Our Resilient Brain:
Nature's Most Complex Creation

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Understanding the brain requires the ability to navigate challenging terminology. Einstein proposed that everything should be made as simple as possible but not simpler. Here are twenty-six key concepts—the ABCs of the brain and behavior.

We recently began a Deep Brain Learning workshop by asking the audience what comes to mind when first hearing that title. One participant piped up, "Something complicated that I don't want to learn!" Following Einstein's prescription, we will offer simple ABCs of the brain and behavior.

A wealth of neuroscience is transforming the education and treatment of troubled children says trauma expert Bruce Perry: "Without understanding the basic principles of how the brain develops and changes, we cannot expect to design and implement effective interventions" (Perry & Hambrick, 2008, p. 39). How can we simplify the relevant findings from this rapidly expanding field? The challenge is to translate key concepts into terms useful for solving real-world problems.

While anything we write about the brain is oversimplifying, Einstein gives permission. Below we offer a buffet of brain facts with 26 paragraph-size bites, one for each letter of the "brain literacy alphabet."

Amygdala. The emotional brain's security system detects strange or threatening stimuli. Amygdala is Greek for "almond" and we have two of these nut-shaped structures which process high-speed emotional reactions. The amygdala's danger/opportunity detector processes social information with input about facial expressions, eye contact, voice tone, and physical bearing. The amygdala activates in novel or stressful situations and stores unconscious emotional memories. With severe or continual trauma, the amygdala may be compromised and either stay on constant alert or tune out emotions. The amygdala is connected to our emotion circuits and stress reaction system. By being aware of the cues used by the amygdala to spot friend or foe, we can work to communicate concern instead of rancor.

Brain Stem. The lower survival brain operates life support systems and defends against threat. This primitive brain keeps our bodily systems in balance, including respiration, heartbeat, and reproduction. Most relevant to work with youth, the survival brain engages automatic defensive behaviors of the Fight, Flight, Freeze systems to protect against threat. Humans have a "triune brain" which serves three separate functions (MacLean, 1990). The lower reptilian brain focuses solely on survival. Mammals have developed an emotional brain, also called the "limbic" brain. At the highest level is the cerebral cortex, which is the seat of logic. As will be seen, our reptilian structures are designed almost exclusively for self-preservation. But our higher brains are designed for social engagement, and humans live in the blessing and tension between our self-preservation and affectional programs (Cory, 2000).

Cerebral Cortex. This higher logical brain area does not fully mature until the mid-twenties. The cortex (Latin for "bark") is folded around the emotional brain. Different regions handle various mental tasks, roughly mapped like this: vision and perception (rear), motor behavior (from ear to ear), language and speech (usually left), rational logic (left), intuitive logic (right), and executive control of lower brain areas (frontal cortex). The executive area handles emotional regulation, attention, evaluating risk, and planning ahead. The left hemisphere rational logic is slow and plodding while the right side intuitive logic is fast and effortless (Kahneman, 2011). Both hemispheres are connected by a huge bundle of nerves, the corpus callosum. Humans have a social brain (Dunbar, 1998). The left brain motivates approach based on social interest. The right brain triggers caution if persons are not trusted, but motivates attachment to those who offer security and safety.

Developmental Trauma. Also called complex trauma and relational trauma, this results from multiple, adverse events, often beginning in early childhood. This complex trauma includes physical, emotional, and educational neglect and maltreatment (van der Kolk, 2014). Disruptions in attachment can alter the stress regulation system. Relational trauma triggers core emotions of fear and anxiety and social emotions of shame and worthlessness. Children who cannot regulate these painful emotions show fight/flight/freeze behaviors. Trauma symptoms often mask underlying grief from the loss of attachment (Steele & Kuban, 2014). This is prominent with youngsters separated from families and placed in the child welfare system (Anderson & Seita, 2006). Racial and cultural trauma can have similar destructive effects (Hardy, 2013). Effective interventions foster safety, trusting bonds, and self-control (Bath, 2015; Perry & Hambrick, 2008). Coercive, depersonalized schools and institutions do the opposite.

Emotions. Inherited ancestral tools for living are genetically coded in brains to motivate action. We learn to repeat experiences that cause positive feelings and avoid those that cause pain. Panksepp and Biven (2012) identify seven "primary emotions" shared by all mammals. Fear and

rage use primitive survival brain circuits. Seeking is goal-directed curiosity in order to master the environment. Attachment in children involves proximity to caregivers and separation distress sparks panic, grief, and behavior to restore belonging. Play strengthens belonging through cooperation with peers, and it also develops impulse-control necessary for independence. Care is tied to empathy and motivates generosity and altruism. Lust ensures reproduction but also releases oxytocin which promotes trust and stable relationships. All mammals share these deep brain primary emotions. Humans also have a sense of self, giving rise to social emotions like pride, shame, jealousy, and gratitude—which serve to maintain social bonds.

Flight, Fight, Freeze. The primitive survival brain activates these extreme responses to threat. Two separate systems can spark the stress reaction: the HPA axis and the sympathetic nervous system. The HPA axis sets in motion a cascade of hormones that circulate in brain and body: the Hypothalamus signals the Pituitary gland to tell the Adrenal glands to produce stress chemicals including cortisol and adrenaline. These mobilize all body systems to meet the emergency. The high speed autonomic nervous system directly connects the brain with visceral organs, signaling the heart's pacemaker to prepare for fight or flight. Under severe threat, logical thinking is temporarily high-jacked (Goleman, 2006). When the higher logical brain determines no threat exists, it can help restore calm. Distress from repeated survival reactions puts an extreme load on the body and is toxic to health and life. Youth experiencing crisis and trauma need adults who can help them manage stress reactions.

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Gene Expression. The new science of epigenetics shows how life experiences can impact genes. The word epi is Greek for "over" so epigenetics can override genetics (Francis, 2011). Humans have over 20,000 genes, and a majority of them affect the brain. All genes are in virtually every bodily cell but only those turned on (expressed) tell the cell what to do. Three million gene switches regulate this gene expression (ENCODE Project Consortium, 2012). Chronic stress, chemicals, diet, and caregiving all can produce epigenetic effects. Michael Meaney (2001) found that nurturing care turns on genes in the brain that regulate stress, making offspring social, curious, and confident. But neglect produces distressed, fearful offspring. Epigenetics is tied to experience, and thus is potentially reversible. Meaney fostered neglected offspring to nurturing mothers and restored resilience. While epigenetics is involved in many physical and mental disorders, healthy environments and cultures produce resilient bodies and brains.

Hippocampus. The brain's librarian indexes and stores memories and maps for later retrieval. The hippocampus (Greek for seahorse) is connected to the amygdala which alerts it to novel or emotionally charged events. These two brain structures share the task of making memories. The amygdala conditions unconscious emotional memories. The hippocampus catalogues conscious memories including facts and life events, retrieving these when needed. Trauma can damage the hippocampus and interfere with memory and learning. Adults with Alzheimer's have hippocampus damage and cannot transfer recent memories into long-term storage. Fritz Redl (1976) was among the first to propose that effective therapy with children should focus on significant life events. This is validated by brain science showing that events stored in memory shape thinking, emotions, and behavior. Rethinking key events can alter distorted thinking and build accurate, adaptive learning.

Intelligence. This ability enables us to cope with challenges and learn from these experiences. This definition also describes resilience (Sylwester, 2005). Brain research has debunked the notion that IQ scores are largely determined by genetics (Nisbett, 2009), a myth perpetuated by racial theories of intelligence (Herrnstein & Murray, 1996). Every healthy brain has the potential to develop high levels of intelligence. Natural variations in how brains process information have been conserved by evolution because diversity fosters group competence. Societies need persons with strong analytic left brain potential as well as those with highly creative right brain capacity. Success is not dependent on IQ but on social, emotional, and practical intelligence (Sternberg, 2000). Mindsets shape success or failure (Dweck, 2006). Persons with a fixed mindset believe intelligence is set in stone—those with a growth mindset believe intelligence can be increased by persistence and effort. Growth mindsets build intelligence.

Joy. This most inspirational social emotion is closely tied to the rewards of human relationships. This is hard science as uplifting chemicals like dopamine, endorphins, and oxytocin underlie social bonding in both adults and children (Perry & Szalavitz, 2011). Adults with insecure attachment histories have difficulty engaging youth in joyful relationships (Barrett & Fleming, 2011). Psychologist Nicholas Hobbs (1982) who founded the Re-ED model for troubled children and youth established the principle that children need joy in their lives each day. In the early twentieth century, Ukrainian youth work pioneer Anton Makarenko (2004) used joy as the centerpiece of reforming delinquent youth. Joy does not come from entertaining youth but from giving them the experience of bringing joy to others (Sukhomlinsky, 1981).

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Kindness. The human brain is designed to care for others as well as to meet self-centered needs. The triune brain has two competing algorithms: sharing and self-preservation (Cory, 2000). The self-absorbed survival brain gets what it wants to stay alive. But the emotional brain evolved in kinship societies where sharing was essential to survival. Charles Darwin saw sympathy as the strongest human instinct, but simplistic "survival of the fittest" views obscure that wisdom. A better rule for human cultures is "survival of the kindest" (Keltner, 2009). Compassion draws on brain programs for empathy. Mirror neurons tune in to the distress of others and we feel their emotions as if our own (Perry & Szalavitz, 2011). Children must experience kindness if they are to develop character strengths (Long, 1997).

Long-Term Memory. Learning that lasts redesigns brain circuits to store information and skills. In contrast, short-term memory temporarily uses existing brain circuits but does not design new brain connections. Neurons that fire together wire together (Hebb, 1949). Eric Kandel (2007) won the Nobel Prize for showing how long-term memories are formed: genes instruct neurons to grow new connections. The brain stores memories of emotionally charged events and experiences which are repeated (e.g., rote learning or immersion in cultural rituals). Explicit memories can be consciously recalled, including facts and autobiographical events. Implicit memories include emotionally conditioned unconscious memories as well as highly practiced procedural memory (like riding a bicycle). Memories of life events form our personal identity and shape views of our self and others (Schacter, 1996). Positive psychology overrides negative emotional memories with positive events and emotions (Peterson, 2013).

Mirror Neurons. These brain cells enable humans to understand emotions and mimic behavior. Mirror neurons are most numerous in humans but are found in some other social animals as well. They are central in learning language, social skills, imitation, and empathy. Just seeing another's emotions activates similar circuits in one's own brain. The Golden Rule in all moral systems is tied to empathy which depends on mirror neurons (Perry & Szalavitz, 2011). Mirroring functions are limited in children on the Autism spectrum who have difficulty interpreting emotions and in knowing what others might be thinking (theory of mind). We mirror another person's negative emotions in conflict cycles. Displaying calm and positive emotions can also create a mirroring effect, as when an adult calms an agitated child. Mirroring is also prominent in group contagion and in the desire to model peer behavior, thinking, and values.

Neurons. The brain has 100 billion of these cells which are central in learning and behavior. Spanish scientist Santiago Ramon Y Cajal won the 1906 Nobel Prize for discovering neurons. He proposed that learning involved changes in the connections between neurons, a view validated a century later by Eric Kandel. The neuron is a single cell with a tubular axon body and thousands of dendrites receiving input from connections with other neurons. When incoming signals are strong enough, the neuron fires and sends a signal along to other cells. Messages travel electrically through a neuron but convert to chemical neurotransmitters to bridge the small gap (synapse) connecting with other neurons. Learning insulates neurons with myelin making them appear as white matter. The more learning, the more layers of myelin, preventing loss of signal strength and increasing information processing up to 3000-fold (Coyle, 2009).

Oxytocin. This hormone is involved in social bonding, building trust, and nurturing behavior. Oxytocin is central to all social relationships including sexual bonding, friendship, and empathy-based behavior. Oxytocin is a key chemical in human tend-and-befriend instincts (Taylor, 2002). Women typically have higher oxytocin levels than men which increases nurturing behavior. However, human males are much more oxytocin-primed for caring behavior than other mammals. Males also have an abundance of a related chemical, vasopressin, which stimulates protective behavior. Oxytocin creates trust, security, and confidence to approach others for social interaction (Panksepp & Biven, 2012). Neglected and unloved children have lower levels of oxytocin and are likely to show more aggressive behavior (Nelson, Fox, & Zeanah, 2014). The antidote is human bonding which increases oxytocin.

Pain-based behavior. Emotional distress leads to defensive and destructive coping strategies. This term was coined by James Anglin (2002) in research with Canadian youth in residential care settings who reported experiencing deep emotional pain. Pain is an adaptive emotion which helps a person protect against further harm. It also telegraphs one's distress to others who can respond with empathy and care. Rejection, loss, and exclusion use the same basic pain circuits as those for physical pain. Social pain is closely tied to frustration of basic emotional needs, which leads to reactive or self-protective behavior. Thus, children with insecure attachment cry, cling, withdraw, or try to tune out emotions. Caregivers need skills to respond to the needs of children in pain rather than react to problems. Since punishment is the intentional application of pain, it often increases pain-based behavior (Brendtro & du Toit, 2005).

Quiescence. Humans can enhance emotional control and happiness by quiet, mindful reflection. While we are intensely social, well-being also requires times for reflection and renewal. The value of quiet reflection has long been known in many faith traditions; St. Augustine (397) coined the word soliloquy, which means talking to oneself at a deep level. This is now called "mindfulness" as persons become attuned to their inner life of thoughts, feelings, and sensations—as well as reflecting on their relationships with others (Siegel, 2007). Mindfulness involves waking up from living on autopilot, interrupting blind behaviors, making better choices, and setting the course of our lives. These reflective processes may lower stress reactivity and improve health, emotional regulation, optimistic thinking, and empathy with others.

Resilience. The ability to surmount adversity and thrive is programmed into our adaptive brains. This term came to psychology from physics: a resilient object springs back after stress. Resilience enables persons to overcome adversity and even become stronger, a process called steeling (Rutter, 2012). Early researchers thought resilience was a rare personality trait of invulnerable persons. But no person is invulnerable, and all humans have capacity to overcome problems and achieve positive life outcomes. Resilience is built into human brains and is strengthened by supportive communities (Masten, 2014). Resilience is a mix of internal strengths and external supports, offset by environmental risks. Humans can thrive in a range of environments, but adverse life events can cause developmental harm. A large body of research points to four universal biosocial needs as central to well-being and thriving: attachment, achievement, autonomy, and altruism (Brendtro & Mitchell, 2015; Werner, 2012).

Stress. This heightened arousal prepares both brain and body to cope with challenge and threat. At manageable levels, stress pumps us into peak performance mode to meet difficult situations. Positive stress (eustress) creates a state of "flow" as we eagerly throw ourselves into some engaging task. Chronic and severe negative stress (distress) taxes all bodily systems and is implicated in virtually all emotional and behavioral disorders. Anxious or traumatized children and those with autism experience heightened stress in the ability to manage the stress response (Steele & Kuban, 2014). An optimistic attitude attenuates stress while dwelling on stress makes it worse. Humans operate best with Just Manageable Difficulties (Hobbs, 1982). Surmounting challenges builds resilience but being overwhelmed creates toxic levels of stress. The pioneer in stress research, Hans Selye (1978), saw altruism as the ultimate antidote to stress.

Temperament. These innate natural variations bias how a child responds to the environment. Such differences are observed very early in life and are inherited, or perhaps shaped by the prenatal or early postnatal environment. An early study found three temperaments: easy, difficult (also called feisty), and slow to warm up (Thomas & Chess, 1977). These are natural variations, and all can thrive if there is goodness of fit with caregiving attuned to the nature and needs of the child (Chess & Thomas, 1999). Research by Kagan (2010) found that low reactive children show little distress but seek out novelty; their amygdala is calm and they are bold and fearless. High reactive children show distress or crying at strange stimuli; their amygdala is aroused and they are timid and fearful. Bold youth are risk takers and need love and limits. Timid children need encouragement to become more confident and assertive. While temperament may be a variation of genes, attuned child rearing strengthens resilience.

Use-Dependent Development. This is adaptive neuroplasticity, meaning that the brain designs new pathways. Humans have a lifelong ability to build neural circuits to respond to unique challenges in the environment, or even to compensate for damage to the brain (Doidge, 2007). An earlier stage of neuroplasticity is experience expectant development, which involves brain programs pre-wired for natural maturation such as crawling, walking, and talking. A critical period in experience-expectant development is formation of early secure attachment to caregivers. If this does not occur, subsequent learning can go awry. The brain keeps reorganizing across years of experience, both in resilient and reactive ways. In time, patterns of coping behavior can become entrenched; specifically, positive or negative states become traits.

Vagal Nerve. This cranial nerve in humans uses trust to put the brakes on the stress system. The vagal circuits activate the sympathetic nervous system preparing for fight/flight reaction. But in mammals, one branch of the vagal nerve reads social cues of safety, and social engagement shuts down stress reactions (Porges, 2011). The term vagal is Latin for wandering, and the vagal nerve was so named because it seems to meander everywhere. It originates in the brainstem where it connects with facial muscles and auditory and vocal systems, making it attuned to human emotions. It also wanders downward to the heart, stomach, and other internal organs, enabling us to experience emotions like gut feelings, warmth in the chest, or a lump in the throat (Keltner, 2009).

Trust triggers release of oxytocin, creating feelings of warmth and openness. The vagal nerve is key in social engagement, communication, self-regulation, and compassion.

Working Memory. This is the capacity to attend to several ideas or stimuli to solve problems. A key executive brain task is to temporarily juggle three kinds of information: visualization (inner eye), language (inner ear), and existing long-term memories (Baddeley, 2002). Working memory is closely related to other executive brain functions like inhibiting distractions, controlling impulsive behavior, and planning ahead. All of these are slow to develop with children diagnosed with ADHD (Barkley, 2012). Not surprisingly, children who improve working memory and inhibition of distractions and impulses can make greater academic gains. Certain video games and other exercises can improve these executive functions (Nisbett, 2009) and develop intelligence. Short-term working memory is crucial in self-regulation, learning, and problem solving.

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XX and XY. These sex-linked chromosomes make males and females different in many ways. Women have two supersized X chromosomes carrying about 1300 genes each (Carey, 2012). Males get only one X chromosome and their Y chromosome weighs in at a wimpy at 78 genes. In addition to bodily differences, there is evidence that women in general have richer connections in the corpus callosum, making them more adept at empathy and communication. Further, male brains may be specialized for systematizing and mechanical-spatial reasoning; some even describe autism as the extreme male brain, able to process details like a computer, but not attuned to emotion (Baron-Cohen, 2003). The higher levels of testosterone in males have historically made them more physically aggressive, while females are more likely to resolve problems through relationships (Taylor, 2002). However, all traits are also shaped by experience, and no sex has a corner on any mental quality.

Youth Development. Specific factors foster resilience, flourishing, and positive life outcomes. The discipline of Positive Youth Development (PYD) is rooted in a century of democratic youth work and education (Jackson, 2014). Since first conceptualized by Gisela Konopka (1973), there have been scores of overlapping definitions for PYD (Small & Memmo, 2004). All approaches attend to meeting developmental needs in an ecology of family, school, peers, and community (Benson, 2010; Bronfenbrenner, 2005). A team of researchers in land grant universities consolidated longer lists into the four parsimonious factors of the Circle of Courage: Belonging, Mastery, Independence, and Generosity (Brendtro, Brokenleg, & Van Bockern, 2002; Kress, 2014). These are central to effective prevention and interventions with youth in conflict and are grounded in research on positive psychology, resilience, and brain science (Brendtro & Mitchell, 2015).

Zeigarnik Effect. The brain keeps thinking about unsolved problems, seeking to find a solution. Early research by Bluma Zeigarnik (1927) showed that we are more likely to recall uncompleted tasks than those we complete. The Zeigarnik effect helps explain achievement motivation (Atkinson, 1953). It also applies to human attachments. When interpersonal problems are not resolved, these events intrude on memory as parties ruminate on conflict, either finding solutions or further eroding trust (Gottman, 2011). The most painful Zeigarnik effects are replays of trauma in the form of intrusive painful memories and terrifying dreams (Siegel, 2012). The brain is primed to keep working solo on unsolved problems, but also to share these with a trusted person. Humans rely on one another to help regulate responses to distress and to meet social and emotional needs. In sum, as Daniel Siegel (2012) observes, relationships and the brain interact to shape who we become.

Conclusion

Before the advent of modern brain science, those working with children and youth had to rely mostly on personal intuition and practical experience, perhaps seasoned by findings from behavioral research. Now, an exciting new body of information is radically redefining what is meant by "evidence-based practice." Using the higher standard of consilience, we can crosscheck information from different fields of knowledge to identify powerful simple truths (Cory, 2000; Wilson, 1999). By integrating social and biological sciences with our practice expertise and values, we are able to deliver what works to those we serve (Duncan, Miller, Wampold, & Hubble, 2010).

Young people also benefit from learning about their brains. Recently, we were presenting ideas about Deep Brain Learning in a visual format to a group of high school youth. After the program, we spoke with a resilient seventeen-year-old student who shared that she was living independently without any family. Still, she was proud that she soon would graduate and enter college. After expressing thanks for the presentation, she said, "Why didn't anybody teach me this about my brain before? This would have helped me manage my life more successfully!" She speaks for all of us.

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