1

Building a Smarter Brain

"Brain plasticity is the stuff of life. As long as you're alive, it's with you as a precious exploitable asset. Don't neglect to take full advantage of it."
—Michael Merzenich[1]

No matter what your age or current abilities, you have the potential to improve the knowledge and skills you need to develop to achieve your goals—in the form of your brain's amazing ability to change in response to learning. Recent research is overturning longstanding assumptions about the capacity of the human brain to change and improve. We now know that people, with the exception of some of those who have suffered traumatic brain injury, dementia, or other brain disorder, have the capability to change and grow their brains, especially those areas of the brain associated with attention, memory, and problem solving. These are the very areas we associate with becoming smarter. The term *neural plasticity* or *neuroplasticity* refers to how our thoughts, actions, and sensory input (what we see, hear, say, and touch) change the structure and function of the brain and how reinforcing that learning through repetition and practice strengthens those neural connections. When we focus our attention on information and engage in

Positively Smarter: Science and Strategies for Increasing Happiness, Achievement, and Well-Being, First Edition. Marcus Conyers and Donna Wilson.

learning activities, the neural networks associated with those activities grow denser and larger, leading to what Fotuhi describes as "enhanced brain performance."[2] In fact, these physical changes in the brain can be so significant that they can be seen by the human eye on MRI scans—and these changes can happen in weeks and months, rather than years.

Neuroplasticity in Action

In a regimen unlike any other in the world, London cabbies in training spend years memorizing their city's 25,000 streets and thousands of landmarks within a 6-mile radius of Charing Cross train station. Some of them take the Knowledge of London Examination, known simply as "the Knowledge," a dozen times, and only about half ultimately earn an operating license from the Public Carriage Office.[3] Neurologists Katherine Woollett and Eleanor Maguire conducted MRI brain scans of 79 taxi trainees and a control group before the training began and again three or four years later after they had completed their exams. Of the three groups during the second round of testing—trainees who had earned their licenses, trainees who had not passed the exam, and control participants—the scans detected an increase in gray matter volume in the posterior hippocampi, the area of the brain associated with spatial memory, of the first group, but not the other two. The researchers concluded that "specific, enduring, structural brain changes in adult humans can be induced by biologically relevant behaviors engaging higher cognitive functions."[4]

The cabbie research is among a number of studies conducted in recent years that show how the brain changes in response to learning. German scientists conducted brain imaging scans of medical students three months before their medical exams and immediately following the tests and compared them to scans of a control group of students. The brains of the medical students showed increased volume in areas of their parietal cortices and the posterior hippocampi, regions of the brain associated with memory retrieval and learning.[5] Another study compared the brains of

professional musicians who practiced with their instruments at least an hour per day to the brains of amateur musicians and non-musicians. The scans showed significant increases in gray matter volume in brain regions associated with motor, auditory, and visual-spatial functioning of the professional musicians in comparison with the other groups; amateur musicians also showed more development in these regions than non-musicians. The researchers concluded that those differences reflect the impact of "long-term skill acquisition and the repetitive rehearsal of those skills."[6] These studies demonstrate neuroplasticity in action as the brain changes in response to learning new knowledge and developing skills. They also disprove long-held assumptions that adult brains cannot build new neurons.

Other research challenges the notion that IQ is unchangeable—that we are born with a certain level of intelligence and cannot "move the dial" on our intellectual capacity. As it turns out, that notion may be wrong on both counts: Research now suggests that we can increase our intelligence throughout life and that heredity may account for only a relatively small portion of our cognitive potential. By conducting DNA analysis and comparing IQ test results from people tested at age 11 and again when they were 65 to 79, Scottish researchers concluded that only about 24 percent of intellectual development is determined by genes; the rest owes to one's experiences and environment throughout life.[7] In another study, 33 adolescents ages 12 to 16 took IQ tests and underwent brain scans in 2004 and then repeated the tests three or four years later, now at ages 15 to 20. There were no cognitive interventions or tests between the two periods; in fact, the teenagers were not even told they would be invited back for further testing. The researchers' aim was to measure whether intellect, as measured by the Wechsler Intelligence Scale for children and adults, would change and to see if IQ changes would be reflected in brain structure. They discovered significant shifts up and down in IQ—ranging from a drop of 20 points for one participant to a gain of 23 points for another in verbal IQ, a range of –18 to +17 in performance IQ (nonverbal skills, including spatial reasoning and problem solving unrelated to language), and a range of –18 to +21

in full-scale IQ—along with corresponding changes in gray matter density and volume in the brain scans.[8]

Scientists have varying opinions about what IQ tests tell us about people's intellectual capacity. These differences of opinion are evident in debates over what causes the "Flynn effect," the steady rise in IQ levels around the world since the 1930s, which was first identified by New Zealand political science professor James Flynn. Are today's students really smarter than their grandparents, or are they just better test takers? Some social scientists attribute these IQ gains to the wider availability of public education, the increase in years spent in formal education, and even on improved nutrition. Others suggest that IQ tests evolve with each generation to emphasize the skills most prized during that era. Still others argue that this trend calls into question the reliability of IQ tests in measuring "pure" intelligence.

As we will explore in more detail later in this chapter, intelligence is multifaceted—and people have the capacity to improve many aspects of their intellectual functioning, including creativity, analytical problem solving, recall, and mental agility. In sum, then, the conclusion we can draw from this research on the mind and brain, notes Edward Hallowell in his book *Shine: Using Brain Science to Get the Best from Your People*, is that "we can all get smarter and wiser and happier the longer we live. The conventional, dreary wisdom that people can't change is scientifically incorrect."[9]

Your Brain at Work: A Continual Construction Zone

As the control center in charge of all aspects of operating a living creature—from controlling basic functions such as heart rate and breathing to accepting and interpreting input from the senses to facilitating thought and experiencing emotions—the brain is understandably complex. As we explore the role of the brain in our efforts to improve our positive outlook, knowledge, skills, and well-being, we will present research findings on the workings of the cerebral cortex and the limbic system. The *cerebral cortex* is the

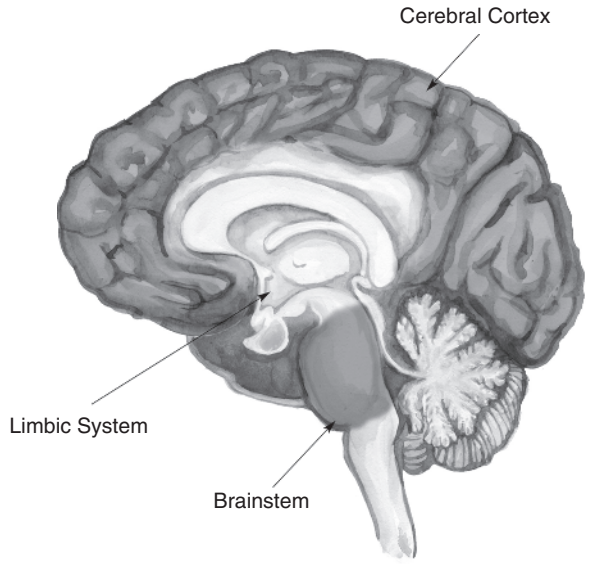

Figure 1.1 A Three-Part Brain Model. © 2015 BrainSMART, Inc.

outer surface of the human brain that grows so extensively that it folds in on itself in labyrinth fashion, giving it a cauliflower appearance. The largest part of the brain is the neocortex, so named because it is the newest part of the human brain (the terms *cerebral cortex*, *cortex*, and *neocortex* are often used interchangeably). In his book *Boost Your Brain*, Majid Fotuhi describes the cortex as "ground zero for ... perceptual awareness, thought, language, and ability to make decisions."[10] The *limbic system* is located directly under the cortex and shares several structures with the cortex. A third major region is the brainstem, which connects the brain to the spinal cord (see Figure 1.1).

The brain reflects the symmetry of the human body: We have two eyes, two ears, two arms, two legs, and two hemispheres of the cerebral cortex. The right and left hemispheres are connected by a band of nerve fibers called the corpus callosum. The right hemisphere controls most motor functions on the left side of the body, while the left hemisphere controls the right side. That's why a stroke or other type of brain damage in the left hemisphere may

hamper motor function on the right side of the face, the right arm, and the right leg.

Though they are near mirror structures, the two hemispheres have some specialized functions. Areas of the left hemisphere are associated with language, math, and logic processing, while the right hemisphere supports spatial abilities, facial recognition, and myriad other functions. But even though some thinking abilities seem to be more dominant in one hemisphere or the other, both sides are involved in most complex cognitive processes. For example, one of the left hemisphere's specialized functions is helping to decipher sounds that form words and applying the rules of syntax to find meaning in the order of words, while the right hemisphere is more attuned to the emotional aspects of language conveyed by rhythm and intonation.[11] The two hemispheres also play differing roles in modulating optimistic and pessimistic responses to external stimuli, with the left hemisphere exhibiting greater activation in positive interactions and the right hemisphere more active in situations involving stress, fear, and negative emotions.[12] These findings underscore that emotions are not just fleeting states but have a biological component.

The hemispheric division provides additional evidence of the brain's plasticity in action. In several much-studied cases, neurologists disconnected the brain hemispheres to eliminate debilitating seizures in patients with severe epilepsy. With extensive support and therapy, these patients have, to varying degrees, been able to "retrain" their brains to take over some of the functions previously handled by one or the other hemisphere. The fact that the brain can so extensively rewire itself demonstrates that "the brain is far more malleable than we once thought."[13]

Each hemisphere of the cortex is further divided into four lobes (see Figure 1.2); these paired lobes have specialized functions:

- The *frontal lobes*, located behind and just above the eyes in front of the central sulcus (a deep groove in both hemispheres that separates the frontal and parietal lobes), are the centers of planning, decision making, problem solving, and control of body

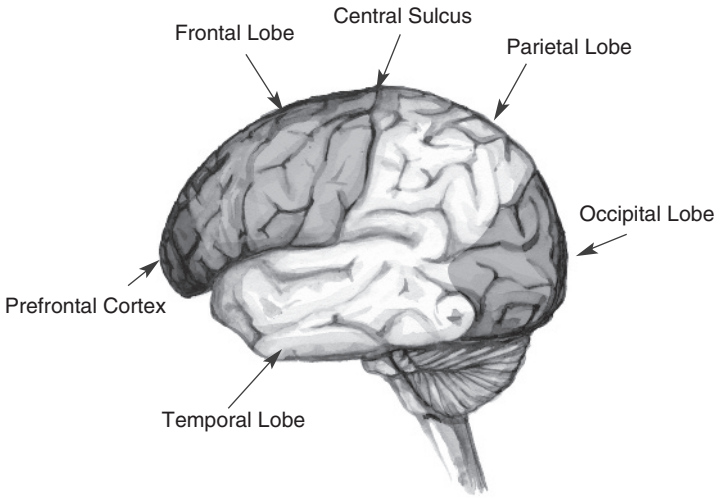

Figure 1.2 The Four Brain Lobes. © 2015 BrainSMART, Inc.

movements. The *prefrontal cortex*, located directly behind the forehead, is interconnected to every distinct functional unit of the brain and thus coordinates and integrates most brain functions. Often referred to as the brain's "CEO" or "conductor," this region is essential to both foresight, which is necessary for rational, logical thought, and the insight required for empathy and social skills.[14] The prefrontal lobes are also the area of the brain that undergo the most extensive postnatal development.[15]

- The *temporal lobes*, on each side of the skull, are the centers for processing what we hear, smell, and taste. These lobes help us understand verbal communications and other auditory input and play a role in higher-level visual processing as well.[16]
- The *parietal lobes*, located between the frontal and occipital lobes and just above the temporal lobes, aid in navigation, the processing of tactile sensations (or input from our skin), and the orientation of our body and limbs.
- The *occipital lobes*, along the back section of the cortex, are the brain's visual processing center, responsible for the recognition

of shape, depth, color, and movement. You can read the print on the pages of this book and distinguish the facial features of people around you thanks to your occipital lobes.

Another area of the brain that plays an important role in how we interact with the world around us is the *limbic system*, a group of interconnected structures in the frontal and temporal lobes and deeper parts of the brain associated with regulating emotional activity and memory.[17] Some neuroscientists refer to this area as the *limbic lobe*; it is sometimes distinguished from the cortex, or "thinking brain," as the "feeling and reacting brain."[18] This region is also key to memory, as the location of the hippocampus, which is "the gateway for new memories and essential for learning [as] the most malleable of brains regions."[19] The hippocampus receives input from throughout the neocortex and the limbic system.

The limbic system is also home to the amygdala, a paired structure in each brain hemisphere with reciprocal connections to many parts of the brain. The amygdala causes that startle response we have to external stimuli we might perceive as threatening, which gives it the nickname "fear button." When it detects the potential for danger, the amygdala immediately signals another structure in the limbic system, the hypothalamus, to take protective action (fight or flight). The frontal lobes also receive signals from the amygdala and process whether the stimuli represents a real threat. When you see a slender object in the grass next to your walking path, for example, the amygdala may sound the alarm of "Snake!" until the frontal lobes process the input and respond, "Nope, just a stick."

New imaging technologies have been useful in pinpointing the functions of these various structures—and in furthering our understanding of the brain's plasticity. How does your brain form new neurons and synapses, and is there anything you can do to optimize those processes? Several functions are at work to power the neurocognitive synergy that supports learning, recall, and the development of knowledge and skills. Fotuhi refers to the "Core 4" of growing your brain: increasing the number of brain cells, adding

synapses, bolstering neuronal connections through myelination, and enhancing blood flow in the body and brain.[20]

Neurogenesis The most basic operating units of the brain are neurons, nerve cells that transmit signals in the form of electrical impulses. For much of the previous century, many scientists believed *neurogenesis*, or the creation of new neurons, to be a function of young brains; this view held adulthood to be a period of steady, inevitable decline in the number of brain cells and, thus, of brain function. A major epiphany in the 1980s was accompanied by bird song, as researchers reported that the brains of adult songbirds formed new neurons as they learned new songs.[21] It seems that you can teach an old bird new songs just as you can teach an old dog new tricks—and both of their brains form new neurons as a result of that learning!

In the years since those findings of neurogenesis in adult brains, there has been an explosion of research about what regulates the formation and development of human brain cells, from the actions of stress hormones called glucocorticoids that appear to impair neuronal production to brain chemicals like BDNF (discussed later in this chapter) that support brain growth. For example, through their research focusing on the hippocampus, Fotuhi and his colleagues have found that it is possible to "not only reverse the brain atrophy associated with aging but also expand the brain's size—even before shrinkage begins."[22] The key is to make the most of the new neurons that form regularly by taking "brain-healthy" actions that enhance neuronal survival.

Synaptogenesis Neurons form neural networks through "synaptic connections" between the cells; the more activity is transmitted through those networks, the stronger the connections. However, when these connections are not reinforced with regular stimuli, they are weakened and ultimately eliminated. The formation of neural connections is known as *synaptogenesis*, while decreases in those networks are referred to as *pruning*. Pruning may sound like a bad thing, but it's a natural and useful process that ensures that the brain operates efficiently. Both of these processes are

behind the structural changes that encode learning and memories in the brain, and they are essential in continually developing the skills and knowledge you need to accomplish the goals you set for yourself.

A primary force at work in developing new knowledge and skills is *experience-dependent synaptogenesis*, the formation of synaptic connections in response to our experiences and environment. These connections don't just form naturally; they are not an automatic product of getting another year older and more mature. Instead, they are a direct result of what we hear, see, taste, smell, do, and think. And the more we think about or do something, the stronger these connections get. Experience-dependent synaptogenesis is behind the learning that results when we expand our vocabulary, take up a new hobby like knitting or woodworking, practice a new piece of music on our instrument of choice, or become familiar with the rhythm of a dance step. It happens because we decide to learn something new, commit the time and effort to do so, and have the proper conditions and resources, such as a good coach or pertinent information, for learning.

Myelination The brain consists of both gray matter, which is primarily neurons, and "white matter," or myelin produced by glial cells and interspersed among neurons to insulate and support neural connections. Myelin, which is composed of fats, protein, and water, is an electrical conductor that increases the speed and strength of the impulses transmitted among neurons. Adequate myelination supports healthy brain and body functioning; conversely, a breakdown in the myelination process, or demyelination in the brain and spinal cord, is a factor in multiple sclerosis (MS) and other diseases that cause nervous system degeneration.

Angiogenesis Blood vessels supply oxygen and nutrients to your body and brain, and the development of new blood vessels, called *angiogenesis*, helps maintain the blood supply to the brain. A healthy diet, rich in fruits and vegetables, and regular exercise

enhance the development of new blood vessels for peak functioning of your body–brain system.

Beyond Conventional Wisdom: Harnessing Your Neurocognitive Synergy

These four processes combine to contribute to the brain's peak functioning. And in terms of the aim to become positively smarter, a key point is that we can take actions to enhance neurogenesis, synaptogenesis, myelination, and angiogenesis. The work of researchers around the world supports two essential aspects of the power of human potential: (1) our conscious choice to commit to the work of learning new information and skills changes the brain with the end result that (2) we can increase our marvelous, malleable intelligence and positive and productive outlook over time. As science writer Sharon Begley notes, these findings expand our understanding of the capacity of all people "to know more, to understand more deeply, to make greater creative leaps, to retain what we read, to see connections invisible to others—not merely to make the most of what we have between our ears now, but to be, in a word, smarter."[23]

Let's consider the implications of the exciting discoveries in recent decades about the brain processes that come together in neurocognitive synergy to support our capacity to become functionally smarter, achieve the goals we set for ourselves, and improve our well-being.

Intelligence Takes Many Forms

Since the dawn of the previous century, when Charles Spearman put forth the *g*-factor theory of intelligence as a single ability that applies to many different tasks, researchers from a variety of fields have continued to explore the nature of intelligence. Multifaceted conceptions put forth in the decades since hold that intelligence encompasses a variety of abilities, such as verbal comprehension and fluency, inductive reasoning, spatial visualization, and

memory.[24] In the 1960s, psychologist Raymond Cattell and colleague John Horn described two forms of intelligence, crystallized and fluid:[25]

- *Crystallized intelligence* refers to the knowledge and skills we have learned and the ability to apply our knowledge and skills. Books we read and retain and every seminar or workshop we participate in adds to our crystallized intelligence. In our work, we read at least 150 books and articles each year that inform our approach to teacher education, and each adds to our "network of knowing" that is crystallized intelligence.
- *Fluid intelligence* is about applying what we know in novel situations. It is where the rubber meets the road in wielding cognitive flexibility and abstract thinking and using problem-solving skills in new circumstances. Fluid thinking is necessary in many work environments, in continuing education, and in life in a global, technologically advanced society.

Crystallized intelligence is generally acknowledged to increase with age. Emerging research suggests that fluid intelligence might also be enhanced in the adult brain.[26] In his book *Future Bright*, the late University of California Professor Michael Martinez wrote of the importance of an active lifestyle as we age. He suggested considering novel learning goals such as tackling a new area of study, pursuing a new career path, exploring the world through travel, or learning a new language as just a few of many possible strategies for maintaining and even improving cognitive abilities.[27]

In *Teaching for Wisdom, Intelligence, Creativity, and Success*, Robert Sternberg, Linda Jarvin, and Elena Grigorenko note that psychologists and educators who view intelligence as multifaceted also tend to believe that it is malleable, that we can become smarter through learning. They put themselves squarely in this camp, professing the belief

> that everyone has some initial abilities, and that these can be developed into competencies, and that these competencies can in turn

> be honed into expertise. . . . We believe that the key to success in the classroom—and in life more broadly—lies in a combination of intelligence, creativity, and wisdom.[28]

Connecting brain research to these theories of intelligence, a group of Canadian scientists captured MRI images of the brains of 16 participants taking a battery of a dozen tasks designed to test planning, reasoning, verbal, attentional, and working memory skills. Their finding that those tests engaged distinct brain networks led them to the conclusion that "intelligence is most informatively quantified in terms of not one but multiple distinct abilities."[29]

People of All Ages Have the Capacity to Improve Their Knowledge and Abilities

An extension of the limiting belief that intelligence is fixed is that current performance predicts future achievement. This belief is evident in the perception that children who begin school without having had the opportunity to develop preliteracy skills are destined for academic failure. It is true that early learning experiences matter: There is as much as a six-year difference in reading skills among kindergartners—from children who are already reading to those who don't yet know the basic mechanics of books (e.g., that English text is read from left to right in rows on a page from top to bottom)—and a four-year difference in understanding math concepts.[30] But that does not mean students at the low end of the achievement scale are doomed to perform below standards throughout their school careers. Almost all can catch up—and even thrive academically—with an education system that ensures effective teaching, formative assessments to identify extra help and reteaching they may need, parental and community support, and their own commitment to learning.

The same dynamic is true for adults. You may have shied away from certain intellectual pursuits and physical activities because "I've never been good at that sort of thing." Applying what you

know now about neuroplasticity and learning new skills, you can see that you can get better!

What We Do Has a Greater Influence on How We Age Than Genetics

Our biology is not our destiny. In fact, according to medical research, our health as we age is only about 25 percent heritable.[31] That means three-fourths of the factors that affect health are environmental and largely within our control. Quality of diet, quantity of exercise, sleep regimen, regularity of preventative health care, and avoidance or existence of risk factors such as exposure to tobacco smoke and overconsumption of alcohol all influence our quality of health and life as we age. As one medical writer suggests, "life span, including maximum life span and healthy life span, can be extended."[32] Our biological clocks may be ticking, but we have a large degree of control over when health alarms begin to sound. We'll review the research and recommendations on nutrition and exercise for a long and healthy life in later chapters of this book.

Maintaining positive health habits also can help to stave off negative changes in aging brains. Neural connections are formed in the brain whenever we learn new information and skills and reinforce our newfound knowledge through practice and repetition. Regular exercise and healthy eating support angiogenesis to ensure adequate oxygenated blood flow to the brain. Exercise has also been shown to boost levels of BDNF (brain-derived neurotrophic factor), which facilitates neurogenesis and synaptogenesis in areas such as the hippocampus, which is associated with learning and memory, and the frontal lobes, which are the center for abstract thinking and executive decision making, such as planning, organization, and analysis.

How We Think Can Influence Our Health

If we believe that our diet and exercise regimen will yield positive results and if we believe we have the capability to achieve our health goals, we are more likely to do so. Harvard researchers

conducted an experiment to demonstrate that "mind-set matters." Housekeepers at seven hotels were divided into two groups. Participants in the first group were told that their work is good exercise and qualifies under the Surgeon General's recommendations for a healthy lifestyle; participants in the control group did not hear this message. Four weeks later, the participants in the first group who believed that their work provided a healthy daily workout lost weight and lowered their blood pressure, body fat, waist-to-hip ratio, and body mass index.[33] This research shows that a positive outlook and being mindful of our health are useful components of a healthy lifestyle. As we will see in Chapter 4, determination and motivation also contribute to the role of thinking our way to better health.

We Can Build Muscle and Become Stronger Well into Our Eighties

Over the past decade, gerontologists and other medical doctors treating older adults have identified frailty as a diagnosable condition, characterized by fatigue, muscle loss, unintentional weight loss, and low levels of physical activity. But they stress that frailty is not an inevitable result of aging.[34] While many people lose muscle mass as they age, strength training offers the same benefits to middle-aged and older adults as it does to younger adults. In Chapter 7, we review the results of several studies of people in their 60s to 90s lifting weights and undergoing resistance training.

It's Hard to Identify the Children Who Are "Destined for Greatness"

The idea that it is easy to accurately predict which children will be future exceptional achievers in academics, athletics, art, and music represents a mindset that may actually do more harm than good for both "prodigies" and their "average" peers. Early high achievers may internalize the message that their accomplishments are the product of natural talent and dismiss the need for continual

practice and learning to continue to build their knowledge and skills. Hearing the same message, their peers may give up trying to excel, accepting that they do not have the "gifts" required for success. The best-selling author Malcolm Gladwell was identified as a running prodigy as a teenager, but after competitive setbacks and a loss of interest, he stepped away from training. When he returned to running a few years later, he realized he was not an elite runner but "simply okay." In a 2006 speech at the Association for Psychological Science, Gladwell made the case that what sets gifted children apart is their dedication to learning. "Really what we mean ... when we say that someone is 'naturally gifted' is that they practice a lot, that they want to practice a lot, that they like to practice a lot."[35] The importance of deliberate practice in progressing toward the goals we set for ourselves is a major theme of Chapter 4.

Perceptions about Malleable vs. Fixed Intelligence Matter—a Lot

How we think about our ability to improve and succeed in achieving the goals we set for ourselves is at the heart of our chances of realizing our potential to become positively smarter. The persistent misconception that intellectual and physical abilities are inherent and cannot be improved holds people back, suggests Heidi Grant Halvorson in her book *Succeed*: "Decades of research suggest that the belief in fixed ability is completely wrong—abilities of all kinds are profoundly malleable. Embracing the fact that you can change will allow you to make better choices and reach your fullest potential."[36]

We have seen the power of this message—that you can become functionally smarter by putting in the effort to learn—resonate throughout our years working in education. As a school psychologist in Oklahoma earlier in her career, Donna assessed many students with learning challenges who made significant academic gains after they were taught that they could do better in school once they "learned how to learn" by using cognitive and metacognitive strategies (see Chapter 5).

A few years later, I had the opportunity to study at cognitive psychologist Reuven Feuerstein's institute, the International Center for the Enhancement of Learning Potential, in Jerusalem. Feuerstein's work dates back to the 1950s when he introduced a new approach to teaching young people who had survived the Holocaust and youth with Down syndrome and other disabilities. The academic progress these young people made is both inspiring and effective in beginning to dismantle the then-longstanding notion of fixed intelligence. Feuerstein looked past the subpar performance on IQ tests of young people who had lived through unspeakable horrors of World War II and lost their entire families, escaping with not even a photograph to remember them. Instead, he focused on their potential to learn and to regain a sense that some good could come into their lives. By offering intensive psychological and educational support, Feuerstein and his colleagues helped these young people recover from their losses, commit to their academic studies, and go on to become flourishing citizens. Introducing the concept of "structural cognitive modifiability," Feuerstein's work helped redefine intelligence not as a fixed attribute but as "the ability to learn."[37] He demonstrated that when teachers provide effective instruction and model an optimistic approach to learning, virtually all students can improve their intellectual performance. We mourned Professor Feuerstein's death in 2014, but his work has reverberated throughout recent decades in findings from other educational psychologists and researchers and will continue to inspire advances in educational practice.

As just one example, psychologist Carol Dweck has assembled a body of research behind the conception of a "growth mindset," or the belief that we can become smarter through education and effort.[38] In comparison, people with a fixed mindset believe intelligence is innate, and no amount of learning and hard work can enhance a person's IQ. As a result, children and adults with a fixed mindset tend to give up easily when faced with a learning challenge; they do not see a reason to work hard because they believe themselves to be limited in their intellectual capacity—thus creating a self-fulfilling prophecy. On the other hand, people with a growth mindset are motivated to work hard and persist in their

efforts to learn new knowledge and skills because they know they can get better at whatever they set their minds to achieve.

Dweck and fellow researchers have tested their mindset theory in academic settings. In one study with seventh graders, students with a growth mindset consistently outperformed peers with a fixed mindset in math grades, and the gap in performance widened over the two years of the study.[39] This is one of several studies demonstrating that people who understand the concept of neuroplasticity and believe in the power of their personal potential can make significant gains through hard work and persistence.

These findings are borne out by the work of K. Anders Ericsson, who set out with colleagues in the early 1990s to determine what sets masters of their crafts and elite performers apart from peers in their chosen fields. Ericsson, Krampe, and Tesch-Romer identified several key elements of "deliberate practice" that lead to expert performance, including at least a decade of hard work; access to effective teachers and coaches, training materials, and facilities; adequate resources; and extraordinary commitment and motivation.[40] Along the way, these cognitive researchers also compiled extensive evidence to discount beliefs that expert performers, including celebrated musicians, elite artists, successful athletes, chess masters, and leading academics, relied primarily on innate talent to rise to the top of their professions. They trace the origins of attributing success to "natural abilities" back to the 19th century, but argue that "the differences between expert performers and normal adults reflect a life-long period of deliberate effort to improve performance in a specific domain."[41] We'll explore the concept of deliberate practice in more detail in Chapter 4, but for now, we underscore one essential conclusion that can be drawn from Ericsson's work: Gains in knowledge and skill are the result of hard work and persistence fueled by neuroplasticity, not innate talent.

Perceptions matter a great deal when it comes to the actualization of our potential to become positively smarter. Ericsson's research indicates how deeply rooted and longstanding these misperceptions are, and Dweck's work shows how such beliefs can

derail potential on an individual level. We believe these misconceptions have a powerful negative influence on policy, practice, and ultimately the success and well-being of millions of people. When people underestimate their own capabilities and those of others—of students, of employees and colleagues, of children and parents—the result may be a collective waste of capacity to do great things. Our aim in writing this book is to set a new course in which all people recognize their potential to seize opportunities and achieve higher levels of performance through their own effort.

Plasticity as a Path to Becoming Positively Smarter

Using the positively smarter lens can help you internalize and optimize the process of enhancing neuroplasticity in your brain. The brain changes naturally in response to your experiences and environment. But you can take charge of "building a better brain" by steering your attention, thoughts, and actions in the right direction to achieve your personal and professional goals. In his book *Soft-Wired*, Michael Merzenich explores how neuroplasticity holds the key for developing "abilities that are the fundamental bases of a happy and fulfilling life for you."[42] The following list offers practical applications and actions you can take to make the most of your potential fueled by plasticity.

1. **What's good for the body is good for brain plasticity.** A nutritious diet, regular physical activity, and adequate sleep are both heart-happy and brain-happy habits that support angiogenesis to get needed oxygen to the brain, neurogenesis to create new neurons, synaptogenesis to forge neural connections, myelination to facilitate and strengthen those connections, and optimal brain activity.[43]
2. **A positive outlook combined with honing your selective attention (see Chapter 2) can enhance plasticity.** When you are engaged, alert, and motivated, the brain releases neurotransmitters that support plasticity.[44] According to Fotuhi, "maintaining a calm and focused mindset actually makes new blood vessels grow and the network of connections between

brain regions become stronger."[45] Consider your own experiences trying to learn something new or solve a problem when you were alert, engaged, focused on the task at hand, and feeling positive about the likely outcome. Now switch gears and think about a learning experience or problem you were faced with while feeling tired, distracted, disinterested, and not hopeful. Which in your experience was the most productive state of feeling and thinking?

3. **Plasticity enables an upward spiral of incremental progress and rewards for the hard work of learning new knowledge and skills.** The gains of successive learning form a platform for the next round of moving forward and over time increase your *brain reserve*, which "enhances brain performance now and results in a more resilient brain as you age."[46]
4. **Conscious effort to SAVE new information aids in long-term recall.** Merzenich uses the term *soft-wired* to underscore that the brain maintains the ability to learn new knowledge and skills throughout the life span but that without reinforcement, the neural connections forged by learning can be dismantled. In other words, learning is not hard-wired permanently into your neural circuits. As we will explore in more detail in Chapter 4, memorization is an essential trait in developing expertise. The more information you have stored in long-term memory, the more easily you can recall and apply it. Learning and applying memory strategies is an effective means of optimizing neuroplasticity. We rely on the metaphor of hitting the SAVE key[47] to describe the steps of transferring new learning from short-term memory into longer-term storage in the brain's memory banks:

    See. Employing the sense of sight aids retention. If you can see something—a demonstration or a diagram, for example—rather than just hearing or reading an explanation, you will be more likely to recall it. Here's an example: What do you remember more the first time you meet someone, the name or the face? Most people

remember the face because visual information is more easily received, retained, and recalled.

Associate. Connect new information to existing knowledge or use a *mnemonic*, a pattern of letters, ideas, or associations that assists in recall. SAVE is an example of a mnemonic, an acronym that sets out the steps of this memory strategy. Making associations is useful because it guides you to analyze new information and make sense of it, which enhances the neural connections formed by learning. Let's say the local library offers a lecture on new ideas for gardening designed to increase yield while decreasing watering requirements. An experienced gardener can associate the new recommendations with existing practices and thus be able to recall them better than someone who has never planted a garden.

Vividly savor emotional responses. Emotional responses enhance memory. If a lecturer shares a funny or moving story, you are more likely to remember the key points that story illustrates. Likewise, those "a-ha!" moments when the metaphorical light bulb goes off above your head when you puzzle out a solution to a tough problem or understand and apply a complex concept evoke strong positive emotions. Take a moment to savor those emotions and the learning that produced them—and your ability to recall that learning will be enhanced.

Experience. Learning that engages the senses—doing, seeing, hearing, smelling, and tasting—boosts recall. Watching a coach demonstrate a new skill is helpful, but doing it yourself puts your body and brain into a more productive learning mode. Adding a physical component to a memory task can also aid retention. A favorite strategy among audiences at our professional development sessions is called Ten Pegs.[48] We call out 10 random words—for instance, tomatoes, molasses, steak, orange, bananas, ice cream,

mustard, string, band-aid, eggs—and ask teachers to recall them. Most remember three or four before their memory begins to falter. Then we ask them to stand and recite the words as they tap a different "peg" on their bodies: tomatoes—tap your head; molasses—touch your shoulders; steak—put your hand on your heart; orange—touch your belly; bananas—put your hands on your hips; and on down to "pegging" eggs with your toes. When we ask teachers to recall the list using pegs, many remember all 10 words! Think about how you can adapt this strategy for remembering important details and helping to "soft-wire" them into your memory.

5. **Repetition and practice make the most of the brain's plasticity.** Analyzing new information and applying it in different situations—in education, we call this "transferring the learning"—reinforces neural connections. For example, if you learn a new organizational strategy at work and apply it at home as well, you have successfully transferred that learning and added a new tool to your practical metacognition toolkit. Along the same lines, practicing a manual process, such as playing a musical instrument, or an athletic move becomes easier with repetition as your brain over time connects all the motor skills involved in that process so that it can direct your body to execute them adeptly. In other catchier words, "practice makes cortex," and once this knowledge or skill is integrated into your brain, you can retrieve it, apply it, and build on it.[49]
6. **If you don't use it, you may lose it.** Remember how the intensive practice and retention demands of memorizing the streets and landmarks of London bulked up the hippocampi of taxi drivers who had attained their operating licenses? You might think that years of studying and decades of applying "the Knowledge" while navigating the London labyrinth would result in permanent brain changes. But even in this extreme example, the researchers behind that study noted that this

pattern of hippocampal development was not as pronounced in the brains of retired cabbies, "hinting that any changes acquired through learning might be reversed or 'normalized' when the call on stored memory representations lessens."[50] Keeping essential knowledge and skills fresh in your mind requires ongoing practice and application.

7. **Mental rehearsal puts plasticity to work as well.** Thus far, we have focused on how external stimuli in the form of new information, sensory input, and experiences create and strengthen neural connections, but Davidson notes that "the brain can also change in response to messages generated internally—in other words, our thoughts and intentions. These changes can increase or decrease the amount of cortical real estate devoted to specific functions."[51] He cites both a physical and a mental example: As an athlete imagines and steps through in her mind the specific sequence of a complicated maneuver, "the regions of the motor cortex that control the required muscles expand."[52] Along the same lines, people can learn to control behaviors associated with obsessive-compulsive disorder by focusing their thoughts on quieting, or decreasing the activity, in the "worry circuit" of their brains.
8. **Plasticity encompasses both neuronal growth and pruning.** Merzenich explains how "positive and negative plasticity" work together:

> The brain's goal is simple. Its positive, connection-strengthening plasticity is increasing the power of connections on and between all the brain cells that fire together at each moment of time, burning in those changes only if their actions contribute to success. Its negative, connection-weakening plasticity is reducing the power of the connections coming into the machinery or from other neurons that did not fire at that important moment. . . . Positive plastic brain changes work to create a brighter and sharper picture of what's happening. At the same time, negative plastic brain changes are erasing a little of that irrelevant and interfering haze or noise that frustrate the construction and recording of a clear picture.[53]

That dynamic of positive and negative plasticity may be the key to another finding in the London cabbie study. Though the taxi drivers who earned their operating licenses had a much better memory of street layouts and landmark locations than study participants in the control group, the cabbies had much poorer recall in tests on new visual information, such as complex figures, than the control group.[54] These findings tie back to the learning gains that result from developing your selective attention (see Chapter 3) so you can focus on acquiring the knowledge and skills necessary to achieve your goals.

9. **Plasticity applies to different forms of intelligence.** Building a better brain can help you improve your knowledge and abilities beyond the skills measured on a standard IQ test. A big-picture view of intelligence is that it encompasses "a person's ability to adapt to the environment and to learn from experience"[55] and "the ability to function well in response to obstacles in life [and] your ability to figure out ways to be successful."[56] In that light, you can set your mind to enhancing your creativity, communication and interpersonal skills, and other aspects of emotional intelligence. And you can look inward to develop a more positive outlook and enhance your resilience. Davidson shares several examples of how "the mind changes the brain" through cognitive-behavior therapy to treat obsessive-compulsive disorders and depression.[57]

These findings about neuroplasticity highlight the many ways your amazing brain can help you to become positively smarter—by forging and reinforcing neural connections to maintain a more optimistic approach to life (Chapters 2 and 3) and to hone the various forms of intelligence you need to thrive in your personal and professional lives (Chapters 4, 5, and 6). The fact that brain plasticity benefits from sustaining a healthy diet and regular exercise regimen (Chapters 7 and 8) rounds out the third component of our formula for becoming positively smarter and underscores the importance of tending to your mind, body, and brain.

A New Positive Paradigm

We can apply these findings about neuroplasticity by comparing two opposing paradigms framed by the ABCs—the assumptions, behaviors, and consequences—of how we think about our capacity to become positively smarter. What we think about our potential to achieve (our assumptions) influences how we act (our behaviors), and how we act leads to certain outcomes (consequences). The first paradigm is based on a view of human potential as relying on innate talent (IT), while the second is founded on a view of potential as present but untapped (UP).

The Innate Talent (IT) Paradigm

Assumptions

1. Our abilities and intellect are fixed and innate, largely the product of genetics.
2. Special talents are obvious early in life.
3. These talents and gifts develop with minimal effort.
4. Talent is limited to a fortunate few.

Behavior Child development, education, and workplace systems focus on identifying individuals with high levels of innate talent and providing a conducive environment to allow them to flourish. Fewer opportunities are offered to those assessed as having less innate talent.

Consequence Many individuals and groups are not provided with opportunities to learn and grow. They internalize the misconception that they lack the capacity to learn, to excel, and to succeed. This reduces their effort in striving to improve their skills and abilities. The Innate Talent Paradigm may have negative ramifications for those identified as talented as well. If they embrace the assumption that their innate gifts will develop naturally with minimal effort, they may fail to develop their true potential by putting

in the hard work necessary to excel. Thus, the full consequences may be a massive achievement gap.

The Untapped Potential (UP) Paradigm

Assumptions

1. We have tremendous untapped potential, the product of the combination of genetic traits and environment.
2. Our intellect and abilities are malleable and improvable.
3. Our intellect and abilities can be enhanced through conscious effort over time.
4. The vast majority of people can get good or better at the abilities of their choosing with learning and practice.

Behavior Child development, education, and workplace systems focus on creating opportunities for all to develop their skills and abilities.

Consequence Many more people realize higher levels of achievement. More confident of their abilities to improve with effort, people put in the hard work necessary to do so—and receive encouragement from others (spouses, parents, teachers, coaches, etc.) in their endeavors. And they learn and employ useful strategies to help achieve their ambitious goals.

The UP Paradigm offers a formulation of our potential to become positively smarter that has the power to transform us as individuals and collectively as a culture, as a nation, and as a world of diverse peoples each with our own unique dreams and talents. What stands in its way? Or, as Robert Greenleaf asked in his classic book *Servant Leadership*, "Who is the enemy?" Greenleaf noted that many people lay the blame for the ills and unreasonableness that plague society at the door of "evil, stupidity, apathy, the 'system.'" He coined a resonant phrase to describe what limits so many people from achieving their full capacity—"fuzzy thinking on the part of good, intelligent, vital people, and their

failure to lead."[58] We must dispel the "fuzzy thinking" that surrounds human potential if we are to realize our dreams.

We will return in the final chapter of this book to the transformational capacity of the UP Paradigm to frame our ability to become positively smarter. But first we will explore the practical aspects of a wide range of research on how we can enhance our happiness, achievement, and well-being.

Notes

1 Michael Merzenich. 2013. *Soft-Wired: How the New Science of Brain Plasticity Can Change Your Life* (2nd ed.). San Francisco: Parnassus, p. 214.
2 Majid Fotuhi. 2013. *Boost Your Brain: The New Art and Science Behind Enhanced Brain Performance*. New York: HarperOne, p. 4.
3 Mark Brown. "How Driving a Taxi Changes London Cabbies' Brains." *Wired*, December 9, 2011. Retrieved from http://www.wired.com/2011/12/london-taxi-driver-memory
4 Katherine Woollett and Eleanor A. Maguire. "Acquiring 'the Knowledge' of London's Layout Drives Structural Brain Changes." *Current Biology*, December 20, 2011, 2109–2114. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3268356/
5 B. Draganski, C. Gaser, G. Kempermann, H. G. Kuhn, J. Winkler, C. Buchel, and A. May. "Temporal and Spatial Dynamics of Brain Structure Changes During Extensive Learning." *The Journal of Neuroscience, 26*(23), 2006, 6314–6317.
6 Christian Glaser and Gottfried Schlaug. "Brain Structures Differ Between Musicians and Non-Musicians." *Journal of Neuroscience, 23*(27), October 8, 2003. Retrieved from http://www.jneurosci.org/content/23/27/9240.full
7 Medical Research Council. "Genetic Study Offers Clues to How Intelligence Changes Through Life." News, January 19, 2012. Retrieved from http://www.mrc.ac.uk/news-events/news/genetic-study-offers-clues-to-how-intelligence-changes-through-life/
8 S. Ramsden, F. M. Richardson, G. Josse, M. S. C. Thomas, and colleagues. "Verbal and Non-Verbal Intelligence Changes in the Teenage Brain." *Nature, 479*, November 3, 2011, 113–116.
9 Edward Hallowell. 2011. *Shine: Using Brain Science to Get the Best from Your People*. Boston: Harvard Review Press, p. 29.
10 Fotuhi, p. 15.
11 N. R. Carlson. 2007. *Physiology of Behavior* (9th ed.). New York: Pearson Education; D. C. Miller. 2007. *Essentials of School Neuropsychological*

Assessment. Hoboken, NJ: Wiley; Carl Zimmer. "Doublethink: The Slight Differences Between the Hemispheres May Soup up the Brain's Processing Power." *Discover Magazine Presents the Brain*, Spring 2011, 69–70.

12 David Hecht. "The Neural Basis of Optimism and Pessimism." *Experimental Neurobiology, 22*(3), September 2013, 173–199. doi: 10.5607/en.2013.22.3.173

13 Zimmer, p. 70.

14 Robert Sylwester. 2005. *How to Explain a Brain: An Educator's Handbook of Brain Terms and Cognitive Processes.* Thousand Oaks, CA: Corwin Press, pp. 69–70.

15 Rand Swenson. 2006. "The Cerebral Cortex," Chapter 11 in *Review of Clinical and Functional Neuroscience*. Hanover, NH: Darmouth Medical School. Retrieved from http://www.dartmouth.edu/~rswenson/NeuroSci/chapter_11.html

16 Sylwester, p. 82.

17 Sylwester, p. 93; Fotuhi, p. 15.

18 Swenson, "Limbic System," Chapter 9 in *Review of Clinical and Functional Neuroscience*. Retrieved from http://www.dartmouth.edu/~rswenson/NeuroSci/chapter_9.html

19 Fotuhi, p. 16.

20 Fotuhi, pp. 26–28.

21 David R. Riddle and Robin J. Lichtenwalner. 2007. "Neurogenesis in the Adult and Aging Brain." In D. R. Riddle (Ed.), *Brain Aging: Models, Methods and Mechanisms* (Chapter 6). Boca Raton, FL: CRC Press. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK3874/

22 Fotuhi, p. 26.

23 Sharon Begley. "Buff Your Brain: Want to Be Smarter in Work, Love, and Life?" *Newsweek*, January 9 and 16, 2012, p. 30.

24 Donna Wilson and Marcus Conyers. 2013. *Five Big Ideas for Effective Teaching: Connecting Mind, Brain, and Education Research to Classroom Practice*. New York: Teachers College Press, p. 70.

25 John L. Horn and Raymond Cattell. "Refinement and Test of the Theory of Fluid and Crystallized Intelligence." *Journal of Educational Psychology, 57*(5), 1966, 253–270.

26 Robert Sternberg. "Increasing Fluid Intelligence Is Possible After All." *Proceedings of the National Academy of Sciences USA, 105*(19), May 13, 2008, 6791–6792; S. M. Jaeggi, M. Buschkuehl, J. Jonides, and W. J. Perrig. "Improving Fluid Intelligence with Training on Working Memory." *Proceedings of the National Academy of Sciences USA, 105*(19), May 13, 2008, 6829–6833.

27 Michael E. Martinez. 2013. *Future Bright: A Transforming Vision of Human Intelligence.* New York: Oxford University Press, p. 39.

28 Robert Sternberg, Linda Jarvin, and Elena L. Grigorenko. 2009. *Teaching for Wisdom, Intelligence, Creativity, and Success.* Thousand Oaks, CA: Corwin Press, p. 5.

29 Adam Hampshire, Roger R. Highfield, Beth L. Parkin, and Adrian M. Owen. "Fractionating Human Intelligence." *Neuron, 76*, December 20, 2012, p. 1236.

30 Lynn Fielding, Nancy Kerr, and Paul Rosier. 2007. *Annual Growth for All Students: Catch-up Growth for Those Who Are Behind.* Kennewick, WA: New Foundation Press.

31 James W. Curtsinger. "Genes, Aging, and Prospects for Extended Life Span." *Minnesota Medicine*, October 2007. Retrieved from http://www.minnesotamedicine.com/Past-Issues/Past-Issues-2007/October-2007/Clinical-Curtsinger-October-2007

32 Ibid.

33 Alia J. Crum and Ellen J. Langer. "Mind-Set Matters: Exercise and the Placebo Effect." *Psychological Science, 18*(2), 2007, p. 165.

34 Marlene Cimons. "Frailty Is a Medical Condition, Not an Inevitable Result of Aging." *The Washington Post*, December 10, 2012.

35 Eric Wargo. "The Myth of Prodigy and Why It Matters." *Observer, 19*(8), August 8, 2006. Retrieved from http://www.psychologicalscience.org/index.php/video/the-myth-of-prodigy-and-why-it-matters.html

36 Heidi Grant Halvorson. 2012. *Succeed: How We Can Reach Our Goals.* New York: Plume, p. 243.

37 Reuven Feuerstein, Raphael S. Feuerstein, Louis Falik, and Yaacov Rand. 2002. *Dynamic Assessments of Cognitive Modifiability.* Jerusalem, Israel: ICELP Press, p. 4.

38 Carol Dweck. 2006. *Mindset, the New Psychology of Success: How We Can Learn to Fulfill Our Potential.* New York: Random House.

39 L. S. Blackwell, K. H. Trzesniewski, and C. S. Dweck. "Implicit Theories of Intelligence Predict Achievement Across an Adolescent Transition: A Longitudinal Study and an Intervention." *Child Development, 78*, 2007, 256–263.

40 K. A. Ericsson, R. T. Krampe, and C. Tesch-Romer. "The Role of Deliberate Practice in the Acquisition of Expert Performance." *Psychological Review, 100*(3), 1993, 363–406.

41 Ericsson, Krampe, and Tesch-Romer, p. 400.

42 Merzenich, p. 59.

43 Fotuhi, pp. 30–33.

44 Merzenich, p. 53.

45 Fotuhi, p. 33.

46 Fotuhi, p. 34.

47 Donna Wilson and Marcus Conyers. 2011. *BrainSMART 60 Strategies for Increasing Student Learning* (4th ed.). Orlando, FL: BrainSMART, pp. 197–199.

48 Wilson and Conyers, pp. 294–295.
49 Emma G. Duerden and Daniele Laverdure-Dupont. "Practice Makes Cortex." *Journal of Neuroscience, 28*(35), 2008, 8655.
50 Woollett and Maguire.
51 Richard J. Davidson, with Sharon Begley. 2012. *The Emotional Life of Your Brain.* New York: Hudson Street Press, p. 162.
52 Ibid.
53 Merzenich, p. 58.
54 Woollett and Maguire.
55 Robert J. Sternberg. "Academic Intelligence Is Not Enough. WICS: An Expanded Model for Effective Practice in School and Later in Life." Paper commissioned for the Conference on Liberal Education and Effective Practice, March 12–13, 2009, p. 2. Retrieved from http://www.clarku.edu/aboutclark/pdfs/sternberg_wics.pdf
56 Fotuhi, p. 35.
57 Davidson, p. 172.
58 Robert K. Greenleaf. 2002. *Servant Leadership: A Journey into the Nature of Legitimate Power and Greatness* (25th anniversary edition), ed. Larry C. Spears. New York: Paulist Press, p. 58.