NORMAL FAMILY PROCESSES

GROWING DIVERSITY AND COMPLEXITY

FOURTH EDITION

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CHAPTER 23

Neurobiology and Family Processes

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The multisystemic discourse of family systems theory is enhanced by recent research in neurobiology and relationships. Current studies in neuroscience address the mutually recursive flow among body, brain, relationships, and context. The science is constantly evolving; the neurobiological data presented here are sure to evolve as well, and are presented as current knowledge. This chapter focuses on the interaction between neurobiology and relationships in families throughout the life cycle.

In the past decade, the field of neuroscience has been transformed through new technologies that allow scientists to observe the brain in action. In addition to the older methods of brain research—animal studies, evaluation of human functioning in the presence of brain damage or disease, and electroencephalographic (EEG) studies—newer scanning techniques such as functional magnetic resonance imaging (fMRI) have allowed unparalleled access to the human brain. The fMRI measures blood flow to the brain; as an area of the brain becomes active, it requires oxygen, which is reflected in blood flow. Thus, as a person lies in a scanner, and is shown a picture of a loved one, a terrifying scene, or an angry encounter, the fMRI identifies what parts of the brain are active. And what the scanner reveals about the human brain is remarkable.

THE SOCIAL BRAIN

Our understanding of the human brain in context has been enriched by both neuroscientists and key synthesizers of neurobiology research as it applies to human development, relationships, and therapy (e.g., Cozolino, 2006, 2008;

Damasio, 1994; Doidge, 2007; LeDoux, 1996; Schore, 2003; Siegel, 2010a, 2010b). This body of work points to our deeply social nature: Our brains are wired through connection with others, and we are wired for connection (Fishbane, 2007). Terms such as "interpersonal neurobiology" (Siegel, 2010b) and "social neuroscience" (Cacioppo & Berntson, 2004) capture the fundamental interconnectedness of human neurobiological processes. Likewise, neuroscience highlights the importance of emotion in our functioning; "affective neuroscience" (Panksepp, 1998) studies emotions as evolutionary processes for survival.

From the viewpoint of interpersonal neurobiology, the narrative of the rugged individualist, fostered by the dominant U.S. culture and by older theories of development and therapeutic approaches, misses the mark. Research indicates that from birth to death we need others for our well-being; interdependence is central to human functioning. Neuroscientists have found that social rejection triggers physical pain centers in the brain (Eisenberger & Lieberman, 2004). Indeed, "[social] exclusion could be a death sentence" to our ancestors (Goleman, 2006, p. 113), since we evolved as a social species. Humans are wired to read others' intentions and motivations beneath awareness. Much of this communication is nonverbal, mostly through reading others' faces and eyes in particular (Baron-Cohen, 2004). The pain of others is felt in the pain centers of one's own brain (Decety & Jackson, 2004). This deep interconnectedness contributes to health—in positive and negative ways. Positive relationships and social support correlate with physical and emotional health; unhappy or toxic relationships negatively affect health (Kiecolt-Glaser & Newton, 2001; Kim, Sherman, & Taylor, 2008). Loneliness is associated with lower immune function and with illness (Cacioppo & Patrick, 2008). The attachment literature interfaces with neuroscience research in emphasizing the importance of safe, attuned, well-attached relationships at all stages of family life.

Neuroscientists have found that nature and nurture are inextricably intertwined. Erik Kandel (2006) won the Nobel Prize for his discovery that learning changes the brain. Many studies have explored how the brain is changed through learning and experience throughout life. This change occurs at both the level of connections between neurons (brain cells), and at the genetic level: Experience influences the expression of genes, a process called epigenetics (see Spotts, Chapter 22, this volume). Early experience is particularly crucial to the baby's growing brain, as it is being wired through interactions with caregivers. The impact on the brain of interconnection with others continues at all ages.

BRAIN: THE BASICS

Humans have approximately 100 billion neurons; each connects to up to 10,000 other neurons at synapses, the space between neurons. There are trillions of synaptic connections in the human brain, making it the most complex entity in the known universe. Neurons are fundamentally social; they survive by connecting with other neurons to form networks. The neurons that do not connect die, through a normal process called apoptosis. Babies are born with many more neurons than they will need; it is the creation of networks and the pruning of disconnected neurons that shape brains and determine function.

Through evolution, the newer, uniquely human brain was built upon older, more primitive forms. The "triune brain" (MacLean, 1990) is composed of brain stem (reptilian brain), limbic system (mammalian brain), and neocortex (human brain). Because we carry our evolutionary history in our heads, our animal self is part of the human experience. Humans are not purely rational creatures; lower brain processes are very active, especially in emotional experience. We share 98% of our DNA with chimpanzees. The 2% difference is mostly in the prefrontal cortex (PFC), which Daniel Siegel (2010a) has called the "cortex humanitas." The brain stem, limbic system, and cortex are intertwined with multiple connections and feedback loops between brain areas. Most human activities—emotion, behavior, thought—do not activate just one brain area, but rather are reflected in circuits of interconnected activity.

One of the key circuits underlying emotional and relational functioning is that of the limbic system–PFC. The limbic system, or emotional brain, has at its core the amygdala, which sets off the fight-or-flight response if it senses threat. The amygdala is constantly scanning for danger. If it gets a whiff of threat, it sets in motion a full-body readiness to flee or to fight, activating the sympathetic nervous system and the HPA (hypothalamic–pituitary–adrenal) axis, which produces cortisol, a chemical in the stress response. When the amygdala is in fight-or-flight mode, it often overwhelms the PFC, which becomes quiet. The amygdala is much faster at processing information (at times erroneously) than the PFC. In a position of high emotional threat, the amygdala "highjacks the brain" (Goleman, 1995). While this system is highly efficient for sudden, life-threatening situations, it can cause crises in couple and family interaction as one person experiences the other as critical or abandoning and goes into full battle mode. The amygdala does not distinguish between threat in the jungle and threat to our well-being or self-esteem in our current relationships. Danger is danger.

One of the reasons the amygdala can so easily overwhelm the PFC is that there are more fibers running from amygdala up to PFC than there are from PFC to amygdala (LeDoux, 1996). Thus, it can be hard to rein in the threat response and respond reasonably. To complicate matters further, it has been proposed that the vagus nerve, which runs between the viscera (heart and intestines) and brain stem in both directions, participates in responding to threat or safety. According to the Polyvagal Theory (Porges, 2007), when safety is assessed, the "smart vagus," the more recently evolved part of the vagal system, signals the body and facial muscles to relax and engage with others. If danger is sensed, the amygdala fight-or-flight response is initiated through the sympathetic nervous system. If the danger is perceived to be life threatening, with no possibility of escape or defeating the enemy, the more primitive vagus nerve takes over, activating the "freeze" response, including fainting and dissociation.

While these processes run on automatic pilot, and mostly beneath awareness, humans do have access to higher brain processing; we have a PFC that comes online and interfaces with our limbic system, calming the amygdala and gaining perspective. The PFC can inhibit amygdala reactivity and bring thoughtfulness, self-regulation, response flexibility, and compassion to shape responses. The more these prefrontal capabilities are cultivated, the more fibers grow from PFC to amygdala. Then, in a potential moment of escalation or reactivity, one can more quickly calm down and gain perspective. But even the most evolved individuals will have irrational moments, amygdala takeovers. Part of the reason for this is that the amygdala holds emotional memories; when a current situation feels threatening, memories of an older, painful experience can become activated. This process has survival value; but it can stress couple and family relationships.

Humans have two brain hemispheres. As currently understood, the left specializes in logic, language, linear thinking, and details. The right specializes in emotions, nuance, and gestalt perception. The right hemisphere is online and functioning at birth; the left develops in the first years of life. The right hemisphere is responsible for much of our automatic and conscious self-regulation, modulation of emotion, and knowledge of how our body feels. The "interpreter" part of our brain (Roser & Gazzaniga, 2004) is a left prefrontal function, narrating and justifying our experience, including our emotional reactions. The corpus callosum connects the two hemispheres and allows for the creation of coherent narratives of life experiences. Integration is key in this and other areas of brain life.

EMOTIONS AND EMPATHY

Neurobiologists have identified the centrality of emotion as well as cognition in human experience; it has been suggested that a counterbalance to Descartes' famous dictum, "I think therefore I am" would be "I feel therefore I am" (Cacioppo & Patrick, 2008). Emotions are body states; feelings occur when these body cues are read and named (Damasio, 1994). The brain is embodied, with a bidirectional flow of input and influence. The vagus nerve carries information from heart and intestines to brain, giving literal meaning to "gut feelings" and "a broken heart." The insula specializes in interoception, reading one's inner body states, and in perceiving pain in self and other. Many important brain processes are subcortical, automatic, and beneath awareness; they involve the limbic system and brain stem, in interface with body processes. The PFC catches up in recognizing and naming these physical sensations as feelings. Some individuals are unable to name their emotions, to read their body cues. This alexithymia can severely impair interpersonal functioning and personal well-being.

To experience emotions fully and safely, humans need the empathy of others. Indeed, emotions are not just interior, individualized states; they are communications with others. Through fine-tuned facial muscles that communicate feeling and intention, and through neurons that specialize in reading the faces and emotions of others, intertwined attunement between self and other is central to emotional life. Parental attunement is particularly crucial to the baby's brain development. Infants come hardwired for empathy; babies cry when another baby is crying in the nursery. Even some primates demonstrate rudimentary empathy (de Waal, 2009). Empathy is considered a necessary ingredient in human well-being throughout life.

The neurobiology of empathy includes several components (Decety & Jackson, 2004). The first is resonance, an automatic process in which one feels what the other feels. Some neuroscientists emphasize the role of "mirror neurons," special neurons that read the actions and intentions of others by creating the same experience in one's own brain–body. First discovered in monkeys, the human mirror neuron system has been mapped by scientists in recent years (Iacoboni, 2008). Other scholars point to different mechanisms of resonance, in which the somatosensory cortex or the insula is activated when one experiences pain or disgust, for example, and when one sees another exhibiting pain or disgust. With this resonance, we feel what the other feels "from the inside out" (Siegel & Hartzell, 2003). We read others—and are affected by them—beneath awareness. This can be salutary, as we share the emotions of others, and can support and help them with empathy. But this "emotional contagion" (Hatfield, Cacioppo, & Rapson, 1993) can be problematic; when family members become reactive with each other, they may be picking up and reacting to each other's emotions before they are aware of what is happening. In a circular process, or vicious cycle, each reaction can intensify the reactions of others, escalating the level of distress for all. Conversely, attuned and positive responses can calm emotions, facilitating a virtuous cycle.

The second component of empathy, cognitive empathy, entails consciously putting oneself in the other's shoes. This prefrontal capacity brings thoughtfulness to the subcortical process of resonance. Individuals differ with regard to their "empathic accuracy" (Ickes, Gesn, & Graham, 2000). Third, empathy requires identification with the other, while maintaining a boundary between self and other. When seeing another in pain, pain centers in one's own brain light up; yet the overlap is not complete. Parts of the brain that are active when one experiences pain do not become activated when watching another in pain (Decety & Jackson, 2004). The brain is wired to know the difference between self and other. This crucial differentiation of self from other—otherwise known as healthy boundaries—allows for empathic connection with another without losing one's self in the process. Finally, empathy requires that one not become overwhelmed with the other's pain. The ability to self-regulate in the face of another's distress is crucial in the empathic process.

A key neurochemical in empathy is oxytocin. Both a hormone and a neurotransmitter, oxytocin is released with orgasm, childbirth, nursing, massage, touch, and empathy. Oxytocin is associated with trust and generosity in laboratory experiments, and it reduces cortisol, the stress hormone. Oxytocin, the "cuddle chemical" (Taylor, 2002), helps modulate attachment. Women have more oxytocin receptors than men; in males, vasopressin, a related hormone, is more plentiful. Oxytocin and vasopressin have been studied in prairie voles, monogamous rodents that live in the Midwest (Carter, 2003). These neurochemicals are key to male–female pair-bonding and monogamy; when oxytocin and vasopressin receptors are blocked, pair-bonding yields to promiscuity. Oxytocin prompts female voles to seek out other females when stressed, while vasopressin prompts males to engage in mate guarding and territory protection.

Oxytocin has also been associated with the "tend and befriend" response (Taylor, 2002). Taylor's data suggest that the fight-or-flight response has been overemphasized in the human response to threat. The amygdala does indeed set off a survival-based sympathetic nervous system response when danger is detected. Taylor proposes that the tend-and-befriend response, or "care and connection system," is equally important in the face of danger. Just as female voles turn to each other and protect their young when faced with threat, female humans often do the same. Research on the interplay between this system and the fight-or-flight system in humans is ongoing. The dynamics of care (identified by neuroscientist Jaak Panksepp [1998] as one of the seven basic emotional operating systems in the brain) are central to family relationships. This "protective urge" is an important factor in intimate relationships (Fishbane, 1998, 2005). Looking for "resources of trustworthiness" (Boszormenyi-Nagy & Ulrich, 1981) in families nurtures this care-and-connection system. This system needs to be studied more fully in both neuroscience and family theory.

STRESS AND TRAUMA

When danger is severe or chronic, care is lacking or inconsistent, or attunement and attachment are distorted or unavailable, the stress response can become overactive. Humans evolved to deal with acute, short-term stress. The sympathetic nervous system and cortisol signal the body to route its resources to the threat at hand. As Sapolsky (2004) wryly notes, on the savannah, a zebra either escapes or becomes another animal's lunch. The stress is intense and short term. We humans, however, often live in conditions of chronic stress. And long-term stress can impair the immune system. It can also impair memory, since cells in the hippocampus (mediator of explicit or conscious memory) are highly affected by cortisol. If the stress is long-lasting and severe enough, cells in the hippocampus die, leading to hippocampal shrinkage and impairment of memory and cognitive function.

Trauma—especially interpersonal trauma—is the most toxic form of stress for humans. Severe abuse and neglect affect the young child's developing brain and can cause long-term cognitive and memory impairment, as well as problems in self-regulation and social relating (Perry, 2001, 2002). Traumatic memories are often held in the brain in the implicit memory system. This system, online at birth, holds memories without conscious awareness. It is only with the development of the hippocampus, around age 2, that the explicit or conscious memory system develops. Implicit memories—for nontraumatic as well as traumatic events—are processed in the right hemisphere and can affect one in the present even if the event is not consciously remembered.

Stress and trauma often arise from the larger context in which the family is embedded. Poverty, war, living in violent neighborhoods, or experiencing discrimination can negatively affect even well-attached parents and children. While research on the impact of poverty on the developing human brain is new, data point to the negative impact of poverty-related stress for child development (Hackman & Farah, 2009).

HABITS AND CHANGE: NEUROPLASTICITY AND HUMAN ADAPTATION

Humans are creatures of habit. The human brain, an "anticipation machine" (Siegel, 2010a), is an organ structured for habit. Habits reflect circuits of interconnected neurons firing over and over again. This process is captured in Hebb's theorem: "Neurons that fire together wire together" (Siegel, 1999). The more a neuronal network fires, the more likely the whole network will fire when one of the neurons fires in the future. This process underlies habits, behaviors, thoughts, and feelings. The more we do, think, or feel something, the more likely we will do so in the future. In that sense, we are what we do, as the brain changes and rewires to reflect our repetitive behaviors. Indeed, habits are hard to change for this very reason.

Humans are also creatures of change and adaptation. The brain mechanism for change is neuroplasticity, the ability of neurons to create new synaptic connections with other neurons. In addition, through neurogenesis, new neurons are created from stem cell neurons. The old assumption was that neural growth and change were only possible in youth, that the adult brain was unchangeable. However, it is now well established that adults are capable of both neuroplasticity and neurogenesis throughout the life course. For adult neuroplasticity to flourish, we need to be open to new experience, learn new things, pay attention, and exercise both physically and mentally (as children do naturally). Being stuck in our (neural) ruts, living with "hardening of the categories" (Cozolino, 2008), and being physically inactive will not facilitate neuroplastic change as we age.

Neuroplasticity is the basis for resilience in human functioning, for change in therapy, and for transformation in couple and family relationships. For new habits to take hold and override old habits, "massed practice" (Doidge, 2007) is necessary, as new neuronal networks are activated over and over again to become the new default position. Neuroplasticity and brain development, especially in the prefrontal cortex, continue throughout life—if we nurture them and are open to new possibilities.

CULTURE AND THE BRAIN

Current thinking in cultural neuroscience emphasizes the mutually reciprocal influences between the biological and the sociocultural, between brain and culture (Zhou & Cacioppo, 2010). Indeed, "human brains are biologically prepared to acquire culture" (Ames & Fiske, 2010, p. 72), and are shaped by culture. From perception to neurobiological correlates of the self-concept, culture affects brain processes (Ames & Fiske, 2010). Research comparing Eastern (Asian) and Western (European and American) subjects finds that while Western perception favors figure over ground, Eastern perception emphasizes context and a holistic view. Self-concept, as revealed in both psychological studies and fMRI scans, focuses on the independent self-versus-other view in Western subjects, and on the interdependent, self-and-other view among Asian subjects (Zhu, Zhang, Fan, & Han, 2007). Similarly, definitions of self and of family include a wide network of others, kin and nonkin, in African American culture, captured in the African saying, "We are, therefore I am" (Hines & Boyd-Franklin, 2005, p. 88).

The "contact zone" (Wexler, 2006) between cultures and races has been studied in recent years. Empathy, as measured by fMRI, was found to be higher in subjects observing faces of their own in-group undergoing pain than faces of other races (Xu, Zuo, Wang, & Han, 2009). Culturally learned racial prejudice is evidenced in amygdala activation; the greater the implicit prejudice, the greater the amygdala activity (Phelps et al., 2000). However, conscious social goals can ameliorate these amygdala activations (Wheeler & Fiske, 2005).The interplay between automatic and controlled cognitive processes of perceiving others (including racial prejudice) is a current topic in neuroscience.

Immigration from one culture to another can pose neurobiological challenges, as the environment in which one's brain was shaped is left behind (Wexler, 2006): "Culture shock is brain shock" (Doidge, 2007, p. 299). Immigrants often create mini-versions of their home country in the new land, " 'as if' environments" that "help transform the receiving culture into more familiar places" (Falicov, 2003, p. 293). Recent conceptualization of immigration identifies creative and ongoing adaptations that integrate the two cultures; in an age of easy communication, the Internet, and transportation, "transnationals" maintain relations that transcend geographic borders, creating "flexible bicultural identities" (Falicov, 2008). The ongoing process of "selective adaptation" to the new culture (Garcia-Preto, 2008) continues to reshape the brain as immigrants find creative ways to "construct the bridges they need for this journey between cultures" (Garcia-Preto, 2008, p. 273).

Even within the same culture, evolving social practices and technology such as the Internet affect the plastic brain. The Internet and its distractions are reshaping the ways we think, leading to greater distractibility and multitasking, and less access to "deep reading" and sustained attention (Carr, 2010). The easy accessibility of Internet pornography is affecting couples' relationships. Individuals who become addicted to porn are rewiring their own brains, and are often unable to relate sexually to their real-life partners (Doidge, 2007). The far-reaching impacts of technology on the brain and on culture are yet to be determined. The Internet, social networks, smartphones, and constant (non-face-to-face) connection that constitute our new context will surely reshape our brains that evolved to navigate face-to-face communication.

NEUROBIOLOGY AND PARENT–CHILD INTERACTIONS

The child's brain is shaped by early family experience: "Parents are the active sculptors of their children's growing brains" (Siegel & Hartzell, 2003, p. 34). In infancy, most of this occurs through right-brain to right-brain interaction (Schore, 2003). The infant's right brain is functioning at birth; this hemisphere processes nonverbal cues and emotions, and is prepared for the "protoconversations" (Trevarthen, 1995), the lilting prosody of give-and-take between parents and baby in early preverbal life. Infants are not blank slates; they are born with specific genetic potential, temperament, and limitations. Much of a child's genetic potential is then shaped by experience as nature meets nurture. The newborn is immature neurobiologically and requires intensive adult care. Fortunately, infants come ready to connect, endowed with reflexes that allow parents, grandparents, and other caregiving adults to fall in love with the baby. The earliest infant smile is a reflex; the social smile develops later. But the smile reflex makes the caregiver feel loved by the baby, bringing the adult into the loving loop that is so necessary for the infant's survival (Tronick, 2007). Through this "lyrical duet" (Cozolino, 2006) of sound, touch, and eye contact, endogenous opioids are released in the child's brain (Schore, 2003) as the bonds of attachment are formed and oxytocin is released in both child and adult.

Matching states, or "contingent communication" (Siegel & Hartzell, 2003), is central to this lyrical duet, as parent and infant coregulate each other. In a series of studies, Tronick (2007) examined this coregulation and found that parents and infants are in a constant process of responding to each other nonverbally, each one's behavior evoking the other's. While well-attached pairs enjoy the attunement and attachment of their bond, research has found these parent–baby pairs to be mismatched or out of sync 70% of the time (Tronick, 2007). What matters is what comes after the mismatch: the repair. Well-attached babies and parents repair their break, their out-of-sync moment, and come back together into sync. Child development researchers have suggested that these breaks in attunement allow the child to develop a sense of confidence and mastery in interpersonal repair, a capacity that is vital for healthy adult functioning. Most studies of attachment in early childhood focus on dyadic relationships (especially between mother and baby). However, recent systemic research points to the baby's competence in handling triadic interactions, navigating differences in contingent communication between two parents (Fivaz-Depeursinge & Favez, 2006).

Babies are born with the necessary equipment for attachment, and are active participants in the dance of attachment with parents. Newborns can differentiate mother from father from stranger within days of birth. The baby relies on parents or other adult caregivers for affect regulation. As the adult responds and soothes the infant's distress—a process of dyadic regulation—the baby's brain is developing structures that ultimately allow that child to learn self-regulation, an internalization of the parent's soothing. While these right-brain processes of attunement, attachment, and emotion regulation are developing, as the child grows, the PFC, left hemisphere, and hippocampus develop as well, making possible the acquisition of language and development of explicit memory in the first and second years of life.

The baby's brain is in a constant state of attention and curiosity; all is new to the infant. The nucleus basalis in the brain, necessary for paying attention, is in the "on" position in infants, releasing acetylcholine, which promotes learning (Doidge, 2007). The infant is born with many more neurons than exist in the adult brain. Through early experience, some of these neurons form networks with other neurons; the neurons that do not connect die off through a process called pruning or apoptosis (programmed cell death). Thus, the baby's brain comes ready to engage and be shaped by experience, most especially by the family. Early life experience matters; attuned caregiving matters.

Throughout the child's life, attunement and attachment with parents and other family members are vital for development of brain and self. Connections are not perfect and constant, however, even in the best of circumstances. As with babies, there will be many moments of mismatch between the parents' and the child's needs and states. Indeed, the oscillation between connection–disconnection–reconnection is part of the flow of any intimate relationship. The key is *repair* throughout childhood. Even in healthy relationships, parents may become reactive with their child in the face of current stress overload or as old implicit memories from their childhood—held in the amygdala—are triggered while they struggle in the current moment. A dispute between parents can spill over, or be deflected, into upset with a child. Parents can be reduced to the level of a screaming toddler while reexperiencing a sense of helplessness and rage felt as a young child or in other situations beyond their control. In trying to repair these moments with their child, parents should wait until their own reactivity has calmed; trying to hold a repair conversation while still emotionally flooded is likely to fail (Siegel & Hartzell, 2003). The activated amygdala does not easily share airspace with a reasonable PFC, and the fight can quickly reignite if parents have not had time to regroup and regain some calm. Later, after the storm, reflective conversation is called for as parents and child revisit their reactivity and repair the connection.

THE ADOLESCENT BRAIN: CHALLENGES FOR FAMILY LIFE

From a neurobiological perspective, adolescence is a second period of exuberant brain growth and transformation. There is a disparity between early changes brought on by puberty that heighten emotional arousal and intensity, and later adolescent brain development that allows for greater self-regulation and control. With puberty, emotional intensity and reactivity increase, along with sexual urges and romantic interest. Risk taking, sensation seeking, and sensitivity to peer influence rise dramatically as well (Dahl, 2004). In later adolescence, changes in the PFC allow for greater emotion regulation and executive functioning. Synaptic pruning and myelination (the development of a fatty sheath around the axon of the neuron, which provides speed and efficiency in the transmission from one neuron to the next) within the PFC continue from adolescence through the mid-20s. So the young adolescent is subject to massive doses of hormones, intense affect, and heightened responsiveness to social pressure, while prefrontal processes of "regulatory competence" (Steinberg, 2005), planning, and impulse control are slower to develop. The adolescent brain is at particular risk for substance abuse, because of both its fluid nature during this second pruning and rewiring process, and the social pressures on youths to engage in risky behavior. Sexual urgency may trump common sense or caution, as the PFC has difficulty catching up to the exuberance of the emotional brain, sexual urges, and peer pressure.

The desire for independence often outruns the adolescent's capacity to self-regulate, think carefully, plan, and use good judgment (all prefrontal functions). Parents at times need to lend their PFC to their adolescents, helping them make better choices. This is easier said than done with an adolescent who wants nothing more than freedom and autonomy. Cross-culturally, adolescents do best in close, nonconflictual families with authoritative (firm, warm) parenting that nurtures both their autonomy and connection (Garcia-Preto, 2011; Steinberg, 2001). Adolescents use this "social scaffolding" (Dahl, 2004), involvement and monitoring by parents and other adults, while they learn the necessary skills of emotion regulation and self-control. Such monitoring of adolescents by responsible adults in the community is especially important, for example, for African American youth in high-crime neighborhoods (APA Task Force, 2008).

While current research departs from the "storm-and-stress" model of normal adolescence, this period in the family life cycle can be stressful, especially for parents dealing with their critical or oppositional adolescents (Steinberg, 2001). Relationship plasticity, made possible by neuroplasticity and flexibility in response to changing circumstances, is key for adolescent and parents as they evolve and develop a more mature and complex connection. It is precisely this evolving connection with parents—along with greater autonomy—that characterizes healthy adolescence, not a radical separation from parents. Likewise, the adolescent is not becoming "independent" in the sense of a solo actor; rather, the teenager's need for connection is largely transferred to the peer group. The social brain does not stop needing others in adolescence. While the change processes at this time of life can be daunting for the whole family, understanding the normal developmental trajectory of the adolescent—and of the teenage brain—can give perspective and potentially some wisdom during this challenging time.

ADULTHOOD: NEUROBIOLOGICAL MATURITY AND FLEXIBILITY

The PFC continues to evolve throughout the lifespan. These changes allow for growing maturity with age. With myelination of the PFC, greater thoughtfulness, judgment, and response flexibility are possible, and it appears that myelination, along with neuroplasticity, continues into adulthood (Siegel, 2010b). In the normal maturing brain the PFC develops greater control over the reactive amygdala; with intentional practice, this influence can increase. Since experience changes the brain by creating new neuronal connections, practices that activate the PFC can build new pathways to the amygdala, thus increasing emotion regulation. Mindfulness meditation in particular has been found to impact emotion and well-being positively, facilitating compassion, positive mood, and immune functioning (Davidson et al., 2003).

Self-regulation and self-soothing (achieved through processes of dyadic regulation with parents and in transactions with others in childhood and adolescence) are important aspects of adult emotional competence. While the PFC does exert an inhibitory role on the amygdala, this is not a suppression of emotion. Rather, it is a collaborative working with and soothing of emotion that constitute neurobiological maturity. Identifying or naming an emotion, reading body cues, and labeling the feeling give one the ability to shape it—we "name it to tame it" (Siegel, 2010a). Naming the emotions activates the PFC. This self-regulation has been called "parenting yourself from the inside out" (Siegel & Hartzell, 2003). Siegel (2007) has noted that intrapersonal attunement, reading one's own emotions and sensations, uses the same resonance circuitry as interpersonal empathy. The skills of empathy for self and other are central to emotional and social intelligence in adulthood.

Neurobiological maturity dovetails with the family systems concept of differentiation (Bowen, 1978). Differentiation requires self-regulation, so one can engage with others in a nonreactive, thoughtful, compassionate manner without losing oneself, responding with heart and mind in a calm way (McGoldrick & Carter, 2001). Differentiation involves integration of PFC and limbic system, thought and feeling, left and right hemispheres, mind and body, self and others. Differentiation is an ongoing developmental process, not a state achieved at one time. Changing circumstances in the family, new perspectives, and ongoing prefrontal development all provide challenges and opportunities for further growth. Flexibility, aided by neuroplasticity, allows for adaptation to new challenges in the family system and in one's own life course. Siegel (2010b) offers the image of navigating the "river of integration," without landing on either the bank of rigidity or the bank of chaos. Research on family functioning emphasizes the importance of flexibility in couple and family well-being and resilience (Walsh, 2003).

Flexibility in current relationships can be undermined when one becomes reactive in an interpersonal encounter as old, implicit memories in the amygdala are activated. The past can haunt an individual (and relationships) in the present. Working through unfinished business with one's family of origin can liberate a person from the grip of these old patterns of reactivity. As myelination of the PFC continues through the mid-20s and beyond, life experience combined with brain maturity allows an adult child to view parents with a more sympathetic and curious perspective. "Waking from the spell of childhood" (Fishbane, 2005, p. 550) enables one to see parents as real people with their own strengths and limitations. Holding "interactional awareness" (Byng-Hall, 2008) of parents' experience and feelings as well as one's own, facilitates this shift. Using this perspective to invite parents to a "loving update" of relationships (Fishbane, 2005) can be empowering and transformative for both generations.

In this process, outdated, constraining narratives give way to new narratives of resilience and possibility. From a neurobiological perspective, a transformative narrative integrates thoughts and feelings. Indeed, attachment research has found that having a coherent narrative about one's childhood, incorporating the positives and the negatives, integrating both thought and feeling, is predictive of having children with a secure attachment (Siegel, 2010b). Even when adults have had difficult, painful childhoods, if they have wrestled with past issues and come to a more integrative, differentiated intergenerational perspective, they can parent well and create a secure bond with children.

INTIMATE COUPLE BONDS

Our need for connection with others is intensely expressed in adult love relationships. Neurobiology sheds light on many of the dynamics of adult love. According to Fisher (2004), love relationships entail three separate stages, each fueled by different brain chemicals, and each serving a different evolutionary purpose. Lust is fueled by testosterone in both men and women. Romantic love, which focuses on a specific person with great intensity, is associated with dopamine and norepinephrine. And long-term couple attachment is fueled by oxytocin and vasopressin. As Fisher points out, sometimes these systems work against each other; for example, attachment neuromodulators may dampen lust at times. Fisher, studying madly-in-love people in the fMRI machine as they looked at a picture of their beloved, found that the brain circuits for this state are the same as the addictive cocaine state: Love is a drug high. Studying the recently jilted, she found that their brains fire like those in withdrawal from drugs. She points out that this romantic drug high can only last so long in the brain; at some point (around 18 months or so into the relationship) it yields to a saner, more realistic approach to the partner. For many people, however, the loss of the romantic high is interpreted to mean that one is with the wrong partner, and that it is time to move on. The assumption that one "falls in love" or "falls out of love" is a remarkably passive description, in which the lover has no power or responsibility. Understanding the brain processes of romantic love can facilitate a more mature and proactive way of loving. Nurturing passion in long-term relationships can be challenging, but is important. Touch, massage, and sex all release oxytocin, the neurochemical that both facilitates attachment and reduces cortisol, the stress hormone.

The power of intimate relationships to heal or to harm is enormous. The strain of unhappy love relationships is associated with morbidity and mortality (Robles & Kiecolt-Glaser, 2003; Slatcher, 2010). Happy couples come to look like each other over the years, as their facial muscles are co-sculpted through ongoing synchrony with each other. The happier the relationship, the more the partners resemble each other (Iacoboni, 2008). Holding a loving partner's hand lessens the experience of physical pain (Coan, Schaefer, & Davidson, 2006). Unhappy relationships, by contrast, can be deleterious to health, as can loneliness (Kiecolt-Glaser & Newton, 2001; Cacioppo & Patrick, 2008). Unhappy couples tend to dysregulate each other, setting each other off in a "limbic tango" (Goleman, 1995). As each feels vulnerable, automatic survival strategies are triggered (Scheinkman & Fishbane, 2004), fueled by the amygdala's fight-or-flight reaction.

Adult love entails an oscillation between connection–disconnection–reconnection. Like well-attached parent–infant bonds, secure adult partner attachments include many moments of out-of-sync experiences; what is key in both cases is repair. Happy couples have conflict, but they repair well and often (Gottman & Gottman, 2008; see Driver, Tabares, Shapiro, & Gottman, Chapter 3, this volume). When reactive, with amygdala activation, partners are unable to repair successfully. Using a time-out to calm down is essential before beginning the repair process. Flooding, or DPA (diffuse physiological arousal; heart rate over 100 beats per minute) interferes with the ability to think clearly and solve problems (Gottman & Gottman, 2008).

The power of repair is crucial to successful relationships. Relational wounds (Johnson, Makinen, & Milliken, 2001), when not addressed by the couple, tend to fester and get retriggered over and over as the amygdala associates a current slight to an older, unprocessed wound in the relationship. The normative need to be understood by one's partner fuels repeated attempts to get through to the partner about one's pain. These attempts may misfire as the wounded partner speaks in an angry, accusatory tone, leading to a defensive response in the other. Learning to speak without attacking and to hear without becoming defensive are key processes for successful relationships.

Empathy is key to repair. "Feeling felt" (Siegel & Hartzell, 2003) allows one to relax, to be held by the partner emotionally, and to let down one's neurobiological guard. One mechanism for feeling felt is eye contact, which activates the medial prefrontal and orbitofrontal cortex, among other areas

(Senju & Johnson, 2008). Early in a relationship, as partners are falling in love, each looks in the lover's eyes and sees the self reflected back in a loving, affirming gaze. The mutual empathy of partners can soothe distress, an interpersonal process of coregulation. While self-regulation and differentiation are crucial in relational functioning, soothing each other is a powerful source of well-being in happy couples (Greenberg & Goldman, 2008). The balance between coregulation and self-regulation is part of the dynamic of a healthy relationship.

AGING BRAINS, AGING FAMILIES

Given that families change with the evolving developmental needs of their members, it is good news that neuroplasticity can continue throughout the life course. Even as young adults are navigating their new lives with changing brains, their parents, in middle age and beyond, need to adjust their expectations and behaviors accordingly. It can be difficult for parents of young adults to learn that their children no longer welcome advice or guidance unless requested. Young adults want to be accepted by parents and are sensitive to perceived criticism. Yet they often need emotional and financial support, and may even need to return home to live with parents in harsh economic times. At this phase of family life, parents often find that they have little leverage over their adult children and need to mind their boundaries and their manners—a delicate balancing act. Navigating relationships with adult children, sons- or daughters-in-law, and grandchildren can be daunting for parents who have been responsible for guiding their children's entire development and ensuring their well-being.

The aging brain is more resilient and capable of change than previously thought. While there is cognitive and memory loss with age, the resilient mature brain compensates—for example, using both hemispheres for a task in which younger brains use one hemisphere. These adaptations in the aging brain can foster greater integration and wisdom (Cozolino, 2008). Older adults tend to approach problems in a more positive, integrative, and thoughtful manner, achieving greater perspective (Cacioppo & Patrick, 2008; Mather & Carstensen, 2005). Emotion regulation and social processing—tasks involving the middle PFC—often improve with age. "The taming of the amygdala may be one of the primary gifts of aging and an important component of becoming a wise elder" (Cozolino, 2008, p. 154). Thoughtfulness about the meaning of one's life and efforts to achieve "family integrity" (King & Wynne, 2004) in intergenerational relationships are key processes in successful aging. This focus on integration and meaning reflects the capacities of the mature brain and can enhance well-being in the whole family.

Resilience, wisdom, and neuroplasticity in the aging brain are not guaranteed, however. Luck plays a role, as do genes and life circumstances; disease or injury can limit neural capacity with aging. And lifestyle habits matter:

Regular exercise, nutrition, and healthy habits in middle age can affect later brain plasticity (Ratey, 2008; Strauch, 2010). Mental exercise and exposure to new challenges also promote neuroplasticity, as does paying attention. Whereas paying attention, modulated by the nucleus basalis, is the baby's natural state, for the older adult, attention needs to be more intentional. Recall that the human brain is an anticipation machine, always predicting what will happen based upon past experience; there is a pull for relying on old habits in the adult brain as it ages. For the aging brain to keep growing and adapting, it needs stimulation—cognitive, social, and emotional. Attention, curiosity and a readiness for surprise prime the aging brain for adaptability and change. Focus, new learning, and practice affect neuroplasticity: "Use it or lose it" characterizes adult brain function. How we live affects our brain, which in turn affects our life choices. Keeping vital, alert, socially connected, and active, both cognitively and physically, enables neuroplasticity to flourish into old age.

For all the positive news of brain potential, there are undeniable losses associated with aging. Memory and cognitive loss, even in the absence of dementia, can have painful impacts on functioning and self-esteem. And dementia rates rise with age. Loss of a spouse can be a traumatic blow that affects the survivor's health and longevity, and is a neurobiological challenge as well, as the intimate environment to which the brain has adapted is lost (Wexler, 2006). The loneliness of old age as partners, friends, and relatives die can leave the older adult without the social supports so necessary for healthy functioning. Losses due to illness can be debilitating for the whole family. When an older adult is ill or experiences dementia, the primary caregiver in the family, often a spouse or an adult daughter, can experience massive stress that negatively affects the caregiver's immune system (Kiecolt-Glaser, Dura, Speicher, Trask, & Glaser, 1991). Yet old age and the challenges of caregiving offer opportunities for care and repair in the multigenerational family system (Walsh, 2011). Utilizing the care-and-connection system (Taylor, 2002) can enhance the well-being of elders and their adult children,

IMPLICATIONS FOR CLINICAL WORK

Clients come to therapy to change, yet they may be ambivalent about change. Neuroscience sheds light on this dynamic. Some difficulties with change stem from neural wiring and the tenacity of habits. Understanding how habits or behavioral ruts reflect—and reinforce—neural ruts enables therapists and clients to have more compassion for the challenges of change. In other language, clients' survival strategies, which have helped them navigate the world in the past, may be interfering with current relationships (Scheinkman & Fishbane, 2004); but survival strategies are protective and deeply wired. Helping clients build on their own strengths and addressing change in a collaborative manner allows them to balance the stability of their familiar modes of coping with the flexibility of new adaptations. Offering “neuroeducation” (Fishbane, 2008) about the challenges of change and neuroplasticity in the adult brain can be empowering. Maintaining new habits can be difficult, as old habits tend to reappear in times of stress. Therapists can normalize this and suggest that overlearning and “massed practice” (Doidge, 2007) are often necessary for new behaviors to become wired as the “new normal” in relationships. Thus, neuroeducation can be used both to normalize setbacks and to offer hope and a blueprint for change.

Emotional reactivity and power struggles can pose dilemmas in couple and family therapy. Mutual escalation and blame often ignite quickly as family members become dysregulated and resort to attacking or stonewalling behavior. Partners in unhappy relationships may turn away from or against each other rather than turning toward each other (Gottman & Driver, 2005; see Driver et al., Chapter 3, this volume). This dynamic has neurobiological underpinnings. According to the Polyvagal Theory (Porges, 2007), we automatically assess for safety or danger with others. A sense of safety prompts social engagement (turning toward); threat prompts turning against or turning away—fight or flight. The freeze response may be activated in situations of extreme threat or trauma. It can be empowering to help clients identify the neurobiological underpinnings of their reactive moments, to give them a “peek inside” their own brains.

If couples or family members are caught up in a recursive pattern of criticism–defense, with each becoming dysregulated, the therapist can help them calm down, become more thoughtful about their own reactivity and mutual escalation, and learn how to self-regulate when upset. Techniques such as focused breathing, mindfulness meditation, naming one’s feeling with compassion, or holding a hand on one’s heart can soothe the agitated amygdala and bring the PFC back online. Imagery work, such as picturing one’s own PFC soothing one’s rowdy amygdala, promotes resilience in the face of interpersonal upset (Fishbane, 2007). These techniques help family members become more relationally competent and empowered, and less prone to power struggles with each other (Fishbane, 2010, 2011).

For clients who become agitated and hyperaroused, or for those who shut down and go to hypoarousal, expanding the “window of tolerance” for affect (Fosha, 2000; Siegel, 2010b) is important. Learning to read and label one’s own emotions is key; the PFC–limbic system circuit is activated in this process. Likewise, learning to speak one’s needs respectfully in a relationship is important. Therapists can encourage clients to “make a relational claim” (Fishbane, 2001), in which they speak their needs while holding the needs of their partner and of the relationship at the same time. These skills involve integration of PFC and limbic system, mind and body, left and right hemispheres, and self and other. Siegel (2010b) considers these levels of integration key to mental health.

Helping family members listen to each other with empathy can be transformative in mind and body, since empathy releases oxytocin, which reduces cortisol, the stress hormone. The therapist can frame empathy as a skill that can be learned. Indeed, empathic accuracy has been shown to increase with motivation (Ickes et al., 2000). Clients who find empathy difficult can develop this skill by learning to pay attention to their body cues, through guided body visualizations and body scans (Kabat-Zinn, 1990; Siegel, 2010b), and by explicit empathy-building exercises such as the speaker–listener technique. Family members can also be encouraged to offer each other gentle hugs and other forms of safe touch, which release oxytocin and lower the stress hormone cortisol. Facilitating the care-and-connection system in the family offers an antidote to cultural messages of competition and individualism that contribute to reactivity and polarization in relationships.

Neuroscience points to our fundamentally social nature. Helping couples and families to utilize the social contexts in which they are embedded and to seek out additional social resources is key in therapy. The impact of poverty, marginalization, racism, isolation, or violence can be devastating. The therapist must use a wide lens to understand clients-in-context. Social support is vital to mental and physical health; however, forms of social support may differ culturally (Kim et al., 2008). Therapists must be attuned to clients' cultural traditions, beliefs, and expectations in order to facilitate new adaptations while building on resources and strengths within the family and larger community.

Therapy often challenges clients' familiar modes of operating, beliefs, and survival strategies. Deep internal or relational change—the work of therapy—can feel at times like venturing into foreign territory. Learning new skills, shifting perspectives, and changing constraining practices can feel disorienting. The therapist's respect, acceptance, and empathy ground this process of transformation. For clients to work toward rewiring their brains, habits, and relationships, they need to feel safe. It is imperative for the therapist to create a shame-free, blame-free zone in the therapeutic setting (Fishbane, 2010), so clients can risk the journey of change. When working with couples or families, extending "multilateral partiality" (Boszormenyi-Nagy & Spark, 1973), concern and care, to all of the individuals involved promotes safety and facilitates change. To do therapy with the brain in mind, to participate in neurobiological change, the therapist joins clients in the limbic zone, bringing prefrontal thoughtfulness to the process of personal, relational, and contextual transformation.

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