CHAPTER

2 The Brain: A Primer

There is perhaps no greater untapped resource
in the universe than the human brain. . . .
The human brain is no longer
the domain of academia and medicine.
—*Paul D. Nussbaum, clinical neuropsychologist*

Objectives

After studying this chapter, you will be able to:

- Describe the brain's features and functions and distinguish between the brain and the mind
- Demonstrate the special capabilities of the brain's left and right hemispheres
- Explain your lifelong learning potential as a result of the brain's neuroplasticity
- Contrast the workings of the conscious and subconscious minds
- Discuss the dominance of habits and explain how to change them
- Articulate why multitasking is a poor use of time and likely to cause errors
- Summarize the brain's negativity bias and explain how it could frustrate your success
- Restate the characteristics of left- and right-handedness
- Establish the value of understanding brain-related gender differences
- Illustrate how we know what we know about the human brain
- Describe exercise, diet, and mental stimulation tips for brain care

2.1 INTRODUCTION TO YOUR BRAIN

Let's consider brain basics. I suggest this on the assumption that you want to change some of your behavior. If you would like to work smarter, live smarter, replace some bad habits with good habits, and/or be more creative or innovative, then an

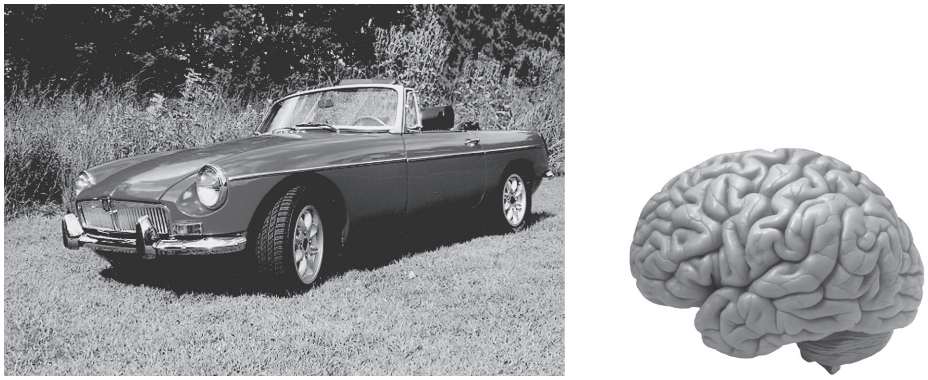

Figure 2.1
Just like you don't have to become an expert auto mechanic to improve your car's performance, you don't have to be a brain surgeon to more effectively use your brain.
(Stuart Walesh; Danheighton/ Fotolia)

understanding of brain basics will help you. As noted by consultant Cooper (2006, 6), "It's an amazing instrument, your brain, but it's up to you to see that it plays the tune you want." Playing that tune requires a basic understanding of how the instrument works.

Scientists and medical professionals have learned much about this instrument in the last few decades. "Ninety-five percent of what we know about the capabilities of the human brain has been learned in the last twenty years," according to Gelb (2004, 3). Physician Restak (2009, 5), wrote, "We have learned more about the brain in the past decade than we did in the previous two hundred years." With the help of this text, you can immediately acquire and use that new knowledge.

You may be thinking I'm going off on a tangent. You're studying engineering and want to be a good or great engineer—not a brain surgeon. I want to help you achieve your goal. However, to be a good or great engineer, you should know a little to a lot about your brain: how it works and how to use and care for it.

Consider an analogy. You bought a classic car (Figure 2.1), and the engine ran rough. Therefore, you read about the engine, experimented with various aspects of the electrical and fuel systems, and solved the problem. You didn't have to become a certified auto mechanic to get better engine performance, and you don't have to become a brain surgeon to make better use of your brain. However, you do need to know brain basics; you need mental literacy (Gelb 2004).

The human being is the only living thing able to think about the future (Baumeister and Tierney 2011; Gilbert 2006; Medina 2008). "The greatest achievement of the human brain is its ability to imagine objects and episodes that do not exist in the realm of real," according to psychology professor Gilbert (2006, 5), "and it is this ability that allows us to think about the future." Get ready to learn more about your "thinker."

HISTORIC NOTE: BRAIN VIEWS OVER THE CENTURIES

For centuries, some societies thought that the human brain was relatively unimportant. For example, before mummifying their dead, the Egyptians—who thought that the heart was the source of intelligence and emotion—scooped out and discarded the brains (Gibb 2012). The Greek philosopher Aristotle thought that the heart was superior, while the brain was simply a radiator for cooling the blood. However, his predecessor Plato, who lived several centuries BC, had more foresight; he viewed the brain as the seat of mental processes (Carter 2009). Hippocrates, the Greek physician who lived at about the same time as Plato, was the principal author of a medical book that expressed the opinion that the brain was the body's control center (Finger 1994). Before the advent of anesthesia, the practical Romans performed a form of brain surgery called trepanation—a practice that may go back thousands of years, during which a hole is drilled in the patient's skull to relieve pressure on the brain and cure headaches (Gibb 2012; Shields 2014).

Reflecting the atmosphere of inquiry characterizing the Renaissance, Leonardo da Vinci studied brains of cadavers and then illustrated the three-dimensional form of some of the brain's structure. In 1664, Englishman Thomas Willis (who would later become a founding member of London's Royal Society) published a brain anatomy book with detailed drawings and included new words such as *neurology* and *hemisphere*. Neuroscience was born when Spanish neuroscientist Ramon y Cajal published a text in 1889 that described the human nervous system, including the role of neurons; this text led to him receiving the 1906 Nobel Prize for Medicine.

The twentieth century saw the development of various brain-imaging techniques, as described in Section 2.15.3. These techniques greatly advanced neuroscience and led to many discoveries, some of which are described in this chapter and are the basis for this text's advice to work smarter and be more creative and innovative (Gibb 2012).

2.2 SOME THOUGHTS FOR RATIONAL ENGINEERS

Student or practitioner engineers tend to be very rational (Culp and Smith 2001; Herrmann 1996). We approach our work and many other aspects of our lives in a systematic and logical manner. Our rational approach is powerful in that it enables us to define, analyze, and resolve difficult issues, problems, and opportunities (IPOs).

Although I doubt that we engineers are as fully rational as we and others think we are, many of us may be sufficiently rational to be initially suspicious of, if not turned off by, some of the content of this text. For example, this text explores topics such as brain lateralization, neuroplasticity, the subconscious mind breaking through to the conscious mind, the dominance of habits, negativity bias, gender and the brain, and whole-brain thinking, many of which may seem alien to the study and practice of engineering.

Furthermore, we will discuss many and varied thinking tools, some with strange-sounding names and unusual features, such as Borrowing Brilliance, Fishbone Diagramming, Ohno Circle, and Six Thinking Caps. Finally, I will repeatedly claim that as a result of studying brain basics and then understanding and applying whole-brain tools, you and others will be empowered to work smarter and be more creative and innovative. I welcome your healthy skepticism, provided it is balanced with your openness to new possibilities.

You may be saying, "Give us a break! We're open to new concepts, ideas, approaches, and tools." I hope you are. My experience in recent years speaking to engineering students and faculty has been neutral to receptive and, therefore, encouraging. However, during that period, I have also spoken with and written to engineering practitioners and have experienced significant lack of interest and some strong pushback.

You may be in or soon will enter that practitioner world; therefore, my experiences with it may interest you. A large fraction of engineering practitioners seem to view brain basics as irrelevant and as too academic, theoretical, philosophical, and esoteric. However, I will continue to share with practitioners what I have learned about the human brain and how that knowledge can help them, individually and organizationally, to work smarter and be more creative and innovative. Although my focus in this text is on you—tomorrow's engineers—I will continue to try to communicate with today's practitioners because I want to build a bridge from what we have recently learned about the human brain to how engineers practice their profession.

PERSONAL: PUSHBACK TO BRAIN CONVERSATION

In response to a request for topics that I could present at the annual senior managers meeting in a multioffice, engineering/science consulting firm, I proposed the topic "Working Smarter Using Brain Basics." I explained that "working smarter" meant being more effective, efficient, and innovative and was built on brain basics. The response from the firm's top executives was unanimously strongly negative. Therefore, I presented other topics, which were well received.

I asked the executives why they rejected the proposed brain-based, working-smarter topic. They said that brain talk "turned them off"; they worked in the "trenches" ten hours per day and therefore had no interest in or time for peripheral topics such as learning more about their brains and being more effective, efficient, and innovative. This incident is consistent with my negative experiences in the world of engineering practice. My view is that learning how to work smarter and be more creative and innovative could shorten the work day—leading to less time in the "trenches."

Given the considerable effort I, an engineer, have put into the creativity and innovation research summarized in this text, all I ask is that you at least temporarily set aside your perhaps overly rational nature and consider what may initially appear to be this text's irrational or strange elements. Maybe you'll think about and experiment with what initially appear to be unusual (if not irrational) concepts, ideas, and methods; as a result, maybe you'll work smarter and be even more creative and innovative.

2.3 BRAIN FEATURES

We begin our discussion of the human brain with an overview of its appearance and description of some of its elements that are essential to our later brain discussions. This initial look at the brain includes discussion of the Triune Brain Model and the structure and function of neurons.

2.3.1 Overview

About the size of a small head of cauliflower, the human brain (Figure 2.2) weighs two to four pounds, or roughly 3 percent of your weight. It is very soft, tan-gray on the outside, has a surface resembling a walnut, and is yellow-white on the inside. The brain contains one hundred billion nerve cells, called *neurons*, which can

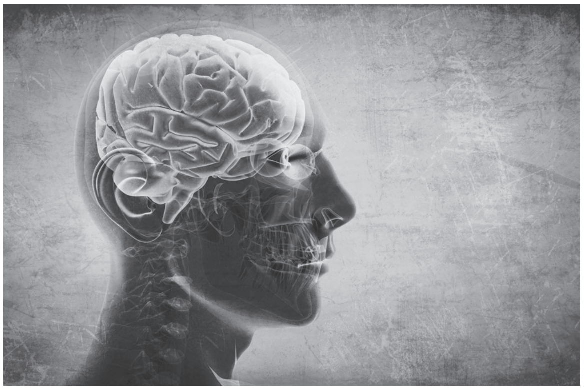

Figure 2.2
The human brain may be the most magnificent mechanism in the universe.
(Adimas/Fotolia)

receive and send electrochemical signals stimulated by neurotransmitters. A *neurotransmitter* is a chemical that is released from a neuron and helps to amplify or modulate a signal that passes from one nerve cell to another or to a muscle.

A network of about one hundred thousand miles of nerve fibers, comprising what is called the *white matter*, interconnects the various parts of the brain. Each neuron has an average of ten thousand connections (*synapses*) with other neurons. To get an idea of the size of a neuron, a piece of brain tissue the size of a sand grain would contain one hundred thousand neurons. Moving deeper into this system, each neuron contains tens of thousands of molecules, and each molecule is a group of atoms. We are born with nearly all the neurons that we will have as an adult, but the neural networks—the systems of connected neurons—have yet to mature.

The adult brain receives blood through four arteries, at a rate of 0.75 to 1.0 liters per minute (up to sixteen gallons per hour), which accounts for about one-fifth of the blood pumped by the heart. The brain consumes one-fifth of the energy used by the body; it is an energy-hungry machine. The blood transports glucose (blood sugar), nutrients, and oxygen to the brain and carries away carbon dioxide and other waste products. These substances and others with similar small molecules readily pass through the blood-brain barrier, which protects the brain from many dangerous substances. Glucose is the brain's source of fuel, and it interacts with oxygen and nutrients to provide energy to brain cells. The brain cannot store glucose and therefore needs a continuous supply (Amen 2008; Baggaley 2001; Benyus 1997; Carter 2009; Freudenrich and Boyd 2014; Gibb 2012; Medina 2008; Nussbaum 2010; Pinker 2009; Wait 2009; University of Washington 2014; Zimmer 2014).

2.3.2 Triune Brain Model

Scientists use the Triune Brain Model (Figure 2.3), based on function, physiology, and evolutionary development, to describe the overall, three-part structure of the human brain (Herrmann 1996; Medina 2008; Mlodinow 2013). The first of the three parts, the *cortex*, is the most dominant and the newest part of the brain in an evolutionary sense. The cortex is the surface of your brain and covers the *cerebrum*, which is the largest part of the brain and is composed of two hemispheres.

The cortex consists of an approximately three-square-foot sheet of neural tissue (an area approximated by that of an opened newspaper) and is heavily folded so that its large surface area fits within the confines of the skull. Nerve centers for thinking, voluntary movement, the senses, and personality reside in the cortex and the rest of the cerebrum (Baggaley 2001; Carter 2009; Freudenrich and Boyd 2014; Medina 2008; Mlodinow 2013; Nussbaum 2010). More specifically, the cortex is

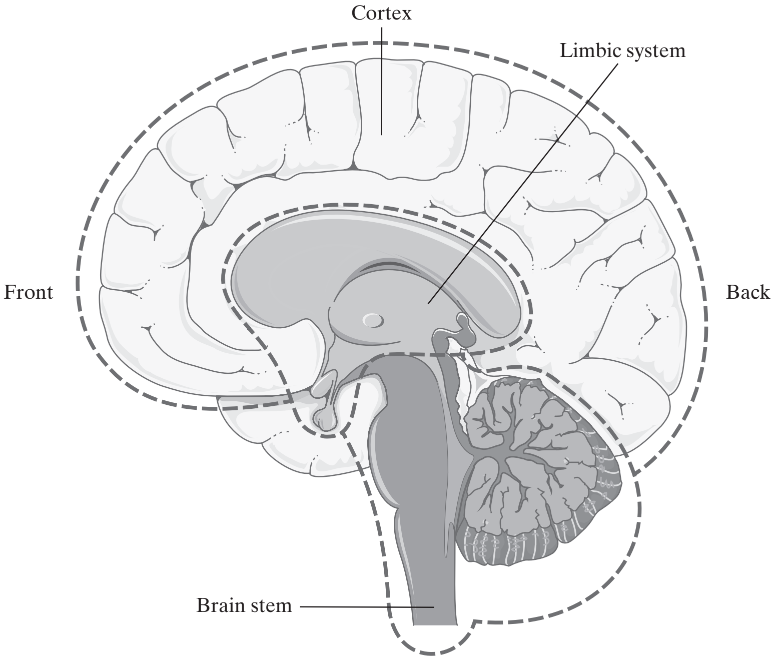

Figure 2.3
Scientists use the Triune Brain Model to describe the overall, three-part structure of the human brain.
Source: Adapted from Baggaley 2001; Herrmann 1996; Medina 2008.

responsible for concept formation, hearing, language, memory storage, mood, voluntary movement, pain detection, planning, problem solving, seeing, spatial interpretation, speech, temperature sensing, and touch. Cortex functions are conscious and intentional (Baggaley 2001; Nussbaum 2010).

Next, working downward and as shown in Figure 2.3, you will see the portion of the brain that includes the *thalamus*, *amygdale*, and *hippocampus*. This area, which is also called the *limbic system*, controls fighting, feeding, fleeing, and reproductive behaviors. More specifically, the egg-shaped thalamus is the "control tower for the senses." From its position in the brain's center, "it processes signals sent from nearly every corner of your sensory universe, then routes them to specific areas throughout your brain" (Medina 2008). Regulation of emotions such as fear, rage, and pleasure and memories of the same reside in the almond-shaped and -sized amygdale, which lies beneath the thalamus. The amygdale also plays a role in formation of long-term memory (Gibb 2012; Medina 2008; Restak 2009; Wait 2009). Finally, the hippocampus is involved with learning and converts our short-term memories into long-term forms (Baggaley 2001; Medina 2008).

The final third of the human brain in the Triune Brain Model, and the oldest and lowest part, is the always-active *brain stem*, which controls basic body functions such as breathing, heart rate, blood pressure, sleeping, and being awake (Medina 2008). The *cerebellum*, or little brain, is a major part of the brain stem and responsible for involuntary movement. It occupies about one-tenth of the brain's volume while accounting for approximately half of the neurons (Gibb 2012).

The brain can't feel pain because it does not have sensory nerves. Therefore, neurosurgeons can "poke around" in a brain when a patient is alert (Wait 2009). Although the brain has no sensory receptors, it does sense pain from all parts of the body (Carter 2009), including pressure on nerve tissue or blood vessels surrounding the brain, which causes headaches. See Section 2.9 for further discussion of the cortex and the remainder of the brain and possible connections to conscious and subconscious thinking.

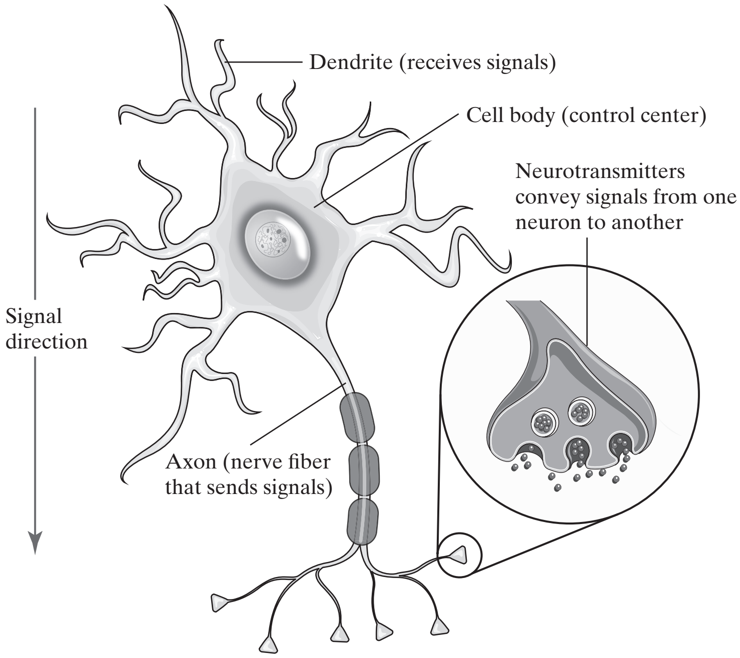

Figure 2.4
The most common type of neurons usually have a tree-like structure, and signals pass through them from top to bottom.
Source: Adapted from Gibb 2012; Nussbaum 2010.

2.3.3 Neurons

Let's look a little closer at one of those one hundred billion brain cells or neurons so small that a grain-sized piece of brain tissue would contain one hundred thousand of them. As shown in Figure 2.4, the most common type of neuron has a tree-like structure and signals passing in one direction from the top to the bottom. The "foliage" portion of the neuron consists of dendrites that detect and receive chemical signals from neighboring neurons. The cell's body (its control center) composes the middle portion of the "tree." The tree's "trunk" is the *axon*, also called a *nerve fiber*, which is used to transmit signals to the dendrites of other neurons. Axons originating in the human brain vary widely in length, ranging from those that transmit from neuron to neuron within the brain to those that transmit from the brain to the ends of our toes.

For a given neuron, chemical signals from the axons of other neurons are received at the ends of the dendrites of the neuron. The signals are sent within the dendrites in the form of an electrical charge (charged ions) to the cell body, where they are processed. The cell body produces new signals that are sent down the axon as an electrical charge and transmitted in the form of chemicals called *neurotransmitters*, released from the axon's end to the dendrites of other neurons. The site of communication between neurons, which is a minute gap where neurons don't touch, is called a *synapse* (Baggaley 2001; Gibb 2012). For discussion of neurotransmitters, see Section 2.14.3.

2.4 BRAIN FUNCTIONS

Having reviewed the brain's features and essential elements, let's now explore its functions. We'll note the body processes controlled by the brain and stress the dominance of vision among our six senses.

2.4.1 Overview

As suggested by the preceding information, and mostly without us having to think about it, various parts of the human brain fulfill the following roles:

- Control body processes such as temperature regulation, blood pressure, heart rate, and breathing.
- Accept and act on information received from our six senses—that is, vision, hearing, smell, taste, touch, and proprioception. The last term means "sensing of body position, movement, and posture" (Carter 2009).
- Manage physical motion such as walking, talking, standing, and sitting.
- Enable us to dream, think, plan, create, and innovate.

In my view, the human brain is the universe's most engaging entity, intriguing instrument, and magnificent mechanism.

VIEWS OF OTHERS: TRYING TO DESCRIBE THE BRAIN

Individuals from a variety of professions and specialties have tried to capture the essence of the brain's appearance, structure, or functions. For example, journalist Rita Carter (2009) wrote that the brain is "three pounds or so of rounded, corrugated flesh with a consistency somewhere between jelly and cold butter." According to brain imaging expert Daniel G. Amen (2008), "the brain is comprised of 80 percent water and is the consistency of soft butter or custard" and is the "most complicated organ in the universe." Continuing that theme, marketing consultant Neale Martin (2008) calls the brain "the most complicated complex object in the cosmos." Neuroscientist Jill B. Taylor (2009) says, "The focused human mind is the most powerful instrument in the universe." As viewed by neuropsychologist Paul D. Nussbaum (2010), even with all of the technology at our disposal, the human brain is "the most impressive portable and wireless system."

2.4.2 Vision Dominates

Before leaving this introductory discussion of brain functions, consider further the brain and the six senses. In any given learning or human interaction situation, many of the senses are engaged. For example, they are used by each of us as we try to understand someone or learn something and by others as they strive to understand our message.

However, vision is the most important of the six senses, as stressed by biologist Medina (2008) when he says that "vision trumps all other senses" and states that vision is the most dominant of the six senses, "taking up half of our brain's resources." He mentions one research study that concluded that when information was presented only orally, individuals remembered about 10 percent when tested seventy-two hours later. However, remembering jumped to 65 percent when images were also used to present the information.

Recognizing the major role of vision in learning, educator Zull (2002) urges teachers to "make extensive use of images to help people learn," and Hardiman (2003), another educator, advocates "visually stimulating environments." Consider the dominance of vision from the perspective of a presenter trying to convey ideas and information to an audience. Many presentation slides consist of a statement followed by bullet points. However, research reveals that the most effective slide contains a declarative statement with a supporting image. Audience members tend to learn and remember better from words and pictures than from words alone (Atkinson 2010; Medina 2008).

You, as an engineering student and later as a practitioner, will be offered many learning and presenting opportunities. Therefore, leverage the fact that "vision trumps all other senses." For example, when you or your group is trying to understand a process or mechanism, make one or more freehand sketches (see Section 7.4 for an in-depth discussion of freehand drawing). The next time you or your team prepares a presentation, get beyond communicating with just words. Use supplemental photographs, props, graphs, and other visual elements. Also recognize that although the audience will listen to your words and look at your visual aids, your expressions, gestures, grooming, and overall appearance are also part of your message.

2.5 BRAIN AND MIND

Before going on, let's distinguish (as suggested by Figure 2.5) between the brain, our principal topic in this chapter, and the mind. The brain "is an organ of the body, a collection of cells and water, chemicals and blood vessels, that resides in the skull," according to neuroscientist Levitin (2006). In contrast, he goes on to say, "The word mind refers to that part of each of us that embodies our thoughts, hopes, desires, memories, beliefs, and experiences." Pinker (2009), a psychologist, writes that the mind is "the generator of human behavior: the package of information-processing and goal-pursuing mechanisms." Levitin (2006) continues this theme, noting that "activity in the brain gives rise to the content of the mind." Simply stated, the brain is the organ and the mind is what we do with it.

Our focus now is on the brain, recognizing that the brain and mind are related. In other words, knowledge of our brain and how we use that knowledge can influence our mind—our "thoughts, hopes, desires, memories, beliefs, and experiences" and our creativity and innovation. Although your brain looks similar to others, you as defined by your mind are probably unique.

We mentioned memories; very few of our experiences are encoded as brain memories, where a *memory* is a reactivation of neurons involved in the original

Figure 2.5
Our brain is the organ, and our mind is what we do with it.

experience. Memories are not exact replays of that original experience. Some aspects may be left out, added, or changed. "Memories are dynamic and must be reconsolidated each time we remember them" (Restak and Kim 2010). "We generally retain only those experiences that are in some way useful" and our recall of the past is "selective and unreliable" (Carter 2009). As part of a discussion of memories, author and journalist Jonah Lehrer (2008) observes that "our recollections are cynical things, designed by the brain to always feel true, regardless of whether or not they actually occurred." In using your memory to understand yourself and interact with others, forewarned is forearmed.

2.6 HEMISPHERES AND SYMMETRY

When the brain (minus the skull) is viewed from above, as illustrated in Figure 2.6, we see the cerebrum, which is the brain's largest part and includes nerve centers for thought, personality, the senses, and voluntary movement. It has symmetrical left and right halves or hemispheres. Specific areas of the halves are connected by a band or bridge of about two hundred million nerve fibers, called the *corpus callosum* (Baggaley 2001; Carter 2009; Freudenrich and Boyd 2014). "Every fiber is a neuron's axon, the long, spindly protrusion that connects brain cells" (Wolf 2013).

Each of the brain's hemispheres interacts with the opposite side of the body. Imagine being above the body and brain and looking down at it, as shown in Figure 2.7. Lateralization means that, in general, the left side of the brain interacts

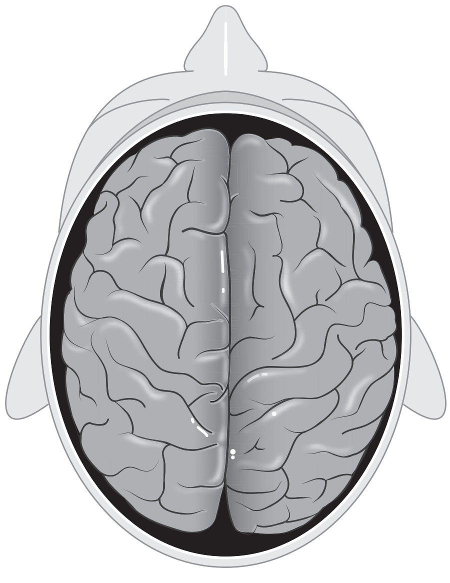

Figure 2.6
The cerebrum has symmetrical halves or hemispheres.

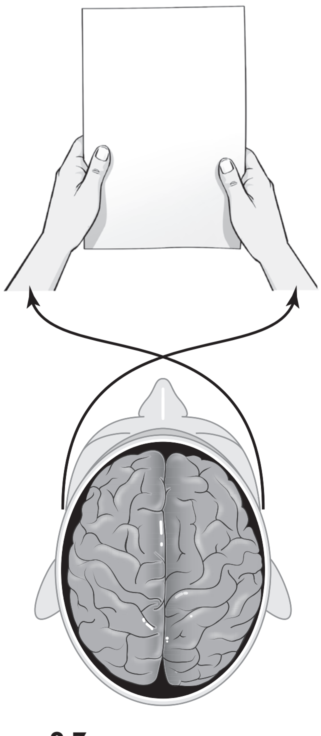

Figure 2.7
Lateralization of functions means that the left side of the brain interacts with the right side of the body and vice versa.

with the right side of the body and vice versa (Restak and Kim 2010). For example, if you inadvertently touch this text with your right hand, the result is sensed in your brain's left hemisphere. If you want to pick up the text with your left hand, the command comes from your right hemisphere. Therefore, just as the two hemispheres are symmetrical in appearance, they are also largely symmetrical in function.

Why does the brain exhibit lateralization? We don't know. According to neuroscientist and medical doctor Restak (Restak and Kim 2010), "No one has satisfactorily explained the brain's odd anatomical arrangement whereby information to and from one side of the body is processed on the opposite side of the brain."

2.7 ASYMMETRICAL CAPABILITIES: AN EXCEPTIONAL EXCEPTION

Although your brain exhibits some symmetry, as just discussed, it is also asymmetrical. That asymmetry leads us to left- and right-brain capabilities and the resulting powerful potential of whole-brain thinking.

2.7.1 Left- and Right-Hemisphere Capabilities

As you may have concluded from the preceding section, there are exceptions to functional symmetry. These exceptions, which are very relevant to this text, are presented in summary form in Table 2.1. The two sides of the brain tend to be specialized with respect to their capabilities and the tasks they perform.

Note the first comparison: The left hemisphere is *verbal* and the right hemisphere is *nonverbal*. Assume you are recalling an afternoon at the beach with your significant other. You were there on a Saturday in August from about 2:00 p.m. to 4:30 p.m., the air temperature was in the low 80s, and there was a light breeze off the sea. That part of your memory is courtesy of your left hemisphere. As you recall that afternoon, you also feel the sand on your feet, taste the salt air, and experience the pleasure of just being with your loved one. That part of the memory is provided by your right hemisphere. Total recollection of the wonderful afternoon requires your whole brain.

Recall that the purpose of this text, as stated at the beginning of the preceding chapter (Section 1.1), is to help you acquire creativity and innovation knowledge,

Table 2.1 The brain's two hemispheres are asymmetrical with respect to some capabilities.

Left Hemisphere	Right Hemisphere	Source
Verbal	Nonverbal	Edwards; Taylor
Analytic	Synthetic	Edwards
Logical	Intuitive	Edwards
Literal	Emotional	Taylor
Temporal	Nontemporal	Edwards; Taylor
Linear processor	Parallel processor	Taylor
Symbolic	Actual; real	Edwards
Abstract	Analogic	Edwards
Digital	Spatial	Edwards
Judgmental	Nonjudgmental	Taylor

Sources: Edwards 1999; Taylor 2009.

skills, and attitudes so that you can work smarter and achieve more individual and organizational success and significance in our rapidly changing world. Doing that requires use of your whole brain (left and right hemispheres), just like you use your whole brain when you happily recall that afternoon at the beach. Using your whole brain to recall a special emotional event is natural, but using your whole brain in study and work is not necessarily so. Therefore, you may need help such as that offered in this text.

Jill Taylor, a brain scientist, suffered a stroke and needed eight years to completely recover all physical and mental functions. That intense experience provided her with a unique opportunity to learn even more about the brain. Taylor shared her stroke and recovery experience in her book *My Stroke of Insight: A Brain Scientist's Personal Journey* (Taylor 2009). To reinforce the previous reference to using the whole brain in recollecting the memorable afternoon at the beach, Taylor says that "both of our hemispheres work together to generate our perception of reality on a moment-by-moment basis."

Let's elaborate on the comparisons in Table 2.1. Do this as follows by using the insights of Taylor and others:

- Relative to the first comparison in the table, according to Taylor (2009), *verbal* means that we "use words to describe, define, categorize, and communicate about everything," whereas *nonverbal* means that one "thinks in collages of images."
- Consider the *analytic* and *synthetic* entries in the table. The left brain is good at "figuring things out step-by-step and part-by-part," states Edwards (1999), whereas the right brain's strength is "putting things together to form new wholes." "You need your left brain to order and analyze things," according to Elizabeth Miles (1997), an ethnomusicologist (i.e., someone who studies music in cultural context), "but you need an ongoing relationship between the left and right side if you ever expect to contribute anything new to the process."
- Edwards sees *logical* capability as "one thing following another" based on theories, facts, and well-stated arguments. In stark contrast, the *intuitive* capability is described by her as "making leaps of insight, often based on incomplete patterns, hunches, feelings, or visual images."
- The *literal* versus *emotional* pair in Table 2.1, according to Taylor, indicates that the left hemisphere receives the literal content of a message (the facts), while the right hemisphere receives the emotional content. Therefore, the entire brain is needed to fully benefit from the message.
- According to Edwards, the *temporal* capability includes "keeping track of time" and "doing first things first," whereas *nontemporal* means to be "without a sense of time." Similarly, Taylor says that the left hemisphere's *temporal* capability partitions moments into "past, present, and future," whereas for the right hemisphere's *in the now* capability, "no time exists other than the present moment."
- Taylor says that the left brain's *linear processor* capability takes each of those moments and "strings them together in timely succession." In contrast, the right brain's *parallel processor* creates a collage of the present moment, including its "sounds, tastes, aromas, and feelings."
- The left brain's *symbolic* capability, as explained by Edwards, means that it uses symbols to represent things or processes. For example, a plus sign stands for the addition process. In contrast, the right brain's *actual/real* capability means that it experiences or sees things as they are right now.
- According to Edwards, the left hemisphere's *abstract* capability means "taking out a small bit of information and using it to represent the whole thing." The

right brain's *analogic* capability means "seeing likenesses among things; understanding metaphoric relationships."

- *Digital* capability refers to "using numbers, as in counting," as explained by Edwards. In contrast, *spatial* capability means "seeing where things are in relation to other things and how parts go together to form a whole."
- The left hemisphere is *judgmental* in that it "defines boundaries and judges everything as right/wrong or good/bad," as viewed by Taylor. In contrast, the *nonjudgmental* right hemisphere "takes things as they are" and is empathetic, compassionate, and peaceful.

HISTORIC NOTE: SPLIT-BRAIN STUDIES

In the middle of the last century, as a last resort to help individuals severely disabled by epileptic seizures involving both hemispheres, surgeons severed their corpus callosums in an operation called *commissurotomy*. These operations on humans, which were first performed in 1963, occurred after neurobiologist Sperry had performed similar surgeries on cats and monkeys (Shlain 2014).

As noted in Section 2.6, a person's corpus callosum connects the two hemispheres. Therefore, after the surgery, each of a patient's hemispheres was isolated from the other; they were disconnected. Surprisingly, especially given its large size and strategic location, scientists determined that when the corpus callosum is severed, the two hemispheres functioned independently, and "the patients' outward appearance, manner, and coordination were little affected" (Edwards 1999).

In the 1970s, seeing an opportunity, researchers at the California Institute of Technology conducted "split-brain" studies. They worked with the "split-brain" individuals using specially designed tests. These experiments revealed that each hemisphere "perceives reality in its own way" (Edwards 1999), as suggested by the previous discussion of Table 2.1. According to Taylor (2009), "When surgically separated, the two hemispheres function as two independent brains with unique personalities." This historic account begins to tell us how scientists know how the two sides of the human brain function.

Roger W. Sperry, who was awarded the Nobel prize for medicine along with two colleagues for his leadership of this research, said this during his 1981 Nobel lecture: "The same individual can be observed to employ consistently one or the other of two distinct forms of mental approach and strategy, much like two different people, depending on whether the left or right hemisphere is in use" (Taylor 2009). Sperry also said that each hemisphere of the human brain is "a conscious system in its own right, perceiving, thinking, remembering, reasoning, willing, and emoting, all at a characteristically human level" (Gibb 2012). Commissurotomy ceased in the 1970s because new drugs successfully controlled epilepsy (Shlain 2014).

2.7.2 Practical Applications of Hemisphere Knowledge

Of course, the two halves of the brains of most of us are connected, and "when normally connected, the two hemispheres complement and enhance one another's abilities" (Taylor 2009). This text recognizes that each of us uses both hemispheres, and we each tend to be dominated by one—typically the left brain for engineers and most others. Having a dominant side of our brain should not surprise us; our bodies naturally exhibit other types of dominance, such as being left- or right-handed (Herrmann 1996).

We can be more effective if we seek better brain balance. For engineers, that improved relationship between the two hemispheres usually means making more use of the right hemisphere while not diminishing the role of the left hemisphere. Accordingly, this chapter provides a brain primer that describes the brain's asymmetric capabilities and the tendency of most of us to be dominated by the left side. Chapters 4 and 7 provide many methods for proactively engaging both hemispheres. This is part of a whole-brain approach, with the other part being to engage the soon-to-be discussed conscious and subconscious minds.

2.8 NEUROPLASTICITY: A MUSCLE—NOT A MACHINE

Up to several decades ago, the human brain was viewed as "a rigid, fixed, and essentially degrading system from birth" (Nussbaum 2010). Hardwiring of the brain was a metaphor suggesting that the brain was like "computer hardware, with permanently connected circuits, each designed to perform a specific, unchangeable function" (Doidge 2007). Although this hardwired view of the brain (as suggested by Figure 2.8) was first proposed in the seventeenth century and may still find a few adherents, a newer, more accurate view of the brain is that it exhibits neuroplasticity.

2.8.1 The Evolving Brain

As explained by medical doctor Doidge, a researcher and author of *The Brain That Changes Itself* (2007), "neuro is for neuron . . . plastic is for changeable, malleable, modifiable." He goes on to say, and illustrates with examples in his book, that "the damaged brain can often reorganize itself so that when one part fails, another can

Figure 2.8
Until several decades ago, the human brain was viewed as being essentially fixed and hardwired, as suggested by this sculpture.
(Stuart Walesh)
Source: Pam Reithmeier, sculptor.

often substitute . . . thinking, learning, and acting can turn our genes on or off, thus shaping our brain anatomy and our behavior."

He cites neuroplasticity examples such as the woman who felt like she was perpetually falling, and often fell, because of total damage to the balancing apparatus in her ears. After working with an artificial sensor, she eventually regained her balancing ability because her plastic brain reorganized itself. Earlier (Section 2.7.1), I mentioned Jill Taylor (2009), a brain scientist who suffered a stroke. At the outset of the stroke in the left hemisphere of her brain, she "could not walk, talk, read, write, or recall any of [her] life." Over eight years, she completely recovered all physical and mental functions. She describes her neuroplasticity story of recovery as being "about the beauty and resiliency of our human brain."

As another neuroplasticity example, consider drivers of London's black cabs. Research reveals that they have differently shaped hippocampi, which (as noted in Section 2.3.2) is that part of the brain involved with learning and converting short-term memories into long-term forms. This hippocampi effect is thought to be caused by each driver's need to navigate central London's complex street system (Gibb 2012; Restak and Kim 2010). Perhaps you can begin to imagine how some of your oft-repeated skills have reshaped or are reshaping your brain.

Hemispherectomy is a surgery in which either the entire left or right half of the brain is removed to treat intractable epilepsy. According to neuroscientist Eagleman (2012), as long as this surgery is performed on children before they are eight years old, they will be fine. Patients "can eat, read, speak, do math, make friends, play chess, love parents, and everything else that a child with two hemispheres can do." The plastic brain amazingly adjusts.

When stimulated, the brain can grow. According to Doidge (2007), "Mental training or life in enriched environments increases brain weight. . . . Trained or stimulated neurons develop 25 percent more branches and increase their size, the number of connections, and their blood supply." He goes on to note that this kind of brain growth occurs late in life, although the rate of change slows.

Neurons form in our minds until the very end of life, according to Doidge, and he states, as suggested by Figure 2.9, that "the idea that the brain is a muscle that grows with exercise is not a metaphor." Generation of new brain cells is also cited by engineer and consultant James Adams (2008) and neuroscientist William Skaggs (2014), with the latter referring to the process as *neurogenesis* and noting that the hippocampus is one place it occurs. Restak and Kim (2010) reinforce the idea of

Figure 2.9
Scientists now know that the brain is like a muscle and that it can grow.
(Arkady Chubykin/Fotolia)

lifelong changes in the human brain, noting that the changes are more profound when the experiences are richer. The impact of experiences and related activities on neuroplasticity and other aspects of the brain are discussed in detail in Section 2.16.

2.8.2 Significance

Neuroplasticity means that certain uses of the brain can change its physical structure (anatomy) and functional organization (physiology). The significance of neuroplasticity, as summarized here, is the suggestion that we engineers, as students and as practitioners, can change the way we think—that is, change our brains. We can expand understanding of our brains, engage more of our neurons and grow new ones, and, as a result, become more creative, innovative, and effective.

As you age, neurons are lost and impulses are transmitted more slowly, which can lead to slowed thought processes, memory problems, and balance and movement problems (Carter 2009). Your brain's neuroplasticity means that you can offset some of those aging effects. You ignore neuroplasticity at your peril. If you fail to practice self-directed neuroplasticity, your brain will respond to other forces. According to neuropsychologist Hanson (2013), examples of those forces include "pressures at work and home, technology and media, pushy people, [and] the lingering effects of painful past experiences," and we should add aging. Mold your evolving brain, or other people and forces will. Refer to Section 2.16 for tips on how to use your brain's neuroplasticity.

2.9 CONSCIOUS AND SUBCONSCIOUS THINKING

In this section, we'll discuss two modes of thinking—conscious and subconscious—and how each comes into play in your day-to-day life. Let's begin our look into these two modes with an examination of the cortex and subcortex.

2.9.1 Cortex and Subcortex

As explained in Section 2.7, your brain has left and right parts, or hemispheres, that each have very different characteristics. Although the two halves assist each other's abilities, one hemisphere is dominant for you. Further engaging the less dominant hemisphere is likely to enhance your effectiveness.

Another way to partition your brain is to look at conscious and subconscious thinking processes. This text uses the word *subconscious* to refer to brain processes that are below what professor Rollo May (1976) calls our *level of awareness*. Other terms for the subconscious are *unconscious* and *preconscious*.

Discussing conscious and subconscious thinking processes requires considering the cortex and subcortex. As explained by neuropsychologist Nussbaum (2010), we can think of the brain divided from top to bottom with the cortex above and the subcortex below as generally illustrated earlier in Figure 2.3.

To expand on some of the brain structure description provided earlier in this chapter, Nussbaum (2010) says that the cortex "is a convoluted mass of cells, with folds and flaps that sits snug within your skull." He explains that "the cortex is primarily responsible for the most complex thinking abilities, including memory, language, planning, concept formation, problem solving, spatial representation, auditory and visual processing, mood, and personality." Cortex processing is conscious; it is intentional.

Positioned beneath the cortex, the more primitive subcortex processes mostly rote skills and procedures with most of the processing being subconscious (Nussbaum 2010). Examples of subconscious activities are word processing, tying your shoes, and driving—things we do habitually. The cortex and subcortex are connected in many ways and work very effectively together.

Although there is widespread agreement about the existence of conscious and subconscious thinking processes, the location of the processes is somewhat uncertain. For example, although some experts (Clayman 1991; Mlodinow 2013) generally support Nussbaum's cortex–subcortex model, biologist and researcher Medina (2008) says, "We don't know the neural location of consciousness, loosely defined as that part of the mind where awareness resides." Nussbaum (2014) says there is "no real conflict" because "the brain does work in harmony, yet it can also maintain regional specialization." He goes on to explain that "awareness and conscious processing are a cortical specialization. However, such a specialization requires input from more primitive and older subcortical structures."

2.9.2 Workings of the Conscious and Subconscious Minds: Overview

Psychiatrist Peck (1997) says, "The conscious mind [drawing on information from our senses and memory] makes decisions and translates them into actions." As an example of using your conscious mind, you define a problem, develop alternative engineering solutions, compare them, select one, and recommend it. You're aware of the cognitive processing required for that process. With your conscious mind, you're thinking and you know it.

In contrast, the cognitive processing in the subconscious mind occurs without our being aware of it. "The [subconscious] mind resides below the surface"; according to Peck, "it is the possessor of extraordinary knowledge that we aren't naturally aware of." In the case of your subconscious mind, you're thinking and don't know it. During that conscious engineering process described in the previous paragraph, we can be certain that the subconscious mind is influencing the process, unbeknownst to us.

One indication of the functioning of your subconscious mind: That great idea that "pops into your head" or "comes out of the blue." The subconscious mind, if we can more effectively use it, has great potential, as suggested by anthropologist Lagace (2012), who said: "Our conscious mind is pretty good at following rules, but our unconscious mind—our ability to think without attention—can handle a larger amount of information. Studying the unconscious mind offers exciting new avenues for research, including creativity, decision making, and sleep."

Considering further the relative impact on us of our conscious and subconscious minds, neuroscientist Eagleman (2012) writes that "consciousness is the smallest player in the operations of our brain. Our brains run mostly on autopilot." The biggest player is our subconscious mind (Peck 1997). As summarized metaphorically in Figure 2.10, the conscious mind is the tip of the iceberg; the subconscious mind is its bulk. "It is the rule of thumb among cognitive scientists that unconscious thought is 95 percent of all thought," according to academics Lakoff and Johnson (1999), who go on to say, "That may be a serious underestimate." Many of the whole-brain tools described in Chapters 4 and 7 engage or prime our very active subconscious mind. They facilitate collaboration between conscious and subconscious thinking (Irvine 2015).

The following metaphors are intended to help you understand your conscious and subconscious minds and how they complement each other and work together. They also suggest how you can cause them to work even better together. All of the following are from Murphy 1963, except as otherwise noted:

- The conscious mind is the camera and the subconscious mind is the digital image, so point your "camera" at the things you want to capture.
- The conscious mind sees reality, whereas the subconscious mind cannot tell the difference between reality seen by the conscious mind and that which is imagined by the conscious mind (Tice 2002). Therefore, consciously imagine and

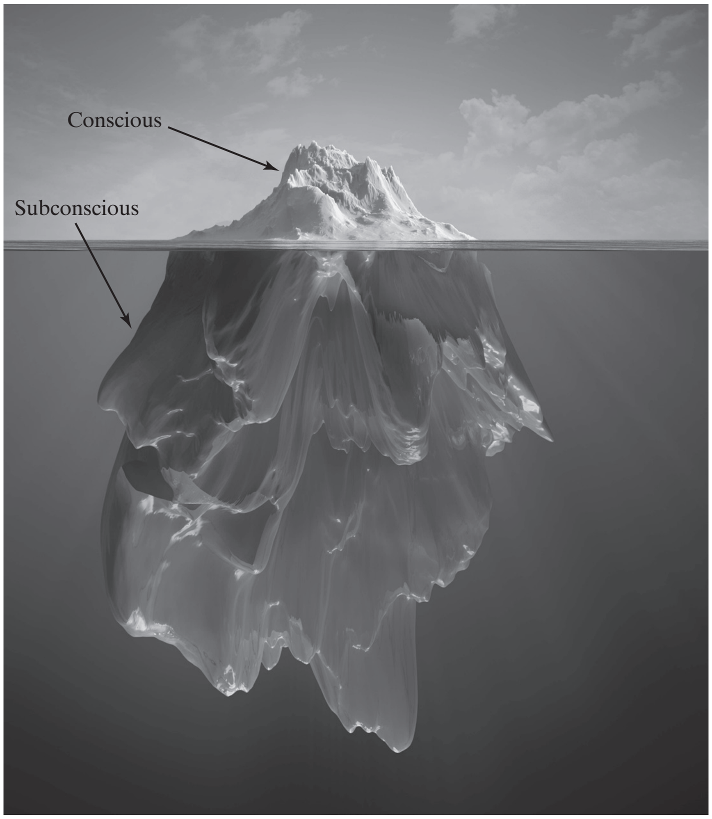

Figure 2.10
The working of the conscious mind is the tip of the iceberg, whereas the much greater cognitive processing of the subconscious mind is hidden.
(Adimas/Fotolia)

visualize those good things you desire, and your subconscious mind will accept and work on them as though they were an evolving reality.

- The conscious mind selects and plants seeds, and the subconscious mind germinates and grows them. Select seeds for the crop you want to harvest.
- Your conscious mind is the cause; your subconscious mind is the effect. Choose your causes carefully.
- The conscious mind is a part-time worker, while the subconscious mind works full-time; it never sleeps (Gibb 2012). Use the limited time available with your conscious mind to direct and fully utilize the 24-7 efforts of your subconscious mind.
- The conscious mind is the ship's captain; the subconscious mind is a fast ship and with an excellent crew.

For additional ideas, see the Views of Others feature in Section 2.9.3.

On learning about our powerful subconscious mind, we might ask how scientists know it exists if we are not aware of its mental activity. This question was first answered in the 1980s by cognitive scientist Libet, who monitored the electrical activity of research subjects. He asked them to press a button whenever they felt like it. "He could see that movement-controlling brain regions became active about a quarter of a second before subjects said they'd consciously decided to push the button. Some subconscious part of the brain decided well before the conscious mind did" (McGowan 2014). The subconscious acts before the conscious (Koch 2012).

Another argument for the existence of the subconscious mind is research that indicates that we often follow, without conscious thought, preset behavioral scripts (Mlodinow 2013). Also recall the reference in Section 2.9.2 to that great idea that "pops into your head" or "comes out of the blue."

HISTORIC NOTE: FREUD STARTED IT

Sigmund Freud, who started his career as a neuroscientist, became the originator of psychoanalysis in the 1890s. His theory included identifying the subconscious mind as the source of powerful impulses that are censored and repressed before we become aware of them. Today, experts say that Freud "underestimated the power and sophistication of unconscious thought. . . . The nature of unconscious thought that emerges from contemporary experiments is radically different from what Freud posited so many years ago: It looks more like a fast, efficient way to process large volumes of data and less like a zone of impulses and fantasies" (McGowan 2014). Freud was correct in the broad sense that "the mind was not simply equal to the conscious part we familiarly live with; rather it was like an iceberg, the majority of its mass hidden from sight" (Eagleman 2012). To this day, we know that much of the behavior of humans is controlled by mental processes outside of our awareness (Mlodinow 2013).

2.9.3 Comparing the Conscious and Subconscious Minds

Let's explore further differences between the conscious and subconscious minds and the thinking that occurs within them by considering the contrasts summarized in Table 2.2. The differences are great, and leveraging them by using the tools described in Chapters 4 and 7 can enhance creativity and innovation. Furthermore, understanding gained from contrasting the conscious and subconscious minds helps us change our habits, as will be described in Section 2.10.

Let's elaborate, row by row, on the differences between conscious and subconscious minds as summarized in Table 2.2.

- Comparison 1: Both minds think, but we are only aware of the conscious. Engineer Bonasso (1983) refers to the work of the subconscious as unconscious simmering, whereas journalist Goleman (2013) says that it is "purring away in quiet to solve our problems." He adds that the subconscious mind "learns voraciously," much of which is outside of our awareness.
- Comparison 2: We sometimes turn off our conscious mind, as when we are sleeping. In contrast, the subconscious mind is going 24-7, which means that it functions even when we are sleeping (Adams 1986; Hill 1960; Restak 2009).

Table 2.2 The conscious and subconscious minds are very different, and leveraging those differences can enhance creativity and innovation.

	Conscious	Subconscious
1.	When thinking, we know it	When thinking, we don't know it
2.	Intermittent	24-7
3.	Linear processor	Parallel processor
4.	Slow	Fast
5.	Prefers complete information in order to decide/do	Can work with pieces
6.	Sees, or thinks it sees, what can be accomplished	Believes that what is imagined by the conscious mind can be achieved and goes to work on it
7.	Does not control dreams	Controls dreams
8.	Can change habits	Source of habits

- Comparison 3: The conscious mind can think of only one topic or thing at a time, but the subconscious mind is a parallel processor (Adams 1986; Medina 2008; Taylor 2009).
- Comparison 4: Engineer and consultant Adams (1986) says that "conscious thinking proceeds in real time" as it draws on information from our memory and senses. Conscious thinking, which is linear, is very slow compared to subconscious thinking, which uses parallel processing.
- Comparison 5: The conscious mind wants complete information (always seeks to know more) so that it can even more rationally decide and act. In contrast, the subconscious mind can work with incomplete information (Adams 1986). Imagine that you are consciously planning a project, a vacation trip, or a night out. You would like to know more but recognize that what you don't know now you will figure out as you go along; now you know that your subconscious mind will help you because it knows what you want to do.
- Comparison 6: The conscious mind sees reality, whereas the subconscious mind cannot tell the difference between reality seen by the conscious mind or that which is imagined by the conscious mind (Hill 1960; Tice 2002). Therefore, if you consciously imagine and visualize the levels of success and significance you desire in your career, your subconscious mind will accept and work toward them as though they were an evolving reality. "A [person] cannot directly choose [his or her] circumstances, but [he or she] can choose . . . thoughts," according to author James Allen (1987), "and so, indirectly, yet surely, shape [his or her] circumstances." That's a positive reality of your powerful subconscious mind; you tend to become what you think. However, be careful; the process also works the other way. Think negatively and you will accomplish little.
- Comparison 7: The subconscious mind is the immediate source of dreams, but "many of us have dreams that reflect previously conscious experience" (Adams 1986).
- Comparison 8: The conscious mind can cause the subconscious mind to create new habits or replace "bad" with "good" habits. The formation and changing of habits are discussed in the next major section of this chapter.

VIEWS OF OTHERS: THE MYSTERIOUS AND POWERFUL SUBCONSCIOUS MIND

Consider the views of others about the subconscious mind. Motivational author Hill (1960), who devoted decades to studying people who achieved success and significance, says that "your subconscious mind works continuously, while you are awake, and while you sleep." He also states, based on his studies, that you can direct your subconscious mind to work for you—that is, "the subconscious mind will translate into its physical equivalent, by the most direct and practical method available, any order which is given to it in a state of belief, or faith that order will be carried out." "Your subconscious mind is like a bed of soil that accepts any kind of seed, good or bad," notes scientist and theologian Murphy (2000). He goes on to claim that the seeds—your thoughts—"will emerge and take shape as an outer experience that corresponds to their content." Gladwell, whose book *Blink* (2005) focuses on snap judgments, writes, "Our unconscious reactions come out of a locked room and we can't look inside the room."

According to Carlson (1997), the subconscious mind is the back burner of your mind and uses a process that "mixes, blends, and simmers ingredients into a tasty meal." He advises us to feed our always-available back burner with a "list of problems, facts, and variables, and possible solutions," let them simmer, and expect a pleasing result. In a similar manner, physician Maltz and consultant Kennedy (Maltz and Kennedy 2001) say that "you can give problem-solving and idea-getting tasks to your [subconscious] mind, send it off on a search while you do other things, even while you sleep, and have it return with useful material you didn't know you knew and might never have obtained through conscious thought or worry." Eagleman (2012) calls the subconscious "the giant and mysterious factory that runs below [the conscious mind]." Finally, introducing what we do in times of crises, scientist Mlodinow (2013) says, "Conscious thought is a great aid in designing a car or deciphering the mathematical laws of nature, but for avoiding snake bites or cars that swerve into your path or people who may mean to harm you, only the speed and efficiency of the unconscious can save you."

I suspect, especially if you are an engineering student or practicing engineer, that you are very aware of the capabilities of your conscious mind. It drives your engineering studies and practice. My hope is that you will, as a result of reading this section about conscious and subconscious thinking, more proactively engage your subconscious mind. Many of the whole-brain tools presented in Chapters 4 and 7 will help you do that.

2.10 HABITS

We turn now to habits, a powerful force in our lives. Let's explore how habits work and then use that understanding to change or replace unwanted habits.

2.10.1 Dominance of Habits in Our Lives

The preceding discussion of conscious and subconscious thinking mentioned habits. A *habit* is an involuntary behavior, a behavior controlled by the subconscious mind. Nussbaum (2014) says that a habit, or what he also calls our *default*, is "an overly-used and very rapid electrical connection between two or more neurons."

How much of what we think, say, and do is habitual? Studies by psychologists suggest that about half of human behavior is habitual (Duhigg 2012; Neal, Wood, and Quinn 2006; Verplanken and Wood 2006). Recall the mention in Section 2.9.2 of subconscious thought being 95 percent or more of all thought. Recognize that much of that subconscious activity is focused on the basic body processes listed in Section 2.4, not on habits as defined here. As suggested by Figure 2.11, let's proceed conservatively, assuming that we are on automatic pilot at least half the time.

We use our conscious mind for new situations, while our subconscious mind—our habits, good or bad—takes care of routine activities. For example, while eating breakfast today, you consciously decide to attend an off-campus meeting later today. While driving to the meeting, your conscious mind thinks about the meeting while your subconscious mind drives your car. You drove your car a few blocks and suddenly realized you couldn't recall having done so. Your driving was largely habit, and your subconscious mind was "at the wheel."

2.10.2 Habits: Good and Bad

When you hear *habits*, what's the first thing you think of? Negative thoughts? "Bad" habits, such as drinking, smoking, drugs, or worse? Or do you think of "good" hab-

Figure 2.11
We are on automatic pilot at least half the time in that our involuntary actions—our habits—dominate what we think, say, and do.
(ID1974/Fotolia)

its, like regularly working out, watching your diet, and saying "please" and "thank you?" Clearly, habits can be good or bad, and both kinds sneak up and capture us. The English writer Samuel Johnson said, "Chains of habit are too weak to be felt until they are too strong to be broken." That observation can be good news or bad news, depending on whether we are referring to good habits or bad habits.

Duhigg (2012) explains that habits are "the choices that all of us deliberately make at some point, and then stop thinking about but continue doing, often every day." In other words, you learned any of your habits—good or bad—and you can unlearn them or, better yet, replace them. Let's explore this promising idea of unlearning and/or replacing habits.

2.10.3 Cue-Routine-Result Process

Duhigg (2012) suggests how habits work when he says that "a habit is a formula our brain automatically follows." The "formula" by which our subconscious mind directs our behavior is illustrated in Figure 2.12 and works as follows:

1. We see or experience a *cue*, such as feeling thirsty.
2. We initiate a *routine*, such as buying a soft drink.
3. We receive a *result*, such as feeling good—which may or not be good for us.

Another example of this automatic process, as also illustrated in Figure 2.12, is that a person meets someone (the cue), starts talking about herself/himself

Figure 2.12
The subconscious mind experiences a cue, initiates a routine, and generates a result.

Thirsty	**CUE** ↓	Meet potential client
Buy soft drink	**ROUTINE** ↓	Tell client about me/us
Feels good	**RESULT**	The client smiles and seems to listen
(But not good for you)		**(But nothing happens)**

(routine), and experiences a frustrating indifference (result). The cue-routine-result process, which is essentially controlled by the subconscious mind, is the key to understanding habits and their results. If we are not pleased with some of the results, such as consuming too much sugar or failing at marketing, that three-step process enables us to change our habits.

2.10.4 Opportunities Offered by Habit Change

You may be thinking further about being on automatic pilot (being governed by habits) most of the time. Maybe it's true for routine activities, but certainly not for serious matters such as studying, working part time, and making important decisions because then you are concentrating and focused, right? Research says no! As succinctly stated by consultant Martin (2008), "Because the workings of the habitual [subconscious] mind are unconscious, the executive [conscious mind] thinks it is in control of most of our behavior." If you believe the research, almost everything you do (including many of your serious activities) is likely to be heavily driven by habits.

So what? Think about this: If so much of what we do is habitual, then improving any aspect of our life, such as roles (e.g., son, daughter, friend, student, employee, service provider) or activities (e.g., studying, analyzing, designing), means that we should examine and maybe change some of our habits. Mandino (1968), in his small but powerful book *The Greatest Salesman in the World*, says this about the power of habits: "In truth, the only difference between those who have failed, and those who have succeeded lies in the difference of their habits. Good habits are the key to all success. . . . I will form good habits and become their slave."

Consider the story of a wise Indian grandfather (Osteen 2007). He said to his grandchild: "A battle rages inside of you between two wolves. One wolf is evil, that is, angry, jealous, unforgiving, and lazy. The other wolf is good, that is, loving, kind, forgiving, and ambitious." The grandchild asked, "Which wolf will win?" Grandfather said, "Whichever one you feed." The grandchild might have asked, "Which wolf will lose?" And the grandfather would probably have answered, "The one you starve."

This story suggests the wisdom of replacing bad habits, which impact whatever aspects of life are most important to you, with good habits; feed the good habits and starve the bad habits. The story implies that each of us has the opportunity to improve our lives, including our likelihood of achieving our desired success and significance, by moving toward a more productive set of habits. Listen again to Mandino (1968): "As a child, I was a slave to my impulses; now I am a slave to my habits. . . . My bad habits must be destroyed and new furrows prepared for good seed. . . . For it is another of nature's laws that only a habit can subdue another habit."

My suggestion: Inventory your habits. Look at relevant portions of, and/or activities in, your daily routine as a student, practitioner, or other. Compare your habitual behavior with your goals and aspirations, your desired mix of success and significance. Are your habits aligned with what you want to achieve? If not, consider applying the process described in the next section.

2.10.5 Method for Changing Habits

Destroying a bad habit or subduing it with another, to use Mandino's terminology, is not easy. This is where basic brain knowledge assists us. Psychiatrist, psychoanalyst, and researcher Doidge (2007) says: "Most of us think of the brain as a container and learning as putting something in it. When we try to break a bad habit, we think the solution is to put something new into the container." He goes on to explain that as we learn a bad habit, it takes over a brain map or processing area. As we repeat the bad habit, it gradually occupies more of that processing area, which prevents

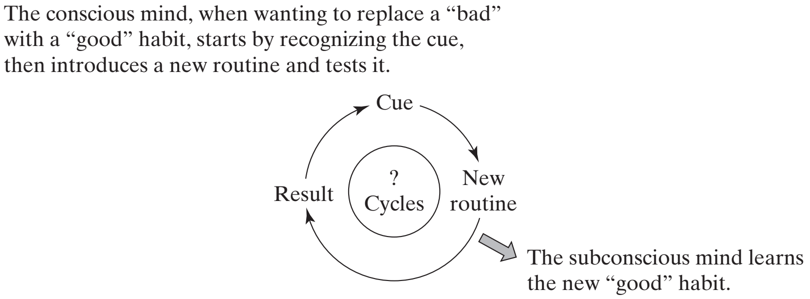

Figure 2.13
This cyclical method, based on neuroscience, will enable you to replace a "bad" habit with a "good" habit.
Source: Adapted from Duhigg 2012 and Martin 2008.

use of that area for good habits. In other words, unlearning is typically more difficult than learning (Doidge, 2007).

Consider a method that you might use for unlearning what you consider a "bad" habit and replacing it with a desired "good" habit. The technique is based on neuroscience and uses the previously mentioned cue-routine-result process. New habits are developed through the process of repetitive cue-routine-result cycles.

Assume you have the bad habit of putting off doing your homework until late at night and you want to replace that habit with doing it earlier and better. Consider what happens now: You come back to your dormitory room after your last class and the *cue* is the television. Your *routine* is to turn it on, and your *result* is to relax and catch up on things. This leads to your next *cue*, which is hunger; your *routine* is to go out for a quick meal; your *result* is feeling good. Other cues probably occur, initiating other routines, none of which move you toward doing your homework. Late that night, you finally get to work on some homework, probably due tomorrow. The work you do is difficult, given the late hour, and the quality reflects neither your ability nor your desire. Therefore, you decide to use the method shown in Figure 2.13 to replace your bad homework habit with a good one.

Starting today, when you come back to your dormitory room after your last class, the *cue* is still the television. However, your new *routine* is not to turn it on. Instead, you enter a new *routine*: do one homework assignment that is due the next day of class, no matter when that day is. Having done that on this, your first day of your new "habit," your *result* is to relax, knowing that your homework is done in a manner that reflects your ability. Now you can watch television and catch up on things.

That one-time change may have been easy, provided you knew, recognized, and acted on the cue. However, you are very far from replacing your old habit with a new habit. You must persist. Next time you experience the cue, you repeat the new routine, or refine it, and follow through. I don't know how many cycles will be needed, but it will be many. Eventually, your subconscious learns the new habit. The payoff is that you reduce your stress and improve your academic performance.

The cyclical habit-change process could also be used to replace the previously posed "thirsty" and "meet a new person" scenarios. In the former, the cue could now lead to buying a bottle of water, and in the latter the cue could now involve asking questions about the other person. If these habit changes are successful, the result could be improved health and making more friends or gaining more clients and customers.

2.10.6 Necessary Number of Cycles

As suggested, no one can predict the number of new cue-routine-result cycles needed for a specific person's subconscious mind to implement a particular new habit. However, my experience suggests that dozens of cycles will be needed, and therefore we must persist. More specifically, my rule of thumb is that thirty days of successful repetitions will enable my subconscious mind to learn a new habit. One study (Jabr 2011) concluded that nine weeks to several months were needed for habit formation, whereas Connellan (2011) suggests twenty-one to thirty days. All of this suggests that the necessary number of cycles is highly variable and you will have to figure it out.

A century ago, philosopher and psychologist James (1917) offered this habit-forming advice, which seems relevant today: “Never suffer an exception to occur till the new habit is securely rooted in your life. Each lapse is like the letting fall of a ball of string which one is carefully winding up; a single slip undoes more than a great many turns.”

2.10.7 There Must Be an Easier Way

You may be thinking, “I like this good habit idea. Habitually practicing productive behaviors—being on smart automatic pilot—appeals to me. However, learning a habit by this tedious cyclical process seems burdensome. It reminds me of how I learned how to use a keyboard, play the trombone, or drive a car. Therefore, I’m going to circumvent the cycle and simply think myself or talk myself out of some bad habits and into some good habits.”

Sorry, it won’t work. Your subconscious mind is illiterate; you can’t talk to it. As stated by Martin (2008), author of the book *Habit*: “The habitual mind is nonverbal, so it doesn’t learn by reading or listening to an explanation. It learns unconsciously through associating an action with an outcome.” He also says, as illustrated by the cue-routine-result cycle, that “the habitual mind learns through cause and effect, reward and repetition.”

2.10.8 The Long View

If the possibility of habit creation and/or change interests you, then consider the long-term potential for you and those you might influence. James (1917) explains the potential this way: “Small, seldom-seen habits have the power to bear us irresistibly toward our destiny.” Because of what you now know about one aspect of the workings of your brain, you have the ability to form positive “small, seldom-seen habits” that will profoundly affect your life and the lives of others. You can also assist receptive individuals in changing their habits. Habit change is one example of brain basics at work for you, and (as will become very apparent as you work through this text) the applications of brain basics offered so far are just the tip of the applied-neuroscience iceberg.

PERSONAL: A HABIT CHANGE

Early in my career, one of my responsibilities was marketing water resources engineering services. Our firm made heavy and effective use of digital computer hydrologic-hydraulic models. Whenever I had the opportunity, I would habitually talk to potential clients about how our computer models worked. This was not effective—as indicated, in part, by the way clients’ eyes glazed over.

I eventually learned from a marketing professional in our firm that instead of stressing *how the models worked*, I should habitually stress the *benefits the models provided*. I focused on benefits, did it enough that describing benefits became habitual, and my marketing effectiveness improved. Although I no longer market modeling-related services, the habit of focusing on benefits, not features, stuck and has served me well in a variety of positions and situations in the business, government, and academic sectors.

2.11 TAKING MULTITASKING TO TASK

Are you a multitasker? Do you, like the grasshopper in Figure 2.14, jump from task to task? You text, email, tweet, Google, blog, and talk—and you did all that in just the last few minutes! You are certainly busy, but are you effective and efficient? That is, are you doing the right things—and are you doing them right?

2.11.1 Costs of Multitasking

If you believe that activity, no matter how energetic, is progress, consider the contrary, neuroscience-based view of multitasking. Brain researcher John Medina (2008) writes, "It is literally impossible for our brains to multitask when it comes to paying attention." Multitasking, which is really jumping or toggling from thinking task to thinking task, is very inefficient because of the time, perhaps unnoticed, needed to resume a task.

Medina goes on to describe the "50-50" negative consequences of multitasking: "Studies show that a person who is interrupted takes 50 percent longer to accomplish a task . . . and he or she makes up to 50 percent more errors." Psychologists Strayer and Watson (2012) report research that concluded that "our performance [on any given task] deteriorates drastically when we attempt to focus on more than one task at a time." Somewhat optimistically, for some diehard multitaskers, Strayer and Watson's research suggests that a very small percent of us may be able to truly multitask, but they indicate that more study is needed.

Moving away from results of neuroscience research, business coach Joe Robinson (2010), in an intriguing and informative article titled "E-mail Is Making You Stupid," says, "People may be able to chew gum and walk at the same time, but they can't do two or more thinking tasks simultaneously." In a similar vein, Publilius Syrus, the Latin writer of maxims, said two millennia ago, "To do two things at once is to do neither."

2.11.2 The Valued Kind of Multitasking

The just-described negative multitasking is characterized by spending a short period, a minute or less, on a task, setting it aside unfinished, and haphazardly jumping to another task, and then to another, and so on. Before going on, briefly consider a very positive type of multitasking.

Let's personalize it. Assume that you are developing a knowledge-skills-attitude (KSA) set that enables you to plan and successfully complete many different kinds of tasks and sometimes groups of tasks that constitute projects. Some of these tasks and projects are design-oriented, whereas others focus on planning, research, experimentation, writing, speaking, and other functions. Some you finish in an hour, but most require elapsed times of days, weeks, or months. In this admirable form of multitasking, you juggle many and varied tasks, eventually finishing all of them—and you are increasingly respected and valued for your contributions. You

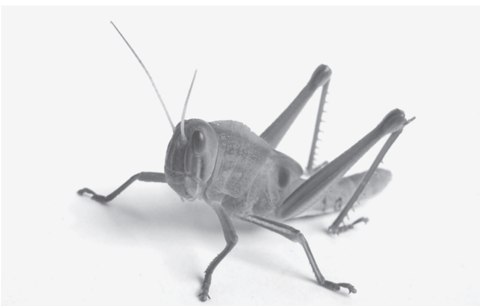

Figure 2.14
Multitasking means frequently jumping, in grasshopper fashion, from task to task.
(Natara/Fotolia)

are proficient at the constructive kind of multitasking. You possess the KSAs needed to take on and complete a wide variety of tasks and projects.

2.11.3 The Interruption Rationale

As noted, the negative type of multitasking increases the absolute amount of time needed to complete a task and increases the likelihood of errors. Perhaps you might argue that you multitask because you are frequently interrupted. Who is interrupting whom? Pattison (2008) reports that half of the interruptions experienced by US office workers in high-tech companies are self-interruptions—that is, "jumping from task to task." We frequently interrupt ourselves! He also notes, as did Medina, that a significant time period is needed to get back "on task." For a similar message, see Jackson's (2008) book, *Distracted: The Erosion of Attention and the Coming Dark Age*. How's that for an ominous message?

2.11.4 Benefits of Not Multitasking

What if, as an experiment, we stopped multitasking for a while? Bregman (2011), a consultant, describes a one-week experiment in which he tried to not multitask. He largely succeeded and realized the following five benefits:

- Noticed more things and interacted more effectively with people
- Made significant progress on projects
- Experienced a dramatic drop in stress
- Lost patience with things that were not a good use of his time
- Gained patience for things that were useful and enjoyable

Bregman reported that there were no downsides to not multitasking. Perhaps his experience will motivate you to conduct a similar experiment or move away from multitasking in some other manner.

2.11.5 Moving Away from Multitasking

Given the costs of multitasking and the benefits of not multitasking, how might you reduce your multitasking? Consider some productive antimultitasking habits that you could develop. First, prioritize your tasks. Then, commit to studying, analyzing, or writing for an hour; calculating for half an hour; or emailing for half an hour. Attempt to stick with a task, or well-defined portion of it, until finished. Try to ignore everything else during these periods or while performing these tasks.

When the task, or a series of tasks, is finished, reward yourself! Kick back, grab a soft drink or cup of coffee, enjoy one of those candy bars hidden in your backpack, or take a walk around the block. "Stressed spelled backwards is desserts! Offset some of that intense and productive work, during which you avoid multitasking, with one or more well-earned and pleasurable desserts" (Walesh 2013).

By the way, try not to take a break (or too many breaks) during a task that you consider unpleasant, like cleaning your room, filling out your timesheet, or doing your taxes. Take the break after the task! Why? Research suggests that the irritating or boring job will seem even worse when you return to it after the break. "Instead of thinking about taking a break as a relief from a chore, think about how much harder it will be to resume an activity you dislike." The opposite is true for pleasant tasks; that is, taking breaks makes them more pleasurable (Ariely 2010). All of this may seem counterintuitive; you'd think that we would want to take breaks from unpleasant tasks and not do so during pleasant ones. However, that isn't how our brains work.

By reducing multitasking, we address how we use one of our most valuable gifts: our time, an essence of our life. To reiterate, brain science supports our antimultitasking efforts in two ways. First, it reveals that the brain cannot perform two thinking tasks at once. Second, it indicates that we can help our subconscious mind acquire antimultitasking habits.

2.12 NEGATIVITY BIAS

Now, let's turn to an aspect of your brain that can prevent you from achieving your desired mix of success and significance. Without basic brain knowledge, you may not even know that it's happening to you.

2.12.1 Origin

As suggested by Figure 2.15, our ancestors lived in a harsh environment, whether on the largely open savanna or in the densely vegetated jungle. These hunter-gatherers frequently faced the threats of predation and starvation. On any given day, they knew they could either be *eating* lunch or *be* lunch.

Therefore, our predecessors learned to be very cautious when considering short-term actions and their possible consequences, to frequently see danger or potential danger in a variety of common daily circumstances, and to act defensively. Sure, some good things happened to them, but our ancestors learned to think mostly negatively in order to survive, to remember what went wrong the last time they were in similar situation, and to not let it happen again. That is, they had a negativity bias (Hanson 2013). A variation on negativity bias is the anger superiority effect (Restak and Kim 2010), which means that we are more likely to see an angry face in a crowd or audience when we are about to speak than a friendly, approving face. Brain expert medical doctor Cohen (2005) says, "This basic brain imbalance between our reason and our emotions leads to all sorts of trouble."

2.12.2 Our Unfortunate Inheritance

The human negativity bias, although not needed anywhere near the extent to which our ancestors needed it, is still with us today. It is in our brain and is not our fault. More specifically, we are seeing the results of the almond-sized and -shaped

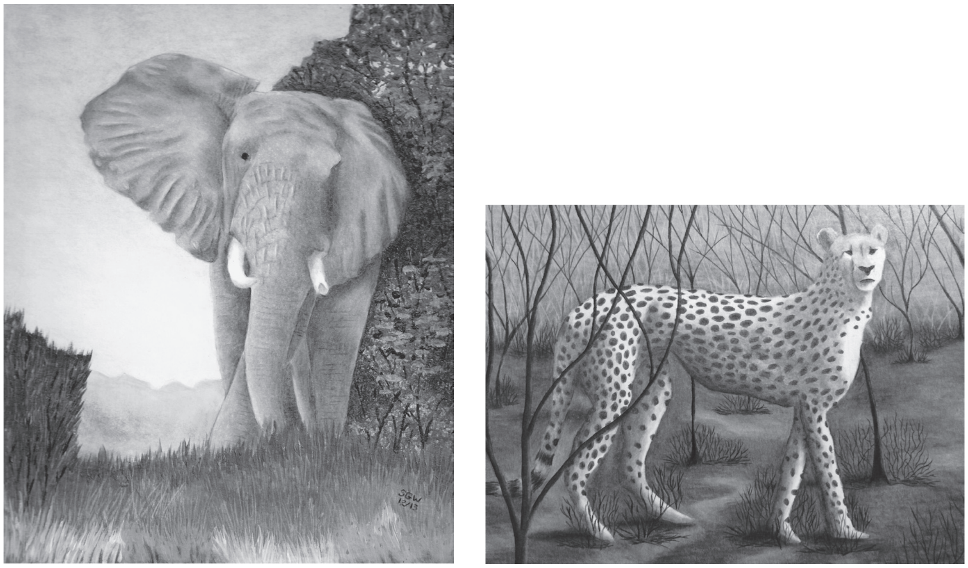

Figure 2.15
Our ancestors faced a harsh environment that caused them to focus on possible negative outcomes.
(Stuart Walesh)

amygdale, which, as noted in Section 2.3.2, lies near the center of our brain and regulates emotions such as fear, rage, and pleasure and memories of the same.

Our evolution reflects the past. Our brains are still, to some extent, like our ancestor's brains. As explained by neuropsychologist Hanson (2013), your brain is "like Velcro for bad experiences but Teflon for good ones." Of course, most of us have many more positive than negative experiences. However, because of evolution, we are still subject to our ancestors' negativity bias. Hanson also says, "The brain is good at learning from bad experiences, but bad at learning from good ones." He goes on to add, "The 'soil' of your brain is more fertile for weeds than for flowers."

Some people claim (e.g., Sharot 2011) that humans tend to be overly optimistic about the future, which may seem to be at odds with negativity bias. When asked to imagine hypothetical broad and long-term future conditions, such as finding a great job, having a happy family life, and avoiding illness, Sharot says that we tend to be optimistic. This observation does not conflict with negativity bias or the anger superiority effect discussed in this section. Negativity bias and the anger superiority effect pertain to immediate, actual situations demanding quick or prompt responses, not to hypothetical, far-off future happenings requiring no commitment now.

2.12.3 Negative Consequences of the Negativity Bias

If you allow the negativity bias or anger superiority effect of your brain to prevail, you will miss out on many rewarding professional and personal experiences. You will be less likely to achieve your desired combination of success and significance, as introduced in Section 1.2. "The greatest mistake you can make in life," according to writer Elbert Hubbard, "is to continually fear you will make one." More specifically, ignorance of the negativity bias or inability to deal with it can have unfortunate consequences, such as the following, the cumulative effect of which is to set you up for major late-life regret:

- As a student, you are asked to speak about your coop experience at the next meeting of the student chapter of your professional society, but you decline because of an earlier speaking disaster.
- A professor offers you the opportunity to work on an especially challenging senior project, but you defer because of an unfortunate project failure during your sophomore year.
- Shortly after earning your professional engineering license, you are asked to manage a construction project, but don't accept the challenge because of an earlier project management setback.
- As a young practitioner, you are about to speak at an engineering society meeting and have just been introduced. The floor is yours. You look at the audience. Because of the brain's negativity bias or anger superiority effect, you are much more likely to see disapproving or angry faces in the audience than supportive or friendly faces. You are intimidated; as a result, your presentation falls far short of what you expected. (Although unfriendly faces will automatically "pop out" because of the anger superiority effect, by looking more intently you are very likely to find friendly faces, and usually there are many more of them. Please remember, the audience wants you to succeed, if for no other reason than that they are investing valuable time in your presentation.)
- You are invited by friends to take a month off and bike across Europe, but you defer because of things that went wrong during an earlier group bike trip across your state.

- In your early thirties, you think about a long-held dream: starting your own business. However, you decide not to follow through after vividly recalling a failed part-time business while in college.

In personal situations like those just described, you immediately remember an event or experience that steers you away from the stated opportunity. You do this essentially without thinking (largely under the control of your subconscious mind) because of negativity bias. With some conscious thought, you probably could also recalled one or more positive events or experiences. This leads us to our next topic: what you can do about the potentially destructive negativity bias.

2.12.4 Offsetting Negativity Bias

When you are initially presented with a special opportunity, don't react. Instead think—think about why, in knee-jerk fashion, you may be about to decline the attractive proposition. Remember the Velcro versus Teflon nature of your brain. It will automatically cause you to recall some negative event or circumstance that is counter to you pursuing this opportunity. Next, consciously recall one or more of your goals, in support of your desired success (Section 1.2), that would be advanced by this opportunity. Also, remember and celebrate some positive experiences consistent with that goal and this opportunity. Then, and only then, decide. Going forward, create a success file and one way of doing this is to develop the habit of asking yourself what is the best thing that happened to me today (Kleon 2012).

The preceding process requires a special effort. However, the payoff is a greatly increased likelihood of you achieving your desired mix of success and significance. "We must all suffer from one of two pains," according to motivational speaker Rohn, "the pain of discipline [now] or the pain of regret [later]. . . . Discipline weighs ounces while regret weighs tons."

PERSONAL: NIX NEGATIVITY BIAS

In my mid-thirties, I was one of several scheduled speakers sitting on a platform in a hotel conference room and facing about two hundred professionals. As the person chairing the session stepped up to the microphone and began to welcome the audience, I fell, with my chair, off the end of the platform and onto the floor. Very embarrassing! While some audience members laughed and others showed concern, I got up, put my chair back on the platform, climbed up onto the platform, and sat down. When my turn to speak came, I self-consciously and nervously gave a presentation that was acceptable, but not one of my best.

Since then, I have been presented with hundreds of opportunities to speak and have taken on most of them. Early on after the "falling" event, when learning about a speaking situation, I would recall falling off the platform and, consistent with the negativity bias, was tempted to decline the opportunity. However, I kept in mind my goal, the formation of which preceded the embarrassing event: to become an effective speaker and realize the related benefits. Accordingly, I consciously recalled and drew on a series of positive speaking experiences, which offset the one disaster, and accepted many speaking opportunities. As a result, I grew and continue to grow as an effective speaker.

Bottom line: Don't let your brain's negativity bias frustrate your personal and professional growth. Don't risk major late-life regrets. Instead, use your conscious mind to overcome that negative force or anger superiority effect and move you toward your desired mix of success and significance.

2.13 LEFT- AND RIGHT-HANDEDNESS

Our earlier discussion of the brain's left and right hemispheres may cause you to think about possible connections to left- and right-handedness. About 10 percent of us are left-handed. In the spirit of first things first, tests indicate that there is no difference in intelligence between left- and right-handers (Carter 2009; Edwards 1999; McManus 2012).

2.13.1 How Handedness Affects Behavior

Our handedness can influence our bias and metaphors. One study (Hutson 2012) concluded that our dominant side can influence our worldview. More specifically, "right-handers associate right with good and left with bad and . . . left-handers make the reverse association."

Studies by psychologist Cassanto (Hutson 2012) observed that presidential candidates George W. Bush, John Kerry, John McCain, and Barack Obama gestured with their dominant hands when making positive points and their weak hands to stress negatives. He also noted that "lefties hold higher opinions of their flight attendants when [the lefties are] seated on the right side of a plane." Presumably, the passengers arrive at this conclusion because the flight attendants are on the passenger's left. Cassanto also learned that children thought that similar cartoon animals on their dominant side "looked nicer or smarter."

2.13.2 Advantages of Being Left-Handed

Recall the discussion of lateralization—that is, the strong tendency of the human brain's hemispheres to be specialized with respect to certain capabilities. Right-handed people are more lateralized than left-handers. For example, "Language is mediated in the left hemisphere in 90 percent of right-handers and 70 percent of left-handers" (Edwards 1999). In other words, left-handers are slightly more whole-brained than right-handers.

"Lefties" have a slight edge on creativity. "Left-handers' brains are structured differently from right-handers' in ways that can allow them to process language, spatial relations and emotions in more diverse and potentially creative ways" (McManus 2012). Or, as already noted, left-hander's brains are less lateralized. Although only about 10 percent of the general population is left-handed, art school enrollments include 30 to 40 percent of left-handers (Shlain 2014).

Left-handers also have a slight edge in music and mathematics. According to McManus (2012), "A slightly larger number of left-handers than right-handers are especially gifted in music and math." This source reports that there are a greater proportion of left-handers in professional orchestras, even among musicians who play instruments like violins that appear to be designed for right-handers. Studies reveal that mathematically gifted adolescents are more likely to be left-handed. The observation that mathematicians are frequently musically inclined is probably not a coincidence. And, for the sports-minded, a left-handed batter is closer to first base when he or she hits the ball.

2.13.3 Advantages of Being Right-Handed

"Righties" are less likely than "lefties" to have learning difficulties, dyslexia, and to stutter. Furthermore, language and custom favor right-handers. For example, the honored guest traditionally sits on the host's right side, we shake our right hands when greeting or meeting someone, and a "left-handed compliment" is anything but (Edwards 1999; McManus 2012).

2.13.4 Closing Thoughts about Handedness

As engineering students and aspiring engineers, you may want to be aware of ways in which your handedness, and that of others, influences bias and behavior. That awareness can provide more self-understanding as well as insight into what others say and do. Depending on your handedness, you may have certain advantages and liabilities and can be prepared to act accordingly.

2.14 GENDER AND THE BRAIN

Having considered many aspects of the human brain in this chapter, your brain may begin to think about gender, which has not been mentioned even once! For example, are female and male brains different? If so, are they different in ways that influence characteristic gender-specific behaviors? The short answer is that if we (metaphorically) remove the tops of adult heads and look down at female and male brains, they look essentially the same. However, they have small internal differences, and those variations may influence some markedly different female and male behavior, and you ought to know about such differences.

This topic warrants your attention because, whatever your gender, the ideas and information offered can help you work smarter and be an even more effective communicator and collaborator with females and males. Relative to creativity and innovation, you will soon see why gender is an important consideration when forming and working with teams. As explained in the Medici Effect discussion (Section 4.6), diverse teams, including gender-diverse teams, tend to deliver highly creative and innovative results. This contrasts with homogenous teams, which typically produce results largely void of creativity and innovation.

PERSONAL: SENSITIVE TOPIC IN SCIENCE

When I proposed this text to an acquisitions editor at a publisher (not Pearson) a few years prior to this text's publication and he realized that I intended to write about gender aspects of the human brain, the editor reacted negatively. He said, "You'll have to take care with gender and the brain. We risk getting clobbered." Later, I encountered biologist John Medina's statement that "characterizing gender-specific behaviors has a long and mostly troubled history," but he went on to address the topic (Medina 2008), and some of his information is cited in this gender section. That "troubled history" probably included discrimination or disparate treatment of women.

After considering the matter, and given what I was learning about the brain and how the basics can help student and practicing engineers work smarter and be more creative and innovative, I knew that the gender aspects of the brain needed to be included in this chapter. Omitting a gender discussion in this brain basics chapter would have created a serious gap, whereas including it will enhance your communication effectiveness, support productive team formation and work, and contribute to creative and innovative results. Leaving gender out of this chapter would be like excluding other basics such as lateralization, neuroplasticity, and habits.

Accordingly, I combed through my large collection of neuroscience-related books and other sources and found that the gender topic was largely omitted. Neuropsychiatrist Brizendine (2010) explains that, until recently, "large areas of science and medicine used the male as the 'default' model for understanding human brain biology and behavior, and only in the past few years has that really begun to change." In other words, gender and the brain is a relatively new science and medical topic; we won't find broad and deep literature. However, I found enough current facts and information to construct this section of the chapter for your benefit.

2.14.1 Caveats

As you read about gender and the brain, please keep these four points in mind:

1. When reference is made to the female versus male brain structure, neurotransmitters, hormones, and pathologies, the intent is to convey tendencies and "averages." Clearly, you and others can readily find individuals of both genders who are exceptions.
2. I report only what appears to be based on scientific research and try to avoid conjecture, whether it be mine or others.
3. Neuroplasticity (Section 2.8) prevails; that is, our brains change throughout our lives as a result of formal education and experiences.
4. Finally, and to reiterate a point made at the beginning of this section, I am sharing this information with you so that you can work more effectively with others, including being more creative and innovative, regardless of your or their gender.

2.14.2 Brain Structure

Let's begin our discussion of the brain and gender with an overview of the female and male brains' structures. The overall volume of adult men's brains is about 10 percent larger than that of women, even after accounting for body size (Brizendine 2006; Gibb 2012; NHS Choices 2014). However, let's not simplistically assume that this larger volume means that men are more intelligent or more creative and innovative. For example, elephant brains weigh three times that of humans, but humans have the intelligence edge, and Albert Einstein's brain weighed about 88 percent of that of the average human brain (Gibb 2012).

Many factors influence male and female thinking effectiveness, including the number of brain cells, the connections between them, and the relative sizes of various parts of the brain (Gibb 2012; NHS Choices 2014). For example, men and women have the same number of brain cells; they are just packed closer together in the females' smaller skulls. There is no overall intelligence difference between genders as measured by IQ tests (Brizendine 2006; Gibb 2012; Stover 2014).

When neuroscientists and medical doctors examine the interiors of adult brains, they find differences in the sizes of certain parts of female and male brains (Stover 2014), which, as we will see in Section 2.14.6, help explain differences in men's and women's behavior. The following are some examples of size differences:

- The amygdale "registers fear and triggers aggression" (Brizendine 2010), "drives emotional impulses," and is larger in men than in women (Brizendine 2006, Stover 2014).
- The prefrontal cortex, the CEO of the brain that resides behind our foreheads and which (among other functions) keeps emotions from running wild, is larger in women than in men (Brizendine 2006). Interestingly, visual stimulation

travels faster to the amygdale than to the cortex, so we are primed for an emotional response before we can produce a cognitive one (Hardiman 2003).

- Women have a larger and more active hippocampus than men (Brizendine 2006; Gibb 2012; Stover 2014). As explained in Section 2.3, this part of the brain is involved with learning and converts our short-term memories into long-term forms.
- Women's brains have greater connectivity between hemispheres via the corpus callous than men's. In contrast, men's brains have greater connectivity within each hemisphere than women's. This is based on a study of one thousand females and males between ages eight and twenty-two, and the results are thought to apply to adults (Paddock 2013). As summarized by Nussbaum (2010), "females tend to utilize both sides of their brains more to process than men, who tend to rely primarily on one side, the dominant hemisphere." "Women tend to use both hemispheres when speaking and processing verbal information. Men primarily use one," according to Medina (2008), who goes on to say that "Women tend to have thick cables connecting their two hemispheres. Men's are thinner."

2.14.3 Brain Chemistry: Neurotransmitters and Hormones

The brain contains one hundred billion nerve cells or neurons, as explained in Section 2.3, which receive and send electrochemical signals. A neurotransmitter is a chemical that is released from a neuron and helps to amplify or modulate a signal that passes from one nerve cell to another or to a muscle. The following are some examples of neurotransmitters (Baggaley 2001; Gibb 2012):

- Serotonin: influences mode, memory, temperature regulation, and sleep
- Dopamine: stimulates bodily movement, feeling good, and excitement
- Noradrenaline: activates the automatic functions of the nervous system

Hormones are chemicals produced by glands and transported by the body's circulatory system to produce effects on cells and organs remote from the point of origin (Hormone Health Network 2014; MedicineNet 2014). Brizendine (2006) explains that hormones help determine what the brain is interested in doing right now—that is, behavior such as being nurturing or aggressive, or social or withdrawn. Four examples of hormones are as follows:

- **Oxytocin:** Tends to settle and calm both women and men (Baggaley 2001; Brizendine 2010).
- **Cortisol:** Rising levels indicate increased stress (Brizendine 2006).
- **Estrogen:** A female sex hormone. It also promotes, for women, neuron growth and maintenance of brain function with age (Brizendine 2006; Stover 2014).
- **Testosterone:** Drives focused, assertive, fast, and unfeeling behavior. Throughout adulthood, male testosterone levels are ten to one hundred times that of females (Brizendine 2006).

2.14.4 Pathology

Consider a highly factual area: brain pathology—that is, brain-related disease. The following pathologies are more common in males than females: alcoholism and drug addiction, antisocial behavior, dyslexia, autism, mental retardation, and schizophrenia (Medina 2008; NHS Choices 2014). The following pathologies are more common in females than males: depression, by a factor of two to one; anorexia, by a ten to one ratio; and anxiety, by a factor of four to one (Brizendine 2006; Gibb 2012; Medina 2008; NHS Choices 2014; Stover 2014).

Consider strokes, episodes in which oxygen-rich blood stops flowing to one or more parts of the brain. Within minutes, brain cells begin to die. Women recover from stroke-induced verbal impairment better than men. This and other medical issues suggest differences in the normal brain functions of men and women. Because women tend to use both hemispheres when speaking and processing information, females have a more robust backup system.

2.14.5 Nature versus Nurture

Recent scientific evidence clearly points to physiological, neurotransmitter, hormonal, and pathology differences in the female and male brains and beyond. There is disagreement, however, on the role nature versus nurture plays in leading to those differences in adults. Arguing for a nature plus nurture position, Brizendine (2010) says, "Certain behaviors and skills are wired and programmed innately in boys' brains, while others are wired innately in girls' . . . These differences are reinforced by culture and upbringing, but they begin in the brain." Brizendine (2006) also declares that "there is no unisex brain" and that "male and female brains are different from the moment of conception" (Brizendine 2010). Male and female brain differences "arise before a baby draws its first breath" (Stover 2014). In strong contrast, and in what appears to be a minority position, neuroscientist Rippon (Knapton 2014) says that the differences in adult male and female brains "are tiny and are the result of environment, not biology."

Although the nature versus nurture debate may be of interest, it does not affect our pragmatic treatment of gender and the brain. Based on the preceding discussion, we now understand some typical differences between the brains of adult men and women. That background enables us to explore the practical significance of brain differences—that is, the possible influence on male and female behavior and what it may mean for each of us.

2.14.6 Examples: How Differences in Female and Male Brains May Influence Behavior

How might differences in female and male brains influence typical female and male behavior and/or help us understand that behavior? To answer this practical question, consider a series of observations of women's and men's behaviors and how their brain characteristics may explain some of the dissimilar results. Although some behavior differences are not readily explained by specific brain dissimilarities, they are probably attributed to one or more of the many structural, neurotransmitter, and hormonal variations between male and female brains. Some suggestions are provided for how to use understanding of brain gender differences to enhance female-male interaction, including creative and innovative collaboration in professional work and beyond.

Recall the caveats in Section 2.14.1, including the statement that I report only what appears to be based on scientific research and try to avoid conjecture. Although the following observations are based on the science presented in Section 2.14, the observations are generalized and recognize that both women's and men's behaviors are on a continuum. In other words, there will be exceptions. With that in mind, the following are my science-based observations of women's and men's behaviors and some related suggestions:

- **Expressing emotions with facial expressions and voice tone:** Men tend to subconsciously suppress showing emotions on their faces, whereas women tend to do the opposite. Research reveals that although both genders immediately experience emotions in stimulating situations, males typically and quickly adopt a "poker face" and corresponding voice tone, whereas female faces and voices tend to practice extended communication of the emotion (Brizendine 2010). Male masking of emotion is often interpreted as not having any. This, of course, is incorrect and is further discussed in the "response to a problem" discussion later in this list.

Suggestions: Men—Try to be a little more expressive of your emotions, with facial expressions and voice, in order to improve your communication with women. Women—Remember that men are feeling much of what you are feeling but not expressing it the way you do.

- **Reading facial expressions and voice tone:** Women do this much better than men. More specifically, women are more likely than men to read nonverbal clues in order to recognize and feel another person's pain (Brizendine 2006; Stover 2014). Recent studies (Woolley, Malone, and Chabris 2015) underline the importance of "emotion-reading skills" in that some teams worked smarter than others because their members communicated effectively, participated equally, and possessed "emotion-reading skills."

  Suggestions: Women—Set the standard for these important modes of communication, mainly to benefit the men. Men—Learn from women and your own experience how to more effectively read expressions, not just see them, and how to listen, not just hear.

- **Reacting angrily:** "A woman is slower to act out of anger" than a man, but can express just as much anger with time and if needed. The difference is the female tendency to exert more up-front control (Brizendine 2006); in comparison, males tend to be aggressive (Stover 2014). Women have more initial control partly because of their larger prefrontal cortex (the brain's CEO), whereas men have a larger amygdale, the brain's fear, anger, and aggression center.

  Suggestions: Women—Continue to set a self-discipline example. Men—Strive to benefit from women's example. One benefit is that you are less likely to say or do something you will regret.

- **Emotional memory:** "Research shows that women typically remember emotional events . . . more vividly and retain them longer than men" (Brizendine 2006). This difference is explained, in part, by the female use of both of the brain's hemispheres when responding to emotional experiences; men tend to use just one (Medina 2008; Nussbaum 2010; Paddock 2013). Another reason for the stronger emotional memory of females is their larger hippocampus. Retaining strong emotional memories of negative events can be a mixed blessing. Although it can prevent repeat mistakes, it can also lead to unproductive rumination about past failures, which in turn can lower confidence (Kay and Shipman 2014).

  Suggestions: Men—Appreciate women's emotional memories and the richness it can add. You may have forgotten that temporary but intense disagreement about the team's project, but she probably hasn't. Women—Patiently remind men about what happened, how it felt, and what they can learn from it.

- **Three-dimensionality:** Males tend to have a better understanding of how an object occupies space and are more adept at mentally rotating that object. This male spatial perception ability shows up early, at about age five. Interestingly, when boys were asked to explain this cognitive ability, they did not answer with words. "Instead they squirmed, twisted, turned, and gestured with their hands and arms to explain how they got the answer. The boys' body movements were their explanations." Researchers then taught a group of girls to use physical explanation, and within six weeks they solved mental rotation problems as quickly as the boys (Brizendine 2010). This research finding may suggest a new, more kinesthetic way to teach and learn engineering and other disciplines requiring three-dimensional abilities.

Suggestions: Men—Quietly celebrate the three-dimensional visualization capability that you bring to joint efforts and diligently apply it. Women—Persist in developing this three-dimensional attribute.

- **Response to a problem:** On learning about a serious problem, both men and women tend to immediately experience emotional empathy. However, while females continue to feel and express emotional empathy, males quickly shift to cognitive empathy. They get analytic sooner; they want to get on with solving the problem, as in "the male is a lean, mean, problem-solving machine" and "is structured to seek solutions rather than continue to empathize." This quick testosterone-driven male shift to cognitive empathy should not be taken as indicating lack of concern but rather the opposite. Concern is just being expressed in a typical male manner (Brizendine 2010). Although men and women tend to show different emotional responses to serious problems and use different means to solve them, both genders are equally adept at problem solving (Gibb 2012).

  Suggestions: Women—Recognize that the men feel empathy but reflect it by acting, perhaps too quickly. Men—Hesitate a little longer and think empathetically about the challenge to more fully understand it.

2.14.7 Application of Gender and the Brain Knowledge

Having worked through this section, you now have more insight into why you exhibit certain behaviors. Equally important, you may more fully understand why others, female and male, say what they say and do what they do. Gender and the brain warrants your attention, as noted at the beginning of this section, because the ideas and information offered can help you work smarter—that is, be a more effective communicator and collaborator with females and males. In doing so, this knowledge can enable you and your team to be more creative and innovative. Because of brain-driven behavior differences and the value they offer, both genders should be represented in teams and groups that take on challenging IPOs. That is one aspect of the Medici Effect (Section 4.6) in action.

2.15 HOW DO WE KNOW WHAT WE KNOW?

The preceding discussion of brain basics is, obviously, just the tip of the iceberg of a vast and growing field of knowledge. Even so, the limited material may cause you to ask: "How we know, from a scientific and medical perspective, what we know?" I am not about to provide a detailed answer to that question in this text; to do so would take us way off topic. However, on the assumption that some readers may want to pursue that "how" question on their own, I offer an introductory discussion that may motivate you to dig deeper. More specifically, let's touch briefly on split-brain studies, studies of large groups over time (cohort studies), and brain-imaging techniques.

2.15.1 Split-Brain Studies

The Historic Note appearing earlier in this chapter (Section 2.7.1) introduced the split-brain studies conducted at the California Institute of Technology in the 1960s.

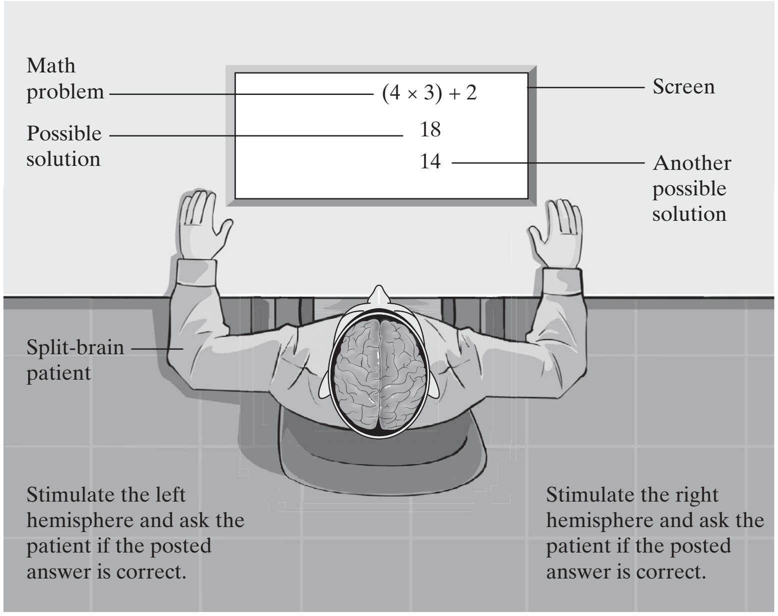

Figure 2.16
One type of test concluded that the human brain's two hemispheres are very different with respect to some capabilities.
Source: Adapted from Funnell, Colvin, and Gazzaniga 2007.

This research showed that the human brain's two hemispheres are very different with respect to some capabilities. The results of these investigations were so profound that the study leader Roger W. Sperry and two colleagues received the Nobel Prize for Medicine in 1981.

To further appreciate their experimental process, consider one of many tests involving split-brain patients. Imagine a vertical blank screen with a split-brain person seated in front of it, as shown in Figure 2.16. A mathematics problem is projected on the screen, and then a possible solution is also projected on the screen. The patient's left hemisphere is gently stimulated, via a probe, and the patient is asked if the answer is correct. Then another possible solution is shown, the patient's right hemisphere is stimulated, and the patient is asked if the answer is correct.

The preceding process is repeated many times. Analysis of the data revealed that the left hemisphere was correct 90 percent of the time. In contrast, right hemisphere results were random. The conclusion: The left hemisphere is much more proficient in mathematics (Funnell, Colvin, and Gazzaniga 2007). See Edwards (1999) and Gibb (2012) for more examples.

2.15.2 Studies Over Time of Large Groups of Similar People

Excellent examples of cohort studies as a means of discovering brain characteristics include the Nun Study and the Rush University Medical Center Study, both of which are described later in this chapter (Section 2.16.3). The decade-long Nun Study found that lowered risk of dementia and higher probability of long life correlated with early language ability, a positive outlook, and ongoing mental and physical activity. Similarly, the Rush University research concluded that more frequent brain activity throughout one's life correlates with slower late-life cognitive decline.

2.15.3 Brain-Imaging Techniques

Brain knowledge improved rapidly over recent decades because of the creative and innovative development of various brain-imaging techniques. Although the functions of many human organs and "parts" (e.g., our limbs) can be readily observed, the brain's electrochemical processes could not be seen by the naked eye prior to the arrival of brain-imaging devices. Before access to these tools, scientists would need to perform an autopsy and relate predeath injuries or malfunctions to the site and extent of brain damage. Now, we can see the brain's workings in real time (Brizendine 2006; Carter 2009). Today's imaging devices include the following:

- Powerful microscopes (Carter 2009; Chin and Upson 2011).
- X-rays: Shadings of the resulting image indicate denseness of various parts of the imaged object, with bone appearing light and tissue dark (Hardiman 2003).
- Computerized Axial Tomography (CAT) scans: A major X-ray advance for investigating brain structure and detecting tumors and nodules that cannot be seen with the traditional X-ray. Output images include slices through the brain in various planes and three- dimensional representations (Davis 2014; Hardiman 2003)
- Electroencephalography (EEG): "A graphic record of the electrical activity of the brain, made by attaching electrodes to the scalp that pick up the underlying brain waves" (Carter 2009). The brain is "awash with electrical activity, miniscule electrical pulses generated by individual neurons" and EEG "massively amplifies them" so that they can be traced over time (Gibb 2012).
- Magnetic Resonance Imaging (MRI): "A brain-imaging technique that provides high-resolution pictures of brain structures" (Carter 2009; Chin and Upson 2011). This device uses a magnetic field and the body's resonating water molecules to generate radio signals that are combined in an image (Hardiman 2003).
- Functional Magnetic Resonance Imaging (fMRI): "A brain scan that uses powerful magnets to look at brain blood flow and activity patterns" (Amen 2008). This imaging device is called *functional* because it identifies brain regions recruited during a specific mental task in three dimensions, via the slight waxing and waning of blood flow, which includes metal ions (Chin and Upson 2011; Gibb 2012; Mlodinow 2013; Zimmer 2014).
- Positron Emission Tomography (PET): "A brain scan that uses isotopes to look at glucose metabolism and activity patterns in the brain" (Amen 2008). Radioactive glucose is injected into a person, who is placed in a PET scanner and asked to do mental tasks. The resulting images show brain areas with the greatest activity for each task (Hardiman 2003).
- Single Photon Emission Computed Tomography (SPECT): "A brain scan that uses isotopes to look at blood flow and activity patterns in the brain" (Amen 2008).
- Magnetoencephalography (MEG): "A non-invasive neurophysiological technique that measures the magnetic fields generated by neuronal activity of the brain. . . . MEG is a direct measure of brain function, unlike functional measures such as fMRI, PET, and SPECT that are secondary measures of brain function reflecting brain metabolism" (MIT 2014).

Imaging devices are listed here to stress why and how we have learned so much about the human brain in recent decades. If any of them interest you, learn more about them. For example, Chin and Upson (2011) provide examples of fascinating detailed images produced by microscopes, MRI, fMRI, and MEG.

2.16 CARE AND FEEDING OF YOUR BRAIN

The entire chapter to this point is a brain primer. It describes, in basic terms, what is probably the most magnificent mechanism, the most amazing assembly, or the most engaging entity in the universe. You have been introduced to the human

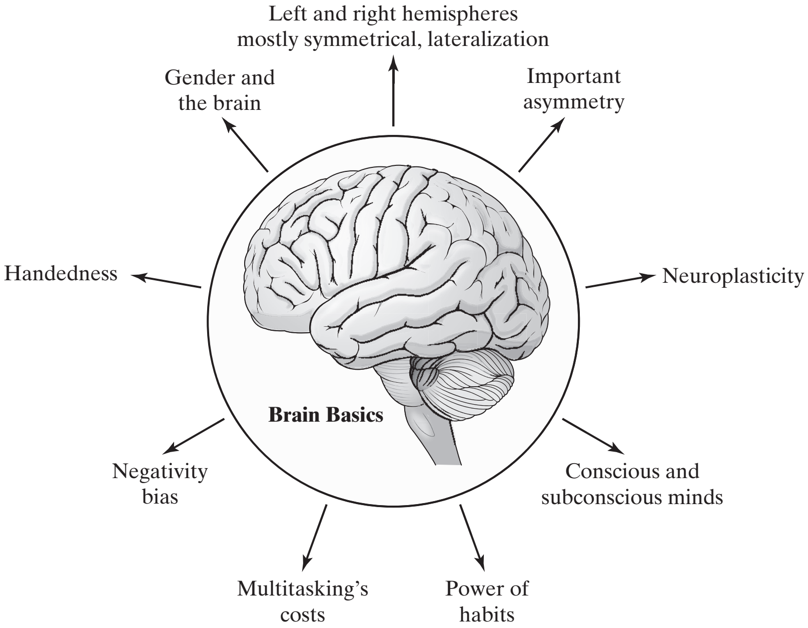

Figure 2.17
This chapter discusses many features of the human brain, all of which are relevant to working smarter and enhancing creativity and innovation.

brain's features and functions and the distinction between the brain and the mind. More specifically, as illustrated in Figure 2.17, you learned about the brain's symmetrical hemispheres and related lateralization and the asymmetrical exception, with our formal education's focus on the left side. You also learned about neuroplasticity and its potential for maintaining lifelong cognitive functions, conscious and subconscious minds, the power of habits and the ability to replace them, the wastefulness of multitasking, built-in negativity bias, the vagaries of handedness, the value of understanding gender differences, and how we know what we know about the human brain.

All of this suggests that the trajectory of your entire professional and personal life—the extent to which you achieve your desired mix of success and significance—will be heavily influenced by

- what you know about your brain,
- how you apply what you know, and
- how you take care of your brain.

Let's address the third item now; the previous portions of this chapter have discussed the first two. Going forward, whether you are twenty years old or several or more decades beyond that, how can you care for that three-pound marvel in your head? In support of knowing about your brain and taking care of it, neuroscientist and psychiatrist Amen (2008) says, "The lack of brain education is a huge mistake, because success in all we do starts with a healthy brain."

2.16.1 Exercise

We exercise for various reasons, such as weight control, stress reduction, participating in our favorite sports, and enjoying the outdoors. Exercise also benefits the brain and does so by increasing the following:

- **Number of blood vessels in the brain:** Brain cells receive more oxygen, glucose, and other nutrients (Medina 2008; Restak 2009).

- **Density of neuron connections:** We think better and faster and also offset brain cell loss (Restak 2009).
- **Number of neurons (neurogenesis):** Occurs in some portions of the brain, such as the frontal lobes (also known as the executive system), the corpus callosum, and the hippocampus (the region that controls learning and memory) (Medina 2008; Nussbaum 2010).
- **Flow of oxygen to the brain:** "Physical activity is helpful, not only because it creates new neurons," according to Doidge, "but because the mind is based in the brain and the brain needs oxygen" (Doidge 2007). Oxygen's main function is to carry away potentially damaging excess electrons that are produced as glucose is consumed by brain cells, according to Medina (2008). He goes on to emphasize the importance of oxygen to the brain by noting that we can live for about thirty days without food and about a week without drinking water, but "cannot go without oxygen for more than five minutes without risking serious and permanent damage" to our brain.
- **Level of neurotransmitters:** This means that the person will be more focused, less stressed, and less impulsive (Costa 2010). As noted in Section 2.14.2, a neurotransmitter is a chemical released from a neuron, creating a signal that passes from one neuron to another or to a muscle (Baggaley 2001). Serotonin, dopamine, norephinephrine, and noradenaline are examples of neurotransmitters (Medina 2008; Restak 2009) associated with mental health.

Clearly, regular physical exercise has many benefits. This leads us to consider what kind of exercise is needed, how much, and when during our life. We do not need extreme measures. Nussbaum (2010) suggests options such as performing aerobic exercise three times per week or walking for thirty minutes or ten thousand steps (which you can measure with a pedometer) each day. Medina (2008) recommends a twenty-minute walk each day or three thirty-minute aerobic exercises per week. Most of us, regardless of our stage in life, can exercise at these moderate levels for the sake of our brain, and we should exercise throughout our life, as indicated by Nussbaum (2010), who, recognizing neuroplasticity, said "I do not believe in a critical period of brain development unless it is defined as life."

2.16.2 Diet

We can also care for and "tune up" our brain by watching our diet. We should adopt what Restak (2009) calls a "brain diet" or what Nussbaum (2010) refers to as a "healthy brain diet." For starters, a brain-friendly diet should achieve the following:

- **Avoid trans fats:** Trans fats are "formed when liquid oils are transformed into solid fats by adding hydrogen to vegetable oil." They "clog arteries in the brain and heart, leading to cognitive decline . . . and heart attacks. . . . In general, foods that come from nature (unprocessed) don't contain trans fats" (Restak 2009).
- **Control weight:** While we have long known that obesity causes heart disease, hypertension, and diabetes, "the effect of obesity on brain function has only recently been uncovered" and "as tests of cognitive performance in humans indicate, obesity is more often associated with cognitive impairment than with age, gender, education, or IQ." We need to restrict calories by reducing "protein, carbohydrates, and unhealthy (trans) fat content of food without [reducing] the nutrient content" (Restak 2009).

Moving from "don't" to "do," consider the following advice on what we should include in our diet:

- **Eat vegetables and fruits:** Particularly green leafy vegetables and tomatoes. Green leafy vegetables provide more vitamin E than other vegetables. This vitamin is an antioxidant and boosts the body's immune system so that it can fight invading bacteria and viruses. Fruits and vegetables contain other chemicals that are antioxidants. Oxidants injure or destroy membranes in the interior of cells (National Institutes of Health 2014; Restak 2009), whereas antioxidants are like a broom "that helps to sweep the toxins out of our bodies" (Nussbaum 2010). How many servings of fruits and vegetables should you consume? Restak (2009) suggests drinking fruit or vegetable juice at least three times per week.
- **Consume "good" fats:** That is, omega-3 fatty acids (Nussbaum 2010). This substance lowers the incidence of depression and, more relevant to our discussion, will "improve memory and the clarity of one's thinking." The brain is 60 percent fat by volume (it may be the fattest part of our bodies), and that fat "insulates our nerve tracts and cells and helps the brain process information rapidly" (Nussbaum 2010). Restak (2009) explains that fish, especially tuna, salmon, herring, mackerel, sardines, sablefish, and trout, are "loaded with . . . omega-3 fatty acids" and recommends two servings per week. Nussbaum suggests unsalted nuts, such as almonds and walnuts.
- **Eat some protein:** Protein is the building block of body tissue in that it is used to grow and repair cells (Baggaley 2001; Costa 2010; Nussbaum 2010). According to Nussbaum (2010), proteins supportive of brain health are found in fish containing good fats, turkey and chicken, lean beef and pork, eggs, and low-fat and fat-free dairy products.
- **Consume some carbohydrates:** The body uses carbohydrates to make glucose, the fuel that gives us energy. Excessive carbohydrate intake can result in high blood sugar levels, which, if not managed by natural insulin response, can damage some organs, including the brain. Some specific carbohydrate sources include whole grains with fiber, oats, dried beans and lentils, nuts, and barley (Baggaley 2001; Nussbaum 2010).
- **Get some caffeine:** From coffee, tea, or soft drinks. "New evidence shows that caffeine can be beneficial to brain function" (Restak 2009). However, you should probably limit it to what is contained in two or three servings per day. Excessive caffeine can restrict blood flow to the brain, resulting in dehydration, which interferes with thinking (Adams 2008).
- **Drink moderately and selectively:** Red wine in moderate amounts enhances brain function. Scientists are not sure why, but the key may be a substance in grape skins; red wine is fermented with the skins and white wine without (Restak 2009). Wine is optional; water is essential. Recognize that about 75 percent of your brain, by weight, is water (USGS 2014) and "anything that dehydrates you makes it harder to think," according to Amen (2008). Water helps your brain produce neurotransmitters and hormones; get glucose, nutrients, and oxygen; and remove waste products (USGS 2014).

Additional brain diet advice is readily available. For example, sociobiologist Costa (2010) provides a list of foods associated with higher brain functioning. Nussbaum (2010) identifies many specific foods needed for a healthy brain diet and provides recipes for many soups, dishes, breads, and desserts.

Figure 2.18
Nourish your brain with a Mediterranean diet.
(Snyfer/Fotolia)

In summary, the "brain diet" described here is similar to the Mediterranean diet (Figure 2.18), which is described as "rich in fruits, vegetables, legumes, and cereals. Olive oil and other unsaturated fatty acids are preferred. . . . fish is eaten more often than poultry or meat. Dairy consumption is low to moderate. Alcohol is taken in mild to moderate amounts in the form of wine with meals" (Restak 2009).

2.16.3 Mental Stimulation

Let's take a look at ways to stimulate your brain and why it's beneficial to do so. We'll review two scientific studies centered on mental stimulation and then discuss how you might benefit from such research in your own life.

The Nun Study

We begin this last portion of the Care and Feeding of Your Brain topic with a review of the Nun Study (Belluck 2001; Snowdon 2001), one of the most unique and revealing investigations ever of the human brain. Starting in 1990, 678 nuns in seven US convents within the School Sisters of Notre Dame order agreed to participate in a groundbreaking study that focused on their brains. The study's purpose was to determine who gets dementia (and especially Alzheimer's disease, which is the principal type of dementia), and why, and what factors affect life expectancy.

The nuns offered an ideal situation for scientific study because they led similar lives, had access to similar health care, ate well, didn't smoke, hardly drank alcohol, and didn't experience physical changes caused by pregnancy. The research process included tracking each nun's writings and other activities beginning in their twenties and extending to death, conducting annual cognitive and physical tests on each participant, and removing and studying the brain of every deceased study participant. Because of the similar lifestyles of its participants, the study was ideal, but the project's leaders also realized that the study's results may not represent the population at large.

The study reached a decade milestone in 2001, which saw the publication of *Aging with Grace*, authored by epidemiologist Snowdon, the principal investigator. The book noted that 383 nuns had passed away. Although the study continues to this day, the comprehensive findings presented thus far in Snowdon's book are highly relevant to our brain care discussion.

The study concluded that early language ability, a positive outlook, and ongoing mental and physical activity correlated with lowered risk of dementia, including Alzheimer's, and also correlated with longer life. The reasons for this correlation are not fully understood. However, that does not significantly diminish their potential value for you, assuming you govern your life accordingly.

The Rush University Medical Center Study

This cohort study, led by neuropsychologist Wilson, started with 294 older persons with, at the beginning, an average age of eighty. Base data on participants included early-life and late-life (current) participation in "cognitively-stimulating activities such as reading, writing, visiting museums, playing challenging card games, doing puzzles, and the like." Somewhat similar to the Nun Study, participants in this investigation participated in annual cognitive function testing until death (a mean of 5.8 years since the beginning of research), when their brains were autopsied. The autopsies enabled the researchers to adjust the data for cognitive diseases such as Alzheimer's (Hughes 2013). The researchers concluded, consistent with the Nun Study, that "more frequent activity across the life span has an association with slower late-life cognitive decline that is independent of common neuropathologic conditions" (Wilson et al. 2013).

The researchers' view of their work: "We have proved for the first time that increased cognitive activity has an association with reduced cognitive decline independent of cognitive-related pathology." The reference to "independent of cognitive-related pathology" means that the researchers analyzed the data to remove the effects of diseases. The researchers' advice: "Start doing some sort of cognitive activity every day if you're not already doing it" (Hughes 2013).

In other words, if you are running mainly on habit and what is comfortable and routine, stop. If you are a successful engineering student or young practitioner, you may react by saying, "I live most days around cognitive activity; I have to in order to survive." That may be true, but I have observed many middle- and advanced-career professionals who have gotten into a rut. For every five years, they have one year of cognitive experience five times instead of five years of cognitive experience. That "in-a-rut thinking" may extend into their personal lives. Avoid that with a vengeance, if for no other reason than to practice faithful stewardship of your gift of a superior intelligence and the opportunities it offers for achieving success and significance.

Other Views

We can readily find many experts who urge us to regularly stimulate our brains. "The human brain operates best when it is regularly subjected to new challenges," according to Costa (2010), "because whenever we learn something new we are burning new biological 'circuits' in the brain that challenge the old circuits we have relied on over and over and over again. . . . We are creating more options and more pathways for the brain to select from." "We can all work to develop our writing and speaking abilities early in life as one means of building a healthier brain," according to Nussbaum (2010), "and perhaps a resistance to neurodegenerative disease later in life." Doidge (2007) states that, based on postmortem examinations, the complexity of interneuron connections increases with level of education. Finally, some say that an idle mind is the devil's workshop. Perhaps that devil's name is dementia.

The principal implication of the preceding studies and views is that we should stay mentally stimulated and physically active throughout our life. Use that amazing muscle called your brain, and leverage its plasticity by giving it many and varied workouts. The sky is the limit on how you might do this; your choices are highly subjective. However, to stimulate your thinking, consider options throughout your life such as the following:

- Earn another degree
- Master a new dance step
- Play brain games, such as crossword puzzles, Sudoku, poker, board games, and solitaire, and experiment with Internet-based services that claim to improve brain capabilities
- Seek speaking opportunities
- Take art lessons
- Request job assignments different than your norm
- Travel to new places
- Join a book club
- Plant and nurture a vegetable or flower garden
- Learn another language
- Engage in a new sport
- Take different routes in your daily travels
- Walk or ride your bicycle instead of driving
- Design and build a boat
- Lead an ad hoc task committee
- Participate in an archeological dig
- Read articles and books from outside of your discipline and/or specialty
- Start a part-time business
- Learn to play an instrument
- Write that book!

2.16.4 Care and Feeding of Your Brain: The Essentials

To reiterate, care for your brain first by regularly exercising because a healthy body tends to mean a healthy brain. Second, watch what you eat and drink. Finally, seek lifelong mental stimulation. Recall this chapter's discussion of habits (Section 2.10). Strive to develop habits that enable you to care for your brain by automatically exercising your body, eating smart, and exercising your brain.

2.17 THE REST OF THE STORY

I began this chapter by stating that if you want to work smarter, live smarter, replace some bad habits with good habits, be more creative and innovative—in short, achieve your desired levels and balance of success and significance—then you need to understand some brain basics. Therefore, I selected, researched, and wrote about, and hopefully you read about, some neuroscience topics. Recall the used car story, in which I argued that you don't need to become a certified automobile mechanic to get better performance out of your car. Analogous with that story, I selected topics that would help you get better performance out of your brain—not make you a brain surgeon. In subsequent chapters, we will draw on that brain primer.

However, knowing some students (and still being one), I suspect that the brain primer may motivate a few of you to delve deeper into neuroscience. You might do so out of simple interest, or maybe you see a possible connection to your formal studies (e.g., senior project, graduate research) or your career (e.g., seeking engineering employment in the neuroprosthetic field). Given that I have touched on only the tip of the brain iceberg in this very introductory treatment, you could dive further into many interesting and fruitful neuroscience topics. Furthermore, given that we have much more to learn about the human brain, your efforts might someday lead to valuable new knowledge. Perhaps one or more of the following topics will entice you as the focus of your research paper, independent study, or capstone course project, which could meld engineering, neuroscience, medicine, and/or other disciplines:

- Functions of various parts of the brain (in the process, the foolishness of the claim that we use only 10 percent of our brains)
- Improved teaching and learning (start with books by Zull [2002] and Hardiman [2003])
- The promise embodied in neuroplasticity for the struggling student who views his or her brain as inferior and fixed
- The structure and electrochemical aspects of neurons
- The fact that seeing and hearing occur in the brain and not in the eyes or ears (Section 8.4.2) and how that reality holds promise to help the blind see and the deaf hear
- Artificial intelligence: Where is it now, how far could it go, and would it encourage or discourage creativity and innovation?
- The new diagnostic and surgery-guidance tools that might be developed because the brain's absence of sensory nerves means that it cannot feel pain (Section 2.3.2)
- Impacts, if any, of brain-training software and websites on thinking ability and IQ
- Ways magicians use brain basics to fool us
- Use of lie detectors and brain-imaging devices in legal proceedings
- Applying brain basics to improve memorization ability
- Telepathy—that is, mind-to-mind communication (e.g., see Rao and Stocco 2014 for an intriguing Internet-based version)
- Effects of the tools and toys we use, such as smartphones, video games, and the Internet, on our brains
- Clairvoyance—that is, gathering information about an object or place using means other than our six senses (Section 2.3.1) of vision, hearing, smell, taste, touch, and proprioception

2.18 LOOKING AHEAD TO CHAPTERS 3, 4, AND 7

After studying Chapters 1 and 2, especially Chapter 2, and because of your practical tendency, you may be tempted to ask, "So what?" That is, you may wonder how you could use your new brain knowledge to help you be more creative and innovative. The partial answer is that I have already offered you some practical tips based on brain basics. For example, because of neuroplasticity, you can continue to maintain your brain, just like you can continue to maintain your muscles. Also if you are willing to work at it, you can use your conscious and subconscious minds to replace bad habits with good ones.

However, those examples are just the tip of the iceberg. Chapter 3 introduces and Chapters 4 and 7 describe and illustrate the use of twenty methods intended to stimulate you and, more powerfully, your group (such as a project, planning, design, research, experimental, marketing, or other team) to think more deeply and widely—to generate more ideas. Deep understanding and effective use of each of the whole-brain tools requires knowledge of brain basics, as offered in this chapter. You now have the necessary foundation to proactively learn about and use those tools.

> Ninety-five percent of what we know about the human brain
> has been learned in the past twenty years.
> Our schools, universities, and corporations are only beginning
> to apply this emerging understanding of human potential.
>
> —*Michael J. Gelb, author of the 2004 book*
> *How to Think Like Leonardo da Vinci*

CITED SOURCES

Adams, J. L. 1986. *The Care and Feeding of Ideas: A Guide to Encouraging Creativity*. Reading, MA: Addison-Wesley Publishing Company.

Allen, J. 1987. *As a Man Thinketh*. White Plains, NY: Peter Pauper Press.

Amen, D. G. 2008. *Magnificent Mind at Any Age: Natural Ways to Unleash Your Brain's Maximum Potential,*. New York: Three Rivers Press.

Ariely, D. 2010. *The Upside of Irrationality*. New York: HarperCollins Publishers.

Atkinson, C. 2010. *Beyond Bullet Points: Using Microsoft PowerPoint 2007 to Create Presentations that Inform, Motivate, and Inspire*. Redmond, WA: Microsoft Press.

Baggaley, A., ed. 2001. *Human Body: An Illustrated Guide to Every Part of the Human Body and How It Works*. London: Dorling Kindersley Limited.

Baumeister, R. F., and J. Tierney. 2011. *Willpower: Rediscovering the Greatest Human Strength*. New York: Penguin Press.

Belluck, P. 2001. "Nuns Offer Clues to Alzheimer's and Aging." *The New York Times*, May 7.

Benyus, J. M. 1997. *Biomimicry: Innovation Inspired by Nature*. New York: Harper Perennial.

Bonasso, S. 1983. "Can We Become More Creative?" *Civil Engineering–ASCE 53* (1): 70–72.

Bregman, P. 2011. "How (and Why) to Stop Multitasking." *Harvard Business Review*, December 4.

Brizendine, L. 2006. *The Female Brain*. New York: Broadway Books.

Brizendine, L. 2010. *The Male Brain*. New York: Three Rivers Press.

Carlson, R. 1997. *Don't Sweat the Small Stuff . . . And It's All Small Stuff: Simple Things to Keep the Little Things from Taking over Your Life*. New York: Hyperion.

Carter, R. 2009. *The Human Brain Book: An Illustrated Guide to Its Structure, Function, and Disorders*. New York: DK Publishing.

Chin, A., and S. Upson. 2011. "Head Shots." *Scientific American Mind*, November/December: 42–47.

Clayman, C. B., ed. 1991. *The Brain and the Nervous System*. Pleasantville, NY: Readers Digest Association.

Cohen, G. C. 2005. *The Mature Mind: The Positive Power of the Aging Brain*. New York: Basic Books.

Connellan, T. 2011. *The 1% Solution for Work and Life*. Chelsea, MI: Peak Performance Press.

Cooper, R. K. 2006. *Get Out of Your Own Way: The 5 Keys to Surpassing Everyone's Expectations*. New York: Crown Business.

Costa, R. D. 2010. *The Watchman's Rattle: Thinking Our Way out of Extinction*. Philadelphia: Vanguard Press.

Culp, G., and A. Smith. 2001. "Understanding Psychological Type to Improve Project Team Performance." *Journal of Management in Engineering*, ASCE 17 (1): 24–33.

Davis, L. M. 2014. "CT Scan." *eMedicineHealth*. Accessed November 13. http://www.emedicinehealth.com/ct_scan/article_em.htm.

Doidge, N. 2007. *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science*. New York: Penguin Books.

Duhigg, C. 2012. *The Power of Habit: Why We Do What We Do in Life and Business*. New York: Random House.

Eagleman, D. 2012. *Incognito: The Secret Lives of the Brain*. New York: Vintage Books.

Edwards, B. 1999. *Drawing on the Right Side of the Brain*. New York: Jeremy P. Tarcher/Putnam.

Finger, S. 1994. *Origins of Neuroscience: A History of Explorations into Brain Function*. New York: Oxford University Press.

Freudenrich, C., and R. Boyd. 2014. "How Your Brain Works." *HowStuffWorks*. Accessed November 10. http://science.howstuffworks.com/life/inside-the-mind/human-brain/brain2.htm.

Funnell, M. G., M. K. Colvin, and M. S. Gazzaniga. 2007. "The Calculating Hemispheres: Studies of a Split-Brain Patient." *Neuropsychologia* 45 (10): 2378–2386.

Gelb, M. J. 2004. *How to Think like Leonardo da Vinci: Seven Steps to Genius Every Day*. New York: Bantam Dell.

Gibb, B. J. 2012. *A Rough Guide to the Brain: Get to Know Your Grey Matter*. London: Rough Guides Ltd.

Gilbert, D. 2006. *Stumbling on Happiness*. New York: Vintage Books.

Gladwell, M. 2005. *Blink: The Power of Thinking without Thinking*. New York: Little, Brown and Company.

Goleman, D. 2013. *Focus: The Hidden Driver of Excellence,* New York: HarperCollins Publishers.

Hanson, R. 2013. *Hardwiring Happiness: The New Brain Science of Contentment, Calm, and Confidence*. New York: Harmony Books.

Hardiman, M. M. 2003. *Connecting Brain Research with Effective Teaching: The Brain-Targeted Teaching Model*. Lanham, MD: Rowman & Littlefield Education.

Herrmann, N. 1996. *The Whole Brain Business Book: Unlocking the Power of Whole Brain Thinking in Individuals and Organizations*. New York: McGraw-Hill.

Hill, N. 1960. *Think and Grow Rich*. New York: Fawcett Crest.

Hormone Health Network. 2014. "Hormones and Health." Accessed October 4, 2014. http://www.hormone.org/hormones-and-health.

Hughes, S. 2013. "An Active Brain throughout Life Slows Cognitive Decline." *Medscape Medical News*. Accessed July 3. http://www.medscape.com/viewarticle/807290#2.

Hutson, M. 2012. "Right Hand, Right Choice." *Scientific American Mind*, July/August: 11.

Irvine, W. B. 2015. *Aha! The Moments of Insight that Shape our World,* Oxford, UK: Oxford University Press.

Jabr, F. 2011. "How to Form a Habit," *Scientific American Mind*, January/February: 7.

Jackson, M. 2008. *Distracted: The Erosion of Attention and the Coming Dark Age*. Amherst, NY: Prometheus.

James, W. 1917. "Habits." In *Selected Papers on Philosophy*. New York: E. P. Dutton & Co.

Kay, K., and C. Shipman. 2014. "The Confidence Gap." *The Atlantic*, May.

Kleon, A. 2012. *Steal Like an Artist,* New York: Workman Publishing Company

Knapton, S. 2014. "Men and Women Do Not Have Different Brains, Claims Neuroscientist," *The Telegraph—Science News*, March 8. Accessed October 4, 2014. http://www.telegraph.co.uk/science/science-news/10684179/Men-and-women-do-not-have-different-brains-claims-neuroscientist.html.

Koch, C. 2012. "Finding Free Will." *Scientific American Mind*, May/June: 22–27.

Lagace, M. 2012. "The Unconscious Executive." *Harvard Business School Working Knowledge*, July 9. Accessed November 10, 2014. http://hbswk.hbs.edu/item/6872.html.

Lakoff, G., and M. Johnson. 1999. *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. New York: Basic Books.

Lehrer, J. 2008. *Proust Was a Neuroscientist*. New York: Houghton Mifflin Company.

Levitin, D. J. 2006. *This Is Your Brain on Music: The Science of Human Obsession*. New York: Plume-Penguin Group.

Maltz, M., and D. S. Kennedy. 2001. *The New Psycho-Cybernetics*. New York: Prentice Hall Press.

Mandino, O. 1968. *The Greatest Salesman in the World*. New York: Bantam Books.

Martin, N. 2008. *Habit: The 95% of Behavior that Marketers Ignore*. Upper Saddle River, NJ: Pearson Education.

May, R. 1976. *The Courage to Create*. New York: Bantam Books.

MedicineNet. 2014. "Definition of Hormone." MedicineNet.com. Accessed October 4, 2014. http://www.medicinenet.com/script/main/art.asp?articlekey=3783.

Medina, J. 2008. *Brain Rules: 12 Principles for Surviving and Thriving at Work, Home, and School*. Seattle: Pear Press.

MIT. 2014. "Basic Principles of Magnetoencephalography." Accessed August 4. http://web.mit.edu/kitmitmeg/whatis.html.

McGowan, K. 2014. "The Second Coming of Sigmund Freud." *Discover*, April: 54–61.

McManus, C. 2012. "Ask the Brains." *Scientific American Mind*, May/June: 70.

Miles, E. 1997. *Tune Your Brain: Using Music to Manage Your Mind, Body, and Mood*. New York: Berkley Books.

Mlodinow, L. 2013. *Subliminal: How Your Unconscious Mind Rules Your Behavior*. New York: Vintage Books.

Murphy, J. 1963. *The Power of Your Subconscious Mind*. Englewood Cliffs, NJ: Prentice Hall.

Murphy, J. 2000. *The Power of Your Subconscious Mind*, rev. New York: Bantam Books.

National Institutes of Health. 2014. "Vitamin E." Accessed July 16. http://ods.od.nih.gov/factsheets/VitaminE-Consumer/.

Neal, D. T., W. Wood, and J. M. Quinn. 2006. "Habits: A Repeat Performance." *Current Directions in Psychological Science* 15 (4): 198–202.

NHS Choices. 2014. "Men's and Women's Brains found to be Different Sizes." February 14. Accessed October 4, 2014. http://www.nhs.uk/news/2014/02February/Pages/Mens-and-womens-brains-found-to-be-different-sizes.aspx.

Nussbaum, P. D. 2010. *Save Your Brain: Five Things You Must Do to Keep Your Mind Young and Sharp*. New York: McGraw-Hill.

Nussbaum, P. D. 2014. Personal communication to author. August 13.

Osteen, J. 2007. *Become a Better You: 7 Keys to Improving Your Life Every Day*. New York: Free Press.

Paddock, C. 2013. "Brain Wired Differently in Men and Women." *Medical News Today*, December 4. Accessed October 4, 2014. http://www.medicalnewstoday.com/articles/269652.php.

Pattison, K. 2008. "Worker, Interrupted: The Cost of Task Switching." *Fast* Company.com, July 28. Accessed July 20, 2015. http://www.fastcompany.com/944128/worker-interrupted-cost-task-switching.

Peck, M. S. 1997. *The Road Less Traveled and Beyond: Spiritual Growth in an Age of Anxiety*. New York: Simon & Schuster.

Pinker, S. 2009. *How the Mind Works*. New York: W. W. Norton & Company.

Rao, R. P. N., and A. Stocco. 2014. "When Two Brains Connect." *Scientific American Mind*, November/December: 36–39.

Restak, R. 2009. *Think Smart: A Neuroscientist's Prescription for Improving Your Brain's Performance*. New York: Riverhead Books.

Restak, R., and S. Kim. 2010. *The Playful Brain: The Surprising Science of How Puzzles Improve Your Mind*. New York: Riverhead Books.

Robinson, J. 2010. "E-mail Is Making You Stupid." *Entrepreneur*, March: 60–63.

Sharot, T. 2011. "The Optimism Bias." *Time*, June 6.

Shields, R. 2014. "Skeleton Reveals Ancient Greek Brain Surgery." *The Independent*, London, March 14.

Shlain, L. 2014. *Leonardo's Brain: Understanding da Vinci's Creative Genius*. Guilford, CT: Lyons Press.

Skaggs, W. 2014. "New Neurons for New Memories." *Scientific American Mind*, September/October: 49–53.

Snowdon, D. 2001. *Aging with Grace: What the Nun Study Teaches Us about Leading Longer, Healthier, and More Meaningful Lives*. New York: Bantam Books.

Stover, E., ed. 2014. *His Brain, Her Brain*. New York: Scientific American.

Strayer, D. L., and J. M. Watson. 2012. "Supertaskers and the Multitasking Brain." *Scientific American Mind*, March/April: 22–29.

Taylor, J. B. 2009. *My Stroke of Insight: A Brain Scientist's Personal Journey*. New York: Penguin Group.

Tice, L. 2002. "Winners Circle Network with Lou Tice." E-newsletter from *The Pacific Institute*, April 25. http://www.thepacificinstitute.com.

University of Washington. 2014. "Brain Facts and Figures." Accessed November 9. https://faculty.washington.edu/chudler/facts.html.

USGS. 2014. "The Water in You." *USGS Water School, US Geological Survey*. Accessed September 16, 2014. http://water.usgs.gov/edu/propertyyou.html.

Verplanken, B., and W. Wood. 2006. "Interventions to Break and Create Consumer Habits." *Journal of Public Policy and Marketing*, American Marketing Association 15 (1): 90–103.

Wait, M. 2009. *No More Brain Drain: Proven Ways to Maintain Your Mind and Memories*. Pleasantville, NY: The Reader's Digest Association.

Walesh, S. G. 2013. "Taking Multi-Tasking to Task," *Leadership and Management in Engineering*, ASCE, January: 61–62.

Wilson, R. S., P. A. Boyle, L. Yu, L. L. Barnes, J. A. Schneider, and D. A. Bennett. 2013. "Life-Span Cognitive Activity, Neuropathologic Burden, and Cognitive Aging." *Neurology*, July 3.

Wolf, C. C. 2013. "The Mystery of the Missed Connection." *Scientific American Mind*, January/February: 54–57.

Woolley, A., T. W. Malone, and C. F. Chabris. 2015. "Why Some Teams are Smarter than Others." *The New York Times*, January 16.

Zimmer, C. 2014. "Secrets of the Brain." *National Geographic*, February.

Zull, J. E. 2002. *The Art of Changing the Brain: Enriching the Practice of Teaching by Exploring the Biology of the Brain*. Sterling, VA: Stylus Publishing.

EXERCISES

Notes:

1. The goal of the exercises is to provide students, usually working alone, with the opportunity to think about and use the ideas, principles, and information offered in the chapter.
2. However, many circumstances and corresponding teaching/learning opportunities may arise. For example, a stated situation may be altered to meet specific concerns or needs. Rather than work with the largely hypothetical situation described in a particular exercise, an individual or team may wish to take on an actual issue, problem, or opportunity facing the team or one or more of its members. These and similar variations are encouraged, subject to the concurrence or direction of the instructor.

2.1 BOOK REVIEW: The purpose of this exercise is to provide you with an opportunity to study, in depth, one book about the human brain and identify the book's key ideas/information, summarize the book, critique it, and determine the book's relevance to your study and work. In so doing, you will be further introduced to the broad range of neuroscience literature, with the hope that you will continue to read critically in this area as one means of growing professionally. Suggested tasks are as follows:

- **a.** Tentatively select one neuroscience book. Some possible sources are books listed in the Cited Sources sections of this text's chapters, books reviewed in newspapers and magazines, books recommended by others, and books you find by searching for "brain," "neuroscience," "innovation," or similar words.
- **b.** Request approval of the book from your instructor.
- **c.** Read the book and prepare a review in which you do the following: a) Cite your book (e.g., name, author, publisher, date), b) describe some of the key information/ideas and/or theses presented in the book, c) identify the supporting evidence, d) indicate whether or not you agree with the key ideas/theses, and e) comment on the relevance, or lack thereof, to your study and work.

2.2 ORIGINS OF A FAVORED FACILITY/PRODUCT OR SERVICE: Each of us often sees or uses interesting or appealing facilities/products or services. Some examples:

- Facilities/Products: Wind farm, iPad, weed whacker, bicycle
- Services: Design-build, Facebook, Twitter, YouTube

We can learn more about being creative and innovative by studying the creative and innovative endeavors of others—that is, by learning what motivated them, how they first discovered the basic idea, who they collaborated with, and what obstacles were encountered and how they overcame them. The purpose of this exercise is to give you that learning experience. Suggested tasks are as follows:

- **a.** Select one facility/product or service that you admire and use or benefit from. Do not necessarily limit your topics to those within engineering or other technically oriented professions.

b. Conduct your research, then write a short report that cites all sources (e.g., websites, reference books, published articles or papers, experts) and answers questions such as the following:

- Why do you admire the selected facility/product or service?
- Who (individual or team) is credited with the original idea?
- What motivated the creative or innovative effort? That is, what were the circumstances? Stated differently, what issue, problem, or opportunity (IPO) was being addressed?
- How did the creative or innovative idea arise? For example, did the individual or team follow some systematic process (like those described in Chapters 4 and 7 of this text), or did the idea simply "appear?"
- What obstacles were encountered, and how were they overcome?
- What was needed (expertise, finance, legal advice, prototyping, testing) to implement the creative or innovative idea?

2.3 RESEARCH PAPER (INDIVIDUAL STUDENT VERSION): The intent of this exercise is to provide you with a means of studying, in depth, a neuroscience-related topic largely of your choice. This can broaden and deepen your knowledge, increase your awareness of neuroscience literature and other resources, and strengthen your research and writing abilities. Suggested tasks are as follows:

a. Select a neuroscience-related topic. To get you started, but at the risk of unintentionally confining your thinking, drill down into one of the brain basics discussed in this chapter or refer to the topics listed in Section 2.17.

b. Request approval of the topic by the instructor.

c. Research your topic by drawing on a variety of sources. Consider using one or more personal sources that you contact in person or by telephone, e-mail, or letter. If you use a personal contact, cite that contact at the end of your paper using this format: Smith, J. A., 2015. Director of Engineering, XYZ Company, Chicago, IL. Personal communication via email. October 27.

d. Write the paper. Assume your principal readers are engineering or other technical profession students who know little about your topic.

2.4 RESEARCH PAPER (TEAM VERSION): Similar to the preceding exercise, except that the topic is to be selected and researched and the paper written by a team. The purpose of this exercise, in addition to the purpose stated for the preceding exercise, is to simulate the team-oriented manner in which engineering work is done in practice.

2.5 MUCH MORE THAN A COMPUTER: Think of your favorite material possession. Now consciously imagine how you would destroy it. Describe the destruction process you would use and your likely emotions during the process. (Adapted from Adams 1986.)

2.6 ONE AT A TIME: Take one minute and think about as many things as possible that you did yesterday. Make a note for each one and count them when you finish. Then reflect on and answer this question: Regardless of how many things you identified, were you ever thinking of two or more at the same time—that is, in parallel? (Adapted from Adams 1986.)

2.7 HABIT CHANGE: This exercise is likely to be very personal and, therefore, not assigned by your instructor. However, it could be one of the most revealing and useful exercises in this exercise set because habits—that is, ways we speak, act, and react—control a major part of our lives.

Try to identify some of your "smaller" bad habits, such as interrupting others; failing to say please and thank you; procrastinating with your homework, as described in this chapter; talking too much about yourself; jumping to conclusions; and being negative.

Select one bad habit that you want to change. Identify the cue; this is critical. Commit for one month to recognizing the cue, trying a new routine in response to the cue, assessing the "reward," recognizing the cue the next time it occurs, and refining the new routine as needed. This process takes great self-discipline, but it works, based on my experience and (more importantly) neuroscience.

2.8 TAKING MULTITASKING TO TASK: Recall Bregman's experiment (Section 2.11.4) in which he stopped multitasking for one week. Perform a similar experiment, but for one day. Then, prepare a brief summary of your experience. The purpose of this exercise is to test the alleged long-term negative results of multitasking—that is, more time required to do a task and greater probability of making errors. Did your experience support those two points, or did you have a contrary outcome?