1

Brain Basics

The biological mind is, first and foremost, an organ for controlling the biological body . . . . Minds are not *disembodied logical reasoning devices.*

— ANDY CLARK

THE BRAIN'S prime directive has always been to keep the organism alive and functioning optimally, whatever the situation. It does so by monitoring everything going on in and around the body. In fact, your brain can do a lot of things sophisticated medical diagnostic systems can do—and some they cannot. For example, in addition to continuously analyzing all body systems and states, your brain also responds instantly when those readings are out of whack, working to put things back in balance, called *homeostasis*.

Now, imagine what might have happened way back at the beginning when the brain had to face a saber-toothed tiger. In such situations, it is designed to go into survival mode: adrenaline rushes through the body, extra blood flows to muscles, and respiration rate increases. Though our current brain has ways to keep our more primitive emotions at bay, fear-based systems still affect much of our conscious and unconscious behavior. More than anything else, the brain wants *out of there*! The parts of the brain that can focus on problem solving and rational reflection are on hold. For many adults, taking a test is just about the modern equivalent of the tiger.

This is also true, though less intensely, in any new learning situation. Fortunately, adults have two competing states of mind: whereas one says, "I'm anxious," the other says, "I'm curious." Negotiating this ongoing tension is a major factor for adult learning facilitators in any setting (ALFAS) seeking to facilitate meaningful, lasting learning—but in our experience, it is one that is not sufficiently addressed in many learning environments.

Two States of Mind

It makes perfect sense that the brain's most basic imperative is self-preservation because if it can't manage that, nothing else much matters. We are constantly on the alert for potential threats. In fact, the brain suffers from *negativity bias*; that is, it is many times more likely to focus on and remember negative interpretations of experience.

Negativity bias affects thinking, feeling, and acting. Daniel Kahneman (2011) also describes this in terms of negativity dominance, in which "negativity and escape dominate positivity and approach" (p. 300). We see and respond to visual threats (a scary picture) or verbal threats (words like *war*) more quickly than we do to positive stimuli (happy faces, pleasant words). Furthermore, when presented with positive and negative stimuli (such as words or photographs on a screen), we unconsciously—and almost imperceptibly—lean our bodies toward the positive and away from the negative. And in interactions with others, we may dwell more intensely on what we perceive as negative input than on positive.

Anxious Brain

Here is a metaphorical description of our threat-anticipating, defensive, certainty-seeking, anxious, ready-to-fight-or-flee, no-time-to-think-about-learning brain figure 1.1. Its response to the basic question, "What do I have to do to save myself?" is:

- I have to *know* what's happening.
- I have to *focus narrowly* on the immediate potential danger.
- I have to be *certain*.
- I have to be *right* (uncertainty or ambiguity can mean annihilation!).
- I have to *avoid threat*.
- I have to be *always prepared to react*, just in case.

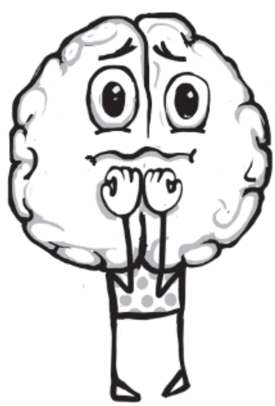

Figure 1.1 Anxious Brain

Curious Brain

Fortunately, a few hundred million years ago, our brains began refining and elaborating the systems designed to respond to threats. We now also have a very well-developed novelty-seeking,

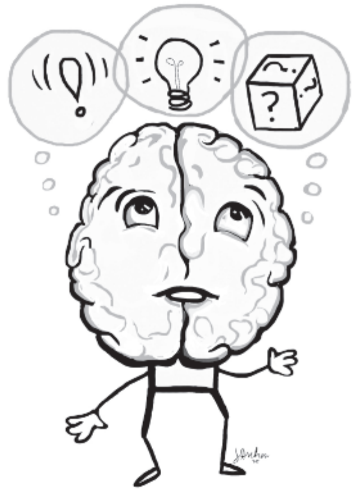

Figure 1.2 Curious Brain

pattern-constructing, cause-seeking, meaning-making, analogy-directed brain figure 1.2. Its major focus is still and always self-preservation, but it comes at it in a completely different way:

- I have to *seek* experience.
- I have to *categorize and associate* by comparison (analogy) what's happening now with what happened before.
- I have to *construct and elaborate* patterns.
- I have to *determine* cause and effect.
- I have to *reward myself* for figuring things out with "feel-good" hormone release.
- I have to *focus more widely*, on possibilities beyond the immediate.

To be most effective, our practice as ALFAS has to account for both of these states of mind. But unless we first attend sufficiently well to threat mediation, adults may literally not have enough presence of mind to learn. They may dutifully try to memorize and

> **Mezirow on Learning**
>
> "Learning is understood as the process of using a prior interpretation to construe a new or revised interpretation of the meaning of one's experience in order to guide future action" (Mezirow, 1996, p. 162). This is especially relevant in the context of adult learning and the brain because it (1) frames learning as a process rather than merely an outcome; (2) places meaning making, which is the essence of adult learning, at the core of the process; (3) includes the role of prior experience and interpretation of that experience; (4) refers to the brain's construction and reconstruction of knowledge, key to literally changing one's mind; and (5) alludes to the relationship between reflection and action, which is the essence of praxis. (For more on Mezirow, see chapter 9.)

follow procedures, but until the brain can pull itself together, it is likely to have difficulty with more substantive learning.

Learning and State of Mind

We must be attuned to situations likely to trigger the always-on-alert anxious brain to go into threat overdrive. People in a state of heightened anxiety, such as during tests or performance appraisals, are on brain overload. They may not see or hear correctly, "which causes them to misinterpret and give the wrong answer . . . . Their brains are so busy dealing with the [intensity that the brain can't] perceive accurately. Our brains are not infinite. They run out of space, out of gas, as it were," as worry and anxiety leave less room for perceiving (Ratey, 2002, pp. 61–62).

Most ALFAS intuitively realize this—but not all of us and perhaps not consciously. Moreover, we may not recognize that some of our favorite strategies for enhancing learning, such as detailed feedback and group activities, need to be carefully reviewed with the anxious brain in mind. (More on this in chapter 8.)

Think of it this way: In terms of learning, when the brain is scared, it has a foot on the brake; when it is curious, it has a foot on the accelerator (figure 1.3). With a foot on the brake and none on

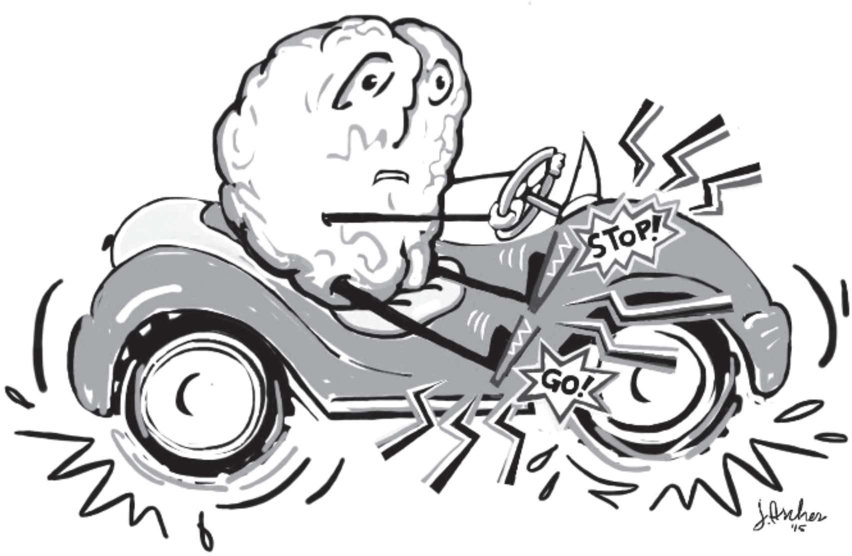

Figure 1.3 Foot on Gas and Foot on Brake

the gas, such as at a stoplight, the car idles. Many adults, including those with impressive experience and credentials, start off a new learning situation that way. Even if they have willingly chosen to participate (sometimes they are there for other reasons), stress inevitably is associated with a new setting, new facilitator, and perhaps new approaches to new ideas. As Julie Willans and Karen Seary (2011) found in their study of adults returning to formal learning environments, they may feel bombarded from all directions. As they settle in and become more familiar with what will be required of them—and, one hopes, some thoughtful intervention by the facilitator—foot-on-brake can start to relax. By itself, though, that slight letup still doesn't get anywhere. The car needs some foot-on-gas as well. A skilled facilitator provides this by focused attention on motivation and engagement. But unless similar attention has also been paid to the potential for threat, there may now be a foot on each pedal. The car may be revving yet still not moving.

Once that foot-on-brake lets up, though, *zoom*! In other words, these two states of mind are not simply the inverse of one another. Increasing curiosity doesn't ensure less anxiety; lowering threat doesn't guarantee curiosity. This is why many of the approaches described in part 2 feature effective responses to both imperatives.

We now briefly examine biology. The brain is a relentless, whirling, ongoing, multifaceted process. Its fundamental activity relies ultimately on electrochemical signals at the cellular level. Most people are familiar with the basic structure of a typical brain cell, often drawn in a way that appears treelike (see figure 1.4).

The cell body of the neuron, which contains the nucleus, is analogous to the crown of the tree, with bushy *dendritic* branches. The trunk is the *axon*, and the roots are the *axon terminals*. Dendrites receive stimulation from other neurons, which causes an electrical impulse to travel down through the cell body and along

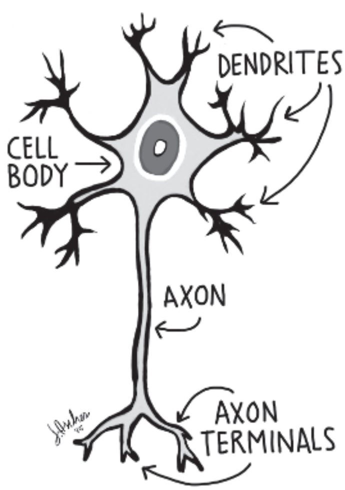

Figure 1.4 Typical Neuron

the length of the axon. When the impulse reaches one of the axon's terminal buttons, it triggers the release of chemical messengers (*neurotransmitters*) that cross a tiny space (*synapse* or *synaptic cleft*) to the dendrites of another neuron. That stimulates specialized receptors on the dendrites of the next neuron, thus passing along the message. This process continues from neuron to neuron, usually requiring only milliseconds from one to the next.

The words we commonly use to name what the brain does—*think, identify, feel, understand, imagine, decide, know, plan, distinguish, believe, remember*—are descriptions of what we experience when vast networks of neurons are activated in ever-changing patterns of connection. Neuroscientists currently studying microscopic activity along these neural pathways are attempting to unpack the anatomy of particular brain functions. As ALFAS interested primarily in the activity called learning, which involves millions of neurons engaged in various combinations of tasks, we find it more meaningful to tell the story of brain history and function from a more macrolevel.

The Brain Then

Brains eventually emerged from the basic stimulus-response mechanisms that all animals share. Even one-celled organisms swim toward nutrients and away from danger. As life-forms crawled out of the ocean and evolved into various creatures, these responses evolved along with early brain structures. The modern brain took hundreds of millions of years to evolve. Much of what we understand about human brain development has been inferred from changes in the prehistorical skeletal evidence and comparative studies of the brains of other species. In our case, the gradual increase in the size of the most frontal portion of the brain—which we identify as its more "civilized" part—led to less sloped foreheads. (The increasing proportion of the brain's *white matter* also contributed to pushing hominid foreheads toward the vertical.)

We can also think about changes in our brain as similar to an archaeological dig, where more recent structures were built on top of earlier ones. But in contrast to the built-over remains of civilizations that had died out or been destroyed, the older structures of the brain had to keep operating. Evolution can't suspend current activity while it goes back to the drawing board; neurobiological economy requires building on whatever is working at the time. Over eons, as modifications emerged that were better suited to the environment, the updated versions had the edge in the ongoing evolutionary process. The brain's additional and increasingly complex capacities enabled still further development within progressively more varied surroundings.

A well-known model that attempted to account for the historical development of major brain structures refers to the *triune*, or three-part, *brain*. Though it was later critiqued as being oversimplified, Paul MacLean's model (1990), first developed in the 1960s, became widely known because it seemed to account for human nature, such as our tendency for both primitive and civilized ways of thinking and acting. More recent analyses of brain architecture focus on other spatial relationships in the brain. We will later look more closely at the right and left hemispheres.

Using the triune model in figure 1.5 as our framework, we're going to borrow a time machine to observe how early hominid brains probably functioned about 2 million years ago. Here is Mr. Oog (*Homo erectus*—not the earliest hominid, but a long way from *Homo sapiens,* who appeared only 200,000 years ago), walking through the primeval savanna. *Wait!* He hears noises up ahead but can't determine the source. His brain is on high alert. Is this situation, *I can eat that?* or is it *That can eat me?* Either

Figure 1.5 Triune Brain

way, his life may hang in the balance. If there is food ahead (or a potential mate), continued existence is enhanced; if not, it could be the end of him.

It is unknown whether Mr. Oog's group was capable of what we now call *reflection*, but two pointers suggest the capacity for language. The first is the brain structure of early hominids. Endocasts—molds made of the inside of ancient skulls—seem to reveal brain areas we know to be associated with language. The second is archaeological evidence that their toolmaking was a communal process, hence one that required fairly explicit communication.

Brain Stem

Just as it is now, the brain's primary task was to keep the organism alive and functioning optimally, whatever the circumstances. The part of Mr. Oog's brain that controlled his reflexive fight-or-flight response, the *brain stem*, still has the same job it did then: to continuously monitor and react to internal and external environments. The brain stem is located at the hindmost part of the brain and looks like a tail as it extends down to become the spinal cord. It regulates the functions of internal organs, blood vessels, and activities such as heart rate, breathing, and blood pressure, over which we usually have little conscious control.

The earliest version of the brain stem (about 500 million years ago) was essentially the entire brain of primordial fish, followed by amphibians and, eventually, reptiles. It is sometimes, and rather inaccurately, referred to as the "lizard brain." Just as the brains of lizards continued to evolve, the brain stem has also evolved. Nevertheless, it is still focused on what sociobiologists call the 4 Fs: feeding, fighting, fleeing, and mating.

The brain works unnoticed most of the time, quietly and effectively controlling homeostasis, but it also springs into heart-thumping action if danger threatens or appears to. ALFAS need to be aware that when the reflexive brain is sharply stimulated—perhaps when an adult is suddenly put on the spot (especially if everyone else is watching)—the capacity of the rest of the brain to reflect, reason, or learn is severely curtailed.

Limbic System

Mr. Oog pauses. As he remembers that the place he is approaching is a good source of food, his threat level decreases. Rather than responding only reflexively, he can intentionally seek pleasure and avoid pain. The *limbic system,* the second major brain component, gives him the basic capacity for memory, learning, and emotion (see "Limbic System Structures").

Mr. Oog and his mate are members of a small community of hunter-gatherers. The men make tools and hunt together; the women care for children and gather nuts and berries. Whereas the earlier brain was focused primarily on individual survival, the limbic system helps enable the emotional and feeling responses

Limbic System Structures

Sometimes referred to as the *mammalian brain,* the limbic system is not a single organized system; it is a group of structures related by their location and functions. For our purposes, the most important structures are those critical to memory and emotion, the hippocampus and amygdala. They exist bilaterally (in both hemispheres) in the inner side of the temporal lobes (between and just a little behind the temples). Their names, *hippocampus* (seahorse) and *amygdala* (almond), are derived from the Greek words for the objects they are thought to resemble. A major criticism of the triune brain model is its identification of the limbic system as the emotional brain. We now know both that the limbic system has functions other than emotions and that emotions involve much more than just the limbic system.

needed to cooperate and form communities as part of an evolutionarily stable strategy. It also appears to act as a mediator or brake on the harsh survival-focused behaviors of the more primitive structure that would otherwise dominate.

With the limbic system as moderator, Joshua Greene (2013) says, we are less likely to engage in violent behavior toward those we consider part of our group. It also contributes to altruistic behavior in mammals, such as self-sacrifice for the good of the collective or a mother's fight to the death when her young are in danger. If our brains had not developed the capacities to bond with and nurture our young, we would not have survived as a species. In fact, Matthew Lieberman (2013) claims, establishing and maintaining connection with others is the "*central problem of mammalian evolution*" (p. 99). As we will later describe, these bonds depend in part on the brain's ability to interpret what someone else is thinking or feeling. Whether we know it or not, we all need to read others' minds; fortunately, most of us do so relatively easily. Indeed, social connections are so essential to our survival that their loss can cause physical pain; at the same time, intense connection can cause enormous pleasure.

Social Complexity

The growing complexity of social groups may have been a major factor in the dramatic increase of the frontal part of the brain (Dunbar, 1998). Individuals had to develop behaviors of mutual assistance and cooperation, which required understanding potential trade-offs between short-term costs and long-term gains. Although the limbic system is the source of direct emotional response, the complex calculus of ongoing social give-and-take occurs in the newer prefrontal cortex, which therefore expanded over time. Social evolutionary models further suggest that three group-focused capacities probably coevolved: social intelligence (understanding and using one's connection to others), environmental intelligence (figuring out how things work), and language (sharing and exchanging with others what one knows, thinks, and feels) (Deacon, 1997). As each developed incrementally toward greater complexity, that put pressure on the other two to develop in tandem. The physical locations of parts of the brain facilitated such interactions. Roughly speaking, the reactivity of the brain stem, at the bottom, is mediated by the limbic system, located above it and below the cortex, where thinking is processed.

Neocortex

Arriving at the hunting ground, Mr. Oog lifts his axe and signals to his fellow hunters. The third, and latest-to-develop and most complex part of the primate brain, the *cerebral cortex* (or new cortex: *neocortex*), makes possible more complex responses to the changing environment. (See "Social Complexity.") For example, the discovery of fire and learning to clothe themselves in animal skins will ultimately allow Mr. Oog's descendants to expand his tribe northward, out of Africa.

Seen from the top, the cerebral cortex is what we tend to visualize as *brain*. A lump of matter appears to have been messily pushed together into a walnut-shaped pile of soft bulges and valleys with a ridge running down the center between the left and right hemispheres. From this view, we cannot see that the cortex, composed of cell bodies, or *gray matter,* is only about one-eighth inch thick; it covers the *white matter* beneath it, like a rind.

White matter is composed of axons insulated with a fatty white substance, *myelin*, which improves the transmission of signals to and from various centers of brain activity. The higher ratio of white matter to gray matter (along with the wrinkling and folding of the cortical surface, allowing more cortical neurons to fit inside the hominid skull) has greatly increased the brain's capacity to make new synapses, thus the potential for creativity and complexity. As we will see in chapter 2, this is a factor in memory and all that implies for learning, planning, and assessing.

The cortex as a whole accounts for 80 to 90 percent of the weight of the adult brain and endows aspects of ourselves that we consider uniquely human, such as language (spoken and written), rational analysis, imagination, and self-understanding. These capacities give rise to art and science; they also enable us to review the past in ways that change over time and to imagine a future rich with possibilities. Although most of our attention as ALFAS is directed toward the cognitive functions that the cortex facilitates (especially the prefrontal cortex, the part closest to the forehead), we are likely to be more effective when we take into account the influences of other aspects of brain function, as well.

The Brain Now

Despite all the amazing changes that the last several hundred million years of evolution have wrought, our brains have never forgotten where they came from. When pressed, they are likely to revert to their more primitive responses. The unconscious in-the-moment default mode of the earliest hominid brains was simply reflexive. They *acted*! That historical imperative is still very much with us.

Right and Fast

To survive in that long-ago environment, brains had to be right and fast. "What's up ahead?" requires immediate action.

Brains that over (lots of) time began to compare this moment to some other moment had an edge in the Darwinian sweepstakes: staying alive longer allowed them to pass that capacity on to their progeny. Thus, the speed and accuracy with which one could identify and connect new experiences with earlier experiences profoundly affected the course of human development.

This may also account for our modern brain's negative bias. For most people, anxiety about possible bad outcomes strongly outweighs the positive potential of a good outcome. As they say, the tiger has to be right once, but you have to be right all the time. Our brains are geared to flash warning signs, and the brain is several times faster at arriving at a negative appraisal than a positive one. Then, when something bad does happen, negative bias is confirmed; unfortunately, when a negative prediction does not come true, the brain is likely to assume it was just lucky that time.

An offshoot of the desire to be right is the need to know. Not knowing creates anxiety. Unfortunately, the desire to avoid that discomfort can encourage us to take risky choices rather than remain undecided. When these are well-calculated risks based on sufficient experience and thoughtful assessments of potential losses and gains, there may be positive outcomes. But less informed adults may also rush to arrive at far less considered decisions. Moreover, when we feel, "Whew! that's taken care of," the brain rewards itself with a rush of feel-good hormones such as *dopamine*. (That is why some folks play bridge, do Sudoko, and solve crossword puzzles.)

To be in a state of not knowing is to venture out in the wilds without self-protection. Anything could be out there, just waiting to pounce. Most of us therefore avoid ambiguity and what researchers call "ill-structured" or "messy" problems (Schön, 1983)—terminology that seems to suggest the problem is poorly framed. In reality, for our species to survive, our modern brains have to figure out how to address just such increasingly complex and multifaceted problems.

Because an open-ended problem sparks anxiety and stress, our brains do their best to construct stories that appear to account for the evident facts. In seeking to resolve the ambiguity, the brain will also fill in missing details, such as finding relationships and patterns where there aren't any. The brain effectively counters its discomfort by projecting certainty—or at least cause-and-effect explanations—onto the environment. People especially prone to such behavior are likely to be superstitious, believe in conspiracies, and be gullible about the supernatural. Shermer (2011) also draws connections between 9/11—the anxiety and uncertainty that it created—and the bumper crop of conspiracy theories it engendered. Furthermore, once people have decided that there is a causal relationship between two phenomena, they will subsequently consciously or unconsciously seek out confirming data, thus demonstrating *certainty bias*.

What's more, if two things happen in rapid succession, we are likely to assume, even if only momentarily, that the earlier one *caused* the later one—thus being right, fast, *now!* The following is an instance of the brain creating an immediate story around an unexpected feeling of threat that one of us experienced. A friend was on a ladder organizing a high shelf containing dozens of greeting-card-sized boxes, when he accidentally knocked a small stack off the shelf. I was standing below him, and in the first startled moment they rained down on me (I did not see them start to fall), my brain told me that he had unaccountably started slapping my head and shoulders. "Stop it!" I cried and backed away, shaking the ladder in a reflexive attempt at self-protection. (Fortunately, he didn't fall.)

That instantaneous associative response is the brain doing its job of self-protection: "The brain evolved to detect patterns of immediate significance in do-or-die, fight-or-flight situations" (Geary, 2012, p. 36). It would much rather react defensively in a situation that turns out to be safe than not react in one that turns out to be dangerous. In addition, the brain does not, without prompting, think in terms of correlation. The associative process does not consider, "Hmm, these two things may have occurred more or less together, but does that mean one caused the other, or can there be some as yet unknown third element, that causes both?" Nor is it geared to consider whether it is reasonable to ascribe every perceived effect to a particular cause. It wants to *know*!

We are capable of thinking in terms of correlation only when we become aware of the connections our brain is making. But most of these associations never reach consciousness. If someone we have just met reminds our brain of an experience that involved strong emotions, we almost instantly connect those emotions with the new acquaintance without knowing we are doing so. Of course, whatever similarities the brain thinks it found can be based on only superficial criteria.

The brain's tendency is to construct a plausible story. Daniel Kahneman (2011), a Nobel Prize–winning behavioral economist, observed, "We are prone to exaggerate the consistency and coherence of what we see" (p. 114)—or think we see. Daily changes in the financial indexes, for example, are sometimes occasioned by current events or new economic data, but more often they are random fluctuation. But even when nothing noteworthy has happened, the evening news is likely to present a rationale, however tenuous: *Markets moved lower[higher] on news of ________ in Somewhereville*. Nor are experts immune from believing their own stories (see "Experts Pick Stocks").

Left to its own devices, the brain will be the decider. Many people have experienced a version of the following scenario. An electrician had been working on the wiring in our ninety-year-old house. The job was more challenging and time consuming than expected because we did not want to break into the original six-inch-thick lathe-and-plaster walls. He had to thread new wires down from the attic inside the existing walls, then move to the crawl space under the floor to complete the connections. At the end of the day, I walked back into the home office and switched on the overhead light. A computer screen suddenly went black! *Oh no!* I thought. *He miswired something!* That made perfect sense, given that he had worked by touch more than by sight—except, as soon as I touched the keyboard, the screen came back on. It had merely gone into sleep mode at the same moment I flipped the light switch.

Experts Pick Stocks

In the 1990s, the *Wall Street Journal* conducted a study in which stock picks carefully selected by experienced professionals were compared over time to those "selected" by throwing a dart at a list of stocks (http://www.investorhome.com/darts.htm). On a week-by-week basis, sometimes the experts were ahead, and sometimes a lucky dart throw proved more profitable. However, the results over many months revealed no significant difference between the stock pattern–picking experts and random dart throws. (*Coincidentally*, the experiment was discontinued shortly there after.)

The brain is also very effective at constructing explanations that self-protectively leaves us blameless about whatever undesirable result may have occurred. "Mistakes were made" is a lot more tolerable than "I blew it":

> Even a small amount of ambiguity triggers increased activity in the . . . deep brain structures that play a major role in our response to threats . . . . The brain doesn't merely prefer certainty over ambiguity—it craves it. Our need to be right is actually a need to "feel" right . . . . When we feel right about the decision or a belief—whether big or small—our brains are happy. (DiSalvo, 2011, pp. 31–32)

This contributes to the *certainty bias* described earlier.

Need to Know

A corollary to *right and fast* is the need to *know*. Most adults are used to being in the know. Even—perhaps, especially—those with impressive professional credentials may be anxious about revealing or acknowledging what they do *not* know. However enthusiastic adults may be about the idea of new learning, being in a learning situation—whether in a classroom or boardroom—is cause for anxiety. A man who fits this profile revealed, "I went from an environment—my work—where I knew all there was to know, to an environment of feeling like I didn't know anything. This was challenging and scary!"

On the positive side, the curious brain's drive to know—to figure things out, to come to closure—encourages us to continue learning. However, the period during which an adult moves from not knowing to coming to know and, finally, to understanding is uncomfortable at best. As one woman described it, "I was so worried about earning the points that I lost the focus of finding what was most relevant for my topic."

The Feeling of Not Knowing Robert Burton (2008) offers an interesting activity that will help you experience your brain's need to know. Read the following paragraph slowly and carefully; maybe even read it twice, paying attention to your feelings as you read. (Don't skip this paragraph. Once you understand the key, it will be impossible to go back to not knowing.)

> A newspaper is better than a magazine. A seashore is a better place than the street. At first it is better to run than to walk. You may have to try several times. It takes some skill, but it is easy to learn. Even young children can enjoy it. Once successful, complications are minimal. Birds seldom get too close. Rain, however, soaks in very fast. Too many people doing the same thing can also cause

> problems. One needs lots of room. If there are no complications, it can be very peaceful. A rock will serve as an anchor. If things break loose from it, however, you will not get a second chance. (Burton, 2008, p. 5)

As you read the quote, you almost certainly experienced the feeling of slight disorientation, perhaps even the frustration that comes when something just doesn't make sense. Maybe you even frowned a little. Clearly, there are no technical words or difficult concepts to contend with, so your brain may say, with some annoyance, *I ought to be able to figure this out!*

Now notice the shift in your experience at the introduction of the idea of a kite. As you reread the paragraph with that in mind, you may find yourself smiling or even chuckling out loud. As Burton describes it, "In an instant, without due conscious deliberation, the paragraph has been irreversibly infused with a *feeling of knowing*" (p. 5). You may also relax as the tension you felt on first reading dissipates with the explanation of the kite: your brain once again feels secure and in charge, its preferred state.

Highly creative people may be an exception to the brain feeling anxious in the face of the unknown. According to Gregory Berns (2008), rather than run from not knowing, those he calls *iconoclasts* respond with increased curiosity and greater energy to explore further. Their brains appear to delight in novelty and avoid default patterns. Because they seem to perceive things differently, they are likely to make the creative leaps of imagination that can lead to significant discoveries others failed to consider.

Knowing "Facts" Adults are also dismayed to discover that even their certainties may be up for grabs. New learning can challenge long-held beliefs. Occasionally new facts can simply be swapped for old facts. But even something as seemingly uncontroversial as how fast water freezes may be connected to one's sense of "who I am" and "how thing are." Such beliefs are not easily challenged, as the narrator of the following incident discovered:

> We stopped for coffee in a roadside café near the Donner Pass in midwinter. The conversation turned to freezing water. People assured us that they had lived here a long time and knew, for certain, that hot water freezes faster than cold. Our protests were rejected. Because it was snowing heavily and we had time on our hands, we suggested a test: taking a cup of boiling water and a cup of refrigerated water outside to see what would happen. When the cold water froze first, the locals' reaction was to stubbornly—and testily—insist that it had been a trick.

It turns out that in rare circumstances, hot water does freeze more quickly. When we first heard this, our immediate reaction (including that of an engineer husband), based on a lifetime of assumptions was, *It can't be!* Then we looked on the Internet: the Mpemba effect exists, though scientists are uncertain why. Our subsequent reactions after learning this changed to acceptance, interest, satisfaction. Why so different from the folks in the diner? We were not committed to our initial belief; we *sort of just* knew. Being told otherwise—first by a friend (who had heard of the unusual Mpemba effect exception), then confirmed by an authoritative Internet source—was intriguing rather than distressing. We even felt a little smug, because now we knew more and might be able to tell someone else this fascinating tidbit.

Why didn't it work that way for the folks who lived near the diner? Given the special conditions required for hot liquid to freeze faster, it seems likely that most of them had never actually seen it; they also *just knew*. Having some city slicker contradict them did not go down well; it had become less about the objective phenomenon than about the brain's need to know (and be right).

Not knowing had become a source of anxiety, and anger is one response to fear.

We do not intend to overemphasize the brain's capacity for anxiety, but based on what experienced ALFAS and adult learners have shared with us over the years, in general too little attention is paid to this reality. Our concern is that well-planned approaches to facilitation and meaningful learning may still fall flat if we have not taken into account adults' emotional responses to having their beliefs and certainties challenged.

Adults are especially anxious about being wrong. As one observed, "I grew up seeing mistakes or doing something wrong as failure." Such vulnerability can lead to insisting that what they already know is all there is to know or to not speaking up when they are confused and have questions that might reveal their lack of knowledge to their peers and the facilitator. Or they might apologize in advance: "This is a dumb question, but . . . "

Similarly, when asked to consider a situation or idea from an unfamiliar perspective—which, as far as the brain is concerned, may be like walking into a dark, unknown jungle—adults may adamantly not want to go there. The history of science and medicine is littered with disastrous examples of such resistance (see "Certainty and Tragedy").

The anxious brain resists change for many reasons. In the case of childbed fever, aside from the threat to their established ways of doing things, doctors simply could not accept they were the cause of the problem, even in the face of compelling evidence. Brains that want to be certain and right will do their utmost not to acknowledge, "I did it. I caused all this tragedy." In the early twentieth century, resolution of another scientific issue, the cause of pellagra, a disease characterized by dermatitis, diarrhea, and sometimes mental disturbances, was delayed for socioeconomic and political reasons. Most victims of pellagra were sharecropping African Americans in the Deep South of the United States. It took

> ### Certainty and Tragedy
>
> In the mid-nineteenth century "childbed fever" killed many poor women in hospitals but far fewer wealthy women, who gave birth at home. Also at that time, demonstrating active interest in dissection elevated a doctor's status among his peers. Many went directly from dissecting corpses to examining women in labor, their hands and medical aprons soiled with evidence of their scientific pursuits. However, when one young doctor required his medical staff to disinfect their hands before attending laboring mothers, the death rate in his hospital plummeted. He was quickly shunned and reviled by the medical establishment, which *knew* that all disease was caused by a "miasma"—an invisible cloud of pestilence that hung over hospitals and where poor people lived. Physicians were affronted at his demand that they change their practice and refused to participate; they even sabotaged his experiments. Not until the discovery of microscopic pathogens two decades and thousands of maternal deaths later was Ignaz Semmelweis's insight accepted.

decades to accept that the cause of pellagra was neither infection nor bad agricultural practices but a nutritional deficiency caused by diet. Accepting that reality shone an unwelcome spotlight on inequality and poverty.

What the brain is willing to accept is also deeply and invisibly influenced by *what I want* (or *don't want*) *to be true*. As philosopher of science Thomas Kuhn (1962) famously said, significant scientific advancement often requires a paradigm shift. Such a major break in continuity is needed for scientists to accept a radical new framework. Of course, even when many do recognize the new reality, others can still discount overwhelming evidence if the implications require them to change both their minds and their behaviors (a good example is climate change).

Cultural norms and expectations of all kinds can limit openness to new thinking. As one adult reflected, "When I have to get out of my comfort zone, . . . I tend to focus on getting the task done rather than understanding the concepts or rationale." Both of us frequently see this tendency demonstrated by our doctoral students as they start to design their dissertation research. They almost always begin with the tacit notion that they will prove what they already know or believe. It takes considerable effort to wrap their minds around a lengthy project based on questions to which they do not already have answers.

And the Brain Still Changing

As Darwin noted, when ordinary variations within a species prove to be more successful than others, especially with regard to matching the demands of changing environments, creatures with those variations are more likely to survive and reproduce. Many improvements in brain and brain function over eons are evidence of this. However, some early adaptations have proven less advantageous in the long run.

Maladaptation

Though serial brain enhancements have managed to get us to now, a feature that enabled our primitive ancestors to survive in that earlier environment may, in this vastly different environment, have become a bug (Buonomano, 2011), and thus now be deemed maladaptive:

> Although we currently inhabit a time and place we were not programmed to live in, the set of instructions written down in our DNA on how to build a brain are the same as they were 100,000 years ago. Which raises the question, to what extent is the neural operating system established by evolution well tuned for the digital, predator-free, sugar-abundant, special-effects-filled, antibiotic-laden, media-saturated, densely populated world we have managed to build for ourselves? (p. 16)

And this is to say nothing of a world in which the possibilities for both instantaneous (nuclear) and longer-term (climate change) annihilation are a reality.

Furthermore, given the current rate of change, an increasingly pressing question is whether our brains can develop fast enough to keep pace with it. As one example, it was crucial that our early forebears quickly distinguish between those whom we considered like us (our community or tribe, therefore presumably safe) and not like us (therefore possibly dangerous). Our modern brains still make such discriminations, subconsciously and more or less instantly, but these can be unhelpful assessments in our modern global village. And because we don't realize what our brain is doing or why, we cannot challenge the highly questionable criteria it uses to determine who is us versus who is them, nor do we realize how easily we can be manipulated.

Our early ancestors were benefited by establishing groups of "our kind" in terms of mutual defense or allocating scarce resources. Since making such distinctions conferred a greater chance of survival, brains with those tendencies persisted. However, though our brains (and that of other primates) are wired to distinguish between us and them, which Greene (2013) calls *tribalism,* we have to *learn* to make distinctions on the basis of racial characteristics. Early on, there was no racial diversity, so this was not wired into the brain's distinctions. Our modern tendency to use race as a mark of difference is an outgrowth of cultural rather than brain-based distinctions—and something that modern demagogues consistently exploit.

An important question therefore is what role we ALFAS can play in improving the brain's set of instructions and thus contribute to developing more effective responses. Fortunately, we are not limited to evolving in geological time; plasticity enables our brains to adapt within our lifetimes.

Plasticity

It was once thought that we were born with all the brain cells we would ever have. Actually, after a spurt of neural growth in the first two years of life (which is also severely pruned soon after), we can continue to grow neurons throughout the life span, though relatively few in number. The bad news is that we continually lose neurons throughout the rest of our lives. The good news is that at the rate of about one-millionth of the total per day, even with a life span of 100-plus years, the cumulative loss is inconsequential in terms of our capacity to learn and change.

From the standpoint of brain function and learning, dendritic connections are far more important than total number of neurons. Because each neuron may make up to 10,000 synaptic connections to other neurons, "the theoretical number of different patterns of connections possible in a single brain is approximately forty quadrillion" (Ratey, 2002, p. 9). These connections make up the neural networks that enable your brain to examine, reflect on, and evaluate your current experience while also constructing your remembered past and imagining various possible futures.

As we age, our brain cells continue to generate such connections, thus increasing our capacity for interpretation of experience and therefore imagination and insight. Plasticity also means these connections are adapted, elaborated, and reorganized as new experiences strengthen or weaken existing synapses. Put simply, *experience consistently and continuously changes the brain*. (We explore this more fully in the next chapter.) The challenge for facilitators is to design experiences that take full advantage of this capacity for change.

Learning While Aging

Average cognitive capacity reaches its peak around forty years of age and begins a slow decline thereafter (Hertzog, Kramer, Wilson, & Lindenberger, 2009). Since we two are decades past

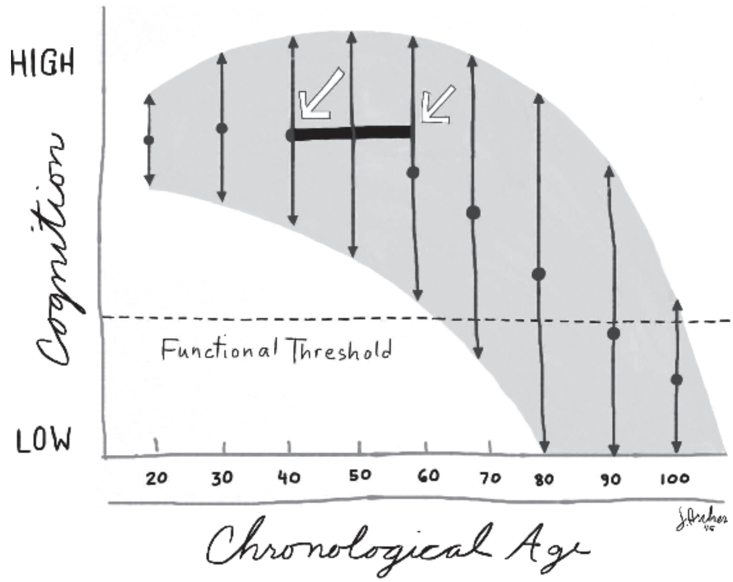

Figure 1.6 Brain Function over Time
Source: Adapted from Hertzog et al. (2009, p. 5).

that point, we want to underscore how *not* predictive of adequate brain function that single statistic is! More important is the range of capacity. As demonstrated in figure 1.6, the upper ranges (top curving line; vertical arrows within the shaded portion mark the top and bottom of each range) in one's seventies and even eighties are above the average capacity (dots) in one's forties. Therefore, as the angled arrows (pointing to the dark horizontal line) indicate, a sixty-year-old operating somewhat above average is just as cognitively effective as an average forty-year-old.

Many factors contribute to where in the range any individual may be located. Though genetics plays some role, there is clear evidence that what one starts with is profoundly affected by what happens next. Certainly good nutrition and overall health are significant factors, as is ongoing physical activity. And so is ongoing learning: being a lifelong learner is likely to enhance one's cognitive capacities (see "The Nuns' Story.")

The Nuns' Story

A long-term study of over four hundred Catholic sisters, several of them centenarians, has demonstrated that consistently challenging one's brain—for example, many continued to teach well into their eighties and nineties—led to far fewer clinical symptoms of dementia than postmortem analysis of their brains would have indicated. Though not all the nuns had been teachers, those who demonstrated the fewest symptoms were generally those who had more formal education or kept their minds busy with other cognitive challenges, such as debating politics (Ratey, 2002).

Though there may be optimum periods of brain development with regard to specific kinds of learning (language learning is one example), the curtain does not fall when that period is over. Older brains are not as fast, but they are likely to have a broader, more varied experience base to draw from. More experienced adults are likely to have the edge in the pattern-recognition department, which, we will see in the next chapter, is the fundamental brain process associated with learning and knowing. The final bit of good news for aging brains is that normal, healthy brains retain substantial *neuroplasticity*—the ability to change and adapt neural connections.

Key Ideas

- Unless ALFAS attend sufficiently well to threat mediation, adults may literally not have enough presence of mind to learn.
- Increasing curiosity doesn't ensure less anxiety; lowering threat doesn't guarantee curiosity.
- When the reflexive brain is sharply stimulated—perhaps when an adult is suddenly put on the spot (especially if everyone else is

watching)—the capacity of the rest of the brain to reflect, reason, or learn is severely curtailed.

- Our brains are geared to flash warning signs, and the brain is several times faster at arriving at a negative appraisal than a positive one.
- To be in a state of not knowing is to venture out in the wilds without self-protection. Most of us therefore avoid ambiguity.
- The brain will fill in missing details, such as finding relationships and patterns even where there aren't any. The brain effectively counters its discomfort by projecting certainty—or at least explanations—onto the environment.
- The period during which an adult moves from not knowing to coming to know and finally to understanding is uncomfortable at best.
- Well-planned approaches to facilitation and meaningful learning may fall flat if we have not taken into account adults' emotional responses to having their beliefs and certainties challenged.
- What the brain is willing to accept is deeply and invisibly influenced by *what I want (*or *don't want) to be true*.
- Experience consistently and continuously changes the brain. The challenge for facilitators is to design experiences that take full advantage of this capacity for change.
- Because we don't realize what our brain is doing or why, we cannot challenge the highly questionable criteria it uses to determine who is us versus who is them, nor do we realize how easily we can be manipulated.
- Older brains are not as fast as younger ones, but they usually have a broader, more varied experience base to draw from. More experienced adults are likely to have the edge in the pattern-recognition department.

Pause for Reflection

Consider using this space to comment on, question, or freewrite any thoughts and reactions to this introduction to knowing more about the brain. You may even wish to doodle or sketch your feelings about the material.

1. Did the readings confirm what you already understood about the brain? Were you able to elaborate on that understanding? Did you make any unexpected connections?
2. Did the readings contradict your understanding? How will you reconcile the differences?
3. Does any of the information seem to apply to your sense of yourself as a learner, and/or to your practice?