PREFACE

Marilee J. Bresciani Ludvik

Is higher education preparing our students for a world that is increasingly complex and volatile, one in which they will have to contend with uncertainty and ambiguity? Are we addressing the concerns of employers who complain that graduates do not possess the creative, critical thinking, and communication skills needed in the workplace? In the face of the evidence that our colleges and universities are failing at precisely these preparations, this book not only harnesses what we have learned from innovations in teaching but also offers intentional out-of-classroom experiences, along with emerging neuroscience, to transform how we deliver and create new knowledge, and indeed transform our students, developing their capacities for adaptive boundary spanning.

Starting from the premise that our current linear, course-based educational practices are frequently at odds with how our neurological systems facilitate learning and personal development, the authors of *The Neuroscience of Learning and Development* set out an alternative model that emphasizes a holistic approach to education that integrates mindful inquiry practice with self-authorship and the regulation of emotion as the cornerstones of learning, while demonstrating how these align with the latest discoveries in neuroscience. This book challenges all of us in higher education to move away from the degree (made up of a combination of several courses and an accumulation of credit hours) as the commodity of higher education to focus on the learning and development process itself as the primary commodity that we organize ourselves around.

This book presents the science that informs key learning and development constructs plausibly missing from today's educational systems. In addition, this book presents the science that informs the practice of compassion and peace—the science that explains the very real benefits of intentional movement and mindful inquiry. It demonstrates their application to the classroom and to the cocurriculum, and their implications for the administrative leaders who make the decisions that affect student learning; student development; and the environment within which faculty, administrators, and students reside.

Neuroscience experts, learning and development theory experts, and health practitioners outline their research and insights into how providing seemingly unintellectual learning and development opportunities for students actually stimulates portions of the brain that are needed for students to become adaptive problem solvers; creators of knowledge; and effective, compassionate social collaborators who promote the responsible use of resources to enhance sustainable change.

The book closes by offering practical ideas for implementation, showing how simple refinements in classroom and cocurricular experiences can create foundations for students to develop key skills that will enhance adaptive problem solving; creativity; overall well-being; innovation; resilience; compassion; and, ultimately, world peace.

Introduction: Rethinking How We Design, Deliver, and Evaluate Higher Education

Many recent discoveries in neuroscience are affirming some things we knew to be true about how the brain functions, while simultaneously causing us to rethink how the brain learns and develops. These neuroscience discoveries affirm much of the previous research about how to improve student success. Other discoveries cause us to question some fundamental infrastructure design for student success. In this introduction, Marilee J. Bresciani Ludvik posits the question of whether higher education is actually organized in alignment with how the brain best learns and develops. This introduction sets the stage for what follows in this book: detailed discussions of specific practices, along with the neuroscience that informs them, that can be used to significantly improve the quality of holistic student learning and development in higher education while remaining committed to access, equity, and student success.

Chapter 1: Basic Brain Parts and Their Functions

In this chapter, authors Matthew R. Evrard, Jacopo Annese, and Marilee J. Bresciani Ludvik focus on what they understand to be true about the related functional areas of specific portions of the brain important in learning and development. Mark Baxter and Thomas Van Vleet provide review. The chapter highlights the intricacies of the brain, the interrelatedness of the brain areas, and where we currently understand key aspects of learning and development to take place.

Chapter 2: Unpacking Neuroplasticity and Neurogenesis

Matthew R. Evrard and Marilee J. Bresciani Ludvik examine neuroplasticity and neurogenesis in this chapter with review by Thomas Van Vleet. The authors highlight how changeable the connections in the brain are and emphasize the researched strategies that illustrate what we understand about our ability to intentionally change certain portions of the brain.

Chapter 3: Strategies That Intentionally Change the Brain

In this chapter, with review by Thomas Van Vleet, authors Marilee J. Bresciani Ludvik, Matthew R. Evrard, and Phillipe Goldin discuss the clinical research that highlights brain plasticity and its relevance to student learning and development. They also discuss emerging studies that provide the authors with an understanding of how educators can intentionally change the brain in manners that may heighten student learning and development. This chapter further discusses the importance of developing body awareness and compassion as key concepts in enhancing desired student learning and development outcomes.

Chapter 4: (Re)Conceptualizing Meaning Making in Higher Education: A Case for Integrative Educational Encounters That Prepare Students for Self-Authorship

Emily Marx and Lisa Gates introduce the theory of self-authorship as a theoretical learning and developmental building block for supporting students' ability to integrate their internal voices in learning and developmental contexts in higher education. The theory of self-authorship is unpacked in a manner that illustrates the importance of students' self-awareness and its relevance to their ability to learn, develop, and thrive in educational experiences. The chapter offers suggestions for promoting self-authorship in both academic and student affairs contexts and explores its relationship to enhancing students' holistic learning and critical thinking.

Chapter 5: Intentional Design of High-Impact Experiential Learning

Patsy Tinsley McGill uses James Zull's work to align neuroscience with high-impact experiential learning practices. She uses data from her research on capstone experiences to illustrate how experiential learning connects with specific learning and development theories to illustrate practical implications for enhancing overall student success.

Chapter 6: Enhancing Well-Being and Resilience

Resilience and well-being remain critical concerns of higher education faculty and administrators. Christine L. Hoey discusses the interrelationship of neuroscience with specific strategies that can be used to enhance well-being, and their potential to promote resilience, creativity, critical thinking, and several other learning and development outcomes.

Chapter 7: Enhancing Creativity

Creativity remains a desired outcome for employers who recognize that simple knowledge acquisition will not create the problem solvers needed today, let alone address the seen and unforeseen complex social, economic, and environmental problems we are facing in the future. Shaila Mulholland discusses the interrelationship of neuroscience with specific strategies that can be used to enhance creativity and foster critical thinking.

Chapter 8: Enhancing Compassion and Empathy

This chapter defines *empathy* and *compassion* and explains the underlying neuroscience of such characteristics. Sarah Schairer, educated at Stanford University's Compassion Cultivation Training Program, explains how compassion can be taught to undergraduates, graduates, faculty, and staff and further explains the importance of the practice of compassion to advancing higher education outcomes.

Chapter 9: Balance Begets Integration: Exploring the Importance of Sleep, Movement, and Nature

In this chapter, physician Bruce Bekkar offers considerations on how an individual's desire for life balance can be achieved by attending to the natural world and intentionally engaging all regions of the brain. Bekkar discusses how the typical student's and educator's persistent imbalance in brain function results paradoxically in a loss of creativity, problem-solving skills, and overall well-being. Numerous strategies are suggested to restore a more holistic, integrated distribution of brain function, including engagement with nature. Emerging research validating these concepts is cited.

Chapter 10: Enhancing and Evaluating Critical Thinking Dispositions and Holistic Student Learning and Development Through Integrative Inquiry

This chapter explores methodologies used to enhance and evaluate the efficacy of critical thinking as well as many of the proposed learning and development methodologies posited in this book. Using mindfulness methodology and mindful inquiry as a foundation, Marilee J. Bresciani Ludvik, Philippe Goldin, Matthew R. Evrard, J. Luke Wood, Wendy Bracken, Charles Iyoho, and Mark Tucker introduce a way to organize and evaluate these methodologies into something they call integrative inquiry (INIQ). INIQ uses what we know (intellect), what we sense (body), and what we don't know (curiosity) to deepen the inquiry process while embracing ambiguity, thus fostering critical thinking dispositions.

Chapter 11: Mindfulness at Work in Higher Education Leadership: From Theory to Practice Within the Classroom and Across the University

In this chapter, the reader discovers how implementing previous chapters' practices for attending to our lives moment by moment can afford us some of our most creative and productive experiences. In addition, authors Les P. Cook and Anne Beffel illustrate how to develop integrated mindfulness practices to create a compassionate campus culture where colleagues and students find the space they need to recognize themselves and their connectedness to the world they help steward.

Chapter 12: A Mindful Approach to Navigating Strategic Change

In this chapter, Laurie J. Cameron provides the reader with mindful change management methodology to move the ideas presented in this book into practice. How can leadership adopt those ideas and garner organizational buy-in? How does leadership embody the principles represented in this book as it manages organization change? This chapter addresses many of these concepts in a dynamic and strategic manner.

Afterword: Adoption, Adaptation, and Transformation

In this afterword, Marilee J. Bresciani Ludvik focuses on a summary of the key findings in this book in a manner that provides practical considerations for faculty, student affairs practitioners, academic support administrators, and other organizational leaders as they seek to adopt and adapt this research to transform their design, delivery, and evaluation of higher education to impact desirable outcomes in higher education.

1

BASIC BRAIN PARTS AND THEIR FUNCTIONS

Matthew R. Evrard, Jacopo Annese, and Marilee J. Bresciani Ludvik
with review by Mark Baxter and Thomas Van Vleet

> *Everything we do, every thought we've ever had, is produced by the human brain. But exactly how it operates remains one of the biggest unsolved mysteries, and it seems the more we probe its secrets, the more surprises we find.*
>
> —Neil deGrasse Tyson (www.brainyquote.com/quotes/quotes/n/neildegras531089.html)

Many of the traditional student learning and development theories used in higher education are based in developmental theories in psychology and cognitive neuroscience, along with a number of other disciplines (Ansari & Coch, 2006; Coch & Ansari, 2009; Goswami, 2006; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009). With emerging findings, educational neuroscientists are affirming previous assumptions about the brain's role in reading, numerical comprehension, attention, and particular types of learning disabilities such as dyslexia and attention deficit/hyperactivity disorder (Ansari, 2008; Carey, 2014; Davis, 2004; Gabrieli, 2009; Howard-Jones, Pickering, & Diack, 2007; McCandliss & Noble, 2003; Petitto & Dunbar, 2004; Price, Holloway, Räsänen, Vesterinen, & Ansari, 2007). The fascination with the brain is all around us, and so it is indeed time to intentionally incorporate neuroscience discoveries into the design, delivery, and evaluation of higher education.

This chapter sets out to provide a brief framework of the brain. We intend to describe various regions of the brain and generalize their primary functions. But first allow me to share how I, Matthew R. Evrard, arrived at the gates of an emerging field.

Have you ever had the experience of suddenly realizing a past memory—perhaps as a child or teenager—that helped explain why you are who you are? I can recall multiple memories from my early childhood where my mother took me to a store and told me to choose a gift. I always chose books on scientific theory. Such books were well above my comprehension level, but I was unyielding in my attempts to understand as much as I could. If there was a puzzle, I wanted to solve it. Memories such as these, as well as my imperishable love of science, strengthened my belief that I was born a self-challenging scientist, proudly mom-accredited.

Determined to become an academically accredited scientist, I pursued my bachelor of science in psychology at SUNY Buffalo State College, where I became involved with undergraduate neuroscience research. And so it began for me, the linkage of neuroscience and higher education. Just like many who later choose student affairs as a profession, my undergraduate experience was transformational in more ways than I have space to share. This transformation occurred because of the many student leadership roles I took on, which allowed me to facilitate others' meaning making out of class. With each new term, I became more inspired to engage in my academic community. The only thing that was more difficult than turning down a new opportunity was choosing between neuroscience and higher education for graduate school. I recall being questioned by many on how I could even be considering two such "unrelated" fields. Conversation after conversation, the question was deceptively simple: Are you a science guy, or are you a student development guy? It seems ironic that such dichotomous questions came from colleagues who were also emphasizing the importance of integration across majors.

Mentally, I was living a civil war. The part of me that wanted to pursue neuroscience wanted to split from the part of me that wanted to pursue higher education. How could I choose? More to the point, why did I have to choose? I remember asking myself these questions often between late-night phone calls from freshmen locked out of their dorm rooms. Needless to say, I continued to battle this war with no clear victor.

My decision was abruptly put off during my senior year when my mother was diagnosed with cancer and had just a few months to live. In the time I spent with my mother, watching her health deteriorate, memories of the young scientist came flooding back while the nurturing development aspects came into play daily. As I began to contemplate my authentic self, I realized I was neither a "research science guy" nor a "student development guy." How could society demand I pursue only one? Truly, I was both: a man of science and education. So I did both. I pursued my master of arts in student affairs at San Diego State University, where I was able to conduct neuroscience research in a number of labs. That led me to pursue my doctorate in neuroscience at SUNY Downstate, where I continue to explore the interconnections of neuroscience and learning and development. There is no "or" anymore; it is all about the "and."

The way I look to the brain is how I imagine Copernicus looked to the skies as he tried to prove that the center of the universe was, in fact, the sun. It is amazing to think that literally right in front of me (as I am drafting this chapter while in the lab), almost a trillion cells coalesce into the brain. Within these cells, I see the potential to answer some of life's biggest questions. While intimidating to some, I find it empowering to know that scientists have barely scratched the surface of brain science, leaving so much to be discovered. Even so, there have been tremendous achievements in what scientists do "know." The first thing that comes to mind when someone asks me, "What do we know about the brain?" is its ability to change. That is, the brain is an adaptable organ that alters its own structure and function in response to experience. This adaptability has caused some to suspect, with merit, that these changes in the brain can explain many of the learning and behavioral processes. With a better understanding of the brain and its underlying mechanisms, scientists can then ask better, more pointed, questions permitting larger pieces of the puzzle to be revealed. In this way, higher education professionals and others may be able to advance the quality of higher education and its students by providing environments that foster meaningful learning and development.

The field of advertising has already turned to neuroscience to better inform its practices (Plassman, Ambler, Braeutigam, & Kenning, 2007; Ramsoy, 2014). Several companies, such as Twitter, have utilized emerging brain science to quantifiably assess social constructs such as attention (Lindstrom, 2010). The information they gather can be used to design marketing campaigns and assess their effectiveness. The field of advertising is among the first to intentionally incorporate emerging neuroscience research and has allegedly increased its profitability as a result, causing other fields to follow (Duhigg, 2014; Hazeldine, 2013). If advertising and other business practices are reaping the rewards of neuroscience, then why shouldn't higher education?

We feel that higher education's most inspiring characteristic is the potential to engender change in an individual and society. In the current state, it may be hindered by ineffective and/or outdated strategies. What if higher education leaders implemented emerging neuroscience findings into their own practices? Take, for example, a student who has been placed on academic probation because of poor grades; the very essence and existence of "academic probation" may elevate his or her stress and anxiety (Reesor, MacDonald, & Wertkin, 1992; Ross, Niebling, & Heckert, 1999; Winn, 1995; Yaworski, Weber, & Ibrahim, 2000). Chronic stress and anxiety may impede students' ability to perform, consequently curtailing their potential (Sharkin, 2004; Torres & Solberg, 2001; Turner & Berry, 2000; Zajacova, Lynch, & Espenshade, 2005). In such a case, neuroscience can be applied to better the practices in higher education. One example could be introducing practices that reduce acute stress and anxiety while improving the capacity to learn. Another example may be providing students with strategies to improve their grades while concurrently incorporating stress and anxiety reduction techniques. And yet another example could be engaging in strategies to increase activity in specific areas of the brain associated with attention and critical thinking.

These are just a few examples of the presumed benefits that integrating neuroscience into higher education could achieve; there are many others, some of which are proposed in this book. If those working within or with higher education integrate just a few of them, we remain confident that together with the work from leaders in neuroscience and higher education the quality and effectiveness of the higher education learning system can improve. We may even be able to lower the overall cost of higher education or, at the very least, reallocate resources to design effective solutions.

What follows in this chapter is a brief introduction to the brain so readers can navigate the content in the forthcoming chapters with relative ease. Hopefully, this chapter will generate additional ideas of how neuroscience can be integrated into higher education design, delivery, and evaluation. Although this is a complex topic, we have attempted to introduce this material in a manner that is accessible and yet avoids overgeneralization, leading to inaccurate assumptions and uses.

Neuroscience offers new ideas and concepts that can maximize and facilitate meaningful student learning and development. First we offer a brief history of neuroscience showcasing paradigm shifts in theories and modalities used to investigate the brain. Then we introduce basic neuroanatomical structures and their respective functions while emphasizing their interconnectedness. Next we discuss popular modalities used to investigate the brain and explain what those results may mean when interpreted. Finally, we integrate neuroscience knowledge with the forthcoming themes in the book.

How Do We Know About the Brain?

Who are you? What are your aspirations, values, and goals? What do you know? How do you know what you know? What are you currently feeling and sensing? How aware of all of this are you? Tribes in Papua New Guinea believed that the answers to these questions lay in a gray, rather squishy material that was inside your skull (Glasse, 1967). When a member of a tribe died, they would ceremoniously eat this organ with the belief that a person's wisdom, experiences, and personality could be passed down to those who participated in the ceremony. What these people ate is what we now call the human brain. Although this may seem morbid and outrageous to modern Western sensibilities, modern science is confirming the tribe's belief that the brain is the organ that processes who you are.

Questions like "Who are you?" can produce an endless variety of responses that are, at the scientific level, all the result of the brain's processing abilities (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2013; Levitin, 2014). Because the brain is an elaborate system of networks forged from 90 billion neurons interacting with each other, we humans are able to experience existence (Kandel et al., 2013; Seung, 2012). Equally important is that the brain is adaptive and interacts with its surrounding environment on a molecular, cellular, systemic, and behavioral level. This interaction between the environment and the brain/body—which we are denoting as the entire nervous system—enables behavior, personality, survival, learning, and just about everything else you can do or imagine (Kandel et al., 2013). Although scientists have just begun revealing pieces of the mystery, studies correlating the brain to behavior have been traced back to ancient societies.

Fundamental shifts have been made in the science that studies brains in both the tools used to deduce knowledge (e.g., microscope) and the underlying ideology. Scientists are now able to empirically test ideas that have been previously hypothesized or overlooked. Relatively new concepts such as neuroplasticity (the altering of existing neural connections) and neurogenesis (the birth of new neurons) have profoundly advanced the understanding of the brain (Draganski et al., 2004; Kandel et al., 2013). Today, it is widely accepted that the brain is a malleable and an adaptive organ—a paradigm shift from the early twentieth-century ideology that the brain is a static organ (Hanson, 2009; Kandel et al., 2013; Levitin, 2014).

These discoveries would have been impossible without the advent of modern technology to provide data along with new conceptual insights to interpret (and extrapolate) their significance. Both neuroimaging and microscopy have unveiled the increasingly complex and intricate ways in which the brain works. In interpreting these data in novel approaches, scientists have come to understand that these connections between neurons, or neuronal pathways, are endlessly changing and are essential in normal brain functioning, specifically for learning and development (Wickens, 2014).

History of the Brain

For almost as long as there have been written records, there has been an acknowledgment of the brain's role in cultivating the sense of being (Hanson, 2009; Kandel et al., 2013; Siegel, 2007). Currently, the oldest written report of the brain's function with a sense of "behavior" dates back more than 5,000 years ago, somewhere around 3,000 BCE, and was written by the ancient Egyptians (Kandel et al., 2013). Of all the known papyruses, the Edwin Smith Surgical Papyrus is the first to depict two cases where an injury to the brain correlated with psychological and physiological changes. In these reports, two individuals suffered injuries to the head and developed aphasia, the loss of the ability to produce or understand speech. People with aphasia may forget specific words or may be unable to speak, write, or even read. Let us quickly note that aphasia affects the ability to access thoughts and ideas through language, not the thought or idea in and of itself (intelligence). The type and extent of aphasia, we now know, can be predicted by damage to specific areas in the brain (Kandel et al., 2013). For as much as these early accounts seem elementary, they are the first systemically written medical records of the brain.

Advancements in technology permitted new inventions that allowed a deeper look into the brain. The advent of the microscope and procedures that could stain neurons allowed for a closer view of the brain and permitted scientists, like Santiago Ramón y Cajal, to classify different types of neurons (Wickens, 2014). Santiago Ramón y Cajal, who is considered one of the founding fathers of modern neuroscience, was the first to illustrate the single functional unit of the brain: the neuron (Carter, 2014; Wickens, 2014). His work earned him the 1906 Nobel Prize in Physiology. Neurons are the cells in the brain that allow parts of the brain to communicate with other areas in the brain and the body. Santiago Ramón y Cajal published the first illustrations of the neuron in 1899. Today, it is estimated the human brain has roughly 90 billion neurons that collectively work together (Seung, 2012). However, in the nineteenth century the neuron was just emerging and much science exclusively focused on sections of the brain and their potential associated responsibilities for behavior.

Modern neuroscience is beginning to understand how the brain operates and the intimate relationship it has with behavior, decision making, and even learning. These discoveries would not have been possible without advances in technology that are able to actually measure these changes. A radical invention in modern neuroscience was conceived at SUNY Downstate Medical Center, in 1972 by Raymond Damadian (Imperato, 2011). Damadian invented the magnetic resonance scanning machine. These machines provided the first methods that could produce a look at the anatomical structure of the human brain in vivo (Wickens, 2014). Today a magnetic resonance image (MRI; the abbreviation can also stand for magnetic resonance imaging) provides a physician or scientist with a black-and-white image of the brain's structure, which can then determine if any abnormalities are present and provide metrics like volume and density while the patient is awake. The advent of the MRI has been the foundation of many other neuroimaging modalities, such as functional MRI (fMRI) and diffusion tensor imaging (DTI), which directly measure function and connections, respectively (Assaf & Pasternak, 2008).

These technologies have thus provided a base for which scientists can begin to investigate how the brain and behavior complement each other. Researchers have, for almost as long as the brain has been studied, debated the importance between structure and function. Park and Friston (2013) suggested,

> (I) the relationship between structure and function is an integration problem, (II) the organization of structural networks supports local and global integration, (III) the inherent context sensitivity of functional integration mandates a divergence of functional connectivity from structural connectivity, and (IV) understanding the dynamic configuration of connectivity will benefit from theoretically informed and realistic neuronal models. (p. 1238411)

In other words, current and future research should seek to champion the integration problem between structure and function by focusing on neuronal pathways at the macro (connections between structures) and micro (connections within structures) levels rather than the traditional anatomical approach, which associates specific regions of the brain with single functions. Just think what following a line of inquiry like this could mean for advancing how we design, deliver, and evaluate higher education.

We next deal with the nuances of neuroimaging and address some common and important questions. Is more activity a good thing? Do I want to increase the size or density of my cortex? And, more important, how do we know that such answers are good or bad?

How Scientists Examine the Brain

The way we think about the brain is influenced by neuroimaging technologies because they are the sole source of images representing the elusive object of cognitive research. Anatomists and pathologists have been immune to this dependency because they observe and handle the real thing. For these scholars, neuroscience begins at autopsy. Upon the removal of the calvarium—the portion of a skull including the braincase and excluding the lower jaw or lower jaw and facial portion—the brain presents itself as a squishy, bloodshot, gelatinous blob encased in a thin membrane (the meninges), just like the egg's yolk. Only after fixation with the preservative formalin—a clear aqueous solution of formaldehyde containing a small amount of methanol—does the brain assume the familiar pale and rubbery appearance and lend itself to neurological scrutiny.

What has been learned about the brain from gross dissection? A great deal. Every neuronal structure or fiber tract was identified and classified postmortem long before computed tomography (CT) and nuclear magnetic resonance (NMR) technologies afforded views of soft tissue inside of our skull (Wickens, 2014). Bear with us as we return to the main idea of this chapter, but consider this—new powerful telescopes have revealed the existence of new moons and solar systems, just as deep oceanic vessels have picked up new marine species and showed us ecosystems worthy of science fiction; conversely, MRI has not led to the discovery of any previously unknown brain structure. Arguably, the giant leap forward (indeed, a giant step for mankind) afforded by MRI was not in the realm of discovery, but in the field of diagnostics as we discovered how the brain functioned.

Noninvasive imaging has been extremely valuable in localizing pathological phenomena underlying neurological symptoms. Leveraging large-scale population-based imaging studies, we have identified markers of neurodegenerative and (far less reliably) psychiatric disease. Lesion and electrode localization studies in the cerebral cortex (Lashley, 1950; Penfield & Jasper 1954; Penfield & Milner, 1958; Penfield & Roberts, 1959) not only established a topography of cortical function (foretold by Franz Gall—yes, the phrenology guy) but also provided the conceptual foundations for modern brain mapping. In recent times, the MRI became the tool of choice not only to investigate structural markers of neurological disease but also to study the functional architecture of the brain.

A structural MRI (occasionally abbreviated as sMRI) relies on a strong, stable magnetic field (the strength of which is measured in Tesla, or "T" units) surrounding the body and the excitation of hydrogen atoms by pulses that gradient coils produce at different angles (Kandel et al., 2013). The technique targets hydrogen atoms of water molecules that are present in "soft" tissue (as opposed to "hard" tissue such as bone or enamel that can be seen with X-rays). Image contrast distinguishing between gray and white matter in the brain is created by the different rates of relaxation of hydrogen atoms toward the original state of alignment with the main magnetic field. If hydrogen atoms were a crowd of cadets being trained on a field and the main magnetic field was the sergeant keeping them at attention, then the gradients would be lieutenants loudly giving them alternate orders to face this or the other direction. If after they face one side of the field they are allowed to spontaneously relax back into their original stance, they would do it at different speeds depending on whether they are standing deeply in sand (white matter) or on cement (gray matter). A tougher, more authoritative sergeant (a stronger magnet), means a more uniform assembly and clearer relaxation effect—and better image quality from higher-strength magnets in MRI machines.

Anatomical images acquired by sMRI provide the topographic substrate for mapping brain activity—that is, determining where particular motor, perceptual, and associative cognitive functions, including learning, are supported in the brain. The fMRI localizes signal related to neuronal activity based on the relative paramagnetic properties of oxygenated versus deoxygenated hemoglobin as blood perfuses areas that are metabolically active and oxygen is exchanged (Jezzard, Matthew, & Smith, 2001). In other words, when an individual engages in a specific activity or thought, an fMRI is able to distinguish between the areas of your brain that are being used and those that are not.

Since the mid-1990s, widespread access to research scanners spurred a "land run" to map functions in the human cerebral cortex combining sMRI, fMRI, and a variety of paradigms that emulated and validated earlier data from electrode or lesion mapping in experimental primates. The cortical surface of the brain gradually subdivided into distinct parcels that "activated" in response of specific tasks or conditions. Often the experimental paradigm involved comparing a condition where a particular element or attribute was present with one where it was absent (a "subtraction" paradigm); this is, for example, how several visual areas specific to color, motion, or faces were identified in the occipital lobes (Tootell et al., 1995; Zeki, 1993). The parcellation of the cerebral cortex by fMRI validated classical anatomical studies of the early twentieth century, such as those of Korbinian Brodmann (1909), where he charted cortical fields based on microscopic features. Actual overlap between functional fields defined by MRI and areas identified in classical monographs and a few modern revivals of the architectonic method that defines cortical areas based on microscopic features of neuronal morphology (Annese, Pitiot, Dinov, & Toga, 2004; Zilles et al., 1995) was a topic of debate, crucial because the human brain, and the cerebral cortex in particular, shows a very large degree of variability across different individuals. It is important to know if there is a common design in spite of differences in shape. In other words, can one predict the position of a specific function based on anatomical landmarks? Neurosurgeons surely would like to know.

In neurosurgeons' pursuit of understanding localized function, we should acknowledge contributions made by a few celebrity lesion patients. We begin with Phineas Gage, the man who survived a metal rod that blasted through his left eye socket and frontal lobe and was left with a bizarre change in character, especially a lack of restraint in social interaction. If Gage's long-term symptoms might have been exaggerated (Macmillan, 1996), Monsieur Leborgne's were pervasive. Leborgne was described by Dr. Paul Broca in 1881 as another lesion patient who suffered from seizures and lost the ability to utter any sound but "tan" after age 30. Moreover, in Leborgne's case, the patient's brain was actually preserved at autopsy. The lesion discovered on the middle part of the patient's left frontal lobe led Broca to the first convincing case of localization of function. Broca's name—and, thus, this cortical region—is indelibly synonymous with language, or, to be more precise, with speech.

In the 1950s, Henry Molaison, formerly known as Patient HM, underwent removal of a portion of his hippocampus and amygdala, a surgery intended to put an end to his life-threatening seizures. However, Molaison's seizures were not the only thing that ended; so, too, did his ability to form any new memories, a condition referred to as anterograde amnesia. While Henry could effortlessly recall events from his entire preoperative life, he could not remember anything just prior to his operation or anything that happened to him after his operation. From this landmark case, scientists have determined that the hippocampus has a fundamental role in memory. Henry was able to learn new skills, such as tracing a five-pointed star while only being able to watch his hand in a mirror. He became better at mirror drawing across the days, achieving a skill equivalent to that of anyone his age with intact temporal lobes, but could not consciously recall that he knew how to perform those new skills (Milner, 1962).

So far, we have talked only about gray matter; truth be told, gray matter mattered most to brain mappers until very recently. That is, until a new application of MRI was used to measure water diffusion in the brain, specifically in the white matter, hence the name of the method, diffusion weighted imaging (DWI). The white matter is principally composed of myelinated fibers (explained in more detail in Chapter 2); therefore, the diffusion of water molecules is at least theoretically restricted (termed *anisotropic* or exhibiting properties with different values when measured in different directions) unless events such as a stroke or tumor disrupt the fabric of the tissue. For this reason, DWI is used as a diagnostic tool; however, if water molecules move uniformly in one major direction, it could be assumed that the restriction follows the trajectory of axonal bundles (movement away from the cell body). Diffusion tensor imaging (DTI) measures the diffusion of water molecules along multiple axes and calculates the predominant orientation of diffusion. The results are displayed as color-coded orientation maps and "solid" connectivity maps. Interesting to note is that the content of the frame also approximates the size of a single pixel in an MRI image.

In highlighting how scientists study the brain, we are hoping you will move into the next section with an awareness of *how* we know *what* we know today. Emerging technology will likely provide us with new understandings in the future. And as Park and Friston (2013) asserted, the important question for higher education leaders revolves around understanding the integration of structure and function and aligning that understanding with design, delivery, and evaluation of higher education.

Regions and Structures of Interest

As we mentioned, at this point, there is agreement among scientists that to experience (or to become aware of) anything (emotional, physical, computational) it must be processed through the brain, the entirety of the nervous system (Hanson, 2009; Levitin, 2014; Siegel, 2008). While we can hope to increase our understanding of which specific structures have specific functions, particularly when it comes to learning and development, there is still a lot we don't know. Perhaps, it is easier to convey this by using a house as an analogy.

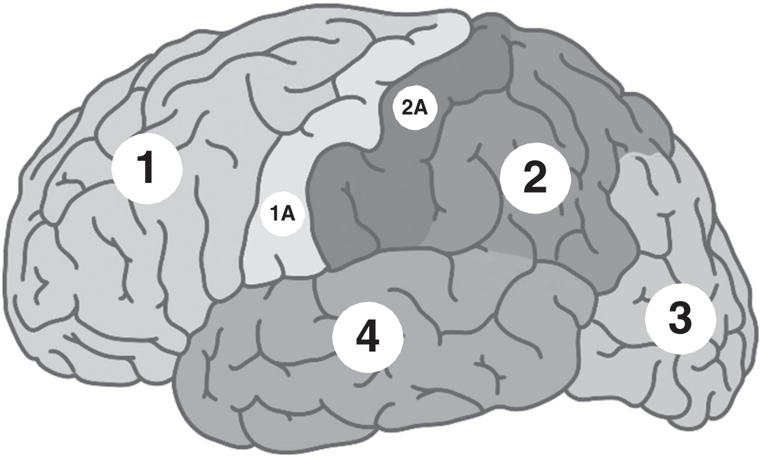
Houses have multiple rooms, and the bigger the house, the more rooms; the more rooms, the more specific each room function becomes. That is to say, most houses have a bedroom, and in that bedroom is a closet for clothes and in that closet are drawers for underwear, socks, and so on. However, there are those houses in well-off places like Beverly Hills that have not only a bedroom but also an additional room for clothes and perhaps another for shoes and coats and so on. Imagine the human brain as a mansion that sits at the summit of Beverly Hills with so many rooms one begins to lose count. However, the "rooms" in the brain have functions that have developed from other functions or behaviors, or "rooms." In addition, the more rooms, the more hallways connecting the rooms in the mansion. The separation of all primary functions into specific rooms ensured our survival, safety, and creativity, among other functions (Penfield & Rasmussen, 1950). So, in the house in Beverly Hills, someone may have pants in the room whose function is to store coats or they may have socks in the room where the hats are kept. That wouldn't make much sense, but it happens and we don't really know why.

Throughout history, many neuroanatomists tried to divide the brain into specific structures that could then be localized for a unique and specific function. However, as we have touched on, that may be an impossible and fruitless endeavor (Hanson, 2009; Seung, 2012; Siegel, 2008). The relationship between structure and function of the brain is now considered to be more about connections between individual neurons and structure (referred to as the *connectome*) and less about attributing a specific function to a specific area (Seung, 2012). While it is common for neuroscience literature to assign a function or set of functions to a specific structural region of the brain, it is important to understand that the connections that lie between and within these regions influence both the function and structure. Thus, neural connections have an equally important role in determining behavior than any isolated structure (in most cases). However, research on the neural connections has just started to emerge and therefore scientists have been able to determine only certain structures, or rooms, and their primary function based on the most common item in that room. Imagine walking into a room and seeing a twin-sized bed, a small fridge, and a Taylor Swift poster. Your first thought may be that this room is a student's dorm room. However, after you spend a little more time in the room other items like a motorcycle and a dishwasher emerge, and the twin-sized bed is actually a long table. Perhaps your first thought was wrong; this isn't a dorm room! It's someone's bedroom. However, what is the dishwasher doing in a bedroom; let alone the motorcycle? This is similar to current methods in neuroscience. We have been to almost all the rooms in the mansion and have attributed a function based on initial observations, and in some areas, scientists are beginning to take a fourth or fifth look, but still have questions about some of the smaller anomalies, like the dishwasher. So, for simplicity, we only discuss relevant structures pertaining to this book.

Toga (2013) provided a comprehensive resource of basic neuroanatomy. The brain is divided into two nearly identical sides: the right hemisphere and the left hemisphere. These two hemispheres are able to communicate with each other via commissures—bundles of fibers that propagate an electrical message between hemispheres—most notably the corpus callosum. The most prominent characteristic of the brain is the cerebral cortex, which is the outmost shell of the brain that covers both hemispheres. This convolving layer, which looks similar to a walnut, is often referred to as gray matter within the literature (Carter, 2014). As previously mentioned, there are two types of "matter" in the brain, gray and white matter. There are two different colors of matter because every neuron has both a "gray" and "white" part, which will be discussed in more detail in Chapter 2. The size of the cerebral cortex distinguishes humans apart from other species, and the convoluted nature of the cerebral cortex permits more neurons to fit into a smaller area. For example, if you take a piece of paper and crunch it into a ball, it fits into a much smaller area. Having more neurons then allows a larger capacity for learning, remembering, and thinking (Roth & Dicke, 2005).

Additionally, the brain is divided into four lobes: frontal, parietal, occipital, and temporal. Figure 1.1 provides a visualization of the location of these lobes. The frontal lobe (notated as 1 in Figure 1.1) is the latest in the evolution of the human brain and is responsible for higher-level thinking such as critical thinking, problem solving, planning, production of speech, and other executive functions. The parietal lobe (2) is responsible for understanding

Figure 1.1 Lobes and structures of the human brain.



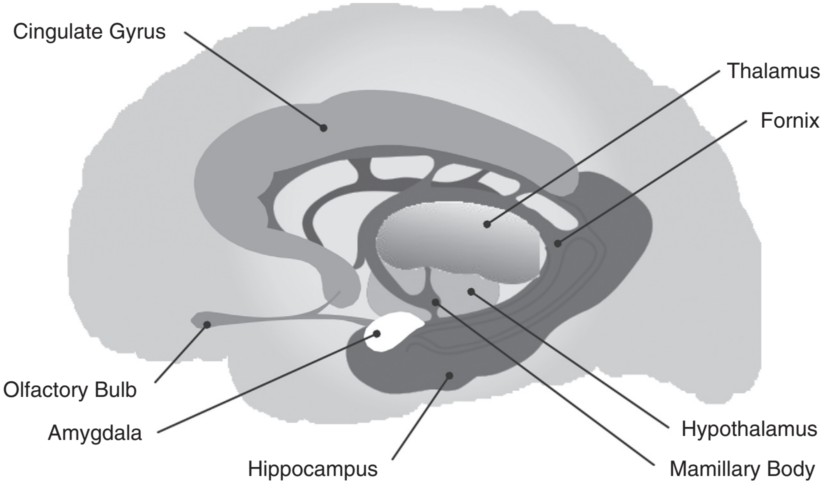
Note. Each number represents a certain area of the human brain that is of interest to this study: (1) prefrontal cortex/frontal lobe; (1A) primary motor cortex; (2) parietal lobe; (2A) primary somato-sensory cortex; (3) occipital lobe; (4) temporal lobe. Created by Matthew R. Evrard, 2014, and reproduced with his permission.

language, integrating visual processes related to "where" an object is, and facets of attention. The occipital lobe (3) is localized primarily for vision. Finally, the temporal lobe (4) subserves memory, navigation, hearing, and the integration of visual processes related to "what" an object is.

However, it is important to understand that at this level of division there are many other areas of the brain such as the midbrain, hindbrain, insula, and limbic system (Toga, 2013). (See Figure 9.1 for an image of these parts of the brain.) It might be helpful to understand that the cerebral cortex covers the entire surface of the brain—the insula is a division of the cerebral cortex hidden in the lateral fissure. The midbrain has many sensory tracts (bundles of nerves) that travel between your brain and body; in addition, it is responsible for reflexes, addiction, reward, and motivation (Kandel et al., 2013; Toga, 2013). On the other hand, the hindbrain controls basic functions like breathing, heart rate, and correcting various motor behaviors (Toga, 2013). In the following sections, we discuss specific brain structures, their function, and how these structures connect to other areas of the brain.

The limbic system (Figure 1.2) refers to a collection of subcortical brain structures that, anatomically, lie in the middle of the brain (medial, beneath the cerebral cortex). The entire system has far-reaching functionality, having a prominent role in emotion, stress, anxiety, memory, learning, navigation, and motivation. Interestingly, while all other senses project through the

Figure 1.2 The limbic system of the human brain.



thalamus, smell is the only sense that has direct limbic system projections. This explains why certain smells can trigger more intense and vivid emotions than other stimuli (Binder, Hirokawa, & Windhorst 2009). Additional structures related to the limbic system include the amygdala, hippocampus, cingulate cortex, fornix, thalamus, and hypothalamus.

As we have mentioned time and time again, the brain is expansively complex with 90 billion neurons and 10 times the amount of connections, called synapses, between those neurons. As such, scientists are just beginning to understand how the brain operates. But what remains evident is that the connections between neurons matter and can influence learning. This means that scientists may finally understand why there is a Britney Spears album or a dishwasher in what they thought was the bedroom. *Connectionism*, the study of the connections between neurons, attempts to describe how areas of the brain work by examining the intricate pattern of neuronal networks (Fodor & Pylyshyn, 1988; Seung, 2012).

Through everyday experiences, the connections between neurons can change, which is one current theory as to why humans are able to learn and remember (Seung, 2012). It is likely that your neurons are reorganizing themselves at this very moment because you are reading this book. As exciting as that is, the connections between neurons are not entirely shaped by experience, but also by genes. In Sebastian Seung's (2012) book, *Connectome*, he describes the brain and its neurons as a forest where the trees are the neurons; the roots and branches are the connections between the neurons. With that example, it becomes easier to envision how the brain's neurons are expansively connected to one another, and how certain experiences can alter the paths between.

We have explained the importance of the connectivity of the brain while also explaining that functional areas are not necessarily completely regulated by specific areas of the brain. We now explain our operational understanding of what scientists know to be true today. As we describe each section of the brain relevant to the content of this book, keep in mind that you have, in essence, two of each section, one in the right hemisphere of the brain and one in the left hemisphere. As you read, also remember the house analogy; shoes can be found in the coat closet.

The Amygdala

The amygdala is one of the primary structures of the limbic system and is the emotional processor of the brain; therefore, its relevant function to the material in this book relates to regulating perceptions, reactions to fear and aggression, reward, and positive affect (LeDoux, 2003). It is located medially in the temporal lobes and is widely connected to other areas of the brain related to fear, facial responses, stress, and aggression (Coccaro, McCloskey, Fitzgerald, & Phan, 2007; Pare & Duvarci, 2012; Roozendaal, McEwen, & Chattarji, 2009). Accordingly, as an area responsible for orchestrating anxiety and the fight-or-flight response (LeDoux, 2003), to what extent the amygdala's activity can be modified is of primary interest. Another interesting point we should mention is that the amygdala resides right in front of the hippocampus; the two share many intimate connections to determine and drive some behaviors associated with memory (Richter-Levin, 2004).

The amygdala is the output of the emotion center. It receives sensory information almost immediately from the thalamus, which provides the amygdala with so-called low-resolution information (Kandel et al., 2013). Sensory information also projects from the thalamus to the cortex and from the cortex to the amygdala, providing so-called high-resolution information (Kandel et al., 2013). While the high-resolution sensory information takes longer to arrive in the amygdala, it carries more information that is beneficial for an emotional response. However, low-resolution sensory information moves quickly to the amygdala and can signal for us to immediately react to threatening situations.

The Hippocampus

The hippocampus is located within the temporal lobes of the brain, immediately behind the amygdala. Additionally, the hippocampus is connected to various areas of the brain important to the regulation of emotion including the prefrontal cortex, amygdala, entorhinal cortex, and hypothalamus

(Amaral & Lavenex, 2006). The primary function of the hippocampus is in learning systems, navigation, and memory, specifically conscious memories for facts and events (Andersen et al., 2007; Bliss & Collingridge, 1993; Jacobs et al., 2013; Kandel et al., 2013; McClelland, McNaughton, & O'Reilly, 1995; Squire, 1992).

The 2014 Nobel Prize in Physiology and Medicine was shared by John O'Keefe, May-Britt Moser, and Edvard Moser for their work connecting the hippocampus to navigation. The hippocampus is also a part of the limbic system (the brain's emotional processor), so when a memory is stored, the context (e.g., emotion) can remain associated with it. The hippocampus has bidirectional projection to the cortex and amygdala (Andersen et al., 2007). The connections between the hippocampus and amygdala are thought to be a mechanism undergirding contextual fear (Andersen et al., 2007). In this way, the amygdala is activated due to a perceived threat and the hippocampus then can associate this fear with other contexts in that moment (Andersen et al., 2007). Accordingly, there is general agreement that the stress response can be modulated by memory, among other things, (Kim & Diamond, 2002; Kim, Lee, Han, & Packard, 2001). Take, for example, the ability of certain memories to elicit an emotion, even if that emotion isn't happening in that exact moment. Memories have the potential to heighten or suppress stress.

The Thalamus

Located between the cerebral cortex and the midbrain, the thalamus is the major relay station for neural connections from one area of the nervous system to another, and because of its pervasive role it has many connections to other areas of the brain (Carter, 2014). The thalamus screens, sorts, and preprocesses sensory information (e.g., movement, vision, touch, pain) and then sends it to the cerebral cortex for integration and decision making (Carter, 2014). As a part of the limbic system, the thalamus regulates sensory information and controls sleep and awake states of consciousness (Kandel et al., 2013). With the exception of smell, all other senses project to the thalamus before reaching the neocortex (Kandel et al., 2013).

The Hypothalamus

The hypothalamus has a major role to play in conscious behaviors, emotions, and instincts (Carter, 2014) and is located between the thalamus and brain stem. It integrates information from the nervous and endocrine system via the pituitary gland, which sits below it (Carter, 2014). (Note that the adrenal glands, parts of the endocrine system that sit atop the kidneys, are responsible for releasing hormones in response to stress, including cortisol, adrenaline, and noradrenaline.) The hypothalamus is known to commonly control fleeing, fighting, feeding, and reproducing (Joseph, 1996). It communicates with the endocrine system by releasing and receiving hormones in the bloodstream (Joseph, 1996). The secretion of hormones into the bloodstream has extensive and long-lasting psychological and physiological responses as the body breaks down these hormones at a slow rate (De Kloet, Karst, & Joëls, 2008). Because hormones influence feelings and the rate of secretion and absorption of hormones can influence stress, the hypothalamus is also a player in the regulation of emotion.

The Prefrontal Cortex

The prefrontal cortex refers to the frontal lobe without the motor or premotor cortex, the most anterior part of the brain. The prefrontal cortex is the most recent lobe of the brain to evolve and is responsible for executive functions such as higher-level thinking and cognitive processes such as attention, planning, focusing, problem solving, comparing and evaluating, judgment, and decision making (Engle, Kane, & Tuholski, 1999; Kane & Engle, 2002; Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Miller & Cohen, 2001; Newman, Carpenter, Varma, & Just, 2003; Shallice, 1982; Shallice & Burgess, 1991).

Markedly, neuroscientists have observed extensive neural connections from this region of the brain to almost all areas of the brain, including the hippocampus, amygdala, thalamus, hypothalamus, and corticocortical connections (e.g., to regions of the parietal and temporal cortex) (Carmichael & Price, 1995; Fuster, 1988; Goldman-Rakic, Selemon, & Schwartz, 1984; Uylings, Van Eden, De Bruin, Corner, & Feenstra, 1991). This has led researchers to believe that the connections of the prefrontal cortex with the limbic system are what lead to prioritization, the linkage of memory and sensory input, and the ability to manage emotions, and thus the ability to self-regulate. Our interest in this part of the brain is most evident. Interestingly, in many psychological diagnoses such as attention deficit disorder, post-traumatic stress disorder, and schizophrenia abnormal prefrontal cortex activity is displayed in some way (Drevets et al., 1997; Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000).

Anterior Cingulate Cortex

The anterior cingulate cortex is the frontal part of the cingulate cortex located in the frontal lobe of the brain. It runs parallel to the corpus callosum (the major pathway that connects the two hemispheres) and is sometimes referred to as the cingulate gyrus. The anterior cingulate cortex has a role in rational cognitive functions, such as emotional control and associating emotional states with behavioral outcomes. In other words, let's imagine that in your reading of this book that the behavioral activity of reading elicited a feeling of joyful inquiry (of happily wanting to know more). What should follow is associative learning between the behavioral act of reading and the feeling of joyful inquiry. It may also signal a need for cognitive control over this association (Hadland, Rushworth, Gaffan & Passingham, 2003; Hayden & Platt, 2010; Kozlovskiy et al., 2012).

Insula

The insula, sometimes referred to as the insular cortex, is an additional layer of cortex (or gray matter) that lies underneath the external cerebral cortex. In fact, the insula cannot be seen from just looking at a human brain. The insula is beneath the temporal lobe, occipital lobe, and parietal lobe and lies posterior to the frontal lobe. The insula has a specific area where it topographically represents sound and has been connected to a host of functions that center on emotion regulation and homeostasis maintenance (Kandel et al., 2013). Such functions as perception, self-awareness, body awareness, sensing or awareness of "gut" feelings, empathy, activation of mirror neurons, and the ability to integrate sensation and emotion have all been associated with this area of the brain.

Sensory-Motor Areas

The sensory-motor areas of the brain reside anterior to the poscentral sulcus. In Figure 1.1, 1A is the primary motor cortex and 2A is the primary somatosensory cortex between these. Where the cerebral cortex convolutes inward is the central sulcus. The motor cortex, which resides anterior to the central sulcus, controls voluntary muscle movement (Kandel et al., 2013). That is to say, the motor cortex is sending messages to your body's muscles telling them to move or not to move. The somatosensory cortex, which resides after the central sulcus, evaluates all the incoming messages from your body (Kandel et al., 2013). In other words, it receives and analyzes a variety of messages from touch to pain.

As you recall, the brain has two hemispheres (right and left), which means the somatosensory cortex can be divided into left and right halves. The right side of your body has neurons that travel to the left side of your brain, and the left side of your body has neurons that travel to the right side of your brain (Kandel et al., 2013).

Basal Ganglia

The basal ganglia were originally believed to be solely involved with movement (the sensory-motor area), primarily because diseases such as

Parkinson's compromise the structure and consequently the function of the basal ganglia (Kandel et al., 2013). But this view is rapidly changing as the basal ganglia also have connections to other areas of the brain, such as the cerebral cortex, thalamus, and brain stem, making them a prominent structure in learning and development (Kandel et al., 2013). Together these structures are involved with not only movement, but also higher-level behaviors, including learning (procedural, habit formation, and developing routines), emotion regulation, executive function, and mood (Kandel et al., 2013). Think back to Henry Molaison, who had lost the ability to form new memories, but his basal ganglia remained untouched. Perhaps this can explain why he was able to learn new skills and procedures without any explicit recollection of having done them before.

There are five smaller subcortical structures (gray matter) that together make up the basal ganglia: the caudate nucleus, putamen, globus pallidus, subthalamic nucleus, and the substantia nigra. In emerging research, you may read about one of these subcortical structures; we thought it might be helpful for you to have this reference.

Language and Communication Centers

Most of language processing occurs in the cerebral cortex (the convoluted exterior on the surface of the brain). There are two distinct centers of the brain that are used in language and communication; both reside in the temporal lobe of the brain (Figure 1.3). Understanding both written and spoken language is made possible by Wernicke's area, which is located in the back of the temporal lobe close to where the occipital and parietal lobes meet (Kandel et al., 2013). The area associated with the ability to produce speech is also on the temporal lobe but located near the front of the brain (Kandel et al., 2013). While up to now you have had two of every structure, comprehension seems to be localized to a single side, and for an overwhelming majority of people it is the left. Thus, comprehension (oral, written, object recognition) appears to be a left-hemisphere process (Kandel et al., 2013).

Table 1.1 correlates the structures we've discussed with their respective area and function in the brain. Moreover, these structures all have a role in regulating emotion (Lupien, McEwen, Gunnar, & Heim, 2009). And we understand that the hippocampus and prefrontal cortex are associated with cognitive regulation.

There are many other structures in the brain, along with endless subdivisions of the ones we have mentioned. Again, we have shared only a few owing to their relevance to the topics in this book. What is important to remember beyond structure and function is that the neural connections between parts of the brain are incredibly dynamic.

Figure 1.3 Sensory-motor and language-processing centers in the brain.

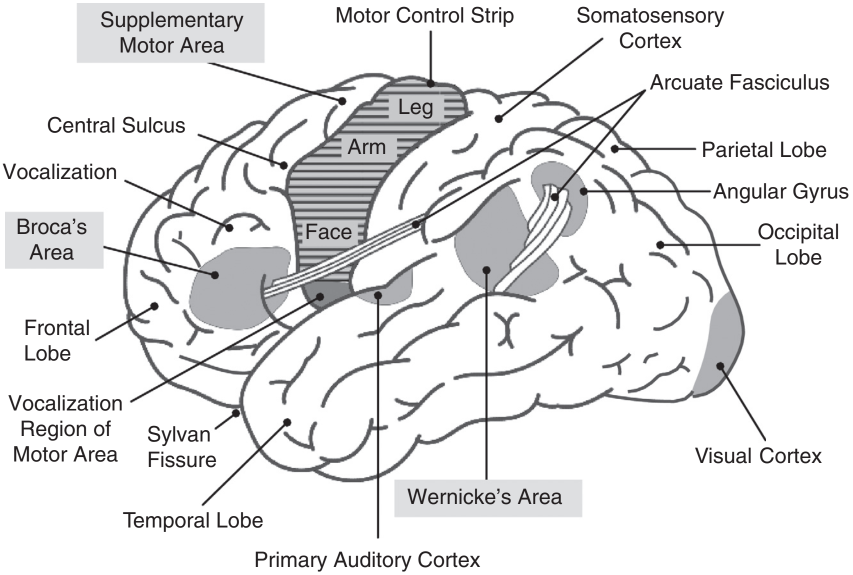


TABLE 1.1

Neurocorrelates of Function

Brain Structure	*Brain Lobe*	*Functions of Interest*
Amygdala	Limbic system	Flight-or-flight response, stress, anxiety
Hippocampus	Limbic system	Memory consolidation (short term to long term)
Prefrontal cortex	Frontal	Executive functions, attention, decision making
Hypothalamus	Limbic system	Communication between brain and body, four Fs (fleeing, feeding, fighting, and mating)
Basal ganglia	Subcortical	Movement, emotion regulation, learning, mood
Sensory-motor areas	Frontal/parietal	Input from environment/voluntary movement
Insula	Subcortical	Emotion regulation and maintaining homeostasis
Broca's area	Temporal	Production of speech
Wernicke's area	Temporal	Understanding speech, writing

Note. Adapted from Joseph, 1996; Kandel et al., 2013; LeDoux, 2003; Shallice & Burgess, 1991; Squire, 1992.

Neuroplasticity and Neurogenesis

As you are most likely aware, emerging research has demonstrated that our brains are malleable; in fact, they can change signficantly in response to our environment, behavior, and/or injury (Alvarez & Emory, 2006; Chan, Shum, Toulopoulou, & Chen, 2008; Chiesa, Calati, & Serretti, 2011; Goldin & Gross, 2010; Hölzel et al., 2011; Kozasa et al., 2012; Lutz, Slagter, Dunne, & Davidson, 2008; Pascual-Leone et al., 2011; Todd, Cunningham, Anderson, & Thompson, 2012). Notably, through intentional (or unintentional) actions, an individual is able to produce functional and structural changes in his or her brain. *Neurogenesis* is the brain's ability to produce new neurons, whereas *neuroplasticity* refers to the brain's ability to modify its connections with other neurons (Taupin, 2006). Granted, neurogenesis and neuroplasticity have not been identified in all regions of the brain, but these processes have been shown to be integral to many of the structures we mentioned such as the hippocampus (Kokaia & Lindvall, 2003; Pittenger & Duman, 2008). Consequently, neurogenesis and neuroplasticity in the hippocampus and prefrontal cortex are disrupted by chronic stress and anxiety (Lucassen et al., 2010; Lupien et al., 2009). We discuss this in more detail in Chapters 2 and 6.

In summary, considering that the amygdala, hippocampus, prefrontal cortex, and hypothalamus all have a role in regulating emotion, and that unregulated emotion may negatively affect neurogenesis and neuroplasticity (specifically in regions localized for memory and executive functions), a training program that seeks to regulate students' emotion as well as cognition, thus promoting critical thinking dispositions, may be effective if these regions can be targeted in the training process.

Editor's Summary Points and Questions to Consider

1. The brain's structure and functions are quite complex. Still, there are specific regions of the brain that can be associated primarily with specific functions. What specific structures and functions are compelling to your design, delivery, and evaluation of all learning and development opportunities?
2. The structures and functions of the brain that integrate emotion, memory, and thought are also quite complex and interrelated. How does reflecting on these integrated aspects motivate you to consider them when you design, deliver, and evaluate your courses and cocurricular programs?

3. Neural connections and pathways between and within functional areas of the brain are dynamic and can be changed. How does this motivate you to explore all of the ways in which you can intentionally design opportunities for students to change their brains in class and out of class?
4. The behavior, emotions, and activities we give our attention to become stronger and more automatic as we strengthen those neural pathways. What neural networks are you strengthening? What have you intentionally and unintentionally directed your attention toward?

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