In the Spirit of Integration

Imagining the Adolescent Brain

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(based on the chapter about teens in the forthcoming book *Being a Brain-Wise Therapist*)

As we learn more about the intricacies of the rapidly changing teen brain, we may conclude that our adolescents are the most poorly understood age group in the western world. Buttressed with this new knowledge, we might want to challenge society's invariant representation (Hawkins & Blakeslee, 2004) of teens as frustrating and troublesome, in favor of informed participation during this unique period of rapid change in brain structure and function.

Sadly, in our present-day society, many parents simply gird their loins for a bad six years when their children turn twelve, either pulling back with a helpless, hands-off attitude, or diving in with a hands-on strangle hold to stave off their fears for their young people. As you read on, it may be helpful to think about your own experience as a teenager, sensing these changes in your brain as well as recalling how you were met during this period. Were there attitudes and actions that might have been more helpful for you?

Jay Giedd

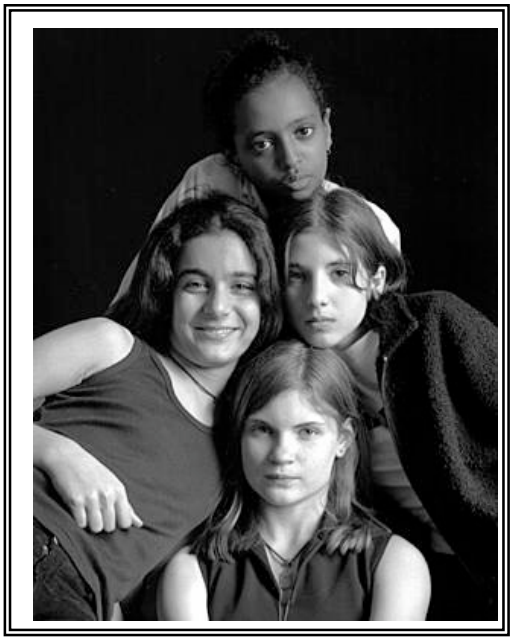
The information that follows applies to all teens, and does not take into account the additional load they may carry from poor early attachment experiences, trauma, possible ongoing socioeconomic stressors, or disturbed family dynamics. When we do factor these in with the adolescents we see in our counseling offices or classrooms, the complexity of their neural situation may inform and deepen our empathic support for these young people.

We can begin the story of teen brain development in the lab of Jay Giedd in 1997. Through fMRI scans of many adolescent brains, as his young people moved from the onset of puberty through late adolescence, he unexpectedly found that at the beginning of puberty (approximately 11 in girls and 12 in boys), there is a genetically-triggered burst of over-production (or *exuberance*, as the scientists picturesquely call it), creating a forest of new dendrites and synapses in several regions of the brain, providing the opportunity for billions of new connections. The carefully sculpted neural pathways that developed throughout childhood now become crowded malls of possibilities. This burst of growth is followed by a dramatic decrease in the number of synaptic connections (called *pruning*), a process that proceeds until the mid-20s (Giedd, et al., 1999). Sowell and colleagues (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999) estimate that between the ages of 12 and 20, the teenage brain loses seven to ten percent of its gray matter. Such pruning gradually creates a more efficient, better-integrated brain. However, it also follows that from puberty through the mid-twenties, we may see some mental and emotional disorganization, followed by the gradual emergence of a more coherent mind and more regulated relationships.

It is also important to remember that when there is a burst of new growth, it may signal a period of rapid learning, of heightened *neuroplasticity* (Diamond & Hopson, 1998). This would make the quality of the environment at the onset of adolescence particularly crucial, since we know that what is genetically awakened is then shaped by experience. In fact, we also know that different kinds of experiences can actually influence which genes are turned on (Siegel, 1999). It is possible that the early teen brain is wide open for

reshaping, not only intellectually, but relationally. This provides a prime opportunity for balanced adults to make a long-term difference in their teens' trajectory toward independent living (Neufeld & Mate, 2006).

As research proceeds, we are just beginning to discover that many structures and processes in the teen brain participate in this reconstruction effort. Perhaps the most central area is the exuberance/pruning of the *middle prefrontal regions* (Giedd et al., 1999). If we recall the nine functions of those circuits, it is easy to see why teens seem to sometimes lose their capacity for sound judgment, attuned communication, empathy, emotional stability, and accurate perception of social cues, particularly under stress. The cerebellum is also rewiring, and is the last area to complete its remodel. We now know that in addition to motor coordination, the *cerebellum* plays an important role in recognizing social cues (Giedd et al.). This means that early teens may be challenged when trying to sort out the meaning of social signals, sometimes reacting in what appear to be irrational and annoying ways. Parents who suddenly find that their very presence is acutely embarrassing to their thirteen-year old can now picture some disruption that may be occurring between limbic, prefrontal, and cerebellar circuits. Most important, we can take a step toward understanding the teen viewpoint by accepting that adolescents perceive the world differently than we adults.



There is also evidence suggesting that during this period, teen prefrontal regions have to work much harder than the adult brain solving a similar problem, so they can become overtaxed and simply shut down when faced with complicated tasks or an intense stressor (Sabbagh, 2006). This may be one factor in the frequent fender benders (and resulting insurance rates) that are part of adolescent life. This gridlock appears to occur partly because pruning has not proceeded sufficiently to facilitate efficient communication of signals within the prefrontal. Additionally, the various structures of the brain aren't communicating well over longer distances yet. As a result, the brain regions that could generate rapid, accurate judgments aren't well connected to the areas making unconsidered snap judgments.

We can think of this period of growth as a time of increased differentiation, in preparation for integration at a higher level of complexity. This exuberance brings the onset of formal operations, the ability to think at higher levels of abstraction about a broader range of issues. However, at the same time, because neural integration of the new structures is just beginning and the map of connectivity is confused by the abundance of pathways, the coordination between different brain regions is temporarily limited. For example, scans reveal that when teens are shown the face of a person who is afraid, their amygdalae light up, triggering a full-body response of fear. When adults are shown the same picture, their middle prefrontal immediately comes online to help them evaluate the actual level of threat. Or we can imagine that when the idea to jump off the roof into the swimming pool makes itself known in working memory, the motor strip has the young person hurtling into space before the dorsolateral prefrontal cortex can receive the middle prefrontal's suggestion that this might not be such a good idea after all. Or when a middle school teacher gives the students homework, the explicit memory of this, encoded in the hippocampus, may not be retrieved and come into working memory until long after the due date has passed. It is a little like a group of creative ballet dancers coming on stage with limited choreography to tell them how to dance in synchrony. However, research also suggests that these difficulties are most noticeable under stressful conditions, so it is not accurate to imagine that all teenagers will respond in these ways.

As pruning proceeds, it follows an interesting pattern that may help to account for increases in balance as our teens move toward their twenties. Not only are there fewer synapses to snarl communication, but more *excitatory* than *inhibitory* synapses are dying away. Some estimate that the ratio goes from seven-to-one in favor of excitement to four-to-one over the course of adolescence (Strauch, 2003). The brain is literally calming itself. At the same time, the *dorsolateral prefrontal cortex* is improving its ability to hold information in the presence of competing information, while increasing integration with the middle prefrontal gradually brings the capacity for well-considered, flexible decision-making. Much of this kind of consolidation happens near the end of adolescence and into the twenties, leaving teens more vulnerable through most of junior high and high school. It helps us understand why a teenager, who holds the rational view that drug use is not a good idea, may lose that thought entirely when presented with a peer-generated opportunity to try something new.

Teen brains also go through a burst of myelination. In this process, tendrils from certain kinds of glial cells wrap themselves around axons, creating a myelin sheath that allows neurons to communicate with one another one hundred times faster, while also giving strength to the synaptic connections. While research in this area is in its infancy, we do know that certain areas increase myelination by up to one hundred percent during this period, a huge and unexpected leap (Benes, Turtle, Khan, & Farol, 1994). One relay station of the brain that receives a myelin boost is the loop linking the posterior part of the cingulate with the limbic regions. These circuits give us an awareness of our gut reactions, and place them in the context of a thought (Benes, 1989). However, initially this new speedy highway is not well connected with the calm judgment of the middle prefrontal regions (an area that myelinates later). As a result of increasing awareness of the gut, any initial fear response gives the sympathetic nervous system a jolt, so that sweaty palms and racing heart may define the truth about the current encounter. The good news is that by the end of adolescence, myelination finally creates support for faster connection between the middle prefrontal and limbic regions, allowing for a notable modulation in emotion.

Another region of the brain also benefits from the increase in speed. The corpus callosum, the band of connecting axons responsible for linking the hemispheres, improves communication between right and left halves of Wernicke's area, gradually helping teens find words for their emotions (Thompson et al., 2000). This is a good thing because young teens, in the grip of exuberance, lose about twenty percent of their ability to name—and, therefore, modulate—their feelings (Strauch, 2003). In addition, the areas of the parietal cortex that support complex logical functions are also being made more efficient by the myelinating corpus callosum, particularly in the earliest days of adolescence. Teens then have a better chance at algebra and may find themselves unexpectedly moved by Emily Dickinson.

Some other useful research tidbits:

1. One reason teenagers go to bed later and rise later is because, at the onset of puberty, *melatonin*, a sleep-encouraging brain chemical, enters their system about two hours later and lingers longer in the morning (Wolfson & Carskadon, 1998). There is also good evidence that teens need about nine hours sleep rather than the seven-and-half or eight required by adults.

2. The propensity for risky behaviors may have to do with a combination of *dysregulated dopamine levels* and disrupted connections with the prefrontal cortex (Bardo et al., 1993). While

the research is far from clear at this point, we do know that the dopamine circuits, which mediate pleasure and direct us toward the new, are frequently running high or low during this period. Whether teens are responding to high levels or seeking to raise low levels, teens can feel the pull to try something new and exciting, whether that is driving too fast or responding to the push of hormones. Because the prefrontal isn't always on call to keep consequences in mind, the act may be committed before reflection can moderate the outcome.

3. Recent research by George Bartzokis (2005), a professor of neurology at UCLA's David Geffen School of Medicine, suggests that extensive drug and alcohol use in the teen years may *disrupt myelination*, leaving the brain vulnerable to impulsivity, while aggravating autism, attention deficit/hyperactivity disorder, and schizophrenia. Since the brain's excitatory circuits myelinate first, followed by inhibitory circuits (a process not complete until age 25), slowing myelination may contribute to addictive behaviors, because the push toward taking the drug is happening one hundred times faster than the message to stop. Since myelination is a genetically-driven aspect of brain development, it is not clear whether once the critical period has passed, myelination can resume if drug and alcohol usage stops.

This is a lot of information to absorb at one sitting. Spending some time rereading and making a picture in our brains of the dynamic pattern of changes in connectivity may make the information more available to share with others at the right moment. We are finding that the parents of our teen clients and the adolescents themselves are able to shift their perceptions fairly quickly when they can hold an image of these changes. It turns out that such knowledge is a powerful resource for breaking down invariant representations and increasing regulation.

All of these findings have emerged in the last fifteen years, so the information can give us only suggestions about some challenges some teenagers face. However, even with just these discoveries, we have enough information to encourage cautious consideration of some ways we might support delinquent adolescents and modify advice to parents, as well as impact the way we do therapy or interact in the classroom or at home with hurting teens.

As at every stage of life, teens need to *attach*, and the vehicle for that is *contingent communication*. However, what is contingent changes across the life span. Instead of guidance, adolescents respond to respect for their ability to find solutions. They blossom when their unique opinions are taken seriously. Instead of remaining sheltered, they need to face the world's inconsistencies and injustices, bringing that conversation to us. Just as when they were younger, their emotional wounds need to be met with listening and understanding, even when their concerns sometimes look out of proportion to our adult minds.

Finding the balance between *respect* and *influence through attachment* is the art of it. Peter Jensen, director of the Center for the Advancement of Children's Mental Health, suggests that we might do well to "function like a surrogate set of frontal lobes" at times (Strauch, 2003, p. 35). What do frontal lobes do? One function is to provide the capacity for flexible thinking, choosing the wisest alternative. This involves bringing these possibilities into awareness (dorsolateral prefrontal cortex), holding them there long enough to contemplate the consequences of each, culminating in a decision. This suggests that we might say something like "What do you think might happen if you …?" If our teens are

confident that we won't just dismiss their answers, giving our own "correct" version, they will often play with various ideas while we listen.

Patty Wipfler (2006), founder of Hand in Hand Parenting, a parent/child organization in Palo Alto, California, is a most powerful advocate for adolescents. Her approach to parenting, through all the developmental stages, is based on connection—interpersonal linking leading to development of neural pathways that embody secure attachment. For teens, this continues to make excellent neurobiological sense. Since these young people sometimes struggle with linking their middle prefrontal cortices to the rest of their brains, it seems wise to foster those neural connections rather than adopt either a rigidly controlling or hands-off approach that will further discombobulate what may already be challenged. We know that when people feel felt, limbic and prefrontal circuits are pulled together. Wipfler (2006) suggests that becoming an ally may be the most effective stance to promote this joining as these young people prepare for adult life. For many parents, this is a radical shift, especially as their first teenager exits childhood. Even for therapists, the challenge may be to calm our anxiety as these young adults come to us with their struggles. In all her work, Wipfler bases her approach on radical trust in adolescents' ability to find their feet when supported by people who have resolved enough of their own issues to be truly present and confident of the teens' emerging abilities.

Neurobiological realities also hint at the importance of nurturing adult contact during adolescence. During this period of exuberance and pruning, teen brains are being dramatically rewired. We know that experience will be shaping these new neural connections, as well as telling some genes whether to express or not; reinforcing certain kinds of synaptic links; and creating, as well as reshaping, representations and implicit assumptions about the relational world. It is certainly not ideal for teens to find their main or only companions among their peers. One unfinished teen brain being the major force shaping another is not the best situation. Instead, teens need to put down roots with people who are not in this same transition, with well-enough integrated brains to help them wire their new neural territory in ways that will support a coherent life.

Even with all this brain knowledge, it isn't helpful to say, "Teenagers are this way because X is happening in the brain." That is a distancing statement that lacks respect for individuality, and doesn't give due weight to the fact that research is still at a very early stage. Instead, we are on firmer ground if we understand the tendencies engendered by this big surge in brain development, while becoming aware of how relationships can help teens make the most of this neural growth spurt. Interpersonal Neurobiology encourages us to take the power of relationship, for good or ill, seriously. We also know that expectations play an enormous part in determining what happens next, because they bias our perceptions and behaviors, limiting the range of what we can imagine.

A good example of this comes from societies that are embedded in more structured and concrete expectations for how children pass from childhood into adulthood. Unchallenged by the need to become fully independent adults, and often not burdened by the array of stressors present in our society, these young ones often slip seamlessly from one stage to the next, with barely a hint of adolescent turmoil (Sabbagh, 2006). Cushioned by continuing primary relationships with adults, their maturing brains are not left to fend for themselves. Perhaps this can be our challenge, to create attachment richness within a culture that pushes the other way. With warm support at each stage of life, coupled with a thorough understanding of the brain/body and mind to guide us, we might be able to assist the next generation in finding a balance between the push toward individuality and the lifelong need for empathic connection.

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