).

Although the brain often attempts self-repair by reorganizing existing tissue, it sometimes attempts to mend itself by producing new brain cells. This process, known as neurogenesis, occurs in the hippocampus (see also FIGURE 12.9). Neurogenesis is significant because it may help us understand why some brain functions seem impossible to overcome.

**Figure 12.9**

**Brain plasticity** Although the brains of young children show the greatest ability to reorganize and adapt to damage, adult brains also have some capacity for self-repair. Former Arizona Congresswoman Gabrielle Giffords lost her speaking ability to a gunshot wound. Her medical care included music therapy, where she worked on forming words to familiar songs such as “Happy Birthday.” Giffords has since partly recovered her speaking ability. Two years after the shooting, she was able to speak at a surprise witness at a 2013 U.S. Senate hearing on gun legislation.

**Teaching Tip**

Plasticity is an important concept for students to understand. The brain is very resilient, figuring out ways to compensate for injury. The younger one is when the injury occurs, the more functioning can be regained. This amazing ability enables us to recover from injury and damage that seem impossible to overcome.

**Teaching Tip**

As Myers points out, certain functions can take over a damaged part of the brain to repurpose that part for a new function. Typically, the new function is related to its original purpose, only it is now used with another sense that has taken over that process, like touch taking over the reading function from vision that has been lost.

**Engage**

**Enrichment**

Christopher Reeve devoted his later life to spinal cord research in an effort to find effective treatments for spinal cord injuries. Through intensive physical therapy, Reeve was able to regain some functioning in his lungs and his fingers, famously moving his finger during a televised event. His work showed that there is some hope for those with spinal cord damage to regain functioning, either through plasticity or neurogenesis.
ENGAGE

Applying Science

Have students contact a neuropsychologist to ask about current research on neurogenesis. They can inquire further about the use of stem cells in creating brain cells. Have them ask what promising applications of this type of research might occur, in their estimation.

CLOSE & ASSESS

Exit Assessment

Take any of the diagrams in this module and blank out the labels. Have students fill in the missing labels or explanations to assess how much they remember from this module. This type of activity will help students with these types of questions on the AP® exam.

Module 12 Review

What are the functions of the various cerebral cortex regions?

- The cerebral cortex has two hemispheres, and each hemisphere has four lobes: the frontal, parietal, occipital, and temporal. Each lobe performs many functions and interacts with other areas of the cortex.
- Glial cells support, nourish, and protect neurons and may also play a role in learning and thinking.
- The motor cortex, at the rear of the frontal lobes, controls voluntary movements.
- The somatosensory cortex, at the front of the parietal lobes, registers and processes body touch and movement sensations.
- Body parts requiring precise control or those that are especially sensitive occupy the greatest amount of space in the motor cortex and somatosensory cortex, respectively.
- Most of the brain’s cortex—the major portion of each of the four lobes—is devoted to uncommitted association areas, which integrate information involved in learning, remembering, thinking, and other higher-level functions.
- Our mental experiences arise from coordinated brain activity.

12-2 To what extent can a damaged brain reorganize itself, and what is neurogenesis?

- If one hemisphere is damaged early in life, the other will pick up many of its functions by reorganizing or building new pathways. This plasticity diminishes later in life.
- The brain sometimes mends itself by forming new neurons, a process known as neurogenesis.

ENGAGE

TRM Enrichment

Researchers are using modern brain imaging to study moral reasoning. Use Teacher Demonstration: Neuroscience and Moral Judgments from the TRM to provide insight on the interplay between emotion and reason in resolving moral dilemmas.

Before You Move On

- Ask Yourself
  - Has what you have learned about how our brains enable our minds affected your view of human nature?
  - Test Yourself
    - Try moving your right hand in a circular motion, as if polishing a table. Then start your right foot doing the same motion, synchronized with your hand. Now reverse the right foot’s motion, but not the hands. Finally, try moving the left foot opposite to the right hand.
    - Why is reversing the right foot’s motion so hard?
    - Why is it easier to move the left foot opposite to the right hand?
  - Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Multiple-Choice Questions

1. Damage to which of the following could interfere with the ability to plan for the future?
   a. Frontal lobe
   b. Temporal lobe
   c. Parietal lobe
   d. Occipital lobe
   e. Somatosensory cortex

2. In general, damage to _______ disrupts speaking, while damage to _______ disrupts understanding of language.
   a. the frontal lobe, the occipital lobe
   b. the temporal lobe, the frontal lobe
   c. the occipital lobe, the temporal lobe
   d. Wernicke’s area, Broca’s area
   e. Broca’s area, Wernicke’s area

3. Stimulation at a point on which of the following may cause a person to report being touched on the knee?
   a. Motor cortex
   b. Cerebellum
   c. Somatosensory cortex
   d. Temporal lobe
   e. Thalamus

4. George can move his hand to sign a document because the _______ located in the _______ lobe of the brain, allows him to activate the proper muscles.
   a. somatosensory cortex; temporal
   b. somatosensory cortex; parietal
   c. motor cortex; parietal
   d. somatosensory cortex; frontal
   e. motor cortex; frontal

5. The most noticeable difference between human brains and other mammalian brains is the size of the
   a. association areas.
   b. frontal lobe.
   c. glial cells.
   d. reticular activating system.
   e. visual cortex.

6. Cognitive neural prosthetics are placed in the brain to help control parts of the
   a. motor cortex.
   b. auditory cortex.
   c. somatosensory cortex.
   d. visual cortex.
   e. parietal lobe.

Practice FRQs

1. Doctors sometimes have to remove a portion of the brain to control life-threatening seizures. Describe what the results of the removal of a portion of the motor cortex would be and explain how this procedure might be affected by brain plasticity.

   Answer
   1 point: Removing part of the motor cortex will result in paralysis in the parts of the body associated with the removed tissue.
   3 point: Because of brain plasticity, the person’s brain may be able to change and reorganize new pathways based on experience. This is more likely if the person is a child.

2. Anthony attends a high school band concert. First, identify and explain which two lobes of his brain are most important for watching and listening to the concert. Second, explain which lobe of the brain is most responsible for analyzing the music and finding personal meaning.

   Answer to Practice FRQ 2
   1 point: The occipital lobes comprise the visual processing center that allows Anthony to watch the concert.
   1 point: The temporal lobes comprise the auditory processing center that allows Anthony to listen to the concert.
   1 point: The frontal lobes are the home of the higher-order thinking skills that allow Anthony to analyze the music and find personal meaning.
Module 13

Brain Hemisphere Organization and the Biology of Consciousness

Module Learning Objectives

13-1 Explain how split-brain research helps us understand the functions of our two brain hemispheres.

13-2 Explain what is meant by “dual processing,” as revealed by today’s cognitive neuroscience.

Our Divided Brain

13-1 What do split brains reveal about the functions of our two brain hemispheres?

Our brain’s look-alike left and right hemispheres serve differing functions. This lateralization is apparent after brain damage. Research collected over more than a century has shown that accidents, strokes, and tumors in the left hemisphere can impair reading, writing, speaking, arithmetic reasoning, and understanding. Similar lesions in the right hemisphere have effects that are less visibly dramatic.

Does this mean that the right hemisphere is just along for the ride—a silent, “subordinate” or “minor” hemisphere? Many believed this was the case until 1960, when researchers found that the “minor” right hemisphere was not so limited after all. The story of this discovery is a fascinating episode in psychology’s history.

Splitting the Brain

In 1961, two Los Angeles neurosurgeons, Philip Vogel and Joseph Bogen, speculated that major epileptic seizures were caused by an amplification of abnormal brain activity bouncing back and forth between the two cerebral hemispheres. If so, they wondered, could they put an end to this biological tennis game by severing the corpus callosum (see FIGURE 13.1)? This wide band of axon fibers connects the two hemispheres and carries messages between them. Vogel and Bogen knew that psychologists Roger Sperry, Ronald Myers, and Michael Gazzaniga had divided the brains of cats and monkeys in this manner, with no serious ill effects.

So the surgeons operated. The result? The seizures all but disappeared. The patients with these split brains were surprisingly normal, their personality and intellect hardly affected. Waking from surgery, one even joked that he had a “splitting headache” (Gazzaniga, 1967). By sharing their experiences, these patients have greatly expanded our understanding of interactions between the intact brain’s two hemispheres.

- Logic is not confined to the left hemisphere. In fact, people with right-hemisphere damage have more severe problems in this area than do people with left-hemisphere damage.
- There is no evidence that either creativity or intuition is an exclusive property of the right hemisphere. For example, researchers have found that both hemispheres are equally skilled in discriminating musical chords.
- It is impossible to educate one hemisphere at a time. The right hemisphere is educated as fully as the left in a literature class; the left hemisphere is educated as much as the right in an art class.
- There is no evidence that people are purely “left-brained” or “right-brained.”
To appreciate these findings, we need to focus for a minute on the peculiar nature of our visual wiring. As Figure 13.2 illustrates, information from the left half of your field of vision goes to your right hemisphere, and information from the right half of your visual field goes to your left hemisphere, which usually controls speech. (Note, however, that each eye receives sensory information from both the right and left visual fields.) Data received by either hemisphere are quickly transmitted to the other across the corpus callosum. In a person with a severed corpus callosum, this information-sharing does not take place.

Knowing these facts, Sperry and Gazzaniga could send information to a patient’s left or right hemisphere. As the person stared at a spot, they flashed a stimulus to its right or left. They could do this with you, too, but in your intact brain, the hemisphere receiving the information would instantly pass the news to the other side. Because the split-brain surgery had cut the communication lines between the hemispheres, the researchers could, with these patients, quiz each hemisphere separately.

In an early experiment, Gazzaniga (1967) asked these people to stare at a dot as he flashed HEART on a screen (Figure 13.3 on the next page). Thus, HE appeared in their left visual field (which transmits to the right hemisphere) and ART in the right field (which transmits to the left hemisphere). When he then asked them to say what they had seen, the patients reported that they had seen ART. But when asked to point to the word they had seen, they were startled when their left hand (controlled by the right hemisphere) pointed to HE. Given an opportunity to express itself, each hemisphere reported what it had seen. The right hemisphere (controlling the left hand) intuitively knew what it could not verbally report.
TEACH
Common Pitfalls
Students often leave this section with the impression that life is difficult for split-brain individuals. In fact, they only experience difficulty in the first months after surgery. As time passes, the “two separate minds” begin to figure out how to work together. Help students understand that split-brain individuals do not experience problems in daily life because the optic chiasm is not severed in the surgery. The optic chiasm is the place where the nerves connecting the eyes and the brain cross, leading to cross-hemispheric processing. Split-brain individuals do receive visual information from both visual fields, so the abnormalities are only noticeable in specialized laboratory conditions.

ENGAGE
Applying Science
Is language only located in the left hemisphere? Michael Gazzaniga reports the case of V. J., a left-handed and divided-brain woman whose case challenges notions of where the capacity for language resides. When a word is presented to her left visual field and thus processed by the right half of her brain, she can write it but not say it. When a word is presented to her right visual field and thus processed by the left hemisphere, she can say it but not write it. This is the first clear scientific evidence that in some people the capacities for spoken and written language may be located in different hemispheres. Linguist Steven Pinker thinks that V. J.’s case provides evidence that reading and writing arose separately from spoken language and may be wired into the brain wherever there are “spare areas.” Have students research other case studies about people with split-brain experiences.

Figure 13.3
*Testing the divided brain* When an experimenter flashes the word HEART across the visual field, a woman with a split-brain reports seeing the portion of the word transmitted to her left hemisphere. However, if asked to indicate with her left hand what she saw, she points to the portion of the word transmitted to her right hemisphere. (From Gazzaniga, 1983.)

(a) *Look at the dot.*

(b) Two words separated by a dot are momentarily projected.

(c) *What word did you see?*

* or

*Point with your left hand to the word you saw.*

When a picture of a spoon was flashed to their right hemisphere, the patients could not say what they had viewed. But when asked to identify what they had viewed by feeling an assortment of hidden objects with their left hand, they readily selected the spoon. If the experimenter said, “Correct!” the patient might reply, “What? Correct! How could I possibly pick out the correct object when I don’t know what I saw?” It is, of course, the left hemisphere doing the talking here, bewildered by what the nonverbal right hemisphere knows.

A few people who have had split-brain surgery have been for a time bothered by the unruly independence of their left hand, which might unbutton a shirt while the right hand buttoned it, or put grocery store items back on the shelf after the right hand put them in the cart. It was as if each hemisphere was thinking, “I’ve half a mind to wear my green (blue) shirt today.” Indeed, said Sperry (1964), split-brain surgery leaves people “with two separate minds.” With a split brain, both hemispheres can comprehend and follow an instruction to copy—simultaneously—different figures with the left and right hands (Franz et al., 2000; see also FIGURE 13.4). (Reading these reports, I fantasize a patient enjoying a solitary game of “rock, paper, scissors” left versus right hand.)
Critical Questions

Myers points out by citing the research that
processing is a left-hemisphere activity, as
MyersAP_TE_2e_U03.indd   117 2/19/14   11:04 AM
M

When the “two minds” are at odds, the left hemisphere does mental gymnastics to
rationalize reactions it does not understand. If a patient follows an order sent to the right
hemisphere (“Walk”), a strange thing happens. Unaware of the order, the left hemisphere
doesn’t know why the patient begins walking. Yet, when asked why, the patient doesn’t say
“I don’t know.” Instead, the interpretive left hemisphere improvises—“I’m going into the
house to get a Coke.” Gazzaniga (1988), who considers these patients “the most fascinating
people on earth,” concluded that the conscious left hemisphere is an “interpreter” or press
agent that instantly constructs theories to explain our behavior.

Right-Left Differences in the Intact Brain

So, what about the 99.99 percent of us with undivided brains? Does each of our hemi-
spheres also perform distinct functions? Several different types of studies indicate they do.
When a person performs a perceptual task, for example, brain waves, bloodflow, and glucose
consumption reveal increased activity in the right hemisphere. When the person speaks or
calculates, activity increases in the left hemisphere.

A dramatic demonstration of hemispheric specialization happens before some types of
brain surgery. To locate the patient’s language centers, the surgeon injects a sedative into the
neck artery feeding blood to the left hemisphere, which usually controls speech. Before the
injection, the patient is lying down, arms in the air, chatting with the doctor. Can you predict
what probably happens when the drug puts the left hemisphere to sleep? Within seconds,
the person’s right arm falls limp. If the left hemisphere is controlling language, the patient
will be speechless until the drug wears off. If the drug is injected into the artery to the right
hemisphere, the left arm will fall limp, but the person will still be able to speak.

To the brain, language is language, whether spoken or signed. Just as hearing people
usually use the left hemisphere to process speech, deaf people use the left hemisphere to
process sign language (Corina et al., 1992; Hickok et al., 2001). Thus, a left-hemisphere
stroke disrupts a deaf person’s signing, much as it would disrupt a hearing person’s speak-
ing. The same brain area is involved in both (Corina, 1998). (For more on how the brain
enables language, see Module 36.)

Although the left hemisphere is adept at making quick, literal interpretations of lan-
guage, the right hemisphere
• excels in making references (Beeman & Chiarello, 1998; Bowden & Beeman, 1998;
Mason & Just, 2004). Primed with the flashed word feet, the left hemisphere will
be especially quick to recognize the closely associated word here. But if primed with
foot, cry, and glass, the right hemisphere will more quickly recognize another word
distantly related to all three: boot. And if given an insight-like problem—“What word
goes with boot, summer, and ground?”—the right hemisphere more quickly than the
left recognizes the solution: camp. As one patient explained after a right-hemisphere
stroke, “I understand words, but I’m missing the subtleties.”
• helps us modulate our speech to make meaning clear—as when we ask “What’s that in
the road ahead?” instead of “What’s that in the road, a head?” (Heller, 1990).
• helps orchestrate our sense of self. People who suffer partial paralysis will sometimes
obstinately deny their impairment—strangely claiming they can move a paralyzed
limb—if the damage is to the right hemisphere (Berti et al., 2005).

Simply looking at the two hemispheres, so alike to the naked eye, who would suppose
they contribute uniquely to the harmony of the whole? Let a variety of observations—of people
with split brains, of people with normal brains, and even of other species’ brains—converge
beautifully, leaving little doubt that we have unified brains with specialized parts (Hopkins &
Cantakup, 2008; MacNeilage et al., 2009; and see Close-up: Handedness on the next page).
Handedness

Nearly 90 percent of us are primarily right-handed (Laask & Beaton, 2007; Medland et al., 2004; Peters et al., 2006). Some 10 percent of us somewhat more among males, somewhat less among females, are left-handed. (A few people write with their right hand and throw a ball with their left, or vice versa.) Almost all right-handers (96 percent) process speech primarily in the left hemisphere, which tends to be the slightly larger hemisphere (Hopkins, 2006). Left-handers are more diverse. Seven in ten process speech in the left hemisphere, as right-handers do. The rest either process language in the right hemisphere or use both hemispheres.

**IS HANDEDNESS INHERITED?**

Judging from prehistoric human cave drawings, tools, and hand and arm bones, this view to the right occurred long ago (Corballis, 1989; MacNeilage et al., 2009). Right-handedness prevails in all human cultures, and even in monkeys and apes. Moreover, it appears prior to culture's impact: More than 9 in 10 fetuses suck the right hand's thumb (Hepper et al., 1990, 2004). Twin studies indicate only a small genetic influence on individual handedness (Vuoksimaa et al., 2009). But the universal prevalence of right-handers in humans and other primates suggests that either genes or some prenatal factors influence handedness.

**SO, IS IT ALL RIGHT TO BE LEFT-HANDED?**

Judging by our everyday conversation, left-handedness is not all right. To be “coming out of left field” is hardly better than to be “gauche” (derived from the French word for “left”). On the other hand, right-handedness is “right on,” which any “righteous,” “right-hand man” “in his right mind” usually is.

Left-handers are more numerous than usual among those with reading disabilities, allergies, and migraine headaches (Geschwind & Behan, 1984). But in Iran, where students report which hand they write with when taking the university entrance exam, lefties have outperformed righties in all subjects (Moreo et al., 2003). Left-handers are also more common among musicians, mathematicians, professional baseball and cricket players, architects, and artists, including such luminaries as Michelangelo, Leonardo da Vinci, and Picasso. Although left-handers must tolerate elbow jostling at the dinner table, right-handed desks, and awkward scissors, the pros and cons of being a lefthander roughly equal.

1 Strategic factors explain the higher-than-normal percentage of lefties in sports. For example, it helps a soccer team to have left-footed players on the left side of the field (Wood & Aggleton, 1989). In golf, however, no left-hander won the Masters tournament until Canadian Mike Weir did so in 2003.

The Biology of Consciousness

What is the “dual processing” being revealed by today’s cognitive neuroscience?

Today’s science explores the biology of consciousness. Evolutionary psychologists speculate that consciousness must offer a reproductive advantage (Barash, 2006). Consciousness helps us act in our long-term interests (by considering consequences) rather than merely seeking short-term pleasure and avoiding pain. Consciousness also promotes our survival by anticipating how we seem to others and helping us read their minds: “He looks really angry! I’d better run!”
Such explanations still leave us with the “hard problem”. How do brain cells jabbering to one another create our awareness of the taste of a taco, the idea of infinity, the feeling of fright? Today’s scientists are pursuing answers.

**Cognitive Neuroscience**

Scientists assume, in the words of neuroscientist Marvin Minsky (1986, p. 287), that “the mind is what the brain does.” We just don’t know how it does it. Even with all the world’s chemicals, computers, chips, and energy, we still don’t have a clue how to make a conscious robot. Yet today’s cognitive neuroscience—the interdisciplinary study of the brain activity linked with our mental processes—is taking the first small step by relating specific brain states to conscious experiences. A stunning demonstration of consciousness appeared in brain scans of a noncommunicative patient—a 23-year-old woman who had been in a car accident and showed no outward signs of conscious awareness (Owen et al., 2006). When researchers asked her to imagine playing tennis, fMRI scans revealed brain activity in a brain area that normally controls arm and leg movements (FIGURE 13.5). Even in a motionless body, the researchers concluded, the brain—and the mind—may still be active. A follow-up study of 22 other “vegetative” patients revealed 3 more who also showed meaningful brain responses to questions (Monti et al., 2010).

Many cognitive neuroscientists are exploring and mapping the conscious functions of the cortex. Based on your cortical activation patterns, they can now, in limited ways, read your mind (Bor, 2010). They can, for example, tell which of 10 similar objects (hammer, drill, and so forth) you are viewing (Shinkareva et al., 2008).

Despite such advances, much disagreement remains. One view sees conscious experiences as produced by the synchronized activity across the brain (Gaillard et al., 2009; Koch & Greenfield, 2007; Schurger et al., 2010). If a stimulus activates enough brainwide coordinated neural activity—with strong signals in one brain area triggering activity elsewhere—it crosses a threshold for consciousness. A weaker stimulus—perhaps a word flashed too briefly to consciously perceive—may trigger localized visual cortex activity that quickly dies out. A stronger stimulus will engage other brain areas, such as those involved with language, attention, and memory. Such reverberating activity (detected by brain scans) is a telltale sign of conscious awareness. How the synchronized activity produces awareness—how matter makes mind—remains a mystery.

**Dual Processing: The Two-Track Mind**

Many cognitive neuroscience discoveries tell us of a particular brain region (such as the visual cortex mentioned above) that becomes active with a particular conscious experience. Such findings strike many people as interesting but not mind-blowing. (If everything psychological is simultaneously biological, then our ideas, emotions, and spirituality must all, somehow, be embodied.) What is mind-blowing to many of us is the growing evidence that we have, so to speak, two minds, each supported by its own neural equipment.

At any moment, you and I are aware of little more than what’s on the screen of our conscious awareness. But beneath the surface, unconscious information processing occurs simultaneously on many parallel tracks. When we look at a bird flying, we are consciously aware of the result of our cognitive processing (“It’s a hummingbird!”) but not of our subprocessing of the bird’s color, form, movement, and distance. One of the grand ideas of recent cognitive neuroscience is that much of our brain work occurs off stage, out of sight. Perception, memory, thinking, language, and attitudes all operate on two levels—a conscious, deliberate

---

**TEACH**

**Interdisciplinary Connections**

The section on the brain and consciousness highlights how early ideas about the nature of consciousness are coming back into vogue. For most of the 20th century, the study of consciousness rested on the back burner as behaviorism and its focus on observable behavior reigned. Now that brain scanning technology enables us to see the brain at work, we can examine how dual processing works, unlocking the effect of unconscious processing on behavior and mental processes.

**Teaching Tip**

Many models that try to explain how the brain works are based on computers. There is one big difference, though. Computers cannot process more than one piece of information at a time. Computers run on serial processing, in which one task is accomplished before another is tackled. Brains run on parallel processing, in which several tasks can be tackled at once. This ability of the brain to process multiple pieces of information at once makes it superior to computers, no matter how fast computers may be.
**TEACH**

Concept Connections

Help students see that the idea of dual processing is reinforced in our study of memory in Unit VII. We process new information both explicitly and implicitly. These 2 ways of remembering information are stored in different parts of the brain. The complexity of the brain is what makes it truly remarkable to study.

**TEACH**

Common Pitfalls

Students often find so-called blindness confusing. Not only can people have blindness like that described by Myers in the text, but if people have damage to the occipital lobe, they can also be blind to understanding what they see with their working eyes. They can't be able to identify objects or even be able to say that they see anything recognizable. If the eyes work, some aspect of vision will be processed in the brain. Whether we can understand what we see, however, is dependent on the brain working as it should.

**ENGAGE**

Active Learning

Have students create their own visual illusions to see whether they can fool their visual system. They can create the “hollow face illusion” to see if they experience this phenomenon of dual processing: seeing one thing, but processing another.
Another patient, who lost all his left visual cortex—leaving him blind to objects presented on the right side of his field of vision—can nevertheless sense the emotion expressed in faces he does not consciously perceive (De Gelder, 2010). The same is true of normally sighted people whose visual cortex has been disabled with magnetic stimulation. This suggests that brain areas below the cortex are processing emotion-related information.

People often have trouble accepting that much of our everyday thinking, feeling, and acting operates outside our conscious awareness (Bargh & Chartrand, 1999). We are understandably biased to believe that our intentions and deliberate choices rule our lives. But consciousness, though enabling us to exert voluntary control and to communicate our mental states to others, is but the tip of the information-processing iceberg. Being intensely focused on an activity (such as reading this module, I’d love to think) increases your total brain activity no more than 5 percent above its baseline rate. And even when you rest, “hubs of dark energy” are whirling inside your head (Raichle, 2010).

Experiments show that when you move your wrist at will, you consciously experience the decision to move it about 0.2 seconds before the actual movement (Libet, 1985, 2004). No surprise there. But your brain waves jump about 0.33 seconds before you consciously perceive your decision to move (FIGURE 13.8). This readiness potential has enabled researchers (using fMRI brain scans) to predict—with 60 percent accuracy and up to 7 seconds ahead—participants’ decisions to press a button with their left or right finger (Soon et al., 2008). The startling conclusion: Consciousness sometimes arrives late to the decision-making party.

Running on automatic pilot allows our consciousness—our mind’s CEO—to monitor the whole system and deal with new challenges, while neural assistants automatically take care of routine business. Walking the familiar path to your next class, your feet do the work while your mind rehearses the presentation you’re about to give. A skilled tennis player’s brain and body respond automatically to an oncoming serve before becoming consciously aware of the ball’s trajectory (which takes about three-tenths of a second). Ditto for other skilled athletes, for whom action precedes awareness. The bottom line: In everyday life, we mostly function like an automatic point-and-shoot camera, but with a manual (conscious) override.

Our unconscious parallel processing is faster than sequential conscious processing, but both are essential. Sequential processing is skilled at solving new problems, which require our focused attention. Try this. If you are right-handed, you can move your right foot in a smooth counterclockwise circle, and you can write the number 3 repeatedly with your right hand—but probably not at the same time. (Try something equally difficult: Tap a steady beat three times with your left hand while tapping four times with your right hand.) Both tasks require conscious attention, which can be in only one place at a time. If time is nature’s way of keeping everything from happening at once, then consciousness is nature’s way of keeping us from thinking and doing everything at once.

**FIGURE 13.8**

Is the brain ahead of the mind? In this study, volunteers watched a computer clock sweep through a full revolution every 2.56 seconds. They noted the time at which they decided to move their wrist. About one-third of a second before that decision, their brain-wave activity jumped, indicating a readiness potential to move. Watching a slow-motion replay, the researchers were able to predict when a person was about to decide to move (following which, the wrist did move) (Libet, 1985, 2004). Other researchers, however, question the clock measurement procedure (Miller et al., 2011).

**Before You Move On**

**ASK YOURSELF**

What are some examples of things you do on “automatic pilot”? What behaviors require your conscious attention?

**TEST YOURSELF**

What are the mind’s two tracks, and what is “dual processing”? Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Module 13 Review

13-1 What do split brains reveal about the functions of our two brain hemispheres?

- Split-brain research (experiments on people with a severed corpus callosum) has confirmed that in most people, the left hemisphere is the more verbal, and that the right hemisphere excels in visual perception and the recognition of emotion.
- Studies of healthy people with intact brains confirm that each hemisphere makes unique contributions to the integrated functioning of the brain.

Multiple-Choice Questions

1. A split-brain patient has a picture of a dog flashed to his right hemisphere and a cat to his left hemisphere. He will be able to identify the
   a. cat using his right hand.
   b. dog using his right hand.
   c. dog using either hand.
   d. cat using either hand.
   e. cat using his left hand.

2. You are aware that a dog is viciously barking at you, but you are not aware of the type of dog. Later, you are able to describe the type and color of the dog. This ability to process information without conscious awareness best exemplifies which of the following?
   a. Split brain
   b. blindsight
   c. consciousness
   d. cognitive neuroscience
   e. dual processing

3. Which of the following is most likely to be a function of the left hemisphere?
   a. speech
   b. evaluating perceptual tasks
   c. making inferences
   d. identifying emotion in other people's faces
   e. identifying one's sense of self

4. The dual-processing model refers to which of the following ideas?
   a. The right and left hemispheres of the brain both process incoming messages.
   b. incoming information is processed by both conscious and unconscious tracks.
   c. Each lobe of the brain processes incoming information.
   d. the brain first processes emotional information and then processes analytical information.
   e. The thalamus and hypothalamus work together to analyze incoming sensory information.

13-2 What is the “dual processing” being revealed by today's cognitive neuroscience?

- Cognitive neuroscientists and others studying the brain mechanisms underlying consciousness and cognition have discovered that the mind processes information on two separate tracks, one operating at an explicit, conscious level and the other at an implicit, unconscious level. This dual processing affects our perception, memory, attitudes, and other cognitions.

Practice FRQs

1. Brain lateralization means that each hemisphere has its own functions. Give an example of a left hemisphere and a right hemisphere function. Then explain how the two hemispheres communicate with one another.

   Answer
   1 point: Left hemisphere functions include language, math, and logic.
   1 point: Right hemisphere functions include spatial relationships, facial recognition, and patterns.
   1 point: The corpus callosum carries information back and forth between the two hemispheres.

2. Because Jerry suffered severe seizures, his neurosurgeon decided to “split his brain.” What does this mean? How might a psychologist use people who have had split-brain surgery to determine the location of speech control?

   (3 points)
Module 14

Behavior Genetics: Predicting Individual Differences

Module Learning Objectives

14-1 Define genes, and describe how behavior geneticists explain our individual differences.
14-2 Identify the potential uses of molecular genetics research.
14-3 Explain what is meant by heritability, and discuss how it relates to individuals and groups.
14-4 Discuss the interaction of heredity and environment.

behind the story of our human brain—surely the most awesome thing on Earth—is the essence of our universal human attributes and our individual traits. What makes you you? In important ways, we are each unique. We look different. We sound different. We have varying personalities, interests, and cultural and family backgrounds.

We are also the leaves of one tree. Our human family shares not only a common biological heritage—cut us and we bleed—but also common behavioral tendencies. Our shared brain architecture predisposes us to sense the world, develop language, and feel hunger through identical mechanisms. Whether we live in the Arctic or the tropics, we prefer sweet tastes to sour. We divide the color spectrum into similar colors. And we feel drawn to behaviors that produce and protect offspring.

Our kinship appears in our social behaviors as well. Whether named Wong, Nkomo, Smith, or Gonzales, we start fearing strangers at about eight months, and as adults we prefer the company of those with attitudes and attributes similar to our own. Coming from different parts of the globe, we know how to read one another’s smiles and frowns. As members of one species, we affiliate, conform, return favors, punish offenses, organize hierarchies of status, and grieve a child’s death. A visitor from outer space could drop in anywhere and find humans dancing and feasting, singing and worshipping, playing sports and games, laughing and crying, living in families and forming groups. Taken together, such universal behaviors define our human nature.

What causes our striking diversity, and also our shared human nature? How much are human differences shaped by our differing genes? And how much by our environment—by every external influence, from maternal nutrition while in the womb to social support while nearing the tomb? To what extent are we formed by our upbringing? By our culture? By our current circumstances? By people’s reactions to our genetic dispositions? This module and the next begin to tell the complex story of how our genes (nature) and environments (nurture) define us.

**TEACH**

**Discussion Starter**

Use the Module 14 Fact or Falsehood? activity from the TRM to introduce the concepts from this module.

**TEACH**

**Interdisciplinary Connections**

Many of the concepts in this module are also covered in biology or anatomy classes. If you are pressed for time, this would be a good section to review quickly because it reinforces content students may already have learned in other courses.

**TEACH**

**Concept Connections**

Use the content in this module to reinforce the idea that studying nonhuman animals helps us understand human behavior and mental processes. Genetics works the same way in all species, making studies of the genetic code of other animals relevant to understanding human genetics.

**ENGAGE**

**Active Learning**

Use these quick demonstrations to show that many traits and behaviors are inherited.

- Have students draw a straight horizontal line on a sheet of paper. When the tip of their ring finger is placed on the line, does the tip of the forefinger also reach the line? (Research indicates that short forefingers are determined by a recessive trait in females, whereas in males it is dominant.)

- When interlocking their fingers, do students place the left or right thumb on top? (Particular characteristics are genetically controlled. Practice or experience has no effect.)
**ENGAGE**

Critical Questions

Students often have preconceptions about the nature–nurture dynamic. Inspire critical thinking in your students by playing devil’s advocate for both sides of the nature–nurture debate. When you do this, students who strongly believe that either nature or nurture is wholly definitive will see that both interact in determining human behavior.

**TEACH**

Common Pitfalls

Scientists have found numerous genes in recent years that predispose people to a wide range of physical and psychological conditions. Help students see that genetics alone does not guarantee that a person will develop a condition, only that it will be more likely to occur if the right environmental influences interact with those genes.

**TEACH**

Teaching Tip

Make sure your students understand **genotype** and **phenotype**. Genotype refers specifically to the set of genes we’re born with, and our phenotype is the set of traits that are “expressed”—our observable characteristics (influenced by genes— genotype—and environmental factors).

**ENGAGE**

Active Learning

Students often discount the interaction of genes and the environment. They especially don’t believe that a person’s genetics can influence his or her environment. Have students do research on whether the way one looks affects prospects for getting a job or a promotion. Some research already done suggests that people who are judged as attractive physically are more likely to get a job or a promotion over those judged less attractive, demonstrating the influence of genes on environment.

---

**Genes: Our Codes for Life**

**14-1 What are genes, and how do behavior geneticists explain our individual differences?**

If Jaden Agassi, son of tennis stars Andre Agassi and Steffi Graf, grows up to be a tennis star, should we attribute his superior talent to his Grand Slam genes? To his growing up in a tennis-rich environment? To high expectations? Such questions intrigue **behavior geneticists**, who study our differences and weigh the effects and interplay of heredity and environment.

Barely more than a century ago, few would have guessed that every cell nucleus in your body contains the genetic master code for your entire body. It’s as if every room in Dubai’s Burj Khalifa (the world’s tallest building) had a book containing the architect’s plans for the entire structure. The plans for your own book of life run to 46 chapters—23 donated by your mother’s egg and 23 by your father’s sperm. Each of these 46 chapters, called a **chromosome**, is composed of a coiled strand of the molecule **DNA** (deoxyribonucleic acid). **Genes**, small segments of the giant DNA molecules, form the words of those chapters (FIGURE 14.1). All told, you have 20,000 to 25,000 genes. Genes can be either active (expressed) or inactive. Environmental events “turn on” genes, rather like hot water enabling a tea bag to express its flavor. When turned on, genes provide the code for creating protein molecules, our body’s building blocks. Genetically speaking, every other human is nearly your identical twin. **Human genome** researchers have discovered the common sequence within human DNA. It is this shared genetic profile that makes us humans, rather than chimpanzees or tulips.

Actually, we aren’t all that different from our chimpanzee cousins; with them we share about 96 percent of our DNA sequence (Mikkelsen et al., 2005). At “functionally important” DNA sites, reported one molecular genetics team, the human-chimpanzee DNA similarity is 99.4 percent (Wildman et al., 2003). Yet that wee difference matters. Despite
Twin and Adoption Studies

To scientifically tease apart the influences of environment and heredity, behavior geneticists would need to design two types of experiments. The first would control the home environment while varying heredity. The second would control heredity while varying the home environment. Such experiments with human infants would be unethical, but hap-

cists would need to design two types of experiments. The first would control the home environment while varying heredity. The second would control heredity while varying the home environment. Such experiments with human infants would be unethical, but hap-

cists would need to design two types of experiments. The first would control the home environment while varying heredity. The second would control heredity while varying the home environment. Such experiments with human infants would be unethical, but hap-

Identical Versus Fraternal Twins

**Identical** (monozygotic) twins develop from a single fertilized egg that splits in two. Thus they are genetically identical—nature's own human clones (FIGURE 14.2). Indeed, they are clones who share not only the same genes but the same conception and uterus, and usually the same birth date and cultural history. Two slight qualifications:

- Although identical twins have the same genes, they don’t always have the same number of copies of those genes. That helps explain why one twin may be more at risk for certain illnesses (Birder et al., 2008).
- Most identical twins share a placenta during prenatal development, but one of every three sets has two separate placentas. One twin’s placenta may provide slightly better nourishment, which may contribute to identical twin differences (Davis et al., 1995; Phelps et al., 1997; Sokol et al., 1995).

**Fraternal** (dizygotic) twins develop from separate fertilized eggs. As womb-mates, they share a fetal environment, but they are genetically no more similar than ordinary brothers and sisters.

Shared genes can translate into shared experiences. A person whose identical twin has Alzheimer’s disease, for example, has a 60 percent risk of getting the disease, if the affected twin is fraternal, the risk is 30 percent (Pieron et al., 1997). To study the effects of genes and environments, hundreds of researchers have studied some 800,000 identical and fraternal twin pairs (Johnson et al., 2009).

Common Pitfalls

Students may not appreciate the importance of the concept of predis-

position. Whereas a person’s genetic code will determine many physical and personal qualities such as eye color, hair color, height, weight, and extraversion/introversion, these qualities inter-

act with the environment to influence things like popularity, interests, and dating choices. Even identical twins, who share 100% of the same genes, can differ in many ways depending on even slightly different environmental influences that occur.

Identical twins are also referred to as monozygotic twins. They come from 1 zygote that split during early pregnancy.

Fraternal twins are also referred to as dizygotic twins. They come from 2 different eggs produced during the same menstrual cycle that were fertilized at the same time.

**Teach**

**Teaching Tip**

- **Identical twins** are unique in that they share 100% of the same genes, but, while sharing the same genotype, they can have different phenotypes.
- Some identical twins are mirror images of each other (one being left-handed, the other right-handed; one having a mole on the left side of the face, the other having one on the right, etc.).
- Others may have different personalities and interests, showing that heritability of a trait doesn’t mean it will occur, even in 2 people who share the same genes.
- Fraternal twins, even though they may look alike and act alike, are as similar to one another as any sibling combination.
ENgage
Active Learning
Have students research other stories of identical twins separated at birth.
- What similarities did the twins share? How were they different?
- How did each twin feel growing up: Did they sense they had a twin or did they not feel a connection to their sibling?
- How did they feel when they reunited with their twin?

ENgage
TRM Active Learning
Although the story of the 2 Jims is extraordinary, it is very common for relative strangers to share many things in common. Create a biographical scavenger hunt for your students by having them find other people in the class who share the same birthday, clothing size, shoe size, height, weight, favorite color, favorite movie, etc. Have students conduct data analysis to determine how common similarities are among their peers in class. Students will likely find they have more in common with their peers than they have differences. This points to the influence of similar environments on development.

Use Student Activity: Striking Similarities from the TRM for students to find even more similarities between themselves and someone they may not even know.

Am identical twins, being genetic clones of each other, also behaviorally more similar than fraternal twins? Studies of thousands of twin pairs in Sweden, Finland, and Australia find that on both extraversion (outgoingness) and neuroticism (emotional instability), identical twins are much more similar than fraternal twins. If genes influence traits such as emotional instability, might they also influence the social effects of such traits? To find out, researchers studied divorce rates among 1500 same-sex, middle-aged twin pairs (McCrae & Lykken, 1992). Their result: If you have a fraternal twin who has divorced, the odds of your divorcing are 1.6 times greater than if you have a not-divorced twin. If you have an identical twin who has divorced, the odds of your divorcing are 5.5 times greater. From such data, the researchers estimate that people’s differing divorce risks are about 50 percent attributable to genetic factors.

Identical twins, more than fraternal twins, also report being treated alike. So, do their experiences rather than their genes account for their similarity? No. Studies have shown that identical twins whose parents treated them alike were not psychologically more alike than identical twins who were treated less similarly (Loehlin & Nichols, 1976). In explaining individual differences, genes matter.

Separated Twins
Imagine the following science fiction experiment: A mad scientist decides to separate identical twins at birth, then rear them in differing environments. Better yet, consider a true story:

On a chilly February morning in 1979, some time after divorcing his first wife, Linda, Jim Lewis awoke in his modest home next to his second wife, Betty. Determined that this marriage would work, Jim made a habit of leaving love notes to Betty around the house. As he lay in bed he thought about others he had loved, including his son, James Alan, and his faithful dog, Toy. Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

On a chilly February morning in 1979, some time after divorcing his first wife, Linda, Jim Lewis awoke in his modest home next to his second wife, Betty. Determined that this marriage would work, Jim made a habit of leaving love notes to Betty around the house. As he lay in bed he thought about others he had loved, including his son, James Alan, and his faithful dog, Toy. Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jay was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.

Jim was looking forward to spending part of the day in his basement woodworking shop, where he had put in many happy hours building furniture, picture frames, and other items, including a white bench now circled a tree in his front yard. Jim also liked to spend free time driving his Chevy, watching stock-car racing, and drinking Miller Lite beer.

Jim was basically healthy, except for occasional half-day migraine headaches and blood pressure that was a little high, perhaps related to his chain-smoking habit. He had become overweight a while back but had shed some of the pounds. Having undergone a vasectomy, he was done having children.
One month later, the brothers became the first twin pair tested by University of Minnesota psychologist Thomas Bouchard and his colleagues, beginning a study of separated twins that extends to the present (Holden, 1980a; Wright, 1998). Their voice intonations and inflections were so similar that, hearing a playback of an earlier interview, Jim Springer guessed “That’s me.” Wrong—it was his brother. Given tests measuring their personality, intelligence, heart rate, and brain waves, the Jim twins—despite 38 years of separation—were virtually as alike as the same person tested twice. Both married women named Dorothy Jane Scheckelburger. Okay, the last item is a joke. But as Judith Rich Harris (2006) notes, it is hardly weirder than some other reported similarities.

Aided by publicity in magazine and newspaper stories, Bouchard (2009) and his colleagues located and studied 74 pairs of identical twins reared apart. They continued to find similarities not only of tastes and physical attributes but also of personality (characteristic patterns of thinking, feeling, and acting, abilities, attitudes, interests, and even fears.

In Sweden, Nancy Pedersen and her co-workers (1988) identified 99 separated identical twin pairs and more than 200 separated fraternal twin pairs. Compared with equivalent samples of identical twins reared together, the separated identical twins had somewhat less identical personalities. Still, separated twins were more alike if genetically identical than if fraternal. And separation shortly after birth (rather than, say, at age 8) did not amplify their personality differences.

Stories of startling twin similarities do not impress Bouchard’s critics, who remind us that “the plural of anecdote is not data.” They contend that if any two strangers were to spend hours comparing their behaviors and life histories, they would probably discover many coincidental similarities. If researchers created a control group of biologically unrelated pairs of the same age, sex, and ethnicity, who had not grown up together but who were as similar to one another in economic and cultural background as are many of the separated twin pairs, wouldn’t these pairs also exhibit striking similarities (Joseph, 2001)? Bouchard replies that separated fraternal twins do not exhibit similarities comparable to those of separated identical twins.

Even the more impressive data from personality assessments are clouded by the reunion of many of the separated twins some years before they were tested. Moreover, identical twins share an appearance, and the responses it evokes. Adoption agencies also tend to place separated twins in similar homes. Despite these criticisms, the striking twin-study results helped shift scientific thinking toward a greater appreciation of genetic influences.
but with a structure that influences argument that infants are not born blank, Steven Pinker also of Human Nature The Blank Slate: The Modern Denial as people generally believe. In his book on the development of their children parents do not have as much influence Judith Rich Harris proposed that The Nurture Assumption In the book Critical Questions

**Teaching Tip**

You may have students who have been adopted. Be sensitive to their possible feelings and visible reactions as you discuss research concerning the impact of nature and nurture on the development of adopted children. Some students in your class may know, for example, that their biological parents had substance abuse problems or other psychological issues, and this knowledge may cause them concern over whether they will face similar challenges. Help them see that although a trait may be heritable, that doesn't necessarily mean that the trait will manifest itself.

**Critical Questions**

In the book The Nurture Assumption, Judith Rich Harris proposed that parents do not have as much influence on the development of their children as people generally believe. In his book The Blank Slate: The Modern Denial of Human Nature, Steven Pinker also argues that infants are not born blank, but with a structure that influences how they behave and think. Have students consider the following:

- How much of your behavior would you attribute to biology? How much to environment? Why?
- How would you feel if you knew that your genes had the greatest influence on your behavior? Why?

**Biological Versus Adoptive Relatives**

For behavior geneticists, nature's second real-life experiment—adoption—creates two groups: genetic relatives (biological parents and siblings) and environmental relatives (adoptive parents and siblings). For any given trait, we can therefore ask whether adopted children are more like their biological parents, who contributed their genes, or their adoptive parents, who contribute a home environment. While sharing that home environment, do adopted siblings also come to share traits?

The stunning finding from studies of hundreds of adoptive families is that people who grow up together, whether biologically related or not, do not much resemble one another in personality (McGue & Bouchard, 1998; Plomin, 2011; Rowe, 1990). In traits such as extraversion and agreeableness, adoptees are more similar to their biological parents than to their caregiving adoptive parents.

The finding is important enough to bear repeating. The environment shared by a family’s children has virtually no discernible impact on their personalities. Two adopted children reared in the same home are no more likely to share personality traits with each other than with the child down the block. Heredity shapes other primes’ personalities, too. Macaque monkeys raised by foster mothers exhibit social behaviors that resemble their biological, rather than foster, mothers (Maestripieri, 2003). Add all this to the similarity of identical twins, whether they grow up together or apart, and the effect of a shared rearing environment seems shockingly modest.

What we have here is perhaps “the most important puzzle in the history of psychology,” contended Steven Pinker (2002): Why are children in the same family so different? Why does shared family environment have so little effect on children’s personalities? Is it because each sibling experiences unique peer influences and life events? Because sibling relationships ricochet off each other, amplifying their differences? Because siblings—despite sharing half their genes—have very different combinations of genes and may evoke very different kinds of parenting? Such questions fuel behavior geneticists’ curiosity.

The minimal shared-environment effect does not mean that adoptive parenting is a fruitless venture. The genetic leash may limit the family environment’s influence on personality, but parents do influence their children’s attitudes, values, manners, faith, and politics (Reifman & Cleveland, 2007). A pair of adopted children or identical twins still, especially during adolescence, have more similar religious beliefs if reared together (Koenig et al., 2005). Parenting matters.

Moreover, in adoptive homes, child neglect and abuse and even parental divorce are rare. (Adoptive parents are carefully screened; natural parents are not.) So it is not surprising that, despite a somewhat greater risk of psychological disorder, most adopted children thrive, especially when adopted as infants (Loehlin et al., 2007; van Ijzendoorn & Juffer, 2006; Wierzbicki, 1993). Seven in eight report feeling strongly attached to one or both adoptive parents. As children of self-giving parents, they grow up to be more self-giving and altruistic than average (Sharma et al., 1998). Many score higher than their biological parents on intelligence tests, and most grow into happier and more stable adults. In one Swedish study, infant adoptees grew up with fewer problems than were experienced by children whose biological mothers had initially registered them for adoption but then decided to raise the children themselves (Bohman & Sigvardsson, 1996). Regardless of personality differences between parents and their adoptees, most children benefit from adoption.
The New Frontier: Molecular Genetics

14-2 What is the promise of molecular genetics research?

Behavior geneticists have progressed beyond asking, “Do genes influence behavior?” The new frontier of behavior genetics research draws on “bottom-up” molecular genetics as it seeks to identify specific genes influencing behavior. As we have already seen, most human traits are influenced by teams of genes. For example, twin and adoption studies tell us that heredity influences body weight, but there is no single “obesity gene.” More likely, some genes influence how quickly the stomach tells the brain, “I’m full.” Others might dictate how much fuel the muscles need, how many calories are burned off by fidgeting, and how efficiently the body converts extra calories into fat (Vogel, 1999). Given that genes typically are not solo players, a goal of molecular behavior genetics is to find some of the many genes that together orchestrate traits such as body weight, sexual orientation, and extraversion (Holden, 2008; Tsankova et al., 2007).

Genetic tests can now reveal at-risk populations for many dozens of diseases. The search continues in labs worldwide, where molecular geneticists are teaming with psychologists to pinpoint genes that put people at risk for such genetically influenced disorders as learning disorder, depression, schizophrenia, and alcohol use disorder. (In Module 67, for example, we will take note of a worldwide research effort to siphon the genes that make people vulnerable to the emotional swings of bipolar disorder, formerly called manic-depressive disorder.) To tease out the implicated genes, molecular behavior geneticists find families that have had the disorder across several generations. They draw blood or take cheek swabs from both affected and unaffected family members. Then they examine their DNA, looking for differences. “The most powerful potential for DNA,” note Robert Plomin and John Crabbe (2000), “is to predict risk so that steps can be taken to prevent problems before they happen.”

Aided by inexpensive DNA-scanning techniques, medical personnel are becoming able to give would-be parents a readout on how their fetus’ genes differ from the normal pattern and what this might mean. With this benefit come risks. Might labeling a fetus “at risk for a learning disorder” lead to discrimination? Preliminary screening poses ethical dilemmas. In China and India, where boys are highly valued, testing for an offspring’s sex has enabled selective abortions resulting in millions—yes, millions—of missing women.

Assuming it were possible, should prospective parents take their eggs and sperm to a genetics lab for screening before combining them to produce an embryo? Should we enable parents to screen their fertilized eggs for health—and for brains or beauty? Millions—yes, millions—of valued, testing for an offspring’s sex has enabled selective abortions resulting in millions—yes, millions—of missing women.

Heritability

14-3 What is heritability, and how does it relate to individuals and groups?

Using twin and adoption studies, behavior geneticists can mathematically estimate the heritability of a trait—the extent to which variation among individuals can be attributed to their differing genes. As Modules 63 and 64 will emphasize, if the heritability of intelligence is, say, 50 percent, this does not mean that your intelligence is 50 percent genetic. (The heritability of height is 90 percent, but this does not mean that a 60-inch-tall woman can credit her mother or father with 90 percent of her height.) More likely, some genes influence how quickly the stomach tells the brain, “I’m full.” Others might dictate how much fuel the muscles need, how many calories are burned off by fidgeting, and how efficiently the body converts extra calories into fat (Vogel, 1999). Given that genes typically are not solo players, a goal of molecular behavior genetics is to find some of the many genes that together orchestrate traits such as body weight, sexual orientation, and extraversion (Holden, 2008; Tsankova et al., 2007).

ENGAGE

Applying Science

Have students debate the merits of molecular genetics. Do the benefits of this research for finding cures to disease outweigh the potential misuse of selective breeding? Be sure to infuse a discussion of heritability into these discussions to help students apply their knowledge.

TEACH

Concept Connections

John B. Watson, the father of behaviorism, believed that environment was the single biggest determinant of behavior and mental processes. He famously wrote in his 1930 book Behaviorism:

Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I’ll guarantee to take any one at random and train him to become any type of specialist I might select—doctor, lawyer, artist, merchant-chief and, yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors. I am going beyond my facts and I admit it, but so have the advocates of the contrary and they have been doing it for many thousands of years. (p. 82)

Have students research studies with infants to see if there is evidence that they are born with innate tendencies for behavior. Have them debate whether such research contradicts Watson’s premise in this quote.
Have students watch the Flip It Video: Heritability prior to class so you can spend time addressing their questions about the topic and engage in active learning.

**TEACH**

**Common Pitfalls**

Students may have some difficulty understanding the concept of heritability. Help them break down the word into its component parts:

- *Herit-* is part of the more familiar word “inherit.” To inherit means to possess something that someone else has given you. We inherit our traits and qualities from our parents.

- *-ability* as a suffix means “capable.” If a trait is genetically passed on from one generation to the next, then it is capable of showing up in the children of people who possess that quality.

Help students see that a heritable trait is one that is capable of being passed down from parent to child.

**AP® Exam Tip**

Heritability is likely to show up on the AP® exam because it’s confusing. The key thing to remember is that heritability refers to variation within a group. It does not refer to the impact of nature on an individual. Be clear on both what it is and what it isn’t.

Heritability—differences due to genes—would be near 100 percent. As environments become more similar, heredity as a source of differences necessarily becomes more important. If all schools were of uniform quality, all families equally loving, and all neighborhoods equally healthy, then heritability would increase (because differences due to environment would decrease). At the other extreme, if all people had similar heredities but were raised in drastically different environments (some in barrels, some in luxury homes), heritability would be much lower.

Can we extend this thinking to differences between groups? If genetic influences help explain individual diversity in traits such as aggressiveness, for example, can the same be said of group differences between men and women, or between people of different races? Not necessarily. Individual differences in height and weight, for example, are highly heritable; yet nutritional rather than genetic influences explain why, as a group, today’s adults are taller and heavier than those of a century ago. The two groups differ, but not because human genes have changed in a mere century’s blink of time. Although height is 90 percent heritable, South Koreans, with their better diets, average six inches taller than North Koreans, who come from the same genetic stock (Johnson et al., 2009).

As with height and weight, so with personality and intelligence scores: Heritable individual differences need not imply heritable group differences. If some individuals are genetically disposed to be more aggressive than others, that needn’t explain why some groups are more aggressive than others. Putting people in a new social context can change their aggressiveness. Today’s peaceful Scandinavians carry many genes inherited from their Viking warrior ancestors.

**Gene-Environment Interaction**

How do heredity and environment work together?

Among our similarities, the most important—the behavioral hallmark of our species—is our enormous adaptive capacity. Some human traits, such as having two eyes, develop the same in virtually every environment. But other traits are expressed only in particular environments. Go barefoot for a summer and you will develop toughened, callused feet—a biological adaptation to friction. Meanwhile, your shod neighbor will remain a tenderfoot. The difference between the two of you is, of course, an effect of environment. But it is also the product of a biological mechanism—adaptation. Our shared biology enables our developed diversity (Buss, 1991).

An analogy may help: Genes and environment—nature and nurture—work together like two hands clapping. Genes are self-regulating. Rather than acting as blueprints that lead to the same result no matter the context, genes react. An African butterfly that is green in summer turns brown in fall, thanks to a temperature-controlled genetic switch. The genes
that produce brown in one situation produce green in another. So, too, people with identical genes but differing experiences will have similar but not identical minds. One twin may fall in love with someone quite different from the co-twin’s love.

Asking whether our personality is more a product of our genes or our environment is like asking whether the area of a field is more the result of its length or its width. We could, however, ask whether the differing areas of various fields are more the result of differences in their length or their width, and also whether person-to-person personality differences are influenced more by nature or nurture.

To say that genes and experience are both important is true. But more precisely, they interact. Imagine two babies, one genetically predisposed to be attractive, sociable, and easygoing, the other less so. Assume further that the first baby attracts more affectionate and stimulating care and so develops into a warmer and more outgoing person. As the two children grow older, the more naturally outgoing child more often seeks activities and friends that encourage further social confidence.

What has caused their resulting personality differences? Neither heredity nor experience dances alone. Environments trigger gene activity. And our genetically influenced traits evoke significant responses in others. Thus, a child’s impulsivity and aggression may evoke an angry response from a teacher who reacts warmly to the child’s model punishment, another does not. In such cases, the child’s nature and the parents’ nurture interact. Neither operates apart from the other. Gene and scene dance together.

Evocative interactions may help explain why identical twins reared in different families recall their parents’ warmth as remarkably similar—almost as similar as if they had had the same parents (Plomin et al., 1988, 1991, 1994). Fraternal twins have more differing recollections of how they had had the same parents (Plomin et al., 1988, 1991, 1994). Although genes have the potential to influence development, environmental triggers can switch them on or off, much as your computer’s software directs your printer. One such epigenetic mark is an organic methyl molecule attached to part of a DNA strand (Figure 14.3). It instructs the cell to ignore any gene present in that DNA segment, thereby preventing the DNA from producing the proteins coded by that gene.

Environmental factors such as diet, drugs, and stress can affect the epigenetic molecules that regulate gene expression. In one experiment, infant rats deprived of their mothers’ normal licking had more molecules that blocked
Concept Connections
To demonstrate genetic influences on behavior, you may want to use the simple Teacher Demonstration: Genetic Effects on Taste from the TRM in Unit IV. This activity demonstrates how people’s ability to taste the bitter substance PROP is genetically determined. About 75% of Americans are tasters; of those, 25% are supertasters. As Unit IV of this resource book notes, you can use tongue painting and a reinforcement ring to assess supertasting.

CLOSE & ASSESS
Exit Assessment
Heritability is an important concept that is confusing for students. Have students give you an example of a highly heritable trait and a nonheritable trait so you can determine whether they understand this concept.

Gene–environment interaction
Biological appearances have social consequences. People respond differently to recording artist Nicki Minaj and concert violinist Hilary Hahn.

Before You Move On

> ASK YOURSELF
Would you want genetic tests on your unborn offspring? What would you do if you knew your child would be destined for hemophilia (a medical condition that interferes with blood clotting)? A specific learning disorder? A high risk of depression? Do you think society would benefit or lose if such embryos were aborted?

> TEST YOURSELF
What is heritability?

Answers to the Test Yourself questions can be found in Appendix E at the end of the book.
Module 14 Review

14-1 What are genes, and how do behavior geneticists explain our individual differences?
- Genes are the biochemical units of heredity that make up chromosomes, the threadlike coils of DNA.
- When genes are “turned on” (expressed), they provide the code for creating the proteins that form our body’s building blocks.
- Most human traits are influenced by many genes acting together.
- Behavior geneticists seek to quantify genetic and environmental influences on our traits, in part through studies of identical (monozygotic) twins, fraternal ( dizygotic) twins, and adoptive families.
- Shared family environments have little effect on personality, and the stability of personality suggests a genetic predisposition.

14-2 What is the promise of molecular genetics research?
- Molecular geneticists study the molecular structure and function of genes, including those that affect behavior.

14-3 What is heritability, and how does it relate to individuals and groups?
- Heritability describes the extent to which variation among members of a group can be attributed to genes.
- Heritable individual differences (in traits such as height or intelligence) do not necessarily imply heritable group differences. Genes mostly explain why some people are taller than others, but not why people are taller today than they were a century ago.

14-4 How do heredity and environment work together?
- Our genetic predispositions and our surrounding environments interact. Environments can trigger gene activity, and genetically influenced traits can evoke responses from others.
- The field of epigenetics studies the influences on gene expression that occur without changes in DNA.

Multiple-Choice Questions

1. Human genome (DNA) researchers have discovered that
a. chimpanzees are completely different than humans, sharing a small DNA sequence percentage.
- b. the occasional variations found at particular gene sites in human DNA are of no interest to science.
- c. many genes do not influence most of our traits.
- d. nearly every other human is your genetically identical twin.
- e. genetic predispositions do not help explain our shared human nature and our human diversity.

2. One reason that identical twins might show slight differences at birth is
a. they did not develop from a single fertilized egg.
- b. one twin’s placenta may have provided slightly better nourishment.
- c. they develop from different sperm.
- d. one twin gestated much longer in the uterus than the other.
- e. their relative positions in the uterus.

3. Generally speaking, heritability is the extent to which
a. differences among people are accounted for by genes.
- b. an individual’s specific traits are due to genes or the environment.
- c. differences among people are due to the environment.
- d. differences among people are due to their cultural heritage.
- e. an individual’s height is related to the height of his or her parents.

4. Which of the following is most closely associated with the idea of epigenetics?
- a. Eye color
- b. Gene display based on environmental factors
- c. IQ as a function of educational experiences
- d. Height at birth
- e. Shoe size

Answers to Multiple-Choice Questions
1. d  3. a
2. b  4. b
5. a

Answer to Practice FRQ 2

1 point: **Heritability** refers to how much of the variability in the heights of a group of people can be attributed to genetics.

1 point: **Heritability** tells us nothing about how much of a person’s height is caused by genetics. Heritability only applies to groups.

Practice FRQs

1. Explain the two positions in the nature–nurture debate.

*Answer (2 points)*

1 point: **Nature** refers to the contributions of heredity and inborn, biologically determined aspects of behavior and mental processes.

1 point: **Nurture** refers to the contributions of environment and the way individuals are raised.

2. What does it mean to say that the heritability of height is 90 percent? What does that tell us about the contribution of genetics to any one person’s height?

*Answer (2 points)*

1 point: Heritability refers to how much of the variability in the heights of a group of people can be attributed to genetics.

1 point: Heritability tells us nothing about how much of a person’s height is caused by genetics. Heritability only applies to groups.
Evolutionary Psychology: Understanding Human Nature

Module 15

How do evolutionary psychologists use natural selection to explain behavior tendencies?

Behavior geneticists explore the genetic and environmental roots of human differences. **Evolutionary psychologists** instead focus mostly on what makes us so much alike. They use Charles Darwin’s principle of natural selection to understand the roots of behavior and mental processes. Richard Dawkins (2007) calls natural selection “arguably the most momentous idea ever to occur to a human mind.” The idea, simplified, is this:

- Organisms’ varied offspring compete for survival.
- Certain biological and behavioral variations increase organisms’ reproductive and survival chances in their particular environment.
- Offspring that survive are more likely to pass their genes to ensuing generations.
- Thus, over time, population characteristics may change.

To see these principles at work, let’s consider a straightforward example in foxes.

**Natural Selection and Adaptation**

A fox is a wild and wary animal. If you capture a fox and try to befriend it, be careful. Stick your hand in the cage and, if the timid fox cannot flee, it may snack on your fingers. Russian scientist Dmitry Belyaev wondered how our human ancestors had domesticated dogs from their equally wild wolf forebears. Might he, within a comparatively short stretch of time, accomplish a similar feat by transforming the fearful fox into a friendly fox?

**TEACH**

Common Pitfalls

Evolution is a controversial subject in many parts of the country. In some communities the majority of people view the theory of evolution as a direct contradiction of religious teaching. Be aware of your local community’s views regarding evolution so that you can address students’ questions in a thoughtful, sensitive way.

**TEACH**

Discussion Starter

Use the Module 15 Fact or Falsehood? activity from the TRM to introduce the concepts from this module.

**ENGAGE**

Applying Science

Now that Darwin’s ideas about evolution are more than 150 years old, have students debate whether they agree with Dawkins’ quote that natural selection is “arguably the most momentous idea ever to occur to a human mind.” Help them use the information from this unit to discuss the merits and unanswered questions about evolution.

To find out, Belyaev set to work with 30 male and 100 female foxes. From their offspring he selected and mated the tallest 5 percent of males and 20 percent of females. (He measured tameness by the foxes’ responses to attempts to feed, handle, and stroke them.) Over more than 30 generations of foxes, Belyaev and his successor, Lyudmila Trut, repeated that simple procedure. Forty years and 45,000 foxes later, they had a new breed of foxes that, in Trut’s (1999) words, are “docile, eager to please, and unmistakably domesticated. . . . Before our eyes, ’the Beast has turned into ’beauty,’ as the aggressive behavior of our herd’s wild [ancestors] entirely disappeared.” So friendly and eager for human contact are they, so inclined to whimper to attract attention and to lick people like affectionate dogs, that the cash-strapped institute seized on a way to raise funds—marketing its foxes to people as house pets.

Over time, traits that are selected confer a reproductive advantage on an individual or a species and will prevail. Animal breeding experiments manipulate genetic selection and show its powers. Dog breeders have given us sheepdogs that herd, retrievers that retrieve, trackers that track, and pointers that point (Plomin et al., 1997). Psychologists, too, have bred animals to be serene or reactive, quick learners or slow.

Does the same process work with naturally occurring selection? Does natural selection explain our human tendencies? Nature has indeed selected advantageous variations from the new gene combinations produced at each human conception and the mutations (random errors in gene replication) that sometimes result. But the tight genetic leash that predisposes a dog’s retrieving, a cat’s pouncing, or an ant’s nest building is looser on humans. The genes selected during our ancestral history provide more than a long leash; they endow us with a great capacity to learn and therefore to adapt to life in varied environments, from the tundra to the jungle. Genes and experience together wire the brain. Our adaptive flexibility in responding to different environments contributes to our fitness—our ability to survive and reproduce.

**Evolutionary Success Helps Explain Similarities**

Although our person-to-person differences grab attention, we humans are also strikingly alike. As brothers and sisters in one great human family, we all wake and sleep, think and speak, hunger and thirst. We smile when happy and favor what’s familiar more than what is foreign. We return favors, fear snakes, grieve death, and, as social animals, have a need to belong. Beneath our differing skin, we all are kin. Evolutionary psychologist Steven Pinker (2002, p. 73) has noted that it is no wonder our emotions, drives, and reasoning “have a common logic across cultures.” Our shared human traits “were shaped by natural selection acting over the course of human evolution.”

**Our Genetic Legacy**

Our behavioral and biological similarities arise from our shared human genome. Our common genetic profile sets apart 95 percent of the genetic differences among humans from population group differences. Some 95 percent of genetic variation exists within populations (Rosenberg et al., 2002). The typical genetic difference between two Icelandic villagers or between two Kenyans is much greater than the average difference between the two groups. Thus, if after a worldwide catastrophe only Icelanders or Kenyans survived, the human species would suffer only “a trivial reduction” in its genetic diversity (Lewontin, 1982).

And how did we develop this shared human genome? At the dawn of human history, our ancestors faced certain questions: Who is my ally, who my foe? What food should I eat? With whom should I mate? Some individuals answered those questions more successfully than others. For example, women who experienced nausea in the critical first three months of pregnancy were predisposed to avoid certain bitter, strongly flavored, and novel foods. Avoiding such foods has survival value, since they are the very foods most often toxic to
embryonic development (Schmitt & Pilcher, 2004). Early humans disposed to eat nourishing rather than poisonous foods survived to contribute their genes to later generations. Those who deemed leopards “ticer to pet” often did not.

Similarly successful were those whose mating helped them produce and nurture offspring. Over generations, the genes of individuals not so disposed tended to be lost from the human gene pool. As success-enhancing genes continued to be selected, behavioral tendencies and thinking and learning capacities emerged that prepared our Stone Age ancestors to survive, reproduce, and send their genes into the future, and into you.

Across our cultural differences, we even share “a universal moral grammar,” notes evolutionary psychologist Marc Hauser (2006, 2009). Men and women, young and old, liberal and conservative, living in Sydney or Seoul, all respond negatively when asked, “If a lethal gas is leaking into a vent and is headed toward a room with seven people, is it okay to push someone into the vent—saving the seven but killing the one?” And they all respond more approvingly when asked if it’s okay to allow someone to fall into the vent, again sacrificing one life but saving seven. Our shared moral instincts survive from a distant past where we lived in small groups in which direct harm-doing was punished, argues Hauser. For all such universal human tendencies, from our intense need to give parental care to our shared fears and lusts, evolutionary theory proposes a one-stop shopping explanation (Schloss, 2009).

As inheritors of this prehistoric genetic legacy, we are predisposed to behave in ways that promoted our ancestors’ surviving and reproducing. But in some ways, we are biologically prepared for a world that no longer exists. We love the taste of sweets and fats, which prepared our ancestors to survive famines, and we heed their call from school cafeterias, fast-food outlets, and vending machines. With famine now rare in Western cultures, obesity is truly a growing problem. Our natural dispositions, rooted deep in history, are mismatched with today’s junk-food vending machines. With famine now rare in Western cultures, obesity is truly a growing problem. Our shared moral instincts survive from a distant past where we lived in small groups in which direct harm-doing was punished, argues Hauser. For all such universal human tendencies, from our intense need to give parental care to our shared fears and lusts, evolutionary theory proposes a one-stop shopping explanation (Schloss, 2009).

An Evolutionary Explanation of Human Sexuality

15-2 How might an evolutionary psychologist explain gender differences in sexuality and mating preferences?

Having faced many similar challenges throughout history, men and women have adapted in similar ways. Whether male or female, we eat the same foods, avoid the same predators, and perceive, learn, and remember similarly. It is only in those domains where we have faced differing adaptive challenges—most obviously in behaviors related to reproduction—that we differ, say evolutionary psychologists.

**FYI**

Despite high infant mortality and rampant disease in past millennia, not one of your countless ancestors died childless.
Common Pitfalls

It may seem that this extended discussion of nature–nurture and evolutionary psychology is a digression rather than a necessity for AP® Psychology. However, students often misunderstand this issue in general and evolution in particular. Making sure students leave this topic with a thorough understanding of the nature–nurture issue is crucial to their understanding of future content in the course.

ENGAGE

Active Learning

Have students examine what today’s teens believe to be attractive. They can do this in several ways:

- Take a sample of magazines directed more toward men (Sports Illustrated, Men’s Health, etc.) and women’s magazines (Vogue, Glamour, Redbook, etc.) as well as magazines that are considered neutral (news magazines, etc.) to see how the people in advertisements are portrayed. Have students count the qualities of the people shown in the ads (hair color, whether they are smiling or not, etc.). Do these data support an evolutionary perspective on attraction?
- Compile pictures of people from different demographics from the magazines (tall, short, blond, brunette, red-headed, ethnic identity, etc.). Have volunteers rate how attractive each person in the picture is, analyzing the data to determine whether a pattern emerges. Do these data support an evolutionary perspective?

Use Student Activity: Mate Preferences from the TRM for students to reflect on their mate preferences as an introduction to mate selection.
There is a principle at work here, say evolutionary psychologists. Nature selects behaviors that increase the likelihood of sending one’s genes into the future. As mobile gene machines, we are designed to prefer whatever worked for our ancestors in their environments. They were predisposed to act in ways that would produce grandchildren—and had they not been, we wouldn’t be here. And as carriers of their genetic legacy, we are similarly predisposed.

Without disputing nature’s selection of traits that enhance gene survival, critics see some problems with this explanation of our mating preferences. They believe that the evolutionary perspective overlooks some important influences on human sexuality (see Thinking Critically About: The Evolutionary Perspective on Human Sexuality).

Thinking Critically About

The Evolutionary Perspective on Human Sexuality

What are the key criticisms of evolutionary psychology, and how do evolutionary psychologists respond?

Evolutionary psychology, says some critics, starts with an effect (such as the gender sexuality difference) and works backward to propose an explanation. They invite us to imagine a different result and reason backward. If men were uniformly loyal to their mates, might we not reason that the children of those committed, supportive fathers would more often survive to perpetuate their genes? Might not men also be better off bonded to one woman—both to increase their odds of impregnation and to keep her from the advances of competing men? Might not a ritualized bond—a marriage—also spare women from chronic male harassment? Such suggestions are, in fact, evolutionary explanations for why humans tend to pair off monogamously (Gray & Anderson, 2010). One can hardly lose at hindsight explanations, which is, said paleontologist Stephen Jay Gould (1997), mere “speculation [and] guesswork in the cocktail party mode.”

Some also worry about the social consequences of evolutionary psychology. Does it suggest a genetic determinant that strikes at the heart of progressive efforts to remake society (Rose, 1999)? Does it undercut moral responsibility (Buller, 2005, 2009)? Could it be used to rationalize “high-status men marrying a series of young, fertile women” (Cooy, 2001)?

Others argue that evolutionary explanations blur the line between genetic legacy and social-cultural tradition. Show Alice Eagly and Wendy Wood (1999, Eagly, 2009) a culture with gender equality, and where women seek status and earning potential in their potential mates. Show Eagly and Wood a culture with gender inequality—where men are providers and women are homemakers—and they will show you a culture where men strongly desire youth and domestic skill in their potential mates, and where women seek status and upbringing potential in their mates. Show Eagly and Wood a culture with gender equality, and they will show you a culture with smaller gender differences in mate preferences.

Much of who we are is not hard-wired, agree evolutionary psychologists. “Evolution forcefully rejects a genetic determinism,” insists one research team (Confer et al., 2010). Evolutionary psychologists reassure us that men and women, having faced similar adaptive problems, are far more alike than different, and that humans have a great capacity for learning and social progress. Indeed, natural selection has prepared us to flexibly adjust and respond to varied environments, to adapt and survive, whether we live in igloos or tree houses. Further, they agree that cultures vary, cultures change, and cultural expectations can bend the genders. If socialized to value lifelong commitment, men may sexually bond with one partner. If socialized to accept casual sex, women may willingly have sex with many partners.

Evolutionary psychologists acknowledge struggling to explain some traits and behaviors such as same-sex attraction and suicide (Confer et al., 2010). But they also point to the explanatory and predictive power of evolutionary principles. Evolutionary psychologists predict, and have confirmed, that we tend to favor others to the extent that they share our genes or can later return our favors. They predict, and have confirmed, that human memory should be well-suited to retaining survival-relevant information (such as food locations, for which females exhibit superiority). They predict, and have confirmed, various other male and female mating strategies.

Evolutionary psychologists also remind us that the study of how we came to be need not dictate how we ought to be. Understanding our proclivities sometimes helps us overcome them.

“...it is dangerous to show a man too clearly how much he resembles the beast, and at the same time showing him his greatness. It is also dangerous to allow him too clear a vision of his greatness without his baseness. It is even more dangerous to leave him in ignorance of both.” —Swinburne Praise, Proverbs, 1659
ENGAGE
Active Learning
Have students examine the interaction of genes and environment by having them research the equal pay issue. The Lily Ledbetter Fair Pay Act, enacted by Congress in 2009, allows greater flexibility for people who believe their employers did not pay them equally compared to their co-workers. This law typically affects women who believe they are not paid the same as men.

Before You Move On

ASK YOURSELF
Whose reasoning do you find most persuasive—that of evolutionary psychologists or their critics? Why?

TEST YOURSELF
What are the three main criticisms of evolutionary psychology’s explanations?
Answers to the Test Yourself questions can be found in Appendix E at the end of the book.

Reflections on Nature and Nurture

15-4 What is included in the biopsychosocial approach to individual development?

“There are trivial truths and great truths,” the physicist Niels Bohr reportedly said in reflecting on the paradoxes of science. “The opposite of a trivial truth is plainly false. The opposite of a great truth is also true.” It appears true that our ancestral history helped form us as a species. Where there is variation, natural selection, and heredity, there will be evolution.

The unique gene combination created when our mother’s egg engulfed our father’s sperm predisposed both our shared humanity and our individual differences. This is a great truth about human nature. Genes form us.

But it also is true that our experiences form us. In our families and in our peer relationships, we learn ways of thinking and acting. Differences initiated by our nature may be amplified by our nurture. If genes and hormones predispose males to be more physically aggressive than females, culture may magnify this gender difference through norms that encourage males to be macho and females to be the kinder, gentler sex.

If men are encouraged toward roles that demand physical power, and women toward more nurturing roles, each may then exhibit the actions expected of them and find themselves shaped accordingly. Roles remake their players. Presidents in time become more presidential, servants more servile. Gender roles similarly shape us.

But gender roles are converging. Brute strength has become increasingly irrelevant to power and status (think Bill Gates and Hillary Clinton). Thus both women and men are now seen as “fully capable of effectively carrying out organizational roles at all levels,” note Wendy Wood and Alice Eagly (2002). And as women’s employment in formerly male occupations has increased, gender differences in traditional masculinity or femininity and in what one seeks in a mate have diminished (Twenge, 1997). As the roles we play change over time, we change with them.

If nature and nurture jointly form us, are we “nothing but” the product of nature and nurture? Are we rigidly determined?

We are the product of nature and nurture (FIGURE 15.1), but we are also an open system, as suggested by the biopsychosocial approach (see Module 2). Genes are all pervasive but not all powerful; people may defy their genetic bent to reproduce by electing celibacy. Culture, too, is all pervasive but not all powerful; people may defy peer pressures and do the opposite of the expected. To excuse our failings by blaming our nature and nurture is what philosopher-novelist Jean-Paul Sartre called “bad faith”—attributing responsibility for one’s fate to bad genes or bad influences.
In reality, we are both the creatures and the creators of our worlds. We are—it is a great truth—the products of our genes and environments. Nevertheless (another great truth), the stream of causation that shapes the future runs through our present choices. Our decisions today design our environments tomorrow. Mind matters. The human environment is not like the weather—something that just happens. We are its architects. Our hopes, goals, and expectations influence our future. And that is what enables cultures to vary and to change so quickly.

I know from my mail and from public opinion surveys that some readers feel troubled by the naturalism and evolutionism of contemporary science. Readers from other nations bear with me, but in the United States there is a wide gulf between scientific and lay thinking about evolution. “The idea that human minds are the product of evolution is . . . unassailable fact,” declared a 2007 editorial in Nature, a leading science magazine. That sentiment concurs with a 2006 statement of “evidence-based facts” about evolution jointly issued by the national science academies of 66 nations (IAP, 2006). In The Language of God, Human Genome Project director Francis Collins (2006, pp. 141, 146), a self-described evangelical Christian, compiles the “utterly compelling” evidence that leads him to conclude that Darwin’s big idea is “unquestionably correct.” Yet Gallup reports that half of U.S. adults do not believe in evolution’s role in “how human beings came to exist on Earth” (Newport, 2007).

Many of those who dispute the scientific story worry that a science of behavior (and evolutionary science in particular) will destroy our sense of the beauty, mystery, and spiritual significance of the human creature. For those concerned, I offer some reassuring thoughts.

When Isaac Newton explained the rainbow in terms of light of differing wavelengths, the poet Keats feared that Newton had destroyed the rainbow’s mysterious beauty. Yet, noted Richard Dawkins (1998) in Unweaving the Rainbow, Newton’s analysis led to an even deeper mystery—Einstein’s theory of special relativity. Moreover, nothing about Newton’s optics need diminish our appreciation for the dramatic elegance of a rainbow arching across a brightening sky.

LEARN

Teaching Tip

The biopsychosocial model is fundamental to an understanding of modern psychology and comes up again and again in this course. It may be useful to have students make a poster of Figure 15.1 for your wall so they can be reminded of this model throughout the course.

Active Learning

Encourage students to do historical studies of the events described here regarding the controversies science and religion have endured through the centuries. Have students consider whether the handling of these scientific discoveries by religious authorities has helped or hurt both science and religion through the years.
When Galileo assembled evidence that the Earth revolves around the Sun, not vice versa, he did not offer irrefutable proof for his theory. Rather, he offered a coherent explanation for a variety of observations, such as the changing shadows cast by the Moon’s mountains. His explanation eventually won the day because it described and explained things in a way that made sense, that hung together. Darwin’s theory of evolution likewise is a coherent view of natural history. It offers an organizing principle that unifies various observations. Collins is not the only person of faith to find the scientific idea of human origins congruent with his spirituality. In the fifth century, St. Augustine (quoted by Wilford, 1999) wrote, “The universe was brought into being in a less than fully formed state, but was gifted with the capacity to transform itself from unformed matter into a truly marvelous array of structures and life forms.” Some 1600 years later, Pope John Paul II in 1996 welcomed a science–religion dialogue, finding it noteworthy that evolutionary theory “has been progressively accepted by researchers, following a series of discoveries in various fields of knowledge.”

Meanwhile, many people of science are awestruck at the emerging understanding of the universe and the human creature. It boggles the mind—the entire universe popping out of a point some 14 billion years ago, and instantly inflating to cosmological size. Had the energy of this Big Bang been the tiniest bit less, the universe would have collapsed back on itself. Had it been the tiniest bit more, the result would have been a soup too thin to support life. Astronomer Sir Martin Rees has described Just Six Numbers (1999), any one of which, if changed ever so slightly, would produce a cosmos in which life could not exist. Had gravity been a tad bit stronger or weaker, or had the weight of a carbon proton been a wee bit different, our universe just wouldn’t have worked.

What caused this almost too-good-to-be-true, finely tuned universe? Why is there something rather than nothing? How did it come to be, in the words of Harvard-Smithsonian astrophysicist Owen Gingerich (1999), “so extraordinarily right, that it seemed the universe had been expressly designed to produce intelligent, sentient beings”? Is there a benevolent superintelligence behind it all? Have there instead been an infinite number of universes born and we just happen to be the lucky inhabitants of one that, by chance, was exquisitely fine-tuned to give birth to us? Or does that idea violate Occam’s razor, the principle that we should prefer the simplest of competing explanations? On such matters, a humble, awed, scientific silence is appropriate, suggested philosopher Ludwig Wittgenstein. “Whereof one cannot speak, thereof one must be silent” (1922, p. 189).

Rather than fearing science, we can welcome its enlarging our understanding and awakening our sense of awe. In The Fragile Species, Lewis Thomas (1992) described his utter amazement that the Earth in time gave rise to bacteria and eventually to Bach’s Mass in B Minor. In a short 4 billion years, life on Earth has come from nothing to structures as complex as a 6-billion-unit strand of DNA and the incomprehensible intricacy of the human brain. Atoms no different from those in a rock somehow formed dynamic entities as complex as a 6-billion-unit strand of DNA and the incomprehensible intricacy of the human brain. Atoms no different from those in a rock somehow formed dynamic entities that became conscious. Nature, says cosmologist Paul Davies (2007), seems curiously and ingeniously devised to produce extraordinary, self-replicating, information-processing systems—us. Although we appear to have been created from dust, over eons of time, the end result is a priceless creature, one rich with potential beyond our imagining.
Module 15 Review

15-1 How do evolutionary psychologists use natural selection to explain behavior tendencies?

- Evolutionary psychologists seek to understand how our traits and behavior tendencies are shaped by natural selection, as genetic variations increasing the odds of reproducing and surviving are most likely to be passed on to future generations.
- Some genetic variations arise from mutations (random errors in gene replication), others from new gene combinations at conception.
- Humans share a genetic legacy and are predisposed to behave in ways that promoted our ancestors' surviving and reproducing.
- Charles Darwin's theory of evolution is an organizing principle in biology. He anticipated today's application of evolutionary principles in psychology.

15-2 How might an evolutionary psychologist explain gender differences in sexuality and mating preferences?

- Men tend to have a recreational view of sexual activity; women tend to have a relational view.
- Evolutionary psychologists reason that men's attraction to multiple healthy, fertile-appearing partners increases their chances of spreading their genes widely.
- Because women incubate and nurse babies, they increase their own and their children's chances of survival by selecting mates with the potential for long-term investment in their joint offspring.

Active genotype–environment correlation occurs when a person with certain genetic predispositions selects a particular environment. For example, high sensation seekers may seek risky environments (e.g., skydiving, motorcycle jumping, even drug taking). Very intelligent individuals may read books, attend lectures, and engage others in vigorous debate. This active selection of environments has been called niche picking and vividly demonstrates how we are not merely passive recipients of our environments but that we mold and create them. They, in turn, mold us.

Larsen and Buss make the important point that genotype–environment correlations may be positive or negative. That is, environments can encourage or discourage the expression of a specific genetic predisposition. Parents of very active children may try to get them to calm down, whereas parents of more passive children may try to foster liveliness. People who are very outspoken may be positively reinforced by an approving audience, but they may also elicit a negative reaction from others who try to “bring them down to size.”


* * *

In this unit we have glimpsed an overriding principle: Everything psychological is simultaneously biological. We have focused on how our thoughts, feelings, and actions arise from our specialized yet integrated brain. In modules to come, we will further explore the significance of the biological revolution in psychology.

From nineteenth-century phrenology to today’s neuroscience, we have come a long way. Yet what is unknown still dwarfs what is known. We can describe the brain. We can learn the functions of its parts. We can study how the parts communicate. But how do we get mind out of meat?

How does the electrochemical whirl in a hunk of tissue the size of a head of lettuce give rise to elation, a creative idea, or that memory of Grandmother?

Much as gas and air can give rise to something different—fire—so also, believed Roger Sperry, does the complex human brain give rise to something different: consciousness. The mind, he argued, emerges from the brain’s dance of ions, yet is not reducible to it. Cells cannot be fully explained by the actions of atoms, nor minds by the activity of cells. Psychology is rooted in biology, which is rooted in chemistry, which is rooted in physics. Yet psychology is more than applied physics. As Jerome Kagan (1998) reminded us, the meaning of the Gettysburg Address is not reducible to neural activity. Communication is more than air flowing over our vocal cords. Morality and responsibility become possible when we come to understand the mind as a “holistic system,” said Sperry (1992) (FIGURE 15.2). We are not mere jabbering robots.

The mind seeking to understand the brain—that is indeed among the ultimate scientific challenges. And so it will always be. To paraphrase cosmologist John Barrow, a brain simple enough to be understood is too simple to produce a mind able to understand it.

Evolutionary Psychology: Understanding Human Nature

Module 15
CLOSE & ASSESS

Exit Assessment

Have students write one sentence detailing something new they learned about evolution during this module.

Answers to Multiple-Choice Questions

1. a
2. a
3. a

Multiple-Choice Questions

1. Which of the following refers to an effect of life experience that leaves a molecular mark that affects gene expression?
   a. Epigenetics
   b. Adaptation
   c. Evolution
   d. Natural selection
   e. Universal moral grammar

2. Which of the following best describes genetic mutation?
   a. Random errors in gene replication
   b. The study of the mind's evolution
   c. The study of behavioral evolution
   d. Passing on successful, inherited traits
   e. Survival of the genetically successful

Answer to Practice FRQ 2

1 point: Biological influences: the prenatal environment or individual genetic influences.
1 point: Psychological influences: gene–environment interaction or beliefs.
1 point: Social-cultural influences: parental or peer influences.

Practice FRQs

1. Explain four of the important ideas behind natural selection.
   Answer
   1 point: Organisms' varied offspring compete for survival.
   1 point: Certain biological and behavioral variations increase an organism's reproductive and survival chances in a particular environment.
   1 point: Offspring that survive are more likely to pass their genes to ensuing generations.
   1 point: Over time, population characteristics may change.

2. Explain the three major influences on individual development, according to the biopsychosocial approach.
(3 points)
Unit III Review

Key Terms and Concepts to Remember

- biological psychology, p. 77
- neuron, p. 78
- dendrites, p. 78
- axon, p. 78
- myelin (MY-uh-lin) sheath, p. 78
- action potential, p. 78
- refractory period, p. 79
- all-or-none response, p. 80
- synapse [SIN-ap], p. 80
- neurotransmitters, p. 80
- endorphins [en-DOR-fins], p. 82
- agonist, p. 82
- antagonist, p. 83
- nervous system, p. 86
- central nervous system (CNS), p. 86
- peripheral nervous system (PNS), p. 86
- nerves, p. 86
- sensory (afferent) neurons, p. 86
- motor (efferent) neurons, p. 86
- interneurons, p. 87
- somatic nervous system, p. 87
- autonomic (aw-tuh-NAH-mik) nervous system (ANS), p. 87
- sympathetic nervous system, p. 87
- parasympathetic nervous system, p. 87
- endocrine [EN-duh-krin] system, p. 90
- hormones, p. 90
- adrenal [ah-DREEN-uhl] glands, p. 91
- pituitary gland, p. 91
- lesion [LEE-zhuhn], p. 94
- electroencephalogram (EEG), p. 95
- CT (computed tomography) scan, p. 95
- PET (positron emission tomography) scan, p. 95
- MRI (magnetic resonance imaging), p. 95
- fMRI (functional MRI), p. 96
- brainstem, p. 97
- medulla [muh-DUL-uh], p. 97
- thalamus [THAL-uh-muss], p. 97
- reticular formation, p. 98
- cerebellum [sehr-uh-BELL-um], p. 98
- limbic system, p. 98
- amygdala [uh-MIG-duh-lah], p. 99
- hypothalamus [hi-po-THAL-uh-muss], p. 99
- cerebral [sehr-KE-bruhl] cortex, p. 104
- glial cells (gli), p. 104
- frontal lobes, p. 105
- parietal lobes, p. 105
- occipital lobes, p. 105
- temporal lobes, p. 1050
- motor cortex, p. 105
- somatosensory cortex, p. 107
- association areas, p. 109
- plasticity, p. 111
- neurogenesis, p. 112
- corpus callosum [KOR-pus kah-LOW-sum], p. 114
- split brain, p. 114
- consciousness, p. 118
- cognitive neuroscience, p. 119
- dual processing, p. 120
- behavior genetics, p. 124
- environment, p. 124
- chromosomes, p. 124
- DNA (deoxyribonucleic acid), p. 124
- genes, p. 124
- genome, p. 124
- identical twins, p. 125
- fraternal twins, p. 125
- molecular genetics, p. 129
- heritability, p. 129
- interaction, p. 131
- epigenetics, p. 131
- evolutionary psychology, p. 135
- natural selection, p. 135
- mutation, p. 136

Key Contributors to Remember

- Paul Broca, p. 110
- Carl Wernicke, p. 110
- Roger Sperry, p. 114
- Michael Gazzaniga, p. 114
- Charles Darwin, p. 135
Answers to Multiple-Choice Questions

1. c  5. e  9. e  
2. a  6. e  10. e  
3. a  7. a  
4. a  8. b  

1. Why do researchers study the brains of nonhuman animals?
   a. It is not ethical to study human brains.
   b. Human brains are too complex to study meaningfully.
   c. The same principles govern neural functioning in all species.
   d. It is too expensive to study human brains.
   e. The technology is still being developed for the study of human brains.

2. What is the brief electrical charge that travels down an axon called?
   a. Action potential
   b. Resting potential
   c. All-or-none impulse
   d. Refractory period
   e. Myelination response

3. An individual is having trouble with cognitive tasks related to learning and memory. Which of the following neurotransmitters is most likely to be involved with the problem?
   a. Acetylcholine
   b. Dopamine
   c. Serotonin
   d. The endorphins
   e. GABA

4. Which is the most influential of the endocrine glands?
   a. Pituitary gland
   b. Adrenal glands
   c. Dendrites
   d. Threshold glands
   e. Parasympathetic

5. What is the purpose of the myelin sheath?
   a. Make the transfer of information across a synapse more efficient
   b. Increase the amount of neurotransmitter available in the neuron
   c. Reduce the antagonistic effect of certain drugs
   d. Establish a resting potential in the axon
   e. Speed the transmission of information within a neuron

6. The peripheral nervous system
   a. connects the brain to the spinal cord.
   b. calms the body after an emergency.
   c. is limited to the control of voluntary movement.
   d. controls only the arms and the legs.
   e. is the part of the nervous system that does not include the brain and the spinal cord.

7. To walk across a street, a person would rely most directly on which division of the nervous system?
   a. Central nervous system
   b. Sympathetic nervous system
   c. Peripheral nervous system
   d. Autonomic nervous system
   e. Parasympathetic nervous system

8. Opiate drugs such as morphine are classified as what?
   a. Antagonists, because they block neurotransmitter receptors for pain
   b. Agonists, because they mimic other neurotransmitters’ pain-diminishing effects
   c. Excitatory neurotransmitters, because they activate pain-control mechanisms
   d. Sympathetic nervous system agents, because they prepare the body for a challenge
   e. Parasympathetic nervous system agents, because they calm the body

9. Which region of the brain controls our breathing and heartbeat?
   a. Pons
   b. Corpus callosum
   c. Brainstem
   d. Hippocampus
   e. Medulla

10. Which of the following does a PET scan best allow researchers to examine?
    a. The presence of tumors in the brain
    b. Electrical activity on the surface of the brain
    c. The size of the internal structures of the brain
    d. The location of strokes
    e. The functions of various brain regions
11. A researcher interested in determining the size of a particular area of the brain would be most likely to use what kind of test?
   a. Lesion
   b. EEG
   c. MRI
   d. fMRI
   e. PET scan

12. Damage to the hippocampus would result in what?
   a. Difficulties with balance and coordination
   b. Memory problems
   c. The false sensation of burning in parts of the body
   d. Emotional outbursts
   e. Death

13. Surgical stimulation of the somatosensory cortex might result in the false sensation of what?
   a. Music
   b. Flashes of colored light
   c. Someone whispering your name
   d. Someone tickling you
   e. A bad odor

14. During which task might the right hemisphere of the brain be most active?
   a. Solving a mathematical equation
   b. Reading
   c. Making a brief oral presentation to a class
   d. Imagining what a dress would look like on a friend
   e. Solving a logic problem

15. Brain plasticity refers to which of the following?
   a. Healthy human brain tissue
   b. The ability of the brain to transfer information from one hemisphere to the other
   c. How a brain gets larger as a child grows
   d. A wide variety of functions performed by the human brain
   e. The ability of brain tissue to take on new functions

16. When Klüver and Bucy surgically lesioned the amygdala of a rhesus monkey's brain, what was the impact on the monkey's behavior?
   a. Lost its ability to coordinate movement
   b. Died because its heartbeat became irregular
   c. Became less aggressive
   d. Lost its memory of where food was stored
   e. Sank into an irreversible coma

17. An individual experiences brain damage that produces a coma. Which part of the brain was probably damaged?
   a. Corpus callosum
   b. Reticular formation
   c. Frontal lobe
   d. Cerebellum
   e. Limbic system

18. Evolutionary psychologists seek to understand how traits and behavioral tendencies have been shaped by what?
   a. Natural selection
   b. Genes
   c. Prenatal nutrition
   d. DNA
   e. Chromosomes

19. Which is one of the major criticisms of the evolutionary perspective in psychology?
   a. It analyzes after the fact using hindsight.
   b. It attempts to extend a biological theory into a psychological realm.
   c. There is very little evidence to support it.
   d. It has not been around long enough to “stand the test of time.”
   e. It seems to apply in certain cultures but not in others.

20. What was one of the major findings of Thomas Bouchard’s study of twins?
   a. It demonstrated that peer influence is more important than parental influence in the development of personality traits.
   b. It proved that the influence of parental environment becomes more and more important as children grow into adults.
   c. He discovered almost unbelievable similarities between adult identical twins who had been separated near birth.
   d. Fraternal twins showed almost as much similarity as identical twins when they reached adulthood.
   e. It provided evidence that heritability is less important than researchers previously suspected.

21. Which of the following statements has been supported by the research of evolutionary psychologists?
   a. Women are attracted to men who appear virile.
   b. Men are attracted to women who appear fertile and capable of bearing children.
   c. The connection between sex and pleasure is mostly determined by culture.
   d. The same factors determine sexual attraction in both males and females.
   e. Most adults are attracted to partners that in some way remind them of their parents.
Rubric for Free-Response Question 2

1 point: **Neurotransmitters** Neurons release neurotransmitters, which influence movement. These neurotransmitters are passed from one neuron to the next, enabling movement like drawing a hand away from a hot pan. (pp. 80–81)

Point 2: **The Endocrine System** Hormones will be released to help react to this emergency situation. The adrenal glands will trigger the fight-or-flight response, releasing hormones that increase heart rate, blood pressure, and blood sugar, providing the person with a surge of energy, and helping to arouse the body in this time of stress. (pp. 90–91)

Point 3: **Thalamus** The thalamus acts as the brain's sensory router and will receive the pain information that was sent to the brain. The message will be transferred to the sensory cortex. (p. 97)

Point 4: **Amygdala** This part of the brain is linked to strong, primal emotions and would be involved in the emotional experience of burning your hand in hot water (e.g., shouting or crying, etc.) (p. 99)

Point 5: **Somatosensory Cortex** The somatosensory cortex, located in the parietal lobes, is the specific area that registers and processes body touch and movement sensations. So the specific spot of the brain that knows that pain has been inflicted would be located in this area. (pp. 106–107)

Point 6: **Pain Reflex** When our skin touches something very hot or very cold, a special reflex is activated. The impulse travels from the skin to interneurons in the spinal cord, which activate motor neurons leading to muscles that would jerk our hand away from the hot water. (p. 89)

### Question 22

22. **Why do researchers find the study of fraternal twins important?**
   a. They share similar environments and the same genetic code.
   b. Data collected concerning their similarities is necessary for calculating heritability.
   c. They are the same age and are usually raised in similar environments, but they do not have the same genetic code.
   d. Results allow us to determine exactly how disorders ranging from heart disease to schizophrenia are inherited.
   e. They are typically raised in less similar environments than non-twin siblings.

### Question 23

23. Heritability refers to the percentage of what?
   a. Group variation in a trait that can be explained by environment
   b. Traits shared by identical twins
   c. Traits shared by fraternal twins
   d. Traits shared by adopted children and their birth parents
   e. Group variation in a trait that can be explained by genetics

### Question 24

24. What is the study of specific genes and teams of genes that influence behavior called?
   a. Molecular genetics
   b. Evolutionary psychology
   c. Behavior genetics
   d. Heritability
   e. Natural selection

### Question 25

25. In an effort to reveal genetic influences on personality, researchers use adoption studies mainly for what purpose?
   a. To compare adopted children with non-adopted children
   b. To study the effect of prior neglect on adopted children
   c. To study the effect of a child's age at adoption
   d. To evaluate whether adopted children more closely resemble their adoptive parents or their biological parents
   e. To consider the effects of adoption on a child's manners and values
Free-Response Questions

1. Charlotte is 88 years old and is feeling the effects of her long life. She suffered a stroke five years ago, which left the right side of her body limp. She also sometimes has trouble understanding when she is asked questions. Her doctors believe that she also may be suffering from the beginning stages of Alzheimer’s disease. Define each of the following terms and explain how each might contribute to Charlotte’s current circumstance:

   - Motor cortex
   - Acetylcholine
   - Association areas
   - Plasticity
   - Epigenetics

Rubric for Free Response Question 1

1 point: Epigenetics is the study of environmental influences on gene expression, which occur without DNA change. (Page 115)

1 point: Perhaps Charlotte has a predisposition for Alzheimer’s disease. If she was in an environment which was not enriching and cognitively engaging, it may have made Alzheimer’s disease more likely. On the other hand, despite having a genetic predisposition for Alzheimer’s disease, if Charlotte was exposed to an enriching environment, her disposition may not have been expressed. (Page 125)

2. If a person accidentally touches a pan filled with hot water on the stove, they will immediately move their hand away from the hot pan before yelling out in pain. Use the following terms to explain what is involved in this reaction:

   - Neurotransmitters
   - The endocrine system
   - Thalamus
   - Amygdala
   - Sensory cortex
   - Pain reflex

3. Dr. Nation is a biopsychologist interested in studying genetic influences on brain development. Briefly describe a twin study Dr. Nation might design to investigate genetic infl uences on brain development. (Page 131)

Point 1: Genes In the study, Dr. Nation would be interested in identifying sets of genes, functional segments of DNA strands, that influence how brains develop. (Page 124)

Point 2: Heritability One of the major goals of Dr. Nation’s study would be to focus on how much the diversity of brain development within a group can be attributed to genetic factors. If Dr. Nation can describe this, he will be describing the heritability of brain development. (Pages 129–130)

Point 3: Epigenetics Because Dr. Nation is a biopsychologist, he knows that brain development, like all physical and mental development, occurs through the interaction of environmental and biological factors. Dr. Nation will probably use findings in the field of epigenetics to describe environmental triggers that turn genes on and off and influence brain development. (Page 131)

Point 4: Fraternal or Identical Twins Because Dr. Nation is using a twin study, he might use the different characteristics of fraternal and identical twins to try to isolate the impact of genetics on brain development. Because identical twins are genetically identical, and fraternal twins share half of their genetic material, these 2 groups can be used in twin studies to isolate the impact of genetics on specific characteristics. (Page 125)

Point 5: fMRI Because Dr. Nation is studying brain development, he may want to use an fMRI machine; it can look at both the structure of the brain and the activity level in parts of the brain during specific tasks. (Page 96)