Notes

Vitality and Youthfulness

Å **1.8 million connections per second:** L. Eliot, 1999, *What's Going on in There? How the Brain and Mind Develop in the First Five Years of Life* (New York: Bantam), 27.

Å **Our brains thrive when creating new information:** Neurobiologists have known that a novel environment sparks exploration and learning, but, until recently, very little was known about whether the brain really prefers novelty as such. Now, researchers Nico Bunzeck and Emrah Duzel report studies with humans showing that the major "novelty center" of the brain—called the substantia nigra/ventral tegmental area (SN/VTA)—does respond to novelty as such, and this novelty motivates the brain to explore, seeking a reward. Bunzeck and Duzel found that novelty enhanced learning in the subjects. N. Bunzeck and E. Duzel, 2006, "Absolute Coding of Stimulus Novelty in the Human Substantia Nigra/VTA." *Neuron* 51 (Aug. 3):369–379; Reported in "Pure Novelty Spurs the Brain," *Medical News Today,* August 6, 2006.

• **We have only to provide our brains with new information:** Nobel laureate Gerald M. Edelman states that "the brains of higher level animals autonomously construct patterned responses to environments that are full of novelty." G. M. Edelman, 2005, *Wider Than the Sky* (New Haven, Conn.: Yale University Press), 38–39.

• **Until quite recently, it was believed:** S. Begley, 2007, "How the Brain Rewires Itself," *Time,* January 19. It was only in 1999 that Torsten Wiesel, who won the Nobel Prize with David Hubel in 1981 for his studies of the development of the visual cortex, after

much public denial, admitted in print that adult neuroplasticity was a genuine phenomenon. T. N. Wiesel, 1999, "Early Explorations of the Development and Plasticity of the Visual Cortex: A Personal View," *Journal of Neurobiology* 41(1):7–9.

- **science has now shown that *neurogenesis:*** Animal studies over the last decade have overturned the assumption that the adult brain is "fixed," showing that *neurogenesis*—the formation of new nerve cells—can be induced easily with exercise in some parts of the brain. A recent study published in the *Proceedings of the National Academy of Sciences* extended that principle to humans for the first time. After working out for three months, all the subjects appeared to sprout new neurons. With moderate athletic activity, or regular daily exercise, our muscles release a variety of chemicals that enter the brain and trigger the production of certain neurotransmitters that fuel activities associated with higher thinking. New brain cells start branching out, sprouting new neurons and establishing new connections with other groups of brain cells. A. C. Pereira, D. E. Huddleston, A. M. Brickman, A. A. Sosunov, R. Hen, G. M. McKhann, R. Sloan, F. H. Gage, T. R. Brown, and S. A. Small, 2007, "An in Vivo Correlate of Exercise-Induced Neurogenesis in the Adult Dentate Gyrus," *Proceedings of the National Academy of Sciences* 104(13):5638–5643. Reported in M. Carmichael, 2007, "Stronger, Faster, Smarter: Exercise Does More Than Build Muscles and Help Prevent Heart Disease; New Science Shows That It Also Boosts Brainpower—and May Offer Hope in the Battle Against Alzheimer's," *Newsweek,* March 26.
- **In recent research by neuroscientist Alvaro Pascual-Leone:** See chapter 9.
- **Our brains are organized through movement:** See chapter 2.
- **combined with attention:** "In all three of the cortical systems where scientists have documented neuroplasticity—the primary auditory cortex, somatosensory cortex, and motor cortex—the variable determining whether or not the brain changes is . . . the attentional state of the animal." J. Schwartz and S. Begley, 2003, *The Mind and the Brain: Neuroplasticity and the Power of Mental Force* (New York: ReganBooks), 338.

One. Movement with Attention—Wake Up to Life

- **our simplest thoughts and feelings involve movement:** It has long been known that a nerve impulse is conducted along nerve fibers by the movement of charged ions across the cell membrane and then the movement of neurotransmitter from one cell to the next at the junctions between cells, but it has only recently been discovered just how much movement is involved in the actual structure of the nerve terminals. "Now, after peering closer than ever before at the elaborate branches of individual nerve cells, scientists have discovered that the twigs, known as dendrites, are decorated with tiny ornaments, called dendritic spines—and that the ornaments can move." Carl T. Hall, 1999, "Structures in Motion Seen at Synapses—Discovery Could Revamp View of Brain Function," *San Francisco Chronicle,* January 5. See E. R. Kandel, 2006, *In Search of Memory: The Emergence of a New Science of Mind*. (New York: W. W. Norton); A. Matus, 2000, "Actin-Based Plasticity in Dendritic Spines," *Science* 290:754–758.
- **Within your brain are billions of brain cells:** At birth, the brain contains something in the region of 100 billion neurons, each of which connects to anywhere between a few thousand to one hundred thousand other neurons through specialized junctions called synapses. A conservative estimate of the total number of synapses in the adult brain is 100 trillion. The formation of synapses begins in the cerebral cortex, for example, during the seventh week of gestation and continues well into childhood. It is estimated that at its peak, each neuron forms an average of fifteen thousand connections. This equates to a rate of formation of 1.8 million synapses per second during the period from the second month in utero until the child's second birthday. Not all of these synapses survive. See A. Gopnik, A. N. Meltzoff, and P. K. Kuhl, 1999, *The Scientist in the Crib: Minds, Brains and How Children Learn* (New York: William Morrow), 181–186; L. Eliot, 1999, *What's Going On in There? How the Brain and Mind Develop in the First Five Years of Life* (New York: Bantam) 27–32; and J. J. Ratey, 2000, *A User's Guide to the Brain* (New York: Pantheon), 26.
- **Movement is the language of your brain:** Nobel laureate Gerald M. Edelman states, "The brain's motor functions . . . are . . . critically important, not just for the regulation of movement, but also for forming images and concepts." He says, "In the mammalian nervous system, perceptual categorization is carried out by

interactions between sensory and motor systems . . . [we first] sample the world of signals by movement and attention and then . . . categorize these signals as coherent through . . . synchronization of neuronal groups." G. M. Edelman, 2005, *Wider Than the Sky* (New Haven, Conn.: Yale University Press), 23, 49.

- **through *bringing attention to our movements:*** One of the great pioneers of neuroplasticity research is Michael Merzenich of UCSF. For an excellent and approachable overview of his work, see N. Doidge, 2007, *The Brain That Changes Itself* (New York: Viking Penguin) especially chap. 3, "Redesigning the Brain," 45–92.

  Merzenich has shown that a prerequisite for plastic change in the brain is attention. Initially, he demonstrated this by training owl monkeys in a sensory discrimination task, rewarding their success in paying attention to a stimulus to their hand with food. In a parallel experiment, he distracted their attention by rewarding attention to an auditory stimulus. Plastic changes were only present in the areas of the brain corresponding to the specific area of attention, that is, somatosensory or auditory. G. H. Recanzone, M. M. Merzenich, W. M. Jenkins, K. A. Grajski, and H. R. Dinse, 1992b, "Topographic Reorganization of the Hand Representation in Cortical Area 3b of Owl Monkeys Trained in a Frequency Discrimination Task," *Journal of Neurophysiology* 67:1031–1056.

  In 1996, he and his colleagues demonstrated such plastic change in the motor cortex. The experiments trained squirrel monkeys to retrieve food pellets from four food wells of differing sizes. The results showed that plastic change occurred in the motor cortex and suggested that use-dependent plastic reorganization occurs in a number of associated structures, including the motor cortex, the basal ganglia, the cerebellum, and the spinal cord. R. J. Nudo, G. W. Milliken, W. M. Jenkins, and M. M. Merzenich, 1996, "Use-Dependent Alterations of Movement Representations in Primary Motor Cortex of Adult Squirrel Monkeys," *Journal of Neuroscience* 16(2):785–807.

- **Movement coupled with attention . . . serve as a rich source of information to the brain:** Much of twentieth-century neuroscientific research centered on the study of cortical sensory perception, particularly vision. Much of that research was done in isolation from brain functioning as a whole. Alain Berthoz, director of the Laboratory of Physiology of Perception and Action at the Collège de France, elegantly presents perception as an action whose devel-

opment is critically dependent upon movement and the information that movement provides. See A. Berthoz, 2000, *The Brain's Sense of Movement,* trans. Giselle Weiss (Cambridge, Mass.: Harvard University Press).

- **What is missing is attention:** To quote Merzenich, "Experience coupled with attention leads to physical changes in the structure and functioning of the nervous system." M. M. Merzenich and R. C. Decharms, "Neural Representations, Experience and Change," in *The Mind-Brain Continuum,* ed. R. Llinàs and P. S. Churchland (Cambridge, MA: MIT Press, 1996), 77.
- **In his book *The Power of Now:*** E. Tolle, 1999, *The Power of Now* (Novato, CA: New World Library) 97.
- **you see brand-new clusters of cells lighting up:** A number of imaging studies have now shown this and publish the images; Dick Passingham of Oxford University used positron-emission tomography (PET) to study differences in brain activity between new learning and automatic performance in normal volunteers. Scans showed high levels of activity in the prefrontal cortex during new learning, but not once the performance became routine. By paying special attention to the now-automatic task, the prefrontal cortex became metabolically active once more. M. Jueptner, K. M. Stephan, C. D. Frith, D. J. Brooks, R. S. J. Frackowiak, and R. E. Passingham, 1997, "Anatomy of Motor Learning: I. Frontal Cortex and Attention to Action," *Journal of Neurophysiology* 77(3):1313–1324.

  Another study headed by Heidi Johansen-Berg, also of Oxford University, used functional magnetic resonance imagery (fMRI). It concluded that "robust . . . widespread attentional effects are found in multiple areas responsible for motor control." H. Johansen-Berg and P. M. Matthews, 2002. "Attention to Movement Modulates Activity in Sensori-Motor Areas, Including Primary Motor Cortex," *Experimental Brain Research* 142(1):13–24.
- **excellent at creating set "templates" or "programs":** Gerald Edelman states that "the brains of higher-level animals autonomously construct patterned responses to environments that are full of novelty." Edelman, *Wider Than the Sky,* 38–39.
- **specifically the brain's organizational abilities:** Esther Thelen and Linda Smith refer to Edelman when they propose that for babies "the correlated activity of looking and reaching [i.e., attention and movement] engenders real changes in brain circuits." E. Thelen and L. B. Smith, 1994, *A Dynamic Systems Approach to the*

Development of Cognition and Action (Cambridge, Mass.: MIT Press), 305.

- **Our brains crave new information:** See chapter 1.
- **"It ain't what you do . . .:** This was first recorded by Ella Fitzgerald in 1939 as "T'ain't what you do, it's the way that you do it." Louis Armstrong released it as "T'ain't what you do, it's the way cha do it."

Two. The Learning Switch—Bring in the New

- **a process I call *turning on the learning switch:*** The switch is a metaphor, not an anatomical entity, describing the clearly observable shift of a person into a learning mode as akin to the change brought about by turning on a light in a darkened room. "We all know that such a state exists, we just don't know what the mechanism is." Mark Latash (author of *Neurophysiological Basis of Human Movement* [Champaign, Ill.: Human Kinetics, 1998]), Distinguished Professor of Kinesiology, Pennsylvania State University, in a conversation with the author.

  The following paragraphs represent some views as to the measurable characteristics of such a state and its potential mechanisms.

  1. Electrical activity of the brain can be measured as "brain waves" by an electroencephalogram on the surface of the skull. Certain patterns characteristic of childhood become less common in adulthood (e.g., so-called theta waves) but are seen in dreaming or "creative" states and meditation. Electrical and other mechanisms of alertness are discussed in B. Oken and M. Salinsky, 1992, "Alertness and Attention: Basic Science and Electrophysiologic Correlates," *Journal of Clinical Neurophysiology* 9(4):480–494.

  2. The most common cells in the brain are not neurons (nerve cells) but glial cells. They support the nerve cells structurally, regulate the environment around synapses and are dramatically altered by challenging experiences and learning opportunities. They thus have the potential to maintain a chemical learning state in the brain. W. K. Dong and W. T. Greenough, 2004, "Plasticity of Nonneuronal Brain Tissue: Roles in Developmental Disorders," *Mental Retardation and Developmental Disabilities Research Reviews,* 10:85–90.

  3. Nobel Prize winner Eric Kandel has done much research on the conversion of short-term to long-term memory. He has identified a self-propogating mechanism based on a short protein fragment called a prion. Prions had previously only been known to be

associated with devastating neurological diseases like BSE (mad cow disease). C. H. Bailey, E. R. Kandel, and K. Si, 2004, "The Persistence of Long-Term Memory: A Molecular Approach to Self-Sustaining Changes in Learning-Induced Synaptic Growth," *Neuron* 44(1):49–57; A. Barco, C. H. Bailey, and E. R. Kandel, 2006, "Common Molecular Mechanisms in Explicit and Implicit Memory," *Journal of Neurochememistry* 97(6):1520–1533. Kandel also talks of experiments in which he bred mice deficient in a particular gene whose learning in response to a stimulus was greatly enhanced. "As a result these mice were brilliant; they had a much stronger spatial memory than normal mice." E. R. Kandel, 2007, *In Search of Memory: The Emergence of a New Science of Mind* (New York: W. W. Norton), 293.

4. Michael Merzenich has done research on the role of a particular brain structure called the basal nucleus and its role in selecting behaviorally important stimuli and ignoring irrelevant ones. See note on pages 270–271.

- **a process that brain researchers call "pruning":** See K. McAuliffe, 2007, "Life of the Brain—Midlife: Adult Behaviors," in "The Brain: An Owner's Manual," *Discover* (Spring): 13–14. McAuliffe quotes research by Jay McLelland, a psychologist from Stanford University. Japanese newborns, like all others, have the potential ability to perceive the difference between "r" and "l," but their language doesn't contain those distinct sounds. As they grow older, the patterns learned from their experience become more and more entrenched. As adults, Japanese speakers can no longer distinguish the two sounds. B. D. McCandliss, J. A. Fiez, A. Protopapas, M. Conway, and J. L. McClelland, 2002, "Success and Failure in Teaching the [r]-[l] Contrast to Japanese Adults: Predictions of a Hebbian Model of Plasticity and Stabilization in Spoken Language Perception," *Cognitive, Affective and Behavioral Neuroscience* 2:89–108. Such grooving as we age can be demonstrated as a reduction of gray matter on MRI scans. N. Raz, U. Lindenberger, K. M. Rodrigue, K. M. Kennedy, D. Head, A. Williamson, C. Dahle, D. Gerstorf, and J. D. Acker, 2005, "Regional Brain Changes in Aging Healthy Adults: General Trends, Individual Differences and Modifiers," *Cerebral Cortex* 15:1676–1689.
- **"cells that fire together, wire together":** In a famous passage in his 1949 book *The Organization of Behaviour* (New York: Wiley), Hebb proposed a neural mechanism for learning: "When an axon of cell A is near enough to excite a cell B and repeatedly

or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased." In other words, the more often one nerve cell excites another, the more likely they are to fire together in the future, or "Cells that fire together wire together." The source of this latter version is unknown, but it is often quoted in discussions of Hebbian learning in neuroscience. See J. L. McClelland, "How Far Can You Go with Hebbian Learning, and When Does It Lead you Astray?" available at www.psych.stanford.edu/~jlm/papers/McClellandIPHowFar.pdf.

- **this capacity of our brains to impose order and meaning:** Anticipation can affect perception. There has been much research by Nancy Kanwisher and her team at MIT to show how, by directing our attention, we can alter what we perceive of our environment. "We are not passive recipients but active participants in our own process of perception." N. Kanwisher and P. Downing, 1998, "Separating the Wheat from the Chaff," *Science* 282:57–58.
- **mouths that do not speak:** Psalms 135:16–17 (New American Standard Bible).
- **"We now know that with proper stimulation and an enriched environment":** M. Diamond, from a lecture to the American Society on Aging, 2001, quoted in D. Amen, 2005, *Making a Good Brain Great* (New York: Harmony Books), 113.
- **our brains switch on and create something new:** Constantine Mangina and Evgeni Sokolov have distinguished two kinds of intelligence in terms of the potential to acquire knowledge. The first, *crystallized intelligence,* is fact-based intelligence (academic learning) and is the intelligence mostly focused on by traditional education. The second one, *fluid intelligence,* operates under novel situations and is responsible for the acquisition of new information (organic learning). They claim that fluid intelligence reaches its peak at around twenty-five years of age and gradually declines thereafter if left on its own (but see below). They defined "optimally high" physiological activation in the brain during which fluid intelligence occurs (i.e., the learning switch is turned on). C. A. Mangina and E. N. Sokolov, 2006, "Neuronal Plasticity in Memory and Learning Difficulties: Theoretical Position and Selective Review," *International Journal of Psychophysiology* 60:203–214.

  Michael Merzenich has identified the role of a subcortical structure in the brain called the basal nucleus. During infant development, it is very active, but its level of activity tends to go

down in later years. When it is reactivated in later life, adults become better learners. In other words, the ability for organic learning is not lost, just dormant. M. P. Kilgard and M. M. Merzenich, 1998, "Cortical Map Reorganization Enabled by Nucleus Basalis Activity," *Science* 279(5357):1714–1718.

A new study from the University of Michigan appears to show that fluid intelligence is *not* innate. The kind of mental ability that allows us to solve new problems without having any relevant experience is a skill that can be trained. S. M. Jaeggi, M. Buschkuehl, J. Jonides, and W. J. Perrig, 2008, "Improving Fluid Intelligence with Training on Working Memory," *Proceedings of the National Academy of Sciences* 105(19):6829–6833. See also N. Balakar, 2008, "Memory Training Shown to Turn Up Brainpower," *New York Times,* April 29.

- **an inevitable offshoot of civilization's demands on us:** S. Freud, *Civilization and Its Discontents* (New York: W. W. Norton).
- **how we handle stress in our lives can either empower us or tranquilize us:** A. Patmore, 2006, *The Truth About Stress* (London: Atlantic Books).
- **" 'flow'—that wonderful state":** R. Gross, "Your Learning and Your Brain," available at http://adulted.about.com/od/learningstyles/a/brain_2.htm.
- **Roger Bannister, the man who, in 1954, broke the four-minute mile, was surrounded by scientists "proving" the human body was not capable of breaking the four-minute mile:** Bannister himself discusses this and believes that the notion of the impossibility of a four-minute mile may have been a myth created by sportswriters and not the view of contemporary experts. R. Bannister, 2004, *The Four-Minute Mile,* rev. ed. (Guildford, CT: Lyons Press).
- **"the finest work of literature in all the annals of science . . .":** P. B. Medawar, quoted in J. T. Bonner's editorial introduction to the Canto edition of D. Thompson, 1961, *On Growth and Form* (Cambridge: Cambridge University Press), xv.

Three. Subtlety—Experience the Power of Gentleness

- **we begin to notice finer differences:** Jay McLelland, of Stanford University, used a computer to exaggerate the phonetic distinctions between "l" and "r" that normally confuse Japanese speakers.

McLelland enabled the Japanese adults to perceive the differences between the two sounds more easily. They thus learned to be able to recognize and reproduce the sounds. B. D. McCandliss, J. A. Fiez, A. Protopapas, M. Conway, and J. L. McClelland, 2002, "Success and Failure in Teaching the [r]-[l] Contrast to Japanese Adults: Predictions of a Hebbian Model of Plasticity and Stabilization in Spoken Language Perception," *Cognitive, Affective and Behavioral Neuroscience* 2:89–108.

- **A scientist and rehabilitation physician by the name of Paul Bach-y-Rita:** See N. Doidge, 2007, *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science* (New York: Viking Penguin), 19–20. Bach-y-Rita extended his exploration to substituting tactile stimulation for other sensory modalities, most notably and extraordinarily with vision, realizing that "we see with the brain and not the eyes." P. Bach-y-Rita, M. E. Tyler, and K. A. Kaczmarek, 2003, "Seeing with the Brain," *International Journal of Human-Computer Interaction* 15(2):285–295; P. Bach-y-Rita, J. G. Webster, W. J. Tompkins, and T. Crab, 1987, "Sensory Substitution for Space Gloves and Space Robots," Space Telerobotics Workshop, Jet Propulsion Laboratory, Pasadena, Calif., January 20–22, 51–57.
- **Ernst Heinrich Weber showed:** Weber's finding, known as the Weber-Fechner law, is mainly founded on experiments in which people were given two nearly identical stimuli (for example, two similar weights) and tested whether they could notice a difference between them. It was found that the smallest noticeable difference was roughly proportional to the intensity of the stimulus. For example, if a person could consistently feel that a 110-gram weight was heavier than a 100-gram weight, he could also feel that 1,100 grams was more than 1,000 grams.

  More recently, it has become evident that the Weber-Fechner principle applies mainly to higher intensities of sight, hearing, and touch and only poorly to most other types of sensory experience. However, the Weber-Fechner principle is still a good one to remember because it emphasizes that the greater the intensity of the background sensory stimulus, the harder it is to perceive a change. See www.neuro.uu.se/fysiologi/gu/nbb/lectures/WebFech.html and A. C. Guyton, 1981, *Textbook of Medical Physiology* (Philadelphia: Saunders).
- **the story of Juan Fangio:** The story of the crash and Fangio's subsequent realization is to be found in D. Kim Rossmo, 2006,

"Criminal Investigative Failures," *FBI—Law Enforcement Bulletin* 75(9):1–10.

Four. Variation—Enjoy Abundant Possibilities

- **A group of brain researchers asked if physical activity alone:** J. E. Black, K. R. Isaacs, B. J. Anderson, A. A. Alcantara, and W. T. Greenough, 1990, "Learning Causes Synaptogenesis, Whereas Motor Activity Causes Angiogenesis, in Cerebellar Cortex of Adult Rats," *Proceedings of the National Academy of Sciences* 87:5568–5572.
- **"motor skill is not a movement formula":** N. A. Bernstein, 1996, "On Exercise and Motor Skill," in *On Dexterity and Its Development,* translated by M. L. Latash, ed. M. L. Latash and M. T. Tuvey (Mahwah, NJ: Lawrence Erlbaum), 181.
- **In an article titled "The Plastic Human Brain Cortex":** A. Pascual-Leone, A. Amedi, F. Fregni, and L. B. Merabet, 2005, "The Plastic Human Brain Cortex," *Annual Reviews of Neuroscience* 28:380.
- **"We are just beginning to realize that the adult brain is more dynamic than static":** M. M. Mezernich, J. H. Kaas, J. T. Wall, R. J. Nelson, M. Sur, and D. Felleman, 1983, "Topographic Reorganization of Somatosensory Cortical Areas 3B and 1 in Adult Monkeys Following Restricted Deafferentation," *Neuroscience* 8:33–55.
- **"By our errors we see deeper into life."** From the novel *The Story of an African Farm,* published in 1883 by the South African novelist, pacifist, and social critic Olive Emilie Albertino Schreiner under her pseudonym Ralph Iron.
- **the sensory receptors—the nerve cells through which we experience all sensations—"react strongly while change is taking place":** A. C. Guyton, 1981, *Textbook of Medical Physiology* (Philadelphia: Saunders).
- **the often-told story of Friedrich Kekulé:** Kekulé himself recounted the anecdote in a speech to the German Chemical Society in 1890, some twenty-five years after publishing his theory. See A. J. Rocke, 1985, "Hypothesis and Experiment in the Early Development of Kekulé's Benzene Theory," *Annals of Science* 42:4, 355–381.
- **To get rid of the pain:** See chapter 1.
- **William Westney, a concert pianist and award-winning educator:** See W. Westney, 2006, *The Perfect Wrong Note: Learning to Trust Your Musical Self* (Pompton Plains, NJ: Amadeus Press), 156.

- **"To fall into a habit is to begin to cease to be":** M. de Unamuno, 2007, *Del Sentimiento Trágico de la Vida (The Tragic Sense of Life)* (Milano, Italy: Dodo Press), chap. 9.

Five. Slow—Luxuriate in the Richness of Feeling

- **Scientific research shows that we can either react automatically with a shorter reaction time of 0.25 seconds or less, or act consciously with a delayed reaction time of 0.5 seconds or more:** In a series of extraordinary and elegant experiments, Benjamin Libet has shown that electrical activity in the brain, called "the readiness potential," precedes our awareness of a consciously willed action by about 0.5 seconds—that is, the brain starts an action half a second *before* we *decide* to act! If this action is in response to a stimulus, the awareness occurs half a second after the stimulus, but the subjective conscious experience is projected back in time closer to the moment of the stimulus (0.02 seconds after, in fact).

  So it takes a little time for us to perceive the outside world, but we relocate the experience back in time so that we experience the world at the right moment.

  Arthur Jensen carried out a series of reaction-time experiments in the 1960s in which subjects demonstrated reaction times of about 0.25 seconds. He wondered if some of the subjects were cheating by deliberately being too slow, so he asked them to gradually increase their reaction time, but none of them could. As soon as they tried to increase their reaction time to more than a quarter of a second, it leaped to at least half a second—a result that was explained by Libet's findings.

  So, things that need to happen quickly happen automatically. For us to have a conscious say in our actions, we need to act a lot more slowly. Libet's findings are discussed extensively in T. Norretranders, 1998, *The User Illusion: Cutting Consciousness Down to Size* (New York: Viking Penguin), chaps. 9, 10, and 11. His writings are based on an interview with Libet on March 26 and 27, 1991, in San Francisco. See also B. Libet et al., 1983, "Time of Conscious Intention to Act in Relation to Onset of Cerebral Activity (Readiness Potential): The Unconscious Intention of a Freely Voluntary Act," *Brain* 106:623–642.

- **Slow gets the brain's attention, increasing its activity and forming new patterns:** Jeffrey Schwartz is a psychologist who specializes in treating the debilitating condition of obsessive-compulsive disorder

(OCD). He describes an OCD "circuit" in the brain that becomes chronically and inappropriately activated and has developed a four-step treatment regime that is informed by his practices in Buddhist meditation. Slowing down and paying attention provide a "way in" to disturb these harmful patterns and enable the formation of newer healthier ones. He says, "Directed mental focusing of attention becomes the mind's key action during treatment." J. M. Schwartz and S. Begley, 2003, *The Mind and the Brain: Neuroplasticity and the Power of Mental Force* (New York: ReganBooks), 55–95, 338–340.

- **In her book *You Are Not the Target,* . . . Laura Archera Huxley:** L. Archera Huxley, 1995. (Portland, OR: Metamorphons Press).
- **"Having someone wonder where you are when you don't come home at night is a very old human need":** Margaret Mead, from a speech published in M. Brown and A. O'Connor, 1985, *Woman Talk* (London: Futura Publications).
- **In his book *Flow:*** M. Csikszentmihalyi, 1990, *Flow: The Psychology of Optimal Experience* (New York: Harper Perennial).
- **"freed from normal restrictions, and are opened to a wider world":** Madeleine L'Engle, 1980, *Walking on Water: Reflections on Faith and Art.*
- **Intentionally slowing down can help us perceive differences:** Paula Tallal and Michael Merzenich developed a program for children with language learning impairment called Fast ForWord, which slows down the sounds that children hear, allowing them to begin to distinguish between the sounds and overcome their limitations. P. Tallal, 1998, "Language Learning Impairment: Integrating Research and Remediation," *New Horizons for Learning.* http://www.newhorizons.org/neuro/tallal/htm.
- **Slow is for creation and learning:** To master anything we do, we need initially to slow way down, and then we can speed up successfully and even develop strong intuition in that area. D. Kahnman, 2003, "A Perspective on Judgement and Choice: Mapping Bounded Rationality," *American Psychologist* 58:697–720.

Six. Enthusiasm—Turn the Small into the Great

- **Enthusiasm can have a powerful impact on our moods, our behavior, and our physical performance:** Enthusiasm amplifies our experience, and amplification is a characteristic of many biological systems, for example, our senses of taste and smell. Taste and

(even more especially) smell are characterized by a very low sensory threshold. One of the principle characteristics of smell is the minute quantity of the stimulating agent in the air often required to effect a smell sensation. For instance, the substance methyl mercaptan can be smelled when only 1/25,000,000,000 milligram is present in each milliliter of air. Because of this low threshold, this substance is mixed with natural gas to give it an odor that can be detected when it leaks from a gas pipe. A. C. Guyton, 1981, *Textbook of Medical Physiology* (Saunders).

Through this process of amplification, one molecule of a fragrant flower can lead us to remember an old friend and travel across the world to visit her.

- **"we can think of emotions, moods and states such as compassion as trainable mental skills":** A. Lutz, L. L. Greischar, N. B. Rawlings, and R. Davidson, 2004, "Long-Term Meditators Self-Induce High-Amplitude Gamma Synchrony During Mental Practice," *Proceedings of the National Academy of Sciences* 101(46):16369–16373.
- **every time he noted a change he liked and amplified it internally:** In his book *Looking for Spinoza: Joy, Sorrow and the Feeling Brain,* 2003, internationally renowned neuroscientist Antonio Damasio argued that the mind and body are unified. He anticipated one of brain science's most important recent discoveries: the critical role of the emotions in ensuring our survival and allowing us to think. See E. Eakin, 2003, "I Feel Therefore I Am," *New York Times,* April 19.

  Current research and theory point ever more clearly to the link between our emotions and our brain's ability and tendency to learn, remember, and create new patterns and possibilities for us. Positive anticipation is shown to play an important role in these domains. S. Ikemoto and J. Panksepp, 1999, "The Role of Nucleus Accumbens Dopamine in Motivated Behavior: A Unifying Interpretation with Special Reference to Reward-Seeking," *Brain Research Reviews* 31(1):6–41.
- **This spontaneous excitement essentially gets her brain to pay attention and select the relevant connections that are being formed and to make sure to strengthen those connections:** An emotionally arousing stimulus places the brain in a "motive state," coordinating information processing across the brain and leading to invigoration. Animals become active or invigorated when dopamine is injected into a particular area in the forebrain called

the nucleus accumbens. Dopamine facilitates synaptic transmission, leading to amplification in circuits that lead to activation of movement-control regions. Novel stimuli and incentives are prime examples of invigorating stimuli. J. LeDoux, 2002, *Synaptic Self: How Our Brains Become Who We Are* (New York: Viking Penguin), 243–259.

- **When we are without enthusiasm, we miss out on a powerful tool:** One of the periods of greatest enthusiasm and change in adult life is when we fall in love. Oxytocin is a neuromodulator (a chemical that enhances or diminishes the overall effectiveness of nerve transmission at synapses) that is released when lovers commit. One of its roles seems to be the "wiping out" of neural patterns, making it possible for the couple to learn new ones. The work of Walter Freeman, a professor of neuroscience at the University of California, Berkeley, in this area is discussed in N. Doidge, 2007, *The Brain That Changes Itself* (New York: Viking Penguin), 118–121.
- **When Winnie-the-Pooh found Eeyore's lost tail:** A. A. Milne, 1926, *Winnie-the-Pooh* (London: Methuen), chap. 4, "When Eeyore Lost a Tail, and Pooh Found One."
- **"offered strong evidence that willful, mindful effort can alter brain function":** J. M. Schwartz, P. W. Stoessel, L. R. Baxter Jr., K. M. Martin, and M. E. Phelps, 1996, "Systematic Changes in Cerebral Glucose Metabolic Rate After Successful Behavior Modification Treatment of Obsessive-Compulsive Disorder," *Archives of General Psychiatry* 53:109–113.
- **"Moment by moment we choose and sculpt how our ever changing minds will work":** M. M. Merzenich and R. C. Decharms, 1996, "Neural Representations, Experience and Change," in *The Mind-Brain Continuum,* ed. R. Llinàs and P. S. Churchland (Cambridge, MA: MIT Press), 61–81.
- **All things in the universe move toward states of greater *entropy:*** The concept of entropy in physics is a measure of the degree of order of a particular system. It is a quantity that, in principle, can be calculated. Increased entropy means loss of order. The entropy of an *isolated* system always increases; for example, leave your backyard furniture outdoors for the duration of a New England winter and see what happens to the shape and color of the cushions. Or leave your brain unattended for a couple of decades and experience increased entropy in your mind and body firsthand! However, the trend in any particular system can be reversed and

moved toward greater order, popularly known as *negative* entropy. For example, order can be increased by cooling a liquid to make it solidify, or, more spectacularly, by humans building high-rise office blocks out of sand and cement or violins out of chunks of wood. It is important to note, however, that order is not the same as complexity, and it is in the realm of complexity that we talk about order in the brain. "Complexity covers a vast territory that lies between order and chaos." H. Pagels, 1989, *The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity* (New York: Bantam), 66.

We will return to complexity in chapter 11.

Order and information are also linked, although, once again, they are not the same. For example, a crystal contains much order but little information, whereas a gas lacks order but its particles represent a lot of information as noise. What is important is the value, or meaning, that it is possible to extract from that information.

It is easy to appreciate how misconceptions have arisen in this complex and challenging field when the father of information theory himself is quoted as saying the following regarding the concept of entropy:

> My greatest concern was what to call it. I thought of calling it "information," but the word was overly used, so I decided to call it "uncertainty." When I discussed it with John von Neumann, he had a better idea. Von Neumann told me, "You should call it entropy, for two reasons. In the first place your uncertainty function has been used in statistical mechanics under that name, so it already has a name. In the second place, and more important, nobody knows what entropy really is, so in a debate you will always have the advantage."

From a conversation between Claude Shannon and John von Neumann regarding what name to give to the "measure of uncertainty" or attenuation in phone-line signals (1949). Quoted in M. Tribus and E. C. McIrvine, 1971. "Energy and Information." *Scientific American* 224(3):179–188.

For an in-depth discussion of information, meaning, depth, and entropy, see T. Norretranders, 1998, *The User Illusion: Cutting Consciousness Down to Size* (New York: Viking Penguin).

- **Another example is the way a flower dies and soon disintegrates:** Noted American biochemist Albert Lehninger has argued that the order produced within cells as they grow and divide is more than compensated for by the disorder they create in their surroundings in the course of growth and division: ". . . living organisms preserve their internal order . . . returning to their surroundings an equal amount of energy as heat and entropy." A. Lehninger, 1993, *Principles of Biochemistry, 2nd ed.* (New York: Worth).

Seven. Flexible Goals—Make the Impossible Possible

- **by holding our goals loosely:** Goal-setting theory has been popular in organizational psychology. Edwin A. Locke began to examine this subject in the mid-1960s and derived the concept for goal setting from the work of the Greek philosopher Aristotle. According to Aristotle, action is caused by a purpose. There are limitations to goal-setting theory, and for complex tasks, an individual may become preoccupied with meeting the goals, rather than performing the task, thereby impairing performance. G. Latham, E. Locke, 2002, "Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey," *American Psychologist* 57(9):705–717.
- **In the documentary film *Animals Are Beautiful People:*** Written, produced, and directed by J. Uys, distributed by Warner Bros., 1975.
- **the Chicago Columbus Day marathon:** A. Wang, 2007, "One Dead in Heat-Shortened Marathon," *Chicago Tribune,* October 7.
- **We even carry our rigid approach to goal setting into raising our children:** Students do better when they focus on becoming proficient rather than on achieving grades. They engage with the task more deeply and persevere in the face of setbacks.

  If their focus is on good grades as a mark of success, these become the indicators of self-worth, and this goal-orientated approach is associated with higher anxiety and an increased tendency to cheat or learn by rote, rather than striving for a deeper understanding. C. Ames, 1992, "Achievement Goals, Motivational Climate and Motivational Processes," in *Motivation in Sport and Exercise,* ed. G. C. Roberts (Human Kinetics: Champaign, Ill.) 161–176.

- **In his award-winning book *Ever Since Darwin:*** S. J. Gould, 2007, *Ever Since Darwin* (New York: W. W. Norton), 68.
- **At birth, our brains are roughly a quarter of their adult size:** "At birth, the brain of a rhesus monkey is 65 percent of its final size, a chimpanzee's is 40.5 percent, but we attain only 23 percent. Chimps and gorillas reach 70 percent of final brain size early in their first year; we do not achieve this value until early in our third year. W. M. Krogman, our leading expert in child growth, has written: 'Man has absolutely the most protracted period of infancy, childhood and juvenility of all forms of life . . . Nearly 30 percent of his life is devoted to growing.' " Ibid.
- **"Play is the best way to reach certain goals":** Bateson is quoted in R. Marantz Henig, 2008, "Why Do We Play?" *New York Times Magazine,* February 17.
- **Instead, we are able to respond to the present, where our brains best perform their creative magic:** Inflexibility of approach is seen at its extreme in patients with obsessive-compulsive disorder (OCD). Current research shows that people suffering from obsessive-compulsive disorder have certain circuits in their brains that keep getting activated, usually by a fear or an anxiety that is created within their brain with no direct correlation to events in the world outside their brain. J. M. Schwartz and S. Begley, 2003, *The Mind and the Brain: Neuroplasticity and the Power of Mental Force* (New York: ReganBooks), 61–65.

  Psychologist Jeffrey Schwartz has developed mindfulness techniques to help people overcome these limiting patterns of thought. Release from these obsessive thought patterns "also results in an extremely rewarding sense of true self-esteem—that empowering inner awareness that the utilization of knowledge has enhanced one's capacity for self-control." J. M. Schwartz, 1999, "A Role for Volition and Attention in the Generation of New Brain Circuitry—Toward a Neurobiology of Mental Force." *Journal of Consciousness Studies* 6(8–9):115–142.
- **Some of the most creative musicians, artists, and scientists have experienced the benefits:** Stuart Brown, president of the National Institute for Play, is quoted as saying: "If you look at what produces learning and memory and well-being, play is as fundamental as any other aspect of life, including sleep and dreams." Henig, "Why Do We Play?"
- **Wolfgang Amadeus Mozart once reflected:** This quotation is from a letter published by Friedrich Rochlitz in the *Allgemeine*

Musikalische Zeitung in 1815 (17:561–566) and purported to be by Mozart. A surviving letter of Mozart's to his father, Leopold, (July 31, 1778) indicates that he considered composition to be an active rather than a passive process: "You know that I immerse myself in music, so to speak—that I think about it all day long—that I like experimenting—studying—reflecting." U. Konrad, 2006, "Compositional Method," in *The Cambridge Mozart Encyclopedia,* ed. C. Eisen and S. P. Keefe (Cambridge, U.K.: Cambridge University Press), 101.

- **In his book *The Farther Reaches of Human Nature,* Maslow said:** A. Maslow, 1971, *The Farther Reaches of Human Nature* (New York: Viking).
- **"The test of a first-rate intelligence":** F. Scott Fitzgerald, 1936, *The Crack-Up.* (New York: New Directions Publishing Corp.).
- **In a recent *New York Times* article, author Gary Rivlin profiled Max Levchin:** G. Rivlin, 2007, "Age of Riches: After Succeeding, Young Tycoons Try, Try Again," *New York Times,* October 28.
- **As Stephen Jay Gould claims:** Gould, *Ever Since Darwin,* 73.
- **Recently, Nobel Prize winner Oliver Smithies, a geneticist, was interviewed:** C. Lee, 2007, "From Child on Street to Nobel Laureate," *Washington Post,* October 9, A01.

Eight. Imagination and Dreams—Create Your Life

- **In a study of how our brains operate during normal day-to-day activities:** M. F. Mason, M. I. Norton, J. D. Van Horn, D. M. Wegner, S. T. Grafton, and C. N. Macrae, 2007, "Wandering Minds: The Default Network and Stimulus-Independent Thought," *Science* 315 (5810):393–395. Reported in H. Jones, 2007, "Daydreaming Improves Thinking," *Cosmos Online,* January 19. http://www.cosmosmagazine.com/node/980.
- **In another study of six thousand men and women:** S. J. Lynn and J. W. Rhue, 1988, "Fantasy Proneness: Hypnosis, Developmental Antecedents, and Psychopathology," *American Psychologist* 43(1):35–44.
- **during sleep, different areas of our brains talk to each other:** D. Y. Ji and M. A. Wilson, 2007, "Coordinated Memory Replay in the Visual Cortex and Hippocampus During Sleep," *Nature Neuroscience* 10:100–107, reported in B. Carey, 2007, "An Active, Purposeful Machine That Comes Out at Night to Play: Some Neuroscientists Say That at Least One Vital Function of Sleep Is

Tied to Learning and Memory, and New Findings Suggest That Sleep Plays a Crucial Role in Flagging and Storing Important Memories," *New York Times,* October 23.

- **In research conducted by Alvaro Pascual-Leone:** Pascual-Leone and his colleagues say that

> mental practice alone led to the same plastic changes in the motor system as those occurring with the acquisition of the skill by repeated physical practice. . . . Mental practice alone seems to be sufficient to promote the modulation of neural circuits involved in the early stages of motor skill learning. This modulation not only results in marked performance improvement, but also seems to place the subjects at an advantage for further skill learning with minimal physical practice.

They were literally thinking themselves into a new brain. A. Pascual-Leone, D. Nguyet, L. G. Cohen, J. P. Brasil-Neto, A. Cammarota, and M. Hallett, 1995, "Modulation of Muscle Responses Evoked by Transcranial Magnetic Stimulation During the Acquisition of New Fine Motor Skills," *Journal of Neurophysiology* 74:1037–1045. For a review of his research with functional MRI imaging from the study, see also A. Pascual-Leone, A. Amedi, F. Fregni, and L. B. Merabet, 2005, "The Plastic Human Brain Cortex," *Annual Revue of Neuroscience* 28:377–401.

- **In an interesting study published in *Psychological Science:*** A. J. Crum and E. J. Langer, 2007, "Mind-Set Matters: Exercise and the Placebo Effect," *Psychological Science* 18(2):165–171.
- **In Marty Klein's book *Beyond Orgasm:*** M. Klein, 2002, *Beyond Orgasm* (San Francisco, CA: Celestial Arts).
- **Most of us have heard the famous speech of Martin Luther King Jr.:** Delivered on August 28, 1963, at the Lincoln Memorial in Washington, D.C., as part of the March on Washington for Jobs and Freedom. The speech marked a pivotal point in the American civil rights movement.
- **"Your health is bound to be affected if, day after day, you say the opposite of what you feel":** B. Pasternak, 1958, *Dr. Zhivago.* (New York: Pantheon Books).
- **Joseph Campbell, who coined the phrase "follow your bliss":** See J. Campbell with B. Moyers and B. S. Flowers, ed., 1988, *The Power of Myth* (New York: Doubleday), 117.

- **"People who follow a dream or have a deep sense of purpose":** D. Jaffe and C. Scott, 1988, *Take This Job and Love It* (New York: Fireside).
- **Bestselling author Gary Zukav calls it our "authentic power":** G. Zukav, 1997, *Authentic Power: Aligning Personality with Soul* (Carlsbad, CA: Hay House Audio Books).
- **And it is what Henry David Thoreau was reflecting on:** H. D. Thoreau, 1989, *Walden; or, Life in the Woods* (Princeton, N.J.: Princeton University Press).
- **Abraham Maslow saw these visions and dreams in a similar light:** A. Maslow, 1998, *Toward a Psychology of Being,* 3rd ed. (New York: Wiley).
- **"You gotta have a dream":** Lyrics from the song "Happy Talk," from *South Pacific,* 1949, music by Richard Rodgers and lyrics by Oscar Hammerstein II.
- **skeptics flourish, ready to proclaim the impossibility of whatever new ideas are being put forth:** The great contemporary neuroscientist V. S. Ramachandran is passionate about how important it is for science to embrace and investigate phenomena that are too frequently dismissed because, for example, there is not enough statistical evidence. V. S. Ramachandran, 2006, "Creativity Versus Skepticism Within Science: More Harm Has Been Done in Science by Those Who Make a Fetish out of Skepticism, Aborting Ideas Before They Are Born, Than by Those Who Gullibly Accept Untested Theories," *Skeptical Inquirer* 30(6):48–51.
- **On October 9, 1903, for example, the *New York Times:*** From J. Garreau, 2007, "The Invincible Man—Aubrey de Grey, 44 Going on 1,000, Wants Out of Old Age," *Washington Post,* October 31, C01.

Nine. Awareness—Thrive with True Knowledge

- **Awareness is different from attention:** On a neurological level, attention can be seen as a combination of sensory processing and working memory. It is a selection process whereby some stimuli are processed more efficiently than others; for example, a moving stimulus is perceived more readily than a stationary one. The complexity of the connections between nerve cells is so great that even the fundamental properties that explain the relationship between perception and action still evade us; however, enough is known for us to imagine, in principle, how this might

occur. In addition, memory can be understood in basic terms of the plasticity of the connections between nerve cells in response to experience.

Awareness, on the other hand, relates to the highest levels of consciousness, for which there are as yet no clear known neural correlates. Part of what needs to be explained is how different aspects of perceived stimuli become "bound" together, and then how we become aware of them when they do. Victor Lamme suggests that the binding results from interactions of groups of neurons, which may grow more widespread and come to include higher centers of the brain involved in so-called executive functions. They are put into the context of the system's current needs, goals, and full history. They may thereby reach awareness. V. A. Lamme, 2003, "Why Visual Attention and Awareness Are Different," *Trends in Cognitive Neurosciences* 7(1):12–18; V. A. Lamme, 2004, "Separate Neural Definitions of Visual Consciousness and Visual Attention: A Case for Phenomenal Awareness," *Neural Networks* 17(5–6):861–72. Department of Psychology, University of Amsterdam.

- **Awareness, as I use the term here, means knowing that you know:** There is a good reason for defining the term so specifically. Until very recently, consciousness and awareness were the domain of philosophers. With the explosion of knowledge from brain research in the past two decades, it has become a legitimate area for exploration by neuroscientists; but such exploration is still in its infancy, and definitions remain vague. Christof Koch, one of the world's leading cognitive neuroscientists, writes in his recent book, *The Quest for Consciousness,* "Throughout the book, I use *awareness* and *consciousness* as synonyms." C. Koch, 2004, *The Quest for Consciousness: A Neurobiological Approach* (Englewood, Colo.: Roberts), 12 n19.

  Eleanor Rosch, a professor in the Department of Psychology at the University of California at Berkeley, acknowledged the difficulties the concept of awareness presents to science in a conversation with the Dalai Lama.

  Dalai Lama: "Now, from the point of view of a Western psychologist, how would you prove the presence of something called awareness, the instrument of knowledge?" Rosch: "Well, you see, that is exactly what Western psychologists do not know how to demonstrate."

J. W. Hayward and F. J. Varela, eds., 2001, *Gentle Bridges: Conversations with the Dalai Lama on the Sciences of Mind* (Boston: Shambhala), 116.

I chose to use the word *awareness* exclusively because I distinguish it from *consciousness,* which is a state during which one could, for example, walk through a door without his body hitting the door frame but not necessarily be aware of it.

- **Other animals have some rudimentary consciousness:** The high level of awareness whereby we have an internal observer of ourselves and those around us that knows what it knows seems to be a capacity of the human mind alone, although there is much evidence that limited consciousness exists in many animal species and that "some monkeys even know what they know." D. R. Griffin and G. B. Speck, 2004, "New Evidence of Animal Consciousness," *Journal of Animal Cognition* 7(1):5–18.
- **Perceiving a stimulus and even reacting to it does not mean that we are aware of it at all:** Although there has been much debate over the phenomenon of subliminal perception, "there is considerable evidence for perception without awareness. In fact it is relatively easy to demonstrate that perception occurs when subjects do not believe they have either seen or heard an adequate stimulus." P. M. Meirikle, 1992, "Perception Without Awareness. Critical Issues," *American Psychologist* 47(6):792–795.

  One striking example of perception without awareness is known as *blindsight.* Some brain-damaged patients claim to be blind yet perform tasks that seem impossible unless they can see. "In a sense we all suffer from blindsight," says V. S. Ramachandran, who uses the example given in this text of driving while deeply engaged in conversation. V. S. Ramachandran, 2003, *The Emerging Mind: The Reith Lectures, 2003* (London: Profile Books), 182. See also F. C. Kolb and J. Braun, 1995, "Blindsight in Normal Observers," *Nature* 377:336–338.
- **Without awareness, we could move our shoulder or arm thousands of times:** Dick Passingham and his colleagues compared new learning and subsequent automatic performance in normal volunteers using PET scans. The scans showed particular metabolic activity during new learning but not during automatic performance. When asked to become aware of the now-automatic task, the silent brain became metabolically active once more. M. Jueptner, K. M. Stephan, C. D. Frith, D. J. Brooks, R. S. J. Frackowiak, and R. E. Passingham, 1997, "Anatomy of Motor Learning: I. Frontal

Cortex and Attention to Action," *Journal of Neurophysiology* 77(3):1313–1324.

- **Whether those automatic behaviors serve us well or not:** Habits are undoubtedly important. Cristof Koch talks about our having a number of stereotyped behaviors, or *zombie agents,* that bypass consciousness. Initial acquisition of these *zombie agents* requires awareness, and then we operate by a combination of these learned automatic responses and a slower but more-flexible conscious response to a situation. Koch, *Quest for Consciousness,* 231–247.

  The important thing is to be able to learn something new. "Brain researchers have discovered that when we consciously develop new habits, we create parallel synaptic paths, and even entirely new brain cells, that can jump our trains of thought onto new innovative tracks." J. Rae-Dupree, 2008, "Can You Become a Creature of New Habits?" *New York Times,* May 4.
- **once we become aware of it, knowledge rushes in:** Jueptner, et al. "Anatomy of Motor Learning," 1313–1324.
- **awareness in one person can bring about a shift in another:** In the social sciences, the term *Hawthorne effect* refers to how people change their behavior when aware of being watched. The Hawthorne effect gets its name from the Hawthorne Works factory in Chicago, where a series of experiments on factory workers were carried out between 1924 and 1932. Although the results are now questionable, the term has come to be used to describe the phenomenon in which being observed by another can and often will shift our behavior. S. R. G. Jones, 1992, "Was There a Hawthorne Effect?" *American Journal of Sociology* 98(3):451–468.

  In science, the term *observer effect* refers to the effect that the act of observation will have on the phenomenon being observed. Jeffrey Schwartz writes, "Quantum physics makes the seemingly preposterous claim (. . . upheld in countless experiments) that there is no 'is' until an observer makes an observation." Until something is observed, it is a "quantum smear" of potential for the occurrence of various possible observed feedbacks. Schwartz has collaborated with Henry Stapp, a physicist at Lawrence Berkeley National Laboratory at University of California at Berkeley. Stapp sees no justification for those quantum physicists who base neuroscience on classical physics by suggesting that once brain activity reaches the level of, say, the firing of a neuron, this quantum jump

from possible to actual has occurred. He argues first for quantum principles of uncertainty at synapses and then extends this to the behavior of the whole brain. In this context, the observer and the observed are each "a smeared out continuum of classically conceivable possibilities," with the observed being partitioned into a set of discrete components by an agent who is himself a continuous smear of possibilities! Stapp's controversial ideas are discussed in chapters 8 through 10 of J. M. Schwartz and S. Begley, 2002, *The Mind and the Brain: Neuroplasticity and the Power of Mental Force* (New York: ReganBooks). See also H. P. Stapp, 2007, *Mindful Universe: Quantum Mechanics and the Participating Observer* (Berlin: Springer-Verlag).

- **Awareness requires the capacity for the observation of self and others:** The human brain has an observational capacity *built in*. In the 1980s, Giacomo Rizzolatti and his colleagues identified a type of brain cell he termed a *mirror neuron*. Present in humans and some other primates, they fire when observing the actions of another. Mirror neurons in themselves, of course, do not explain the highly complex processes behind awareness. Giacomo Rizzolatti et al., 1996, "Premotor Cortex and the Recognition of Motor Actions," *Cognitive Brain Research* 3:131–141.
- **she becomes aware of herself in a new way:** Other research extends this mirror system (see note above) beyond merely seeing an action; that is, they are responsible for more than just *monkey see, monkey do*. "Any sensorial cue that can evoke the 'idea' of a meaningful action activates the vocabulary of motor representations." Moreover, they are thought to be key in the learning of language, empathy, and emotions. L. Craighero, G. Metta, G. Sandini, and L. Fadiga, 2007, "The Mirror-Neurons System: Data and Models," in *From Action to Cognition,* ed. Claes Von Hofsten and Kerstin Rosander, vol. 164 of Progress in Brain Research (St. Louis, MO: Elsevier), 39–59.
- **Awareness, like movement, is something that we do—or not:** Awareness as an action has been practiced and developed for centuries in the Buddhist tradition and is now the subject of intense scientific scrutiny. Researchers are studying the impact of meditation practices, which involve intense self-observation, on brain plasticity and performance. M. Barinaga, 2003, "Buddhism and Neuroscience: Studying the Well-Trained Mind," *Science* 302(5642):44–46.

Move into Life

- **a process called *differentiation:*** K. N. Prasad, 1980, *Regulation of Differentiation in Mammalian Nerve Cells.* (New York: Plenum) 2–3.
- **Scientists are able to measure and track the process of differentiation as it is taking place in the brain:** Dr. Adi Mizrahi, of the Department of Neurobiology at the Alexander Silberman Institute of Life Sciences at the Hebrew University, used time-lapse photography to study how mouse nerve cells develop from an undifferentiated cellular sphere into a rich and complex cell. "The structural and functional complexity of nerve cells remains one of the biggest mysteries of neuroscience, and we now have a model to study this complexity directly," he said. "Scientist Observes Brain Cell Development in 'Real Time.'" *ScienceDaily,* May 29, 2007; A. Mizrahi, 2007, "Dendritic Development and Plasticity of Adult-Born Neurons in the Mouse Olfactory Bulb," *Nature Neuroscience* 10(4):444–452.
- **as we gain a new skill, or improve on an existing one, more brain cells get involved:** When we begin to learn a new skill, such as riding a bike, our initial clumsy efforts result from the use of too much unrefined muscular effort. We are unable to make subtle adjustments in response to the movement of the bike and the pull of the gravitational force, so we fall. As we gain experience, we gain control through using our muscles in a more refined and precise way. This process has been demonstrated in the brain. William Jenkins and Michael Merzenich trained monkeys to touch a spinning disk with one of their fingertips and then mapped their sensory cortex. The map for the fingertip increased in size during training; however, the skin surface area represented by each nerve cell in the brain map became smaller, leading to greater refinement in performing the task. W. M. Jenkins, M. M. Merzenich, M. T. Ochs, T. Allard, and E. Guic-Robles, 1990, "Functional Reorganization of Primary Somatosensory Cortex in Adult Owl Monkeys After Behaviorally Controlled Tactile Stimulation," *Journal of Neurophysiology* 63(1):82–104.

  Subsequent experiments extended similar fi to the motor cortex. Since acquisition and execution of a skilled motor task require the coordinated participation of a number of brain structures, including the motor cortex, the basal ganglia, the cerebellum, and the spinal cord, the experimenters fi it reasonable to assume that

such differentiation through experience is widespread throughout the brain. R. J. Nudo, G. W. Milliken, W. M. Jenkins, and M. M. Merzenich, 1996, "Use-Dependent Alterations of Movement Representations in Primary Motor Cortex of Adult Squirrel Monkeys," *Journal of Neuroscience* 16(2):785–807.

- **While differentiation is most active in the first few years following birth:** During the "critical period" of early development, a child is able to attend and remember what they are experiencing, allowing effortless differentiation of brain maps. In adulthood, such differentiation is possible but requires training our focused attention and awareness. M. P. Kilgard and M. M. Merzenich, 1998, "Cortical Map Reorganization Enabled by Nucleus Basalis Activity," *Science* 279(5357):1714–1718.
- **"improvement or refinement through increased complexity":** One neuroscientist whose view of a possible mechanism of consciousness truly embraces the notion of complexity is Gerald Edelman. He concludes that high values of complexity correspond to an optimal blend of functional specialization (or differentiation) and functional integration within a system. "This is clearly the case for systems like the brain—different areas and groups of neurons do different things (they are differentiated) at the same time they interact to give rise to a unified conscious scene and to unified behaviors (they are integrated). By contrast, systems whose individual elements are either not integrated (such as a gas) or not specialized (like a homogenous crystal) will have minimal complexity." For Edelman, consciousness is a continuously shifting association of groups of neurons showing an overall coherent behavior but able to group and regroup dynamically according to their specific functional interactions. In other words, it is complex. A deteriorating brain has many groups, but they are poorly associated (compare the gas, above). By contrast, brain activity is highly synchronized in epilepsy or slow-wave sleep, showing integration and order but little specialization (compare the crystal). Neither of these dysfunctional states demonstrate complexity. G. M. Edelman and G. Tononi, 2000, *A Universe of Consciousness: How Matter Becomes Imagination* (New York: Basic Books), 130–133.
- ***the impossible possible, the possible comfortable, and the comfortable elegant:*** One of the most quoted of the sayings of Dr. Moshe Feldenkrais in demonstrating the process underlying human progress.

- **Research shows that hours of solving crossword puzzles, traveling to new places, or doing rote exercises do not necessarily increase differentiation:** Researchers at Georgia Tech found no evidence that crossword-puzzle solving reduced, in older adults, the known age-related decline in problem-solving ability. They mostly rely on general knowledge. D. Z. Hambrick, T. A. Salthouse, and E. J. Meinz, 1999, "Predictors of Crossword Puzzle Proficiency and Moderators of Age-cognition Relations," *Journal of Experimental Psychology: General* 128(2):131–164.

  By applying elements of the Nine Essentials, however, any pastimes can be transformed into a supremely beneficial activity for promoting vitality, and a number of researchers are publishing more-positive results in studies that look at programs designed specifically to address brain plasticity. H. W. Mahncke, B. B. Connor, J. Appelman, O. N. Ahsanuddin, J. L. Hardy, R. A. Wood, N. M. Joyce, T. Boniske, S. M. Atkins, and M. M. Merzenich, 2006, "Memory Enhancement in Healthy Older Adults Using a Brain Plasticity–Based Training Program: A Randomized, Controlled Study," *PNAS* 103(33):12523–12528.

  Lawrence C. Katz, Ph.D., a professor of neurobiology at Duke University, says such exercises help the brain to not only maintain connections between nerve cells—and thus preserve memory recall—but also aid in developing new connections. The mental decline most people experience is due to the atrophy of connections between nerve cells in the brain as a result of routine behaviors. J. Volz, 2000, "Successful Aging: The Second 50; Psychologists' Research Is Changing Attitudes About What It Takes to Live the Good—and Longer—Life," *Monitor on Psychology* 31(1). http://www.apa.org/monitor/jan00/cs.html.

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