INSIDE: SAMPLE CHAPTER 3. THE BRAIN AND THE NERVOUS SYSTEM
Dear Colleague,

In the early weeks of introductory psychology, students often are disappointed. They hope, when signing up for a psychology course, to learn why individuals think and act the way they do. But people — real people whose lives unfold within families, relationships, groups, and cultures — receive little coverage in the early chapters of most intro textbooks.

The relative absence of fully functioning people not only lowers student engagement. It also misses out on how “people focused” contemporary psychological science has become. More than ever, researchers in cognitive science, neuroscience, genetics, and related fields investigate questions about human lives in sociocultural contexts: How do cultural experiences shape patterns of thinking? How do social experiences shape brain development? How do interpersonal experiences activate genetic mechanisms? This makes today’s psychology an integrative science: a unified field where findings at different levels of analysis converge. Unfortunately, textbooks often fail to convey this message to intro students.

We deeply believe that both challenges — engaging our students and representing our science — can be met through a simple two-part pedagogical strategy. The first part is to introduce readers to the three levels of analysis around which contemporary psychology is organized: person, mind, and brain. The second is a person-first strategy in which we introduce topics at the level that readers are most familiar with, the level of the person. This enhances student interest and provides a foundation for scientific understanding. We then deepen students’ understanding by exploring those topics at the levels of mind (thinking processes and affective systems) and brain (neural and biochemical systems). By integrating across levels of analysis — person, mind, and brain — we make it easier for students to grasp the significance of research on cognitive processes and biological mechanisms, and thus to see the “big picture” of today’s psychological science.

Each chapter — even the early ones — executes the person-first mission. You can see this in the chapter we provide here, Chapter 3, “The Brain and the Nervous System.” In the brain chapter of many other introductory psychology books, research on persons is scarce. In ours, it is front-and-center, and it contextualizes students’ understanding of the brain. As you will see, the main text’s person-first coverage is enhanced by integrated pedagogical features that further build student interest, scientific comprehension, and critical thinking.

The person-first format overcomes a traditional trade-off. Should a textbook be maximally engaging to students or maximally up-to-date scientifically? It can be both. Focusing on people is most appealing to students and is an optimal way of representing contemporary psychological science.

We’d love to hear what you think of our approach. Please feel free to contact us with any questions or suggestions.

Sincerely,

Daniel Cervone
Tracy L. Caldwell
Because people are the story of psychology

IN PSYCHOLOGY: THE SCIENCE OF PERSON, MIND, AND BRAIN, experienced teacher, researcher, and author Daniel Cervone provides introductory psychology students with a new and exciting way to understand psychology. By introducing the person, mind, and brain levels of analysis and grounding explanations in the person level first, Cervone helps readers engage with psychology and make sense of the latest science through what they understand best: people. With fellow teacher and researcher Tracy Caldwell, Cervone has conceived a text beyond the print experience from the ground up—integrating online immersive research experiences and assessment tools that capitalize on research findings on pedagogy and student learning (e.g., the testing effect).

PEDAGOGICAL AUTHOR, TRACY L. CALDWELL

Working closely with Daniel Cervone, fellow teacher and researcher Tracy Caldwell of Dominican University developed the book’s pedagogical program from the Preview Questions at the beginning of each section to the Self-Tests at the end of each chapter. The pedagogy is designed to engage students at multiple levels of Bloom’s taxonomy and at multiple points in each chapter.

• Preview Questions before major chapter subsections pose questions that are answered in the reading. The Chapter Review repeats and answers these same questions.

• Think About It asks students to pause and think critically about a particular topic from the perspective of a psychological scientist.

• The boxed In Your Life questions appear throughout each chapter in the margins to help students identify applications of the material to their own lives.

• What Do You Know? appears at the end of each section so students can immediately test their understanding of the material through the first three levels of Bloom’s taxonomy.

• Questions for Discussion (p. 118) in the end-of-chapter material support the higher levels of Bloom’s taxonomy through Level 5, Synthesis.

• An end-of-chapter Self-Test (p. 118) consisting of 15 multiple-choice questions is designed to challenge students through the first four levels.
Cevone's book is organized into four parts, but within this organization, both the parts and the individual chapters within them are self-standing, and can be assigned in any order instructors prefer.

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### APPENDIX A: Statistics
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PMB In Action (p. 105) introduces a question central to the chapter and shows how it can be understood at the combined levels of person, mind, and brain. In this chapter, readers can see how information from all three levels contributes to our understanding of Capgras syndrome, introduced in the opening vignette.

PMB Connections (pp. 86, 110) shows students where related topics can be found in other parts of the book. Not only does this orient students to helpful information in other chapters, it also shows them how the information they are learning fits in with the discipline as a whole, allowing them to comprehend and scaffold the material more effectively.
ENRICHMENT FEATURES

The text highlights several key topics in every chapter, including methods, culture, and new research with a series of enrichment features.

- **The Research Toolkit** (p. 93) shows readers how psychology is a science built on experiments and discoveries. Among the methods highlighted is fMRI in Chapter 3.

- **Cultural Opportunities** (p. 104) explores the many ways in which culture influences human behavior and how we use our brains.

- **This Just In** (p. 110) points to highly significant and new research that has overturned a previous way of thinking. Chapter 3 features the 2010 discovery of a new form of neural communication.

These features are not boxed and segregated as is traditional, but are integrated within the flow of the narrative, precisely where students will understand their connection to the related topic/concept.

INTEGRATED MEDIA

TRY THIS!

*Psychology: The Science of Person, Mind, and Brain* is unique in that it integrates the very experience of participating in research. Each chapter features an activity called **Try This!** (pp. 92, 100) which requires students to complete an online research task in LaunchPad, giving them firsthand experience with topics such as false memory, the Stroop test, and mental rotation. After completing each activity and receiving their results, students’ experience with each task is then discussed within the text to deepen their knowledge and engagement.
Psychology: The Science of Person, Mind, and Brain has its own dedicated version of Worth Publishers’ new online course space, LaunchPad. LaunchPad offers acclaimed media content, curated and organized for easy assignability and presented in an intuitive interface that combines power and simplicity. A demo of LaunchPad for this title will be available February 1, 2015, at pmbpsychology.com. Developed with extensive feedback from instructors and students, LaunchPad offers:

- **Pre-built units for each chapter**, curated by experienced educators, with media for that chapter organized and ready to assign or customize to suit your course.

- **All online resources for the text in one location**, including an interactive e-book, LearningCurve adaptive quizzing (see below), the online component of the textbook feature, “Try This,” and more.

- **Intuitive and useful analytics**, with a Gradebook that lets you see how your class is doing individually and as a whole.

- **A streamlined interface** that lets you build an entire course in minutes.

In a game-like format, LearningCurve adaptive and formative quizzing provides an effective way to get students involved in the coursework. It offers:

- **A unique learning path for each student**, with quizzes shaped by each individual’s correct and incorrect answers.

- **A Personalized Study Plan**, to guide students’ preparation for class and for exams.

- **Feedback for each question** with live links to relevant e-book pages, guiding students to the reading they need to do to improve their areas of weakness.
The patient was looking at his father, yet thought he was looking at an imposter. “He looks exactly like my father but he really isn’t. He’s a nice guy, but he isn’t my father, Doctor.”

“But why,” the doctor asked, “was this man pretending to be your father?”

“That is what is so surprising, Doctor—why should anyone want to pretend to be my father? Maybe my father employed him to take care of me.”

—Hirstein & Ramachandran (1997, p. 438)

The case was mystifying. For years, the patient’s relationship with his father was normal. But now, he didn’t even recognize him! What do you think was wrong?

Maybe the patient had amnesia and couldn’t remember his father. But that wasn’t it.

When he talked to his father on the phone, everything was normal: He recognized his father’s voice, remembered their relationship, and they conversed as always. Problems arose only when he saw his father in person.

Maybe a part of the patient’s brain that detects faces was damaged and he couldn’t recognize anybody. But that wasn’t it, either. He easily recognized other people: neighbors, casual friends, and the like. Yet his father was unrecognizable to him.

As it turns out, all the individual parts of the patient’s brain were working properly. Yet something was broken: a connection between parts (Hirstein & Ramachandran, 1997).

Everyone’s brain contains one region that detects faces and another that generates emotions. In most brains, they are interconnected. When a loved one comes into view, both brain regions are activated; the interconnection combines their activity, and the result is a “warm glow of recognition.” You see and feel as if you’re seeing your loved one.

In the patient’s brain, the connection had become severed. Once this happened, he no longer experienced the “warm glow”; upon seeing his father, he didn’t feel as if he was looking at his father. His brain damage—the broken connection—then caused his mind to play a trick on him. Without the feeling
that usually occurred when he looked at his father, the patient concluded that the
man was an imposter.

*Capgras syndrome*, the patient’s disorder, is rare. But the lesson it teaches is broadly
important. When it comes to the brain, connections are key.

The brain is like the Internet. The Internet’s power comes from connections
among vast numbers of computers. The brain’s power derives from connections
among vast numbers of brain cells. Without the Internet connections, you couldn’t
email friends, watch YouTube videos, or play interactive games. Without the brain
connections, you couldn’t sing a song, read this book, or recognize your father.

**WHAT IS THE BRAIN LIKE?** It seems so mysterious: a collection of biological cells
packed under the skull that, somehow, gives you extraordinary powers—to create
works of art; to feel the warmth of the sun; to imagine yourself traveling in a spaceship;
and, even more remarkably, to *think about the fact that* you are creating art, feeling the
sun’s warmth, and imagining yourself in a spaceship.

This chapter begins with some general principles that help to explain the brain’s
workings. Next, we’ll “zoom in” on the brain by reviewing its overall organization and
then its individual cells. Finally, you’ll learn about two communications systems that
run throughout the body: the nervous system and the endocrine system.

**Brain and Behavior: General Principles**

The question “What is the brain like?” is not new. Scholars have speculated about it
for thousands of years.

**Ideas About the Brain Through the Ages**

**Preview Question**

› What analogies have been used to describe the brain through the ages?

Throughout history, scholars contemplating the brain have proposed analogies
(Hampden-Turner, 1981). The mysterious brain, they have said, might be analogous to
some less mysterious object. The similarity might shed light on how the brain works.

› In ancient Rome, inventors devised pumps for propelling water into the city’s
fountains. Romans who contemplated the brain judged that it, too, is a pump
(Daugman, 2001). A physician, Galen, said that the brain controlled bodily
movements by pumping “animal spirits” through the body’s nerves, which he claimed
were like pipes (Vartanian, 1973).

› By the start of the eighteenth century, European inventors had devised complex
new machines (e.g., mechanical clocks), and Isaac Newton had explained that
the universe functions according to physical laws, like a machine. Scholars of the
eighteenth century judged that the brain and the body of which it is a part work
like a machine. The analogy was made most explicit in a book by the French
physician Julien La Mettrie, entitled *L’homme Machine* (“Man a Machine,” 1748;
Wellman, 1992).

› In the nineteenth century, physicists formulated laws of energy, inventors harnessed
energy for industrial use, and Sigmund Freud said that the brain is an energy system
(Breuer & Freud, 1895). According to Freud, different parts of the brain store
mental energy and use it to power behavior. Just as too much pent-up energy in a
steam engine can cause mechanical problems, too much pent-up mental energy in
the brain can cause psychological problems.
In the second half of the twentieth century, society’s new technological toy was the computer, and its favorite brain analogy was that—you guessed it—the brain is like a computer. The physical brain was analogous to computer hardware and the mind’s beliefs and skills were akin to computer software (Simon, 1969). Interestingly, this analogy also worked in reverse: Computers, like brains or minds, are “machines who think” (McCorduck, 2004).

Our opening story introduced another analogy: The brain is like the Internet. The power of both comes from interconnections among large numbers of parts.

Each analogy—pump, machine, energy system, computer, and Internet—tells us something about the brain. Some (computer and Internet) are better than others (water pump; the Romans were better at plumbing than brain science). None is perfect, yet each is useful. The human brain is so massively complex that analogies are, in fact, a valuable first step toward understanding. So let’s look at two more, both of which you should keep in mind throughout this chapter. The brain is like (1) a tool and (2) a muscle.

**WHAT DO YOU KNOW?**

1. With changes in technology come changes in the _____ used to describe the brain.

See Appendix B at www.worthpublishers.com/cervonepreview for answers to What Do You Know? questions.

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**How the Brain Is Like a Tool**

**Preview Question**

What valuable points are highlighted by a brain-as-tool analogy?

The philosopher Rom Harré (2002, 2012) emphasizes that the brain is like a tool. People use their brains to do the jobs of everyday life. The brain/tool analogy highlights two valuable points:

1. You can use any tool for a variety of jobs, including those tasks for which it was not originally designed (Heyes, 2012). A screwdriver, for example, can serve not only as a screw turner, but also as a paint can opener, ice pick, or weapon.
Similarly, although your brain was originally designed to solve problems encountered in the evolutionary past, you can use it to perform contemporary tasks—reading, writing, driving—for which it was not designed originally.

2. When you use a tool to perform a job, it is you—not the tool—that is responsible for executing the job. You don’t say, “My shovel cleared the snow off the sidewalk.” You say that you did it, using a tool (the shovel). Similarly, you don’t say, “My hands typed my paper” or “My legs ran 2 miles in under 11 minutes.” You did those things, using biological tools—your hands and legs. Likewise, when solving a math problem, answering a trivia question, or learning a second language, it’s you—not your brain—that’s doing the problem solving, answering, or learning (Bennet & Hacker, 2003). You need your brain to do these jobs, but you, not your brain, did them.

The brain/tool analogy helps to avoid confusions that can occur when discussing the brain and people’s psychological experience. It is not the brain having the experiences; it’s the people. Although some writers talk about the “emotional brain” (Ecker, Ticic, & Hulley, 2012), “spiritual brain” (Beauregard & O’Leary, 2008), and “political brain” (Westen, 2007), the being who is emotional, spiritual, and political is not your brain; it’s you.

**What do you know?**

2. The following statement is incorrect. Explain why: “The brain-as-tool analogy reminds us that it is the brain that performs tasks, not the person using the brain.”

### How the Brain Is Like Muscle

#### Preview Question

› How have researchers demonstrated that the brain is like muscle?

When you use a muscle repeatedly, it grows. As a result, you gain strength and are better able to perform physical tasks using that muscle.

Like a muscle, the brain also changes when you perform a task repeatedly. The changes make it easier for you to do that task in the future. Evidence of this comes from a study of juggling (Draganski et al., 2004).

Researchers invited to a lab 24 participants who did not know how to juggle and took pictures of their brains using neuroimaging methods (see Research Toolkit). Half the participants then spent three months learning how to juggle. The other half did not learn juggling. Afterward, brain images were taken again. By comparing the two sets of images, the researchers could see whether people’s brains had changed during the three-month period.

They found that jugglers’ brains did change. The changes occurred in an area of the brain critical to processing visual motion, as you might expect because juggling requires close visual attention to multiple moving objects (Figure 3.1). This brain region expanded among people who learned how to juggle; there was a greater volume of brain cells in this area after juggling. No changes occurred in the brains of nonjugglers (Draganski et al., 2004).

The point of this research is not that juggling, per se, enhances the brain. It is more general: Experiences alter brain anatomy. Brain structures are not fixed and unchangeable. Instead, like muscle, they grow with experience. This feature of the brain is called **plasticity**, which is the brain’s capacity to change physically as a result of experience (Zatorre, Fields, & Johansen-Berg, 2013).
Note how plasticity makes the brain unlike a computer. If you run your favorite software application repeatedly, your computer's hardware does not change. But if you yourself perform the same task repeatedly, the biological “hardware” of your brain does change.

**WHAT DO YOU KNOW?**
3. How is the concept of plasticity related to the idea that the brain is like muscle?

**Different Parts of the Brain Do Different Things**

**Preview Question**

What can brain damage tell us about the structure and function of the brain?

The human brain looks a bit like a cauliflower: roundish, off-white, with ridges and bumps on the surface. Yet “the brain is like a cauliflower” is not a good analogy. Of the many ways in which the brain is not like a cauliflower, one is particularly noteworthy. All parts of a cauliflower are essentially the same. Plant tissue is undifferentiated; there are no significant biological differences between one part of the cauliflower and another. Brains are not like this. They are highly differentiated; distinct parts of the brain vary structurally and are involved in different types of mental activity.

**BRAIN DAMAGE EVIDENCE.** How do we know that the brain is differentiated? Cases of brain damage provide convincing evidence.

Whether through injury or illness, people sometimes incur damage to one part of the brain. When this happens, there are, in principle, three possible outcomes for the mind:

1. **No mental ability:** The person won’t have any thoughts or feelings. It might be that every part of the brain must function normally in order to provide the capacity for thought.
2. **All mental abilities are intact but impaired:** The person will be able to think, but thinking will be less quick and intelligent. It might be that each part of the brain contributes equally to its overall speed and power.
3. **Selective loss of specific mental abilities:** Some thinking abilities will remain completely intact, but other abilities will be lost. This would indicate that the brain is differentiated and that the specific part that was damaged is needed for the specific mental ability that was lost.

What usually happens? Commonly it is #3. Brain damage often causes people to lose a specific mental ability. A case of brain damage from a century-and-a-half ago vividly illustrates the point.

**PHINEAS GAGE.** The damaged brain was that of Phineas Gage, a railroad construction worker in Vermont (Damasio et al., 1994). Gage’s job was to supervise explosions designed to level land for laying track. Explosive force was supposed to go down into rock that was standing in the way of the railroad tracks. Unfortunately for Gage (but fortunately for science), an on-the-job error caused an explosion to go in the other direction—up toward Gage’s head, propelling an iron rod up from the ground, into Gage’s face, and straight through part of his brain. The rod then exited the top of Gage’s skull (Figure 3.2).

What happened to Gage? As the *Boston Post* (September 13, 1848) reported, “The most singular circumstance connected with this affair is that he was alive . . . and in full possession of his reason.” Most of Gage’s mental abilities were intact. He could control the movements of his body, his speech was normal, and his memory was so good that he could even remember what happened to him in the accident. Gage seemed no less intelligent than before the accident occurred (Damasio et al., 1994).
Gage’s case, then, contradicts possibilities #1 and #2 above. Despite brain damage,
he still could think, and just as quickly and intelligently as before.

Yet, in one specific way, Gage changed profoundly. Before the accident, he was well
mannered. Afterward, he used profane language that offended friends and coworkers.
Before, he had been industrious and responsible. After, he
was so irresponsible that his employer had to fire him. Gage
no longer could control his social behavior. He was unable
to adhere to the rules, conventions, and responsibilities of
society. His physician, John M. Harlow, summarized the
change as follows:

Previous to his injury . . . he possessed a well-balanced mind,
and was looked upon by those who knew him as a shrewd,
smart businessman, very energetic and persistent in executing
all his plans of operation. In this regard his mind was rad-
ically changed, so decidedly that his friends and acquaintances
said he was “no longer Gage.” [After the accident, Gage was]
fitful, irreverent, indulging at times in the grossest profanity
(which was not previously his custom), manifesting but little
deference for his fellows, impatient of restraint or advice when
it conflicts with his desires, at times pertinaciously obstinate,
yet capricious and vacillating, devising many plans of future
operations, which are no sooner arranged than they are aban-
don in turn for others appearing more feasible.

—quoted in Macmillan (2000, pp. 92–93)

The case of Phineas Gage shows that even major damage
to the brain may not eliminate a person’s ability to think,
or even slow his or her thinking. Instead, brain damage is
selective. It can cause people to lose one type of ability—in
Gage’s case, the ability to align one’s behavior with social
rules and responsibilities—while leaving others intact. This means that different parts of the brain are specialized. A given part of the brain may be critical to some mental activities, and irrelevant to others.

In summary, you’ve already learned a few lessons about the brain. It’s a biological tool that we use to perform the tasks of life. It’s a special kind of tool that becomes stronger the more it is used, like a muscle. It’s a complex tool, with lots of specialized parts. Finally, as you learned in this chapter’s opening story about a patient suffering from Capgras syndrome, even more complexity is involved: The various parts of the brain are highly interconnected. Even simple, everyday tasks require coordination among multiple brain regions.

Let’s now look at this remarkable biological tool in detail, to find out how it gets its jobs done.

**WHAT DO YOU KNOW?**

4. How might Phineas Gage have been affected by his accident if the parts of the brain were not specialized?

**Zooming In on the Brain**

We’ll begin our tour of the brain by examining the big picture: the brain’s overall structure and major subparts. Next, we’ll “zoom in” a bit to look at the communications networks that connect these subparts to one another. We then will zoom in even more, to examine the brain’s individual cells, or neurons, and how they communicate with one another.

**Bottom-to-Top Organization**

**Preview Questions**

- How does Aristotle’s model of the brain compare to more recent conceptualizations of the brain?
- What did MacLean mean when he said that we have “three brains in one”?
- What are the structures of the lowest level of the brain and their functions?
- What are the structures of the middle level of the brain and their functions?
- What are the structures of the highest level of the brain and their functions?

Scholars studying the brain have long noted that its overall structure consists of three main parts. The first such brain model is more than 2000 years old, yet looks remarkably modern.

Aristotle, the greatest scientist of ancient Athens, suggested that the mind and brain have a three-part structure, with some parts being conceptually “high-level” structures that contribute to distinctly human thinking processes. In Aristotle’s model, the lowest level is a vegetative mind responsible for growth and reproduction. One level up is an animal mind responsible for feelings of pleasure and pain. Finally, on top, a rational mind enables people to engage in logical thought (Aristotle, trans. 2010).

When formulating his model, Aristotle completely lacked contemporary scientific knowledge of brain structures. Nonetheless, his work has a contemporary ring to it. The twentieth century’s most renowned conceptual model of the brain, proposed by the neuroscientist Paul MacLean (1990), similarly identifies a three-part, bottom-to-top organization of brain structures.

MacLean’s model is known as the *triune brain*. “Triune” means “three in one.” The *triune brain* model, then, suggests that the overall human brain consists of three main parts, each of which is a distinct functioning brain that carries out its own unique...
activities. You have, in essence, three brains in one. As in Aristotle’s model, some parts of the brain are more advanced, and at a higher level, than others.

MacLean contended that the three levels of brain emerged at different points in the evolution of Earth’s species (Figure 3.3):

1. **The reptilian brain**, the lowest level of the three brain regions, is evolutionarily ancient. It has existed since the evolution of reptiles.
2. **The paleomammalian (ancient mammal) brain**, the midlevel brain system, is newer, yet still quite old. It reached its full development with the evolution of mammals, more than 100 million years ago.
3. **The neomammalian (new mammal) brain** is the newest and highest-level brain system. It reached its fullest development in our species, *Homo sapiens*, somewhere between 50,000 and 200,000 years ago (Mithen, 1996).

According to MacLean, then, you possess not only the unique brain systems of a modern human, but also, tucked underneath, the brain of a nonhuman mammal and, beneath that, the brain of a reptile.

At first, “three brains in one” sounds weird. But consider the following three facts:

> Some of your experiences—which are products of your brain—are easy to put into words. You could, right now, say that “I’m reading my psych textbook” or “I plan to finish the brain chapter by tomorrow.”

> Other experiences—still products of your brain—are strongly felt, yet very difficult to put into words. You may experience “mixed emotions” that you can’t easily describe (e.g., a mix of happiness, sadness, and envy if a close friend announces that she’s been offered a great new job that will cause her to move to a different town).

> Yet other activities of the brain are not “experiences” at all; you aren’t even aware that the brain is doing them. Right now, your brain is regulating your body temperature and breathing rate, but you can’t feel your brain doing so.

MacLean’s triune brain model explains that these different experiences reflect the actions of different levels of brain. When you put experiences into words, you are using your neomammalian brain. Emotions, by contrast, are produced by the paleomammalian brain. It is not capable of producing language (so nonhuman animals aren’t speaking to one another), which helps to explain why the emotions it produces sometimes can’t easily be put into words. Finally, the reptilian brain executes simple functions like regulating body temperature and breathing. By itself, this brain system cannot produce consciously experienced feelings, so you don’t feel your brain at work on the task of regulating internal physiological states. The three parts of the triune brain are connected to one another, and their activities thus can be coordinated. Nonetheless, their functions are distinct.

MacLean first proposed the triune brain model in 1969 (Newman & Harris, 2009). Although enormous scientific advances have been made since that time, MacLean’s three-part, bottom-to-top organization remains a valuable overview of brain structures. So let’s now look at these “three brains” in detail. In doing this, we’ll use their standard contemporary biological names: (1) the **brain stem** (MacLean’s reptilian brain), (2) the **limbic system** (the paleomammalian brain), and (3) the **cerebrum** (the neomammalian brain) and its outermost layer, the cerebral cortex.

**BRAIN STEM.** The lowest region of the brain is the **brain stem**, which sits at the top of the spinal cord. Three main structures of the brain stem—the *medulla*, the *pons*, and the *midbrain*—regulate bodily activities critical to survival (Figure 3.4).
The **medulla** plays a major role in *homeostasis*, which is the body's maintenance of a stable, consistent inner physical state. It contributes to homeostasis by regulating rates of physiological activity, such as heart rate and blood pressure. The medulla also is the key pathway from the brain to the rest of the body; communications between the spinal cord and higher regions of the brain run through the medulla. In addition, the medulla controls the "gag reflex," the contraction of the throat that prevents choking (Urban & Caplan, 2011).

The **pons** is a region of the brain stem located just above the medulla. It performs a number of functions and contains structures that control your rate of breathing. It also generates a distinctive stage of sleeping (REM sleep; see Chapter 9) in which the brain is highly active, generating dreams, but the body is essentially paralyzed. Studies show that if the pons is damaged, an animal, while asleep and dreaming, will move around and attack imaginary prey (Siegel, 2005). The pons also functions as a relay station, conveying signals among other brain regions (which you'll learn about below).

The third main brain stem structure is the **midbrain**, a small yet complex structure that contributes to an organism's survival in a number of ways. One region of the midbrain protects the organism by generating defensive reactions to threatening events. Evidence of this comes from studies in which researchers activate the key region of the midbrain artificially. When the midbrain is activated, animals display defensive responses even when no threat is present. For example, when researchers stimulated the midbrain of a rat, it became highly alert, its heart rate increased, and it began to flee—even though there was nothing in the environment to flee from (Brandão et al., 2005).

In addition to these three main structures (the medulla, pons, and midbrain), the brain stem houses a network of brain cells that you're relying on right now to keep you awake and alert as you read this chapter. This network is the **reticular formation**, a brain system that influences an organism's overall level of arousal (Gupta et al., 2010). This function of the reticular formation was discovered in studies with cats (Moruzzi & Magoun, 1949). Researchers stimulated the reticular formation, a low-level brain system, while recording activity in the cortex (discussed below), a high-level brain region. When they stimulated the reticular formation, activity in the cortex increased. The reticular formation, then, regulated the arousal level of other parts of the brain. Damage to the reticular formation can cause a coma, a state in which a person is alive but motionless, unaware of events, and unable to be awakened (Gupta et al., 2010).

Before we move up from the brain's lowest-level region, the brain stem, we note a significant brain structure located just behind it. The **cerebellum**, which looks like a miniature brain tucked under the back of the brain, regulates motor movement. With a damaged cerebellum, you would still be able to move your body, but those movements wouldn't be as coordinated and precise. Your posture might be altered and your stride less smooth, and you wouldn't be able to accurately perform tasks such as tracing an image on a piece of paper (Daum et al., 1993). The cerebellum is also needed to perform a task that a doctor may have asked you to do during a physical exam: Close your eyes and quickly touch your index finger to your nose (Ito, 2002). The doctor's test assesses your cerebellar functioning.

Controlling motor movements is not the cerebellum's only job. Like most parts of the brain, the cerebellum is connected to many other brain regions. Thanks to these connections, the cerebellum also is active in the control of emotion and thinking, including the accurate perception of passages of time (Strick, Dum, & Fiez, 2009). Compared to others, people with cerebellar damage are less accurate in
perceiving small variations in time intervals and in tapping out timed musical rhythms (Ivry & Keele, 1989).

**Limbic System.** If all you had were a brain stem, you wouldn’t have much psychological life. The brain stem would maintain your basic bodily functions, but you would lack feelings and emotions. For this, you need more brain.

Fortunately, evolution has provided you with more brain. All mammals possess a **limbic system**, which is a set of brain structures that resides above the brain stem but below higher brain regions (Figure 3.5). The limbic system enables mammals to have emotional lives.

MacLean first recognized that these different structures, located in different parts of the brain, should be thought of as a “system,” that is, as a set of parts that work together (Newman & Harris, 2009). Later work confirmed MacLean’s intuition; research shows that the limbic system’s different parts are highly interconnected. Mammals thus possess an interconnected system of brain structures that substantially expands their mental abilities, as compared to evolutionarily older organisms (Reep, Finlay, & Darlington, 2007). Let’s look at the most significant structures in this system.

The **hypothalamus** is a limbic system structure that is small yet critical to survival. It plays a key role in maintaining internal bodily states, such as body temperature. The hypothalamus also triggers behaviors that have been important throughout evolution, such as eating, drinking, and sexual response (King, 2006). The hypothalamus can perform these tasks thanks, in part, to its connections to the nearby **pituitary gland**, which is part of the body’s **endocrine system** (discussed later in this chapter). The hypothalamus sends signals directly to the pituitary, which in turn

**limbic system** A set of brain structures just above the brain stem, including the hypothalamus, hippocampus, and amygdala, that give mammals the capacity to experience emotional reactions.

**hypothalamus** A limbic system structure key to the regulation of bodily states and behaviors such as eating, drinking, and sexual response.

**figure 3.5**

*The limbic system* The limbic system and its most significant structures: the hypothalamus, the hippocampus, the amygdala, the fornix, the olfactory bulbs, and the cingulate gyrus.
communicates to the rest of the body. The hypothalamus is located just underneath the thalamus, a brain structure we'll revisit later. (Hypo means "under," so the name hypothalamus indicates its location.)

Startling research results obtained in the 1950s showed that the hypothalamus also is key to motivation (Olds, 1958; Olds & Milner, 1954). Researchers surgically implanted electrodes directly into the hypothalamus of rats. They connected the electrode to a lever that the rat could press, thereby delivering current to the electrode. By pressing the lever, then, the rat could stimulate its own hypothalamus (Figure 3.6). Would a rat really want to do that? Sure it would! Rats pressed the lever more than 5000 times an hour (Olds, 1958). In later research, rats consistently chose the stimulation even over food, starving themselves to death (Bozarth, 1994).

The brain stimulation was rewarding because the hypothalamus is part of a reward circuit, that is, a set of interconnected brain structures that normally becomes active when an organism pursues a rewarding stimulus or experience, such as food or sex (Haber & Knutson, 2010). Amazingly, even when there is no rewarding stimulus in the environment, activation of the circuit is highly rewarding (see Chapter 7). Although the anatomical details differ across species, contemporary neuroimaging research shows that a reward circuit similar to the one first identified in rats also exists in primates, including humans (Haber & Knutson, 2010).

The hippocampus is a curved, roughly banana-shaped structure in the limbic system that participates in two major tasks of everyday life. One of those tasks is remembering. The creation of permanent memories is carried out, in part, in the hippocampus (Bliss & Collingridge, 1993; Nadel & Moscovitch, 1997). If this biological tool is damaged, permanent memories of experiences cannot be formed (also see Chapter 6). Evidence of the hippocampus's role in memory comes from cases of Alzheimer’s disease, a medical condition that generally strikes people in older adulthood. The hippocampus atrophies (i.e., becomes reduced in size) in Alzheimer’s patients (Barnes et al., 2009), who lose their normal ability to remember events.

A second task the hippocampus helps to accomplish is spatial memory, the recall of geographic layouts and the location of items within them (Nadel, 1991). Have you ever parked your car in a large parking lot (e.g., at a shopping center or sports stadium) and later wandered around trying to find it? It’s good you didn’t leave your hippocampus in the car—you need it to remember where you parked. Evidence that the hippocampus contributes to spatial memory comes from research on a group of people who rely heavily on spatial skills: taxi drivers in London (Woollett, Spiers, & Maguire, 2009).

Prior to obtaining their taxi driver’s license, London cabbies undergo extensive training to learn the location of thousands of city streets and how they interconnect. Researchers hypothesized that, as a result, cabbies’ brains would differ from those of ordinary drivers. To test that idea, they asked taxi drivers and a control group of regular drivers to play a virtual reality video game in which players navigate a car through London streets. While participants played, their brain activity was recorded using fMRI (see Research Toolkit). When researchers compared the brains of the two groups of participants, they found that the hippocampus of taxi drivers was more highly developed. Taxi drivers had a greater volume of brain cells in the rear region of their hippocampus (Woollett et al., 2009).

This finding should remind you of the lesson about plasticity from the beginning of this chapter. The brain has specialized parts that strengthen with use. Just as athletes who exercise their muscles develop more muscle, taxi drivers who exercise their hippocampus develop more hippocampus.
Thanks to your amygdala, you can respond to threatening objects, such as a snake, before higher-level areas in your brain even recognize that a threat exists. Information goes from your eyes through a central brain region (the visual thalamus) and then right to the amygdala, which can generate an emotional response.

If the hippocampus of taxi drivers is more highly developed than that of others, it could mean that learning and navigating complex streets increases brain development. Or it could mean that people with more highly developed hippocampi become taxi drivers. Which is it? (By analogy, tall people are more likely to become basketball players, but playing does not increase their height.)

Recent research that (1) measured people’s brain volume before and after taxi-driver training and (2) compared them with others who did not have that training indicates that the experience of learning complex roadways does, in fact, causally influence brain development (Woollett & Maguire, 2011). If you are thinking critically about psychological research, you will realize that these extra two research steps were necessary to reach this conclusion.

**TRY THIS!**

Research on the hippocampus and memory for spatial locations illustrates the close connection between mind and brain. Performing the specific task of spatial memory requires the use of a specialized biological tool in your brain, the hippocampus. This chapter’s Try This! exercise introduces a different mental activity (one not involving memory) that also illustrates this connection. Try it now! Go to www.worthpublishers.com/cervonepreview. A little later on, we will discuss the activity and detail the parts of your brain that were most active when you did the exercise.

The **amygdala** is a small structure shaped roughly like an almond (from which it gets its name: *amygdala* is the Greek word for “almond”). Like most brain structures, the amygdala is connected to numerous other structures in the brain; as a result, it is active during a variety of psychological processes (Labar, 2007). Yet one psychological process in which its role is particularly central is the detection of threat. Suppose you’re walking in the woods and notice a snake slithering on the ground (Figure 3.7). Before you know it—that is, before you even say to yourself, “Geez, look at that, a snake!”—your body responds: You instantly experience fear and move out of harm’s way. That quick response was generated by the amygdala, which receives inputs from your eyes and rapidly signals other brain mechanisms that, in turn, generate emotional arousal and halt your walking toward the snake (LeDoux, 1994). The amygdala response is so rapid that your body reacts before the rest of your brain has time to create a conscious experience of the snake.

The amygdala is not limited to the processing of information about threats that involve physical harm, however. Another type of threat that it processes is financial. In one study, two research participants with damaged amygdalas played a gambling game (De Martino, Camerer, & Adolphs, 2010). They chose whether to bet on coin flips with varying monetary payoffs. Most players are **loss averse**, that is, they avoid gambles that pose a good chance of
When you use a part of your body intensively, blood flow to that area increases. The technique, called functional magnetic resonance imaging, or fMRI, is a method for depicting the brain regions that are particularly active when people perform mental tasks. fMRI capitalizes on two facts about the body and brain (Cacioppo et al., 2003; Hunt & Thomas, 2008): when you use a part of your body intensively, blood flow to that area increases. The body automatically increases blood flow in order to supply that body part with extra oxygen to fuel its increased activity. Sometimes you can even see this happening; for example, when lifting weights, veins in your arm stand out. In the brain, the same principle holds. The flow of oxygenated blood increases in regions of the brain that are most active. (Oxygenated blood carries oxygen from the lungs to the rest of the body. By contrast, deoxygenated blood cells are those that have released oxygen but have not yet returned to the lungs for a new oxygen supply.)
Blood cells have magnetic properties that differ, depending on whether the cells are oxygenated or deoxygenated. Researchers observing blood flow under a strong magnetic field thus can identify those parts of the body and brain that are receiving relatively high levels of oxygenated blood.

Combining these two points yields the basic principle of fMRI methods: To link brain activity to activity of the mind, researchers can ask participants to engage in a mental task while they are under a strong magnetic field, and obtain images of the brain regions that receive an increased flow of oxygenated blood during this task.

The device that produces the brain images, the scanner, contains a magnet that produces the necessary magnetic field (Figure 3.8). The scanner’s magnets are extremely powerful; many produce magnetic fields more than 50,000 times as powerful as the magnetic field of Earth (the force that moves the needle of a compass). Research participants must be careful to remove watches and other metallic objects before coming near the fMRI magnet—or it will remove the items itself.

fMRI research consists of a sequence of steps. After a participant enters the scanner, the researcher first collects baseline measures, that is, measures of cerebral blood flow that are taken before participants perform the specific mental task that is the focus of the study. Next, the participant is directed to engage in a mental task, and blood flow is measured again. Statistical methods then are used to compare the baseline to task-performance levels of oxygenated blood flow. These methods yield the fMRI brain images in this chapter and throughout this book.

However, fMRI cannot answer all questions of brain science. For example, it only indicates that activity in a brain region is correlated with performance of a task; thus, it cannot, by itself, establish that the brain region has a causal impact on performance. Nonetheless, researchers recognize its unique value in answering fundamental questions about the link between mind and brain (Mather, Cacioppo, & Kanwisher, 2013).

5. ______ magnetic resonance imaging, or fMRI, is a technique for measuring brain activity that uses magnetic fields to track changes in cerebral _____ flow before and after a participant engages in a mental activity.

CEREBRAL CORTEX. The last step up in our bottom-to-top voyage through the brain takes us all the way to the top, to the cerebral cortex, a layer of cells on the outer, top surface of the brain that is only a few millimeters thick. Although thin, it is powerful. This network of brain cells is the biological tool that enables people to have human thinking powers: to contemplate ourselves, our past, and our future; to communicate using language; to create works of art; and to gain some control over the impulses and emotions generated in lower regions of our brains.

When looking at the outer surface of a brain—at its cerebral cortex—the first thing you notice is that it’s folded. The brain contains numerous ridges and grooves, and the cerebral cortex wraps its way around them. These folds in the brain’s outer surface have a big advantage: They allow room for more brain—or, more specifically, for more cortical surface area. Just as folding a large item of clothing helps fit it into a small piece of luggage, the folds in the brain’s surface allow a relatively large cerebral cortex to fit into your relatively small skull. (By way of comparison, you have a lot more brain power than an elephant, yet a much smaller skull.) The surface area of your cerebral cortex is about 2.5 square feet (Kolb & Whishaw, 1990), but thanks to the folds, your head does not have to be greater than 1.5 feet wide and 1.5 feet long to fit it all in there.

The next thing you would notice is that some of the grooves in the brain’s surface are particularly deep. These are fissures that divide the cortex into a number of distinct parts, known as cerebral lobes. Let’s now look at the brain’s various lobes and...
the psychological activities in which they take part (Figure 3.9). But first, a reminder. As you learned in this chapter’s opening, the parts of the brain are highly interconnected. When you perform almost any complex task, the brain’s communication networks automatically coordinate activity in multiple lobes of the brain (Sporns, 2011).

Let’s start our survey of the lobes of the cerebral cortex at the back of the brain. At the brain’s rear is the **occipital lobe**. This region is heavily involved in the processing of visual information—in fact, it is commonly called the **visual cortex**. To see clearly, then, you need not only your eyes, but also your occipital lobe. Evidence of this comes from medical cases in which patients experience seizures (periods of abnormal brain activity) in their visual cortex. Although their eyes are working properly, their visual experience is distorted; they see things that aren’t there and, in some cases, experience temporary blindness (Panayiotopoulos, 1999).

In addition to processing visual information coming in from the eyes, the occipital lobe is active when you generate visual information in your head—in other words, when you engage in mental imagery (see Chapter 8). Researchers find that when people are asked to close their eyes and think of specific images, their visual cortex becomes highly active (Kosslyn et al., 1996). Furthermore, patients whose occipital cortex is damaged may have difficulty generating mental imagery (Farah, 1984). Thus, even though seeing and imagining are two different types of activity—one being a detection of stimuli out in the world, the other an act of fantasy in your head—both activities employ the same biological tool: the brain’s occipital lobe.

Moving from the occipital lobe toward the front and top of the brain, we next reach the **parietal lobes**. The parietal lobes contain brain matter needed for **somatosensory information processing** (Andersen et al., 1997), that is, the processing of information that relates features of your body (or *soma*) to features of the environment (which you detect through sensory systems). When do you use your somatosensory system? All the time! Imagine a simple activity: picking up a paper cup filled with water. This action seems so routine that you don’t even give it a thought. Yet it’s actually quite complex. To pick up the cup, there’s a lot of information to take into account: (1) the exact location of the cup, (2) the amount of force required to pick it up without crushing it, (3) the location of your arm and hand, and (4) the amount of force exerted by your hand when you grasp the cup. The first two pieces of information come into the brain from a sensory system—your visual system, which lets you see where the cup is and what it’s made of. The second two pieces of information come from your soma, or body—your **occipital lobe** The region of the cerebral cortex heavily involved in the processing of visual information and mental imagery; commonly called the visual cortex.

**parietal lobes** The region of the cerebral cortex that processes somatosensory information (i.e., relating the body to the environment).
nervous system provides your brain with information about the location and motions of your body. These two streams of information, sensory and somatic, have to be integrated somewhere. This happens in the parietal lobe (Andersen et al., 1997).

At the front of the parietal cortex is the **sensory cortex**, a strip of brain matter that receives information from all parts of the body. By processing this information, the sensory cortex lets you know that your back is itchy, your foot’s “fallen asleep,” or your arm is extended straight up in the air (something you can feel, without having to look to see where it is).

Nature has given the sensory cortex a remarkably systematic design. The sensory cortex represents each of the various parts of the body; body parts are “mapped” into the cortex (Figure 3.10).

Sensory input from your foot goes to one part of the cortex, input from your knee goes to another, and so forth. This body-to-brain mapping has two notable features:

1. **Adjacent body parts are mapped into adjacent areas of the cortex.**
   
   For example, the part of your sensory cortex that processes information from your lips is next to the part that processes information from your nose. The cortex processes signals from your hand in a region adjacent to where it processes signals from your fingers.

2. **The amount of space devoted to a body part in the brain is not proportional to the physical size of the body part.** Instead, the amount of space in the cortex devoted to a body part relates directly to the sensitivity of that part of the body. Parts of your body that are highly sensitive (e.g., lips, fingers) receive more space in the somatosensory cortex than less sensitive parts (e.g., your elbow or back).

Normally, the sensory cortex is activated by input from parts of the body. But what would happen if it was activated directly—that is, if scientists reached right into the brain and electrically stimulated it? Wilder Penfield, a physician performing surgery on a patient with epilepsy, was the first person to do this (Costandi, 2008; Penfield & Boldrey, 1937). During surgery, the patient was awake. This is possible because there are no sensory receptors in the brain itself, so patients do not feel pain during brain surgery. When Penfield applied a mild electric stimulus to one region of the sensory cortex, the patient felt numbness in his tongue. When a nearby region was stimulated, he felt numbness in a different part of his tongue. When a different region was stimulated, he felt a tingling in his knee (Figure 3.11). By stimulating various regions and noting the sensations produced, Penfield was able to discover the mapping between the brain’s sensory cortex and the rest of the body (Penfield & Boldrey, 1937).

Below the parietal lobes, its location and shape akin to a thumb on a mitten or baseball catcher’s glove, is the **temporal lobe** (see Figure 3.9). Two psychological tasks that rely on the temporal lobe are hearing and remembering. Hearing is accomplished thanks to a region in the upper surface of the temporal lobe known as the **auditory cortex**. This part of the temporal lobe is active whenever you listen to sounds, detecting their pitch, volume, and timing in relation to one another. Listening to both spoken words and music requires use of your auditory cortex (Zatorre, Belin, & Penhune, 2002). As for memory, certain regions in the temporal lobe are key to organizing the multiple brain systems that become active when you remember facts and experiences (McClelland & Rogers, 2003). Damage to the temporal lobe causes people to forget even the names of common objects. For example, one patient with temporal lobe damage, when shown pictures of 24 different animals, was able to name only three correctly: cat, dog, and horse (McClelland & Rogers, 2003).

Finally, moving forward from the parietal lobes, you reach the **frontal lobes**. In humans, as well as in our evolutionary cousins, the great apes, the frontal lobes are the largest region of the brain, comprising about 35% of its total volume (Semendeferi et al., 2002).
Yet human frontal lobes have a number of unique features. These include especially rich interconnections among regions of the frontal lobes and similarly rich connections between the frontal lobes and other parts of the brain. These unique biological features underlie humans’ most distinctive mental abilities (Semendeferi et al., 2002; Wood & Grafman, 2003): to think about ourselves; to set goals for ourselves and stick to them; to control our emotions; to recognize ourselves as social beings who are evaluated by others; in short, to live as members of civilized society. As you saw in the case of Phineas Gage, frontal lobe damage reduces the ability to control one’s behavior according to the rules of society.

The frontal lobes also contain brain matter that is needed to control body movements. At the rear of the frontal lobes, in the area closest to the parietal lobe, is a region of the brain known as the motor cortex. This cortical region sends out signals that move the body’s muscles; as we discuss in more detail below, the signals are sent to the spinal cord, where they are relayed to muscles in the body’s extremities.

Studies by Penfield and colleagues provided early evidence of the functions carried out by the motor cortex (just as they did for the sensory cortex, as described above). Penfield found that electrical stimulation in different areas of the motor cortex triggers different types of motor movement. If you stimulate one area of the motor cortex, the patient’s hand moves; stimulate another area, and an arm moves; and so forth (Penfield & Boldrey, 1937).

Penfield’s findings seemed to suggest that the motor cortex, like the sensory cortex, contains a “map” of body parts, with different parts each controlling a different muscle of the body. Recent research, however, has shown that this idea is inaccurate (Graziano, 2010). Individual parts of the motor cortex do not control individual muscles. Instead, a given part of the motor cortex commonly triggers coordinated activity in a number of different muscles. The activity generally is a meaningful action that, over the course of evolution, was adaptive for organisms of the given species. Stimulating different parts of a monkey’s motor cortex, for example, produces movements such as reaching out to grasp an object, placing the hand to the mouth, or climbing or leaping movements (Graziano et al., 2002; Figure 3.12).

In front of the motor cortex are regions of the frontal lobe containing association areas of the cerebral cortex. Association areas receive sensory input that has been processed by other regions of the brain. They connect these inputs to memories and stored knowledge of the world (Pandya & Seltzer, 1982; Schmitz & Johnson, 2007). These connections between sensory input and stored knowledge enable people to have experiences that are psychologically meaningful. For example, you perceive not just a slowly moving human figure with a hand extended, but an old acquaintance who appears ready to apologize for a past wrongdoing. Your sensory system delivers the sound of a human voice coming through a small speaker, but association areas enable you to hear the loving tones of a parent calling to see how you’re doing at college.

In front of the association areas is the prefrontal cortex. In terms of location, this is the part of the brain that resides immediately behind your forehead. The prefrontal cortex is a complex piece of biological machinery that contains many specialized subsections that contribute to a variety of mental functions. Two types of mental activities, however, stand out as particular specialties of the prefrontal cortex.

One is the ability to keep information in mind—to concentrate on facts, focus your attention, and manipulate information in your mind (Levy & Goldman-Rakic, 2000). The prefrontal cortex gives you a mental “workspace” (Dehaene & Naccache, 2001) where you can combine and manipulate information, whether it is coming in through your sensory systems or stored in memory. This ability enormously increases your mental powers. Without it, the flow

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**What coordinated movements are you engaging in right now?**

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**How many separate pieces of information do you have in your mental “workspace” now?**

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**motor cortex** A region of the cerebral cortex that sends out signals controlling the body’s muscular movements.

**association areas** Areas of the cerebral cortex that receive sensory information from other regions of the brain and connect it to memories and stored knowledge, enabling psychologically meaningful experiences.

**prefrontal cortex** The area of the brain immediately behind the forehead; a complex area that contributes to the ability to concentrate on facts, focus attention, manipulate information, and align behavior with social rules.
of your thoughts would be determined almost entirely by stimuli in the environment. Every sight, smell, and sound would pull your thoughts in one direction or another. The prefrontal cortex, however, gives you the “executive” abilities (Posner & Rothbart, 2007) to concentrate your thoughts on people, objects, and events that are not present in your current environment. You can even think about things that happened long ago or that might happen in the distant future; the prefrontal cortex enables humans, unlike other species, to engage in “mental time travel” (Suddendorf & Corballis, 2007).

The second function of the prefrontal cortex is the one lost by Phineas Gage: the ability to align your behavior with social rules and conventions. Why does frontal lobe damage impair this ability? The explanation involves both thoughts and emotions. Frontal lobe damage breaks the normal connections between (1) thoughts about the social world, which are generated in the cortex, and (2) feelings about the social world, which are generated in lower regions of the brain. As a result, people with frontal lobe damage may fail to experience emotions that normally keep our behavior in line with others’ expectations. These include feelings of embarrassment over not fitting in with a crowd and anxiety about the possibility that others will think poorly of them (Bechara, Damasio, & Damasio, 2000). Frontal lobe damage also reduces empathy (Stuss, 2011; Wood & Williams, 2008), which is the ability to personally feel the emotions experienced by others with whom you interact (Agosta, 2010). This lack of empathy may explain the behavior of psychopathic criminals, that is, people who commit violent criminal acts without experiencing guilt, remorse, or empathy for their victims (Shamay-Tsoory et al., 2010).

In summary, you’ve seen that the brain has a bottom-to-top organization. Low-level structures in the brain stem regulate bodily states and serve basic survival-related needs. Middle-level structures of the limbic system enable organisms to have feelings and to form memories. And the high-level structures of the cerebrum, especially the cerebral cortex, enable people to engage in complex, creative, rational thought. This might already seem like a lot of organization for one bodily organ. Yet there’s more: The brain also has a left/right organization.

WHAT DO YOU KNOW?

6. Match the brain structures on the left with the functions they regulate on the right.

1. Medulla, pons, and midbrain a. Task switching
2. Reticular formation b. Memory formation, spatial memory
3. Cerebellum c. Threat detection
4. Hypothalamus d. Thinking about the self, goal-setting
5. Hippocampus e. Bodily activities critical to survival (e.g., breathing)
6. Amygdala f. Arousal
7. Cingulate gyrus g. Somatosensory information processing
8. Occipital lobe h. Bodily states such as temperature
10. Temporal lobe j. Hearing, remembering facts and experiences
11. Frontal lobe k. Processing visual information
Left/Right Organization

Preview Questions
› What is the relation between the left and right sides of the brain?
› For what functions are the left and right sides of the brain specialized?
› If the left and right sides of the brain were cut off from each other, would you have two brains? How do we know?

You’ve got two legs, one on the left and one on the right. Same with your arms, hands, eyes, ears, kidneys, and many other body parts—you’ve got two of them, left and right.

CEREBRAL HEMISPHERES. The same is true, in a sense, for the brain. Although humans have only one brain, it has two parts, on the left and right, which are separated by a deep groove. The two sides are known as the brain’s two cerebral hemispheres (Figure 3.13).

The relation between the left/right organization of the brain and the left/right organization of the body is surprising. When going from body to brain, signals cross. Information from the left side of the body reaches the right side of the brain, and information from the body’s right side reaches the brain’s left. Similarly, commands sent out from the brain to the body switch sides. The right side of the motor cortex, for example, controls the left side of the body. Even signals from parts of the body located very close to the brain switch sides. Information from your left eye, for example, reaches the right side of your brain. Research suggests that this crossing benefits the complex “wiring” of the brain that occurs early in the development of an organism (Shinbrot & Young, 2008).

The left and right hemispheres are connected through the corpus callosum, a structure containing more than 200 million cells that transmit signals from one side of the brain to the other. The corpus callosum extends from the front to the rear of the brain and thus connects the left and right sides of the frontal, parietal, and occipital lobes. Thanks to these connections, your left and right generally are in synchrony. Your two-handed tennis backhand is a coordinated movement, despite the fact that different sides of your brain control your left and right arms. You experience a coherent stream of music from the sounds coming out of your headphones, even though different sides of your brain process sounds from the earphones on the left and right.

SPECIALIZATION OF THE HEMISPHERES. The left and right hemispheres of a person’s brain look quite similar, but “you can’t tell a brain by its cover.” Despite similar appearance, the hemispheres are specialized to perform different types of psychological activities. Some tasks primarily draw on the left side of the brain, whereas others primarily use the right.

The left hemisphere specializes in language. About 97% of right-handed individuals understand and produce language by using their left hemisphere; among left-handers, the percentage is still high, about 70% (Toga & Thompson, 2003). Two nineteenth-century physicians—Frenchman Paul Broca and German Karl Wernicke—discovered this in studies of people with impaired language ability, or aphasia.

Broca’s insight came from a patient who was nicknamed “Tan” because “tan” was the only word he could speak. After a disease in early adulthood, he experienced an aphasia in which he could understand other people when they spoke, but could not produce words himself—other than, mysteriously, “tan” (Schiller, 1992). After the patient died, Broca examined the man’s brain and found damage in a region of the left hemisphere that has become known as Broca’s area (Figure 3.14). Normal functioning in this area is required for a person to produce words.

Some years later, Wernicke saw patients who had lost the ability to understand language. They could hear the sound of words, but could not determine what those words meant. Wernicke discovered a region in the right hemisphere that is involved in language comprehension. This area has become known as Wernicke’s area (Figure 3.14). Normal functioning in this area is required for a person to understand language.

The right hemisphere is specialized for spatial thinking, the ability to create and think about images. It is also involved in recognizing objects, perceiving emotional expressions, and understanding other people’s gaze. These abilities are not restricted to right-handed people; in fact, left-handed people may be especially good at tasks that require spatial thinking.

Cerebral hemispheres The two sides of the brain; the left hemisphere specializes in analytical tasks including math and language, while the right hemisphere is specialized for spatial thinking, the ability to create and think about images.

Corpus callosum A brain structure that connects the two hemispheres of the brain, enabling them to work in synchrony.
sounds meant (Geschwind, 1970). Again, post-mortem examinations revealed brain damage. But this time, the damage was found in a different area of the brain than was seen in Tan’s brain. This new area, which is needed for the comprehension of spoken language, is now known as Wernicke’s area (Figure 3.14).

Both Broca’s and Wernicke’s areas are in the left hemisphere. Although later research (e.g., Sperry, 1982) showed that the right hemisphere has more involvement in language comprehension than Wernicke had thought, contemporary findings nonetheless confirm that, among the large majority of people, the predominant hemisphere in language production and understanding is the left (Josse & Tzourio-Mazoyer, 2004).

Language isn’t the left hemisphere’s only specialty. Another one is arithmetic. Images of people’s brain activity while they multiply numbers “in their head” reveal that the left hemisphere is significantly more active than the right (Chochon et al., 1999).

Language and arithmetic have a lot in common. In both, individual symbols (words, numbers) are combined in a specific order according to various rules (of grammar or arithmetic). If the symbols are out of order, the result is meaningless; neither “2 2 4 + =” nor “Dog her ran Jane spot after” make sense. Activities that require one to combine symbols or objects in a step-by-step manner, according to specified rules, are called analytical tasks. On analytical tasks, the left hemisphere predominates. Interestingly, the two analytical tasks we just discussed, language and arithmetic, are so similar that the regions of the left hemisphere active during the tasks overlap (Baldo & Dronkers, 2007).

What is not considered an analytical task? Spatial activities differ from analytical ones. In spatial thinking, you create images in your mind. Suppose you were asked how many windows were in the front of the home in which you grew up. You would first picture your home in your mind and then mentally count the windows you see. Mentally picturing the home is an example of spatial thinking.

Can you think of another mental activity that involves spatial thinking? You worked on one in this chapter’s Try This! experiment.

Our ‘Try This!’ activity was a mental rotation experiment. In mental rotation, people form an image in their minds and then try to imagine what that image would look like from a different visual angle. In our experiment, you saw the letter R printed at odd angles and had to rotate it in your mind until it was upright (see Figure 3.15). Mental rotation tasks of this sort are a form of spatial thinking because they involve thinking about images rather than logical relations among words or numbers.

Mental rotation experiments yield two fascinating results. You experienced one of them for yourself: It takes longer to rotate an image through a larger visual angle than a smaller one. Rotating a mental image thus is somewhat like rotating a physical object; just as it takes longer to rotate an object 180 degrees than 90 degrees, it takes longer to rotate an image in your head 180 degrees than 90 degrees (also see Chapter 8).

The second result involves the brain. Findings indicate that spatial thinking such as mental rotation is a specialty of the right hemisphere. Evidence comes from a study in which brain images were taken while participants performed the same task you encountered in our Try This! activity. While people performed the task, the right hemisphere of their brains was most active (Milivojevic, Hamm, & Corballis, 2009a). A big advantage of the right hemisphere during mental rotation tasks is speed: regions in the right hemisphere become active more quickly than do left-hemisphere regions when people try to rotate mental images as fast as they can (Milivojevic, Hamm, & Corballis, 2009b).

**SPLIT BRAIN SYNDROME.** The brain’s two hemispheres, then, are like two teams of workers who specialize in different jobs. Thanks to the corpus callosum, they’re in constant communication, so their overall activities are coordinated.
What if the lines of communication were broken? What would happen if the corpus callosum were cut? You wouldn’t have “two brains” functioning in ignorance of each other, would you?

Incredibly, you would. Without the corpus callosum, the left and right hemispheres do, in fact, function as if they are “two separate brains” (Sperry, 1961, p. 1749)—like two groups of workers laboring on their specialized tasks unaware of the other’s activities. Evidence of this comes from split brain experiments, which are studies of people or animals whose corpus callosum is cut, rendering it unable to transmit information between the hemispheres. Split brain research was pioneered by the neuroscientist Roger Sperry, who won a Nobel Prize in 1981 for his work.

Early research by Sperry and his students was done with cats. Like most animals, cats learn new responses in reaction to specific environmental stimuli (see Chapter 7). Sperry and colleagues taught cats a new response that was triggered by a stimulus displayed to only one eye of the cat; thus, that reached only one side of the cat’s brain. Later, researchers displayed the information to the cat’s other eye, to see whether the response the cat had learned would generalize from one eye—and from one side of the brain—to the other. Among normal cats (i.e., those whose corpus callosum was intact), the learning transferred. However, among cats whose corpus callosum was cut surgically, it did not. Split brain cats could perform the task using one side of their brain, but not the other (Sperry, 1961). The hemispheres therefore were ignorant of each other’s learning if the corpus callosum had been cut.

Later research showed how splitting the corpus callosum affects the psychological experience of humans (Sperry, 1982; Sperry, Gazzaniga, & Bogen, 1969). Some people have their corpus callosum cut for medical reasons; the surgical procedure stops epileptic seizures from spreading from one side of the brain to the other. After surgery, patients seem remarkably normal; based on their everyday behavior, cutting the corpus callosum seems to have little effect. In everyday life, however, any given piece of information reaches both of the person’s eyes or ears and thus is sent directly to both sides of the brain. What happens when information reaches only one side of the human brain?

Sperry and colleagues devised a clever procedure to find out. They placed patients in front of a projection screen, asked them to concentrate on a dot in the middle of the screen, and then briefly flashed words, simultaneously, on the screen’s left and right sides (Figure 3.16). The word on the left thus reached only the brain’s right hemisphere, while the word on the right reached only the brain’s left side. When split brain patients were asked what word or words they saw, they inevitably named only the word on the right (“Ring” in the example shown in the image). You might think, then, that the patient was completely unaware of the fact that the other word (“Key” in the example) had even been shown. This, however, is not the case (Sperry et al., 1969).

Patients were unable to name “Key,” but that’s merely because the word reached their right hemisphere, which is unable to produce language. When given an opportunity, with their left hand (which is controlled by the right hemisphere), to reach behind the screen and pick up an object corresponding to the word that had been displayed, the patient did pick up a key. Thus, the right hemisphere saw and understood the word “key,” but was unable to put the idea of “key” into words. If, before revealing the key from behind the screen, the person was asked what he or she picked up, the patient would say “a ring.” The answer to the question was being given by the left hemisphere, which was completely unaware of what the right hemisphere was doing.

Specialized testing therefore reveals the unique psychological experience of the split brain patient. Without such testing, the patient appears quite normal. The left hemisphere
has such a range of capabilities that it “does not miss” (Gazzaniga & Miller, 2009, p. 261) the right hemisphere from which it has been disconnected; patients seem not to be much bothered by occasional experiences in which they cannot name an object appearing briefly in their left visual field. In fact, people can live a relatively normal life with just the left side of their brain. In 2007, surgeons removed the entire right hemisphere of 6-year-old Cameron Mott, to stop violent seizures that she had been experiencing daily (Celizic, 2010). A few years after the surgery, Cameron was back in school and a good student. When a journalist asked “if she had any lingering effects from the surgery,” she replied, “No. None at all” (Celizic, 2010). (People have more difficulty living with removal of the brain’s left hemisphere, which is required for some complex language abilities; Bayard & Lassonde, 2001.)

WHAT DO YOU KNOW?

7. For each of the “answers” below, provide the question. The first one is done for you.
   a. Answer: The hemisphere in which the sensation of touch on your left arm would be processed.
      Question: What is the right hemisphere?
   b. Answer: The structure that connects the left and right hemispheres.
   c. Answer: For most people, the hemisphere that specializes in speaking and understanding language and in arithmetic.
   d. Answer: The hemisphere that specializes in spatial thinking.
   e. Answer: The field of vision where you would show a split brain patient an object so that she could name it. Hint: Think about where language is processed.

Networks in the Brain

Preview Question

How does the architecture of our brains enable us to process large amounts of information simultaneously?

In addition to its bottom-to-top and left/right arrangement, the brain has yet a third type of organization. We’ll introduce it with an analogy. Imagine a large apartment building. Its organization is both bottom-to-top (e.g., 40 floors atop one another) and left-to-right (e.g., apartments on the east and west sides of each floor might have different floor plans). Yet that’s not all. A third type of organization connects people living in different parts of the building. Communications networks link residents on different floors and different sides of the building. For example, the tenants in apartments 38B, 19D, 21C, 4A, and 6E may be “friends” on a social networking site—as might the residents of 38C, 19A, 17C, 3B, and 8E, and numerous other combinations of residences. The network enables each group of friends to exchange information frequently and rapidly among themselves, despite their residing in different locations. These communications networks, then, are a third form of organization—one that cuts across floors and sides of the apartment building.

The brain works similarly. It has a third type of organization based on communications links that cut across the higher, lower, left, and right sides of the brain (Figure 3.13). These “networks in the brain” connect different regions to one another, enabling rapid communication among them (Bullmore & Sporns, 2009; Sporns, 2011, 2012). Thanks to these communications, brain activity in the different regions is coordinated. Like friends in a social network, the brain regions can share information, integrate knowledge, and synchronize their activities.

SYNCHRONIZING REGIONS OF THE BRAIN. Almost any complex thinking task draws on multiple brain regions that are networked. Consider an everyday example,
such as a recent argument. In your mind, you can “relive” the event: You can picture where you were, feel the emotions you experienced when arguing, and remember words and sentences that were said. Importantly, you can do all of this simultaneously; you can bring the images, emotions, and words into your mind all at once. How—at the level of analysis of the brain—can we explain the ability of the mind to relive the argument?

To explain it, we need to refer to two aspects of the brain’s biology:

1. **Specialized regions of the brain:** As you learned earlier in this chapter, different parts of the brain are specialized for different types of mental activities. Distinct brain regions contribute to the ability to “picture” things in the mind (i.e., form mental images), to generate emotions, and to understand and produce the words and sentences of language. We therefore must refer to each of these specialized regions of the brain to explain how you can relive the argument in your mind.

2. **Brain networks:** Referring to the individual regions of the brain is not enough, however, because we need to explain not only which parts were active but also how they managed to work in an integrated, synchronized way. For this, we need to refer to brain networks: the communications links that integrate activity in different brain regions. It’s thanks to the connections among different parts of the brain—in left and right hemispheres, front and rear areas of the cortex, and lower and upper brain regions—that your mental experience consists of complex, coordinated combinations of images, sounds, and emotions. The networked activity of multiple brain regions, then, is what enables you to relive the argument.

What, biologically, are these networks that enable different parts of the brain to work in synchrony? The networks consist of large numbers of nerve cells in the brain. As we’ll discuss in more detail below, many of these cells are thin and long—so long that they can transmit information from one part of the brain to another.

Many of these transmissions run through a brain structure known as the **thalamus,** which is located near the center of the brain. The thalamus serves as a kind of “relay station” for connections among brain regions (Figure 3.17; Izhikevich & Edelman, 2008). Connections into and out of the thalamus are made so rapidly that the brain as a whole can integrate activity in its higher and lower regions, as well as its left and right sides.

**VISUALIZING BRAIN NETWORKS.** Researchers recently have developed novel methods for visualizing the nerve fibers that connect regions of the brain (Le Bihan et al., 2001). Unlike fMRI methods that reveal activation in a specific brain region (see Research Toolkit), these new methods yield three-dimensional portraits of information networks that cross from one area of the brain to another. Color codings in these images indicate bundles of nerve fibers that travel in the same direction, taking information from one brain region to another.

These methods yield remarkable images of networks in the brain (Figure 3.18). The images immediately transform our understanding of the biological machinery that underlies our ability to think and feel. Beneath the cerebral cortex is an immensely complex web of interconnections that provide much of the brain’s power.

The brain’s power, then, is analogous to that of the World Wide Web. Your computer or smartphone enables you to do a lot of things: communicate with friends, get travel directions, shop, get weather reports, watch live sports events. These abilities are based not just on the machine in your hand, but on the fact that it’s networked, that is, linked into a system that contains hundreds of millions of other computers. Similarly, most of your mental abilities are based not on activity in just one part of your brain, but on the coordinated activity of numerous brain regions that are networked.

Research on brain networks is still at an early stage of development. The major effort in the United States to study these networks was launched only in 2009.
(National Institutes of Health, 2009). The long-term goal of this research is to map the entire connectome, the complete network of neural connections in the brain and overall nervous system of an organism (Sporns, Tononi, & Kötter, 2005). (The term connectome, a map of an organism’s neural connections, is analogous to the word genome, a map of an organism’s genetic information.)

Our discussion of brain networks should remind you of this chapter’s opening story. You learned there that Capgras syndrome results from a breakdown in connections among different regions of the brain (also see Thiel et al., 2014). When this breakdown occurs, people recognize that the face of a loved one is a face, but lack the feelings required to judge that the face is familiar. Your own ability to recognize that, for example, Mom is actually Mom, and not some imposter, thus rests on the complex communications systems that are the “networks” in your brain (Figure 3.19).

**WHAT DO YOU KNOW?...**

8. a. What feature of the brain’s organization enables its structures to share information, integrate knowledge, and synchronize activities?

   b. What structure of the brain acts as a “relay station” for multiple inputs from different areas of the brain?

**CULTURAL OPPORTUNITIES**

**Arithmetic and the Brain**

“3 + 4 = ____?” It’s not a hard one; every educated person can answer the question. In fact, people almost everywhere can answer the question when it’s written using these exact symbols. Arabic numerals (the written digits 0, 1, 2, 3, . . .) are used the world over.

What parts of the brain are most active when people produce the answer “7”? Whatever parts they are, you’d expect them to be the same parts everywhere. Numerals are the same in all cultures. The concept of addition is the same in all cultures. So the parts of the brain that people use to add numerals are the same in all cultures, too, right?

Wrong. Research shows that people in different cultures use different parts of their brains when doing addition. Tang and colleagues asked two groups of people, native speakers of English and of Chinese, to add numbers while they were in an fMRI scanner (Tang et al., 2006). They examined the resulting brain images to identify the interconnected systems within the brain that were active when people performed arithmetic.

There were some commonalities among Chinese and English speakers. For both, the addition task activated an area of the brain that is also known to be active when people look at visual images and think about how objects relate to each other in space. Recall that when you learned about numbers, they were on a line—a one-dimensional space on which the numbers were arrayed. For all people, remembering facts about math (such as 3 + 4 equals 7) activates visual–spatial regions of the brain.
WHY MIGHT A PERSON NOT RECOGNIZE THE FACE OF A LOVED ONE?

At a brain level of analysis, the syndrome reflects a breakdown in the communication between two parts of the brain: the fusiform face processing area responsible for facial recognition (shown in blue) and the amygdala (shown in red), part of the limbic system that produces the emotions that normally confirm you’re looking at a loved one.

In Capgras syndrome (see this chapter’s opening story), people have a strange experience: not recognizing the face of a familiar loved one.

The syndrome reflects a failure in coordination among mental systems: The person recognizes the face but lacks the feelings associated with it.

It’s a face

Is it familiar?

Exactly who is this?

Does it feel like I know this person?

At a brain level of analysis, the syndrome reflects a breakdown in the communication between two parts of the brain: the fusiform face processing area responsible for facial recognition (shown in blue) and the amygdala (shown in red), part of the limbic system that produces the emotions that normally confirm you’re looking at a loved one.
So that’s how the cultural groups were the same. Here’s how they differed: In the brains of English speakers, the addition task activated not only the visual–spatial region, but also Broca’s area, the brain region used in processing language (described earlier). For English speakers, then, arithmetic resembles language; the language processing area of the brain is active during both activities. However, among Chinese speakers, Broca’s area was almost entirely inactive during arithmetic. Furthermore, visual processing areas of the brain were more active than they were among English speakers (Tang et al., 2006). The same task, presented with the same symbols, activated different brain regions in people from different cultures.

Why did Chinese speakers rely more on visual processing regions of the brain than did English speakers? Scientists do not know for sure, but one possibility suggested by the researchers involves the Chinese culture’s educational practices in language and arithmetic (Tang et al., 2006). In school, children’s language learning is visual; they need to learn the precise locations of the multiple strokes that make up Chinese language characters, which are more complex visually than are the letters of English. Furthermore, Chinese students commonly learn arithmetic by using an abacus, a device that explicitly represents numbers and calculations in terms of movements of objects in space (usually the movement of beads on a string). These cultural experiences with visually oriented materials may shape the development of the brain.

WHAT DO YOU KNOW?

9. The following statement is incorrect. Explain why: “Research indicates that when native speakers of either English or Chinese solved an arithmetic problem, both Broca’s area and visual–spatial processing regions of the brain were active, indicating that cultural experiences do not shape brain development.”

Neurons

Preview Questions

› What distinguishes nerve cells from other cells of the body?
› How do neurons communicate electrochemically?
› How do neurons send signals from the axon terminal of one neuron to the dendrites of another?
› What determines whether a neuron will fire?
› How do neurons stay in place?

Let’s continue zooming in on the brain. So far, we’ve discussed parts of the brain that you could see with the naked eye if you were to open up someone’s skull and start looking around. But what would you see if, instead of the naked eye, you looked through a microscope?

What you’d see are individual cells. Like every other structure in the body, the brain is made up of cells. In the case of the brain, there are about 100 billion cells, and they are called neurons. Neurons—also called nerve cells—are the building blocks of the brain.

In many respects, neurons are like any other cell of the body. Each has a cell wall that separates the inside of the cell from its outside environment, a nucleus that contains genetic material, and additional structures that perform basic functions of life, such as providing energy that powers the cell. However, two features of neurons’ anatomy (i.e., their biological structure) distinguish them from the body’s other cells (Kuffler & Nicholls, 1976). The first is their shape, which is unique due to the presence
DENDRITES AND AXONS. If you were asked to imagine a biological cell, you would probably picture something with a round or oval shape. Many cells indeed are shaped like that, but neurons are not. Two specialized structures give neurons a shape that is unique.

The first is dendrites, which are projections that branch out from the main body of the neuron, known as the soma. Like branches on a tree, the dendrites become thinner as they reach out farther from the soma (Figure 3.20).

The dendrites receive incoming signals from other neurons. They are like microphones, listening for signals from the neurons in their vicinity. Large numbers of dendrites can project out from the soma of any neuron, which means that any one neuron listens for, and can receive, incoming signals from many other neurons.

Neurons’ second specialized structure is a thin and long projection known as an axon. Every neuron has one axon, which sends information out to other neurons. You could think of the axon as being analogous to a loudspeaker, broadcasting messages that might be heard by the “microphones”—the dendrites of nearby neurons.

Axons can be very long—as long as about 1 meter in human beings (Maday & Holzbaur, 2012). This means that a neuron can send information across relatively long distances, from one part of the brain to another or from the brain to a different part of the body. The “networks” that connect one brain region to another, which you read about earlier in this chapter, consist of axons that reach across brain regions.

At its far end, the axon branches into a large number of axon terminals. It is at the axon terminals that a neuron transmits its signals to other neurons. We discuss these transmissions below, in the section on synapses and neurotransmitters.

ACTION POTENTIALS. Sometimes neurons are at rest, “just sitting around,” engaging in the same internal biochemical processes that you might see in any other cell of the body. But, periodically, neurons spring to life. They generate action potentials (also known as nerve impulses or spikes), which are electrochemical events in which an electrical current travels down the length of the axon, from the soma to the axon terminals (Bean, 2007). The word “electrochemical” indicates that the electricity generated during the action potential comes from chemical substances that have an electric charge.

Action potentials follow an “all or none” principle (Rieke et al., 1997). The neuron is either “firing” (generating an action potential) or not. There is no “in between,” no small firings or half firings.

dendrites Projections that branch out from the main body of a neuron, receiving incoming signals from other neurons.

axon The thin and long projection from a neuron that sends outgoing signals to other neurons.

action potentials Nerve impulses (or spikes); electrochemical events in which an electrical current travels down the length of an axon.
Like lightning shooting from a thundercloud to Earth, the action potential shoots its way from the neuron’s soma to its axon terminals. The electrical impulse moves down the length of the axon because electrical activity at one channel in the cell membrane acts as a switch that causes the next channel to pop open. When sodium ions rush in there, this electrical activity causes the next set of gates to open. In this way, the nerve impulse rushes down the length of the axon.

And it does rush! Although the process is complex, it’s also quick; nerve impulses can travel down neurons at speeds in excess of 100 meters per second. They are speeded along by the myelin sheath, a fatty substance that surrounds the axon and acts as an electrical insulator. Myelin happens to differ in color from neurons; neurons are grey, whereas myelin is white. Areas of the brain that contain mostly neuron cell bodies and dendrites, which are not covered by myelin, thus are called the brain’s grey matter. Bundles of myelin-covered axons traveling from one region to another are referred to as the brain’s white matter.

This high speed of movement of any one action potential enables the neuron to generate a large number of action potentials in a small amount of time. Neurons can fire more than 100 times a second. The neuron’s firing rate is the key piece of information in the signals that it sends to other neurons (Gabbiani & Midggaard, 2001).

**SYNAPSES AND NEUROTRANSMITTERS.** Exactly how does a neuron send signals to other neurons? Scientists once believed that neuron-to-neuron communications were direct. They thought the axon terminals of one neuron were connected to the dendrites of another, like strings that are tied together. Activating one neuron thus would activate the other directly.

But then they discovered **synapses.** A **synapse** is a small gap that separates any two neurons. Although it is very small—about 20 nanometers, that is, 20 billionths of a meter (Thompson, 2000)—neurons still must communicate across the synaptic gap; neurons are not connected to one another directly. How do they communicate?

Neurons communicate chemically. A sending neuron—that is, a neuron transmitting a signal to a second neuron—releases **neurotransmitters,** which are chemical substances that travel across synapses. When neurotransmitter molecules are released into a synapse, some make their way across the synaptic gap and reach a receiving neuron, that is, a neuron that is receiving a signal from the sending neuron. This chemical connection from sending neuron to receiving neuron is the primary way that neurons communicate. (However, it is not the only way; see This Just In.) Let’s examine the neurotransmitter’s voyage across the synapse in detail (Figure 3.22).

The sending neuron stores neurotransmitters in small sacs known as **synaptic vesicles.** Synaptic vesicles are like tiny bubbles, each of which contains a small amount of neurotransmitter. The synaptic vesicles move within the neuron, down the length of the axon. When they reach the end of the axon and “dock” with the outer edge of the axon terminal (Hammarlund et al., 2007), they are able to release their contents, the neurotransmitters, into the synaptic gap.

Some of the neurotransmitter molecules released from the sending neuron reach **receptors** on the dendrites of receiving neurons. Neurotransmitter receptors are sites to which neurotransmitters can attach. Chemically, the receptors are molecules to which neurotransmitter molecules can bind; the molecular shape of the neurotransmitter molecule determines whether it can bind to a given receptor. When a neurotransmitter from the sending neuron binds to the receptor of a receiving neuron, one bit of communication between neurons is complete.

The brain contains a number of different neurotransmitters. A variety of molecules, in other words, take part in the chemical communications between neurons.
Mind the gap

To communicate with one another, neurons must send messages across a small gap known as a synapse. The diagram on the right shows the axon terminal of a sending neuron, the dendrite of a receiving neuron, and the synapse. On the left is an electron microscope image of actual sending and receiving neurons. The red arrow indicates a location at which one of the sending neuron’s synaptic vesicles is reaching the end of the axon terminal, where it can release neurotransmitters into the synapse.

Some of them are listed in Table 3.1. As shown, different neurotransmitters are found in high concentrations in different parts of the brain and body.

What is the purpose of these chemical communications—that is to say, what is accomplished by the neurotransmitters that travel from the sending neuron to the receiving neuron? Their key function is to affect the receiving neuron’s firing rate. Some neurotransmitters bind to excitatory receptors, which increase the likelihood that the receiving neuron will generate an action potential. Others bind to inhibitory receptors, which decrease the likelihood that the receiving neuron will fire. The receiving neuron integrates inputs from its various receptors, and the integrated information determines the receiving neuron’s firing rate (Gabbiani & Midtgaard, 2001).

### Table 3.1

<table>
<thead>
<tr>
<th>Neurotransmitter</th>
<th>Role in the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylcholine</td>
<td>A neurotransmitter used by spinal cord neurons to control muscles and by many neurons in the brain to regulate memory. In most instances, acetylcholine is excitatory.</td>
</tr>
<tr>
<td>Dopamine</td>
<td>The neurotransmitter that produces feelings of pleasure when released by the brain reward system. Dopamine has multiple functions, depending on where in the brain it acts. It is usually inhibitory.</td>
</tr>
<tr>
<td>GABA (gamma-aminobutyric acid)</td>
<td>The major inhibitory neurotransmitter in the brain.</td>
</tr>
<tr>
<td>Glutamate</td>
<td>The most common excitatory neurotransmitter in the brain.</td>
</tr>
<tr>
<td>Glycine</td>
<td>A neurotransmitter used mainly by neurons in the spinal cord. It probably always acts as an inhibitory neurotransmitter.</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>Acts as a neurotransmitter and a hormone. In the peripheral nervous system, it is part of the fight-or-flight response. In the brain, it acts as a neurotransmitter regulating normal brain processes. Norepinephrine is usually excitatory, but is inhibitory in a few brain areas.</td>
</tr>
<tr>
<td>Serotonin</td>
<td>A neurotransmitter involved in many functions including mood, appetite, and sensory perception. In the spinal cord, serotonin is inhibitory in pain pathways.</td>
</tr>
</tbody>
</table>
GLIAL CELLS. Neurons are not the only cells in the brain. They have neighbors, called glial cells—and lots of them. The brain contains about as many glial cells as neurons (Azevado et al., 2009).

Glial cells support the biological functioning of neurons, by supplying nutrients and disposing of the brain’s biological waste matter. They also hold neurons in place, which is what gives them their name; glia is the Greek word for “glue.” Glia differ from neurons anatomically. Unlike neurons, they do not have axons or dendrites, and do not generate action potentials. Thus, people had thought that glia do nothing other than provide support to neurons. However, recent research suggests that glia may have been underestimated. For example, glia change anatomically as a result of an organism’s experiences, just as interconnections among neurons do (Fields, 2008), and they appear to influence the amount of communication that occurs in networks of connected neurons (Araque & Navarette, 2010; Werner & Mitterauer, 2013). Many scientists expect that future research will reveal unexpected ways in which glia contribute to mental life.

WHAT DO YOU KNOW?...

10. Match the structures on the left with the features and functions on the right.

1. Dendrites
   a. Chemical substances that travel across the synapse
2. Axons
   b. Increase the likelihood that the receiving neuron will fire
3. Myelin sheath
   c. Branchlike projections that receive signals from other neurons
4. Synaptic vesicles
   d. Gap that separates neurons
5. Synapse
   e. Supplies neurons with nutrients and disposes of waste
6. Neurotransmitters
   f. Decreases the likelihood that the receiving neuron will fire
7. Excitatory receptors
   g. Thin, long projection that sends out signals to other neurons
8. Inhibitory receptors
   h. Small sacs in which neurotransmitters of the sending neuron are stored
9. Glial cells
   i. Fatty substance surrounding the axon that speeds neural transmission

THIS JUST IN

Neural Communication

As far as we know, neurons communicate only through synaptic connections.

—Ornstein & Thompson (1984, p. 68)

In the twentieth century, scientists discovered that neurons communicate by sending messages across synapses. Once that was established, many naturally concluded that
it was the only way neurons could communicate. The standard belief was that axon terminals are the one-and-only place where neurons emit neurotransmitters, and synapses the only place to which neurotransmitters are sent. But then, Douglas Fields, a researcher at the U.S. National Institutes of Health, noticed something.

While peering at a neuron through a high-powered microscope, Fields saw it move. It "twitched," as he put it (Hamilton, 2010). The neuron didn’t move very far; in fact, its movement was barely detectable (Fields & Ni, 2010). But move it did, with movement occurring all along the axon, not merely at the axon terminals.

Fields and colleagues knew that the movement could only have been caused by a flow of chemical substance into, and out of, the neuron. What were these substances?

Research on the chemistry of the nervous system provided the answer: The twitching axon was releasing neurotransmitters along the length of its axon. These neurotransmitters were signals being sent to other cells in the brain—particularly to glial cells. This recently discovered signaling system appears to support neuron–glia communication that, in turn, maintains the brain’s normal ability to transfer information rapidly through brain networks (Lohr, Thyssen, & Hirnet, 2011).

The remarkable new finding was that neural communication was occurring outside of the synapse. Unlike what scientists previously had believed, neurons engage in “non-synaptic” communication, in addition to the synaptic communication that had been discovered many decades earlier.

WHAT DO YOU KNOW?...

11. Douglas Fields observed that neural communication can occur outside of the ______, contrary to what was previously thought.

The Nervous System

Your psychological life depends on not only your brain, but also communications systems that link your brain to the rest of your body. The body’s primary communication system is the nervous system, the complete collection of neurons that transmits signals among the parts of the body.

The brain, our focus so far in this chapter, is one part of the overall nervous system. Let’s learn about the rest of the nervous system by examining its two main parts, the central and peripheral nervous systems.

Central Nervous System

Preview Question

› What are the structures of the central nervous system and their functions?

The central nervous system gets its name from its location; it is found in the center of the body. The central nervous system consists of two main parts, the brain and the spinal cord. We have already discussed the brain, so let’s look at the spinal cord.

The spinal cord is a bundle of neurons and glial cells that extends from the brain stem down to the bottom of the spine. These cells run through the bones of the spine, which protects them from damage (Figure 3.23).

The spinal cord participates in two-way communications between the brain and body:

› In one direction, information from the environment is directed into the spinal cord, where it is then passed on to the brain. Specifically, sensory neurons, which respond to external stimuli, send messages about the environment into the spinal cord.
In the other direction, the brain’s instructions for the body are sent through the spinal cord. After outgoing messages from the brain reach the spinal cord, motor neurons send out signals to the body’s muscles. These signals enable the brain to control bodily movement.

Some bodily actions do not require signals that are sent to the brain. People possess reflexes, which are automatic, involuntary responses to external stimulation (Figure 3.24). For example, the leg movement that occurs when a doctor taps you on the knee during a physical examination is a reflex. (By comparison, play-acting that same leg movement is not a reflex.) Reflex actions are executed by neurons in the spinal cord. Sensory information reaches an interneuron, which is a neuron that relays information to a motor neuron that, in turn, puts the body into action.

WHAT DO YOU KNOW?...

12. For each of the “answers” below, provide the question.
   a. Answer: These neurons relay information about external stimuli from the spinal cord to the brain.
   b. Answer: The brain directs the body to move via these neurons in the spinal cord.
   c. Answer: These movements don’t require input from the brain.

Peripheral Nervous System

Preview Question

What are the structures of the peripheral nervous system and their functions?

The peripheral nervous system is found, as the name suggests, in the periphery of the body—that is, away from the body’s center. All neurons outside of the central nervous system are part of the peripheral nervous system.

There are two ways of classifying the various parts of the peripheral nervous system. One method is by their physical location. Cranial nerves are those parts of the peripheral nervous system found in the head. These nerves extend out from the bottom of the brain and connect to structures in the head, such as the eyes, nose, and tongue. Spinal nerves extend from the spinal cord to the body’s neck, torso, and limbs (Figure 3.25).

The second way of classifying the nerves of the peripheral nervous system is functionally, that is, in terms of what they do. The somatic nervous system provides the brain-to-periphery communications that enable you to control your bodily movement. For instance, when deciding to pass a soccer ball to your teammate rather than shooting on goal, the messages from your brain that adjust the movements of your leg and foot to get the ball to your teammate are carried along the somatic nervous system. The autonomic nervous system, on the other hand, provides the communications that control bodily functions that generally are not under your control; they occur without your even thinking about them. As you rush upfield deciding whether to pass or shoot, your heart beats faster than when you are at rest, your sweat glands are more active, your breathing is faster, and the pupils of your eyes are wider. But you don’t make conscious decisions about altering your heart rate, breathing, sweating, and pupil dilation; these changes occur automatically, through signals carried by the autonomic nervous system.

The autonomic nervous system contains two divisions, that is, two subsystems that perform different tasks. The sympathetic nervous system prepares you for action. It activates the biological systems required for rapid activity, such as increased heart rate. This activation enables “fight” or “flight” responses—actions to confront a threat or to flee from it. Revisiting the soccer example above, the sympathetic nervous system was responsible for activating biological systems as you rushed up the field.
But imagine what happens after you pass to your teammate: She scores, the game ends, your team wins, and now your body responds differently. You relax, rest, and may find that you need a bathroom break. Your body’s parasympathetic nervous system is swinging into action. The parasympathetic nervous system is the part of the autonomic nervous system that maintains normal functioning of the body when you are not under threat or stress. It activates “basic housekeeping” functions such as digestion and elimination of bodily waste, and reduces heart rate and blood pressure to low, baseline levels of activity.

The different roles of the sympathetic and parasympathetic nervous systems explain everyday examples in which psychological factors influence physical functioning. For instance, the demands of travel can be stressful, and travelers often experience “traveler’s constipation.” During the stress of travel, the sympathetic nervous system is relatively more active than usual—and the parasympathetic system less active, which interferes with normal digestive system functioning.

**WHAT DO YOU KNOW?...**

13. The division of the peripheral nervous system that enables you to control your body’s movements is the ______ nervous system. The autonomic nervous system is divided into two subsystems: the ______ nervous system, which, when activated, enables “fight or flight” responses, and the ______ nervous system, which restores normal functioning when a threat is no longer present.

**The Endocrine System**

The nervous system is not the only communication system within the body. A second is the endocrine system, which conveys signals from one part of the body to another using biochemicals. The biochemical signals affect activity in the body’s organs.

As you’ll see, the body’s two communication systems are linked: brain activity affects endocrine activity. This link is an important connection between mind and body.
Hormones

Preview Question

› What is the endocrine system and how does it differ from the nervous system?

The biochemicals that the endocrine system uses for communication are **hormones**, which travel through the bloodstream and act as “messengers.” They carry messages to the body’s organs.

Hormone-based communication in the endocrine system differs from communication in the nervous system. The nervous system is fast and specific, whereas the endocrine system is slower and less specific. For example, suppose you’re on a playing field and see, out of the corner of your eye, a football headed straight for your head.

› The nervous system leaps into action, rapidly sending signals specifically to the muscles of your neck and arm. They cause you to duck and to deflect the ball with your hand.

› Less quickly, hormone signaling by the endocrine system increases overall bodily energy. This effect lingers. Even after you’ve deflected the football, you feel “worked up”; the arousal created by the endocrine system persists after the action produced by the nervous system is completed.

The different speeds of these bodily reactions reflect the two systems’ different communications mechanisms. The nervous system, as you learned, communicates electrically: Action potentials zip along axons. The endocrine system communicates chemically: Hormones float through the bloodstream. Electrical “zipping” is faster than chemical “floating.”

Why would your body need the slow endocrine system if it’s got the fast nervous system? Sometimes the brain needs to send signals that are widespread and long-lasting. If that flying football in our example were an opening kickoff and you were one of the players, you would want to arouse multiple biological systems that prepared you for prolonged physical activity. Because hormones spread throughout the body, they are well equipped for the job of increasing the supply of energy to multiple muscles.

**WHAT DO YOU KNOW?**

14. Describe the differences between the nervous system and the endocrine system in speed and in method of communication.

Glands

Preview Question

› What are the major endocrine glands and their functions?

Hormones are produced by **glands**, which are bodily organs that produce and secrete chemicals. The glands of the endocrine system are located throughout the body (Figure 3.26). Two are in the brain. The **pineal gland** (so named because its shape resembles that of a pine cone) produces a hormone called **melatonin** that influences patterns of sleeping and wakefulness. Darkness increases melatonin release that, in turn, induces drowsiness. If people are exposed to bright lights, their melatonin levels decrease (Lewy et al., 1980).
The brain also houses the pituitary gland, an endocrine gland that is tiny (about the size of a pea) but powerful. In fact, it is so powerful that it is commonly called the “master gland” of the endocrine system. Its power derives from the fact that the pituitary gland releases hormones that influence biological activity in other glands. These include glands that respond to stress, contribute to reproduction, and regulate the body’s use of energy. In addition, the pituitary is the point of contact between the nervous system and the endocrine system. Specifically, the brain’s hypothalamus releases chemical substances that affect pituitary gland activity. Through this chain of influence—from hypothalamus to “master gland” pituitary to additional glands—the brain can influence endocrine activity throughout the body.

The body’s other glands are located below the head, as shown in Figure 3.26:

- The thyroid gland releases hormones that regulate the body’s metabolic rate, that is, the rate at which the body burns energy. The body’s rate of burning energy influences a person’s weight. Variations in thyroid functioning thus are correlated with variations in rates of obesity (Knudsen et al., 2005).
- The thymus produces hormones that influence the development and functioning of the immune system, and thus is important to overall health.
- The adrenal glands, which sit on top of the kidneys, produce hormones that respond to stress, as well as sex hormones, which are produced also by the gonads.
- The pancreas releases hormones that include insulin, which regulates the level of sugar in the bloodstream.
- The gonads are the organs that produce reproductive cells; the ovaries in women produce ova (eggs) and the testes in men produce sperm. In addition to eggs and sperm, the gonads also produce hormones. The ovaries produce estrogens, which stimulate the body to develop female sex characteristics such as breasts, and progesterone, which regulates the menstrual cycle. In men, the testes produce testosterone, which stimulates the development of male adult sex characteristics (e.g., deep voice, bone and muscle mass).

### WHAT DO YOU KNOW?...

15. Match the structures on the left with their features and functions on the right.

| 1. Pineal gland | a. Produces hormones that respond to stress |
| 2. Pituitary gland | b. Produces the hormone melatonin, which induces drowsiness |
| 3. Thyroid gland | c. Produces reproductive cells and hormones including estrogen, progesterone, and testosterone |
| 4. Thymus | d. “Master gland” that controls other glands and is the point of contact between the nervous and endocrine systems |
| 5. Adrenal glands | e. Releases insulin |
| 6. Pancreas | f. Releases hormones that influence the development and functioning of the immune system |
| 7. Gonads | g. Releases hormones that regulate metabolism |

### Psychological Effects of Hormones: Estrogens

**Preview Question**

How does estrogen affect memory and behavior?

Hormones clearly are central to biological functioning. What, though, is their psychological relevance? Why discuss them in a psychology textbook?

Hormones impact psychological functioning; they influence people’s moods, motives, and mental abilities. Particularly clear evidence of this comes from research
on women’s hormone levels and psychological functioning. Levels of ovarian hormones vary across the menstrual cycle. If psychological functioning similarly varies across the menstrual cycle, in tandem with hormone levels, this would provide evidence that hormones influence psychology. Let’s look at two examples.

A research team (Maki, Rich, & Rosenbaum, 2002) knew that estrogen can influence the growth of brain cells in areas of the brain needed for memory. They thus predicted that estrogen levels and memory performance would be linked. To test their prediction, they studied women at two time points: early in the menstrual cycle, when estrogen levels are low, and later in the cycle, when levels are high. At both times, women read a list of words and later performed a task that measured whether they retained information from the word list in memory. Women’s memory was found to vary across the menstrual cycle. As predicted, when estrogen levels were high, memory was superior (Maki et al., 2002).

The second example involves estrogen levels and styles of dressing and personal care. Researchers reasoned that, over the course of evolution, it was adaptive for women to appear attractive to mates during a particular time of the month: when they were most biologically fertile. During low-fertility periods, by contrast, it was adaptive to devote time to activities other than mating. The researchers hypothesized that, because we inherit psychological traces of the ancestral past, women today would still tend to pursue mates during biologically fertile periods, with this pursuit revealed in their styles of clothing and personal care. To test this hypothesis, the researchers took photos of women on both low- and high-fertility days in the given woman’s menstrual cycle. Afterwards, raters were asked to judge, for each pair of photos (i.e., photos from the high- and low-fertility period for each woman), “In which photo is the person trying to look more attractive?” (Haselton et al., 2007, p. 42). The judges, of course, did not know which photo was taken during the high-fertility period.

In which photo were women trying to look more attractive? As predicted, it was the photo from the high-fertility period; to a significant degree, judges rated this photo as the one in which women were choosing fashion items to enhance their attractiveness (Haselton et al., 2007). Ratings indicated that, during high-fertility periods, women wore more fashionable clothes that showed more skin (Table 3.2).

As with studies of the nervous system, then, research on the endocrine system reveals interconnections between biological mechanisms that evolved in the past and psychological experiences in the contemporary social world.

### Table 3.2

<table>
<thead>
<tr>
<th>Women’s Clothing Choices</th>
<th>High Fertility</th>
<th>Low Fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing “more fashionable clothes” (70%)</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>Wearing “nicer clothes” (77%)</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Showing more skin (upper body) (77%)</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Showing more skin (lower body) (93%)</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Wearing “sexier clothes” (70%)</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Wearing more “accessories” (63%)</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Wearing a skirt in one session but not the other (100%)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Wearing a lacy top (87%)</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Haselton et al. (2007).
16. Estrogen has been found to influence both memory and how ______ women chose to dress.

**Looking Back and Looking Ahead**

In this chapter, you’ve learned a lot of details about the brain: its bottom-to-top and left/right organization; networks that connect its distinct regions; the functioning of its individual cells; and the brain’s connections to the peripheral nervous system and endocrine system. But don’t focus only on the details. Recall the reason for learning all these brain facts.

In psychology, brain research is important because it enhances our understanding of people: their thoughts, feelings, and actions. Every chapter in this book contains information about the brain. In every branch of psychology, researchers try to deepen their understanding of people’s experiences and the mind’s powers by learning more about the brain’s neural and biochemical systems. By learning more about what the brain is like, we learn more about what people are like, too.

**Chapter Review**

Now that you have completed this chapter, be sure to turn to Appendix B (available at www.worthpublishers.com/cervonepreview), where you will find a Chapter Summary that is useful for reviewing what you have learned about the brain and the nervous system.

**Key Terms**

- action potential (p. 107)
- adrenal glands (p. 115)
- amygdala (p. 92)
- association areas (p. 97)
- auditory cortex (p. 96)
- autonomic nervous system (p. 112)
- axon (p. 107)
- brain stem (p. 88)
- central nervous system (p. 111)
- cerebellum (p. 89)
- cerebral cortex (p. 94)
- cerebral hemispheres (p. 99)
- cingulate gyrus (p. 93)
- connectome (p. 104)
- corpus callosum (p. 99)
- cranial nerves (p. 112)
- dendrites (p. 107)
- endocrine system (p. 113)
- fornix (p. 93)
- frontal lobes (p. 96)
- glial cells (p. 110)
- gonads (p. 115)
- hippocampus (p. 91)
- hormones (p. 114)
- hypothalamus (p. 90)
- limbic system (p. 90)
- medulla (p. 89)
- midbrain (p. 89)
- motor cortex (p. 97)
- motor neurons (p. 112)
- myelin sheath (p. 108)
- nervous system (p. 111)
- neurons (p. 106)
- neurotransmitters (p. 108)
- occipital lobe (p. 95)
- olfactory bulbs (p. 93)
- ovaries (p. 115)
- pancreas (p. 115)
- parasympathetic nervous system (p. 113)
- parietal lobe (p. 95)
- peripheral nervous system (p. 112)
- pineal gland (p. 114)
- pituitary gland (p. 115)
- plasticity (p. 84)
- pons (p. 89)
- prefrontal cortex (p. 97)
- receptors (p. 109)
- reflexes (p. 112)
- reticular formation (p. 89)
- sensory cortex (p. 96)
- sensory neurons (p. 111)
- somatic nervous system (p. 112)
- spinal cord (p. 111)
- spinal nerves (p. 112)
- split brain (p. 101)
- sympathetic nervous system (p. 112)
- synapse (p. 108)
- synaptic vesicles (p. 108)
- temporal lobe (p. 96)
- testes (p. 115)
- thalamus (p. 103)
- thymus (p. 115)
- thyroid gland (p. 115)
- triune brain (p. 87)
Chapter Review

Questions for Discussion

1. You learned that across time, when scholars described the brain, they typically chose some recently developed technology. Currently, we describe our brains as being computerlike or even Internetlike. What are some limitations of these analogies? What, if any, other technologies do you foresee taking their place? [Analyze]

2. As noted in the chapter, we can conceptualize the brain as a tool—one we use for thinking, among other things. This highlights the idea that our brains do not do our thinking for us; rather, we are the ones who use our brains to think. Do you think this suggests that our minds and our brains are separate? How do you conceptualize the relationship between the brain and the person using the brain? [Analyze]

3. A popular myth suggests we use only 10% of our brains. Is such a claim true? Explore the answer by specifying the areas of the brain likely to be active when you have a conversation with someone right before lunch. Is this proportion greater than or less than 10%? [Comprehend]

4. MacLean’s triune brain is a model that suggests we have three brains in one: a reptilian brain, a paleomammalian brain, and a neomammalian brain. What behaviors and capabilities would be affected if any of these three levels were removed from the individual? Would we still be human if the neomammalian brain were removed? What about the paleomammalian brain? [Analyze]

5. Mnemonics are techniques used to organize information in memory so that it is easier to retrieve later. What mnemonics can you use to memorize the structures of the brain and their functions? How might MacLean’s triune brain model help you organize this information? [Comprehend]

6. Name a part of the body whose sensory processing takes up a lot of “real estate” in the sensory cortex. Why might this particular body part take up so much space in the sensory cortex? [Analyze]

7. Name a part of the body whose motor processing takes up a lot of “real estate” in the sensory cortex. Why might this particular body part take up so much space in the motor cortex? [Analyze]

Self-Test

1. The hippocampus of London taxi drivers is larger than that of the average driver. What feature of the brain does this best illustrate?
   a. Its stability
   b. Its myelination
   c. Its plasticity
   d. Its reflexivity

2. The effects of Phineas Gage’s accident on his intellect and personality illustrated which of the following about the brain?
   a. We use only 10% of it.
   b. Its parts are specialized.
   c. It is highly plastic.
   d. It can repair itself.

3. Which part of MacLean’s triune brain is responsible for regulating bodily functions critical to survival?
   a. Neomammalian
   b. Paleomammalian
   c. Reptilian
   d. Vegetative mind

4. Damage to which of the following areas would cause your movements to become uncoordinated, even clumsy?
   a. Pons
   b. Midbrain
   c. Cerebellum
   d. Reticular formation

5. Of the following, which structure of the limbic system would be most active if you were to walk into your most challenging class and notice students clearing their desks, as if preparing to take a test (one for which you aren’t prepared)?
   a. Hippocampus
   b. Amygdala
   c. Fornix
   d. Cingulate gyrus

6. On which of the following properties of the body does fMRI capitalize to produce images?
   a. Radioactive substances are absorbed by organs.
   b. Blood flows to the areas of the body that are in use.
   c. The electricity of action potentials is very powerful.
   d. Skin conductance changes when sweat glands are active.
7. Damage to which of the following lobes would make it difficult for you to touch your finger to your nose with your eyes closed?
   a. Parietal
   b. Temporal
   c. Occipital
   d. Frontal

8. The rich interconnections between _____ lobes and other areas of the brain enable us to possess uniquely human capabilities, including the ability to think about ourselves and consider how others view us.
   a. parietal
   b. temporal
   c. occipital
   d. frontal

9. This area of the frontal lobes enables you to concentrate on taking this self-test, while simultaneously blocking out irrelevant stimuli.
   a. Motor cortex
   b. Association areas
   c. Sensory cortex
   d. Prefrontal cortex

10. That we’re able to coordinate complex activities is due largely to the fact that the brain is
   a. plastic.
   b. specialized.
   c. networked.
   d. hemispheric.

11. Which of the following was not a finding in research comparing brain activation among English and Chinese speakers doing arithmetic?
   a. For both, the visual–spatial regions of the brain were activated.
   b. Among Chinese speakers, visual processing areas of the brain were activated.
   c. Among Chinese speakers, visual processing areas of the brain were activated.
   d. Patterns of brain activation were nearly identical among English and Chinese speakers.

12. Which particular structure of the neuron can be as long as a meter (a little over 3 feet), allowing neurons to send information across relatively long distances?
   a. Axon
   b. Dendrite
   c. Synapse
   d. Glial cell

13. The incredible speed with which action potentials are able to rush down the length of an axon is enhanced by which of the following structures?
   a. Myelin sheaths
   b. Glial cells
   c. Synaptic gaps
   d. Dendrites

14. When used by neurons in the spinal cord, this neurotransmitter controls muscles, and when used by neurons in the brain, it regulates memory.
   a. Serotonin
   b. Norepinephrine
   c. Dopamine
   d. Acetylcholine

15. Unexplained weight gain would most likely be related to a decrease in the functioning of which of the following glands?
   a. Gonads
   b. Adrenal glands
   c. Thymus
   d. Thyroid gland

Answers

You can check your answers to the preceding Self-Test and the chapter’s What Do You Know? questions in Appendix B, available at www.worthpublishers.com/cervonepreview.
Student Questionnaire

We'd like to hear from you about your experience working with this sample chapter. To complete this questionnaire online, please visit: macmillanhighered.com/cervonesurvey
PSYCHOLOGY: THE SCIENCE OF PERSON, MIND, AND BRAIN
by Daniel Cervone | Student Questionnaire

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PLEASE FILL IN THE FOLLOWING INFORMATION:
Your name: __________________________ Your school: __________________________
Your instructor’s last name: ______________ Your email address: __________________

1 | Did you enjoy reading this chapter?
   □ Very much □ Somewhat □ Not at all

2 | What did you like best about Psychology: The Science of Person, Mind, and Brain?

3 | Psychology: The Science of Person, Mind, and Brain takes a “person-first” approach by exploring human experiences and scientific questions about those experiences at the start of each chapter. What did you think of this compared to your current book?

4 | Did the chapter explain the concepts clearly?
   □ Very much □ Somewhat □ Not at all

5 | Do you feel that this chapter helped you better prepare for quizzes/exams than your current text?
   □ Very much □ Somewhat □ Not at all
6 | Compared to other texts you have seen, what is your opinion of the design/layout, photos, and illustrations?
   □ Looks great
   □ Looks okay
   □ I don’t like the looks of it

7 | Did you find the material to be relevant to your life?
   □ Very much
   □ Somewhat
   □ Not at all

8 | Of the features contained in this chapter, which one did you like best, and why?

   PMB Connections (p. 86, 110)
   Try This (p. 92)
   Research Toolkit (p. 93)
   This Just in (p. 110)
   Cultural Opportunities (p. 104)
   PMB In Action (p. 105)

   Comments:
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

9 | How does the readability of *Psychology: The Science of Person, Mind, and Brain* compare to your current book?
   □ *Psychology: The Science of Person, Mind, and Brain* is easier to read and understand.
   □ My current book is easier to read and understand.
   □ Both books are equal.

10 | Based on the chapter you reviewed, how would you describe *Psychology: The Science of Person, Mind, and Brain* to a fellow student?
   ____________________________________________________
   ____________________________________________________
   ____________________________________________________

11 | Which book would you prefer to use in your introductory psychology course, *Psychology: The Science of Person, Mind, and Brain* or your current text?
   □ *Psychology: The Science of Person, Mind, and Brain*
   □ My current text

12 | Would you recommend this book to your professor for this course?
   □ Yes
   □ No

THANK YOU FOR YOUR FEEDBACK!
DANIEL CERVONE is Professor of Psychology at the University of Illinois at Chicago, where he has spent his entire career. He earned his B.A. at Oberlin College where he majored in mathematics and psychology, and his PhD from Stanford University as a student of Albert Bandura. He has held visiting faculty positions at the University of Washington and the University of Rome ‘La Sapienza,’ and has been a Fellow at the Center for Advanced Study in the Behavioral Sciences.

In addition to introductory psychology, Dan teaches courses in personality psychology, social cognition, and research methods to the diverse student body at UIC. He is graduate advisor to students in both social/personality and clinical psychology in UIC’s doctoral program in psychology, and serves as a Fellow in UIC’s undergraduate Honors College.

Dan is the author of a graduate-level and undergraduate texts in personality, and co-editor of four volumes in personality science. He has published numerous scientific articles, primarily in the study of social-cognitive processes and personality. He has served as the Program Chairperson of the annual convention of the Association for Psychological Science on three occasions, and is the U.S.-based Chairperson of the inaugural International Convention of Psychological Science.

TRACY L. CALDWELL is Associate Professor of Psychology at Dominican University, where she was recently appointed a Diversity Fellow. She earned her B.A. at The College of New Jersey and her Ph.D. in personality and social psychology from the University of Illinois at Chicago.

She caught the teaching bug during graduate school, when as a teaching assistant for a large section of introductory psychology, she led several smaller discussion sections. In her post as visiting faculty at North Central College, she had the opportunity to teach smaller sections of introductory psychology and to develop her pedagogical skills.

In addition to teaching introductory psychology, Tracy teaches personality psychology, social psychology, the psychology of gender, and research methods and statistics. She has also taught seminars in social cognition and the psychology of romantic relationships. She is the faculty advisor for Dominican University’s Psychology Club and its chapter of Psi Chi, the International Honors Society in Psychology.

Tracy has published articles on a variety of topics including how stereotypes are formed, how people with a repressive coping style process threat, and on how to best assess humor styles. She currently conducts research on the scholarship of teaching and learning, sex differences in the attractiveness of humor in romantic relationships, and on the accommodation of learning styles.
Because people are the story of psychology

Daniel Cervone
PSYCHOLOGY: THE SCIENCE OF PERSON, MIND, AND BRAIN

INSIDE: Sample Chapter 3
The Brain and the Nervous System

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