

1 Teen Brain

Under Construction

Neuroscience has recently put forward the startling fact that teen brains resemble blueprints more than they resemble skyscrapers. Secondary educators who once considered a teenage mind an empty house that needed furnishings would do better to understand it as the framing of a house that still needs walls, wiring, and a roof.

Did you know that . . .

- The brain, not hormones, is to blame for the inexplicable behavior of teens
- Short-term memory increases by about thirty percent during adolescence
- The activities teens invest their time and energy in influence what activities they'll invest in as adults
- Teens are ruled far more by their emotions than by logic

A group of middle school boys was sitting around the lunch table telling “Yo’ Mama” jokes. Everyone was having fun until one boy went too far; tempers started to flare. A boy at an adjoining table stepped in to avert the fight that threatened to brew. Before anyone knew it, a fight had erupted between two boys who hadn’t been telling jokes in the first place! A teacher, Mr. Kenith, broke up the fight and asked them, “Why are you fighting?” Both boys answered, “I don’t know.” And they really didn’t.

CATERPILLARS TO BUTTERFLIES

Teenage behavior—nothing is more unpredictable, volatile, or intriguing. Teens want more privacy on the computer and minimize the screen as soon as you enter the room. They cycle earnestly through the roles of vegetarian, stand-up comedian, and swing dancer. They streak around the block in subfreezing weather on New Year’s Eve. The sweet boy who blushed and hid his head under a sofa pillow when the Victoria’s Secret commercials came on now watches and comments on the models.

Common knowledge used to be that adolescence was a phase all kids went through and that adults should wait it out. Quips like “raging hormones” and “rebel without a clue” attempted to explain the erratic thought patterns and subsequent behavior of adolescents. In their frustration, teachers and parents pondered the question, “Why can’t they act like adults?” The real explanation provides a remarkable answer: They can’t act like adults because they don’t think like adults. Neuroscience confirms what we’ve always thought—the adolescent brain is still under construction.

The implications of the transitioning state of the adolescent’s brain are exciting and unsettling. It’s a time of great vulnerability. Teenagers’ brains are growing and changing by adding gray matter and pruning old synapses. Choices teens make during adolescence potentially affect their brains for the rest of their lives. For parents and teachers, this discovery can be disconcerting. They had a great deal of power and influence over preschool and elementary school brains. Parents could ensure that young children were not exposed to excessive television, videos, computer games, and other passive activities. Teachers could monitor the books students read in class, assign projects for kids to work on (during academic work and during free time), and design a curriculum that applied to every student. But adult influence is much less effective on adolescents; to a great degree, teenagers are the masters of their own destiny and determine the fate of their brains (Spinks, 2002).

Secret Revealed



Hormones are off the list of primary suspects! The teenagers-act-crazy-because-of-hormones theory is incomplete. Think of it this way: Adults have hormones in their bodies, too, yet manage to write memos and grade homework even while thinking about a hot date later that evening. Adolescents aren’t victims of chemicals coursing through their veins and

turning their fancies to thoughts of love or mayhem; if they have trouble sitting still in school and concentrating on their lesson plans, it's because their brains aren't finished yet! MRI scans performed by Dr. Jay Giedd (Giedd, Blumenthal, Jeffries, Rajapakse, et al., 1999) of the National Institute of Mental Health have revealed that rather than leaving childhood with a brain ready to take on the responsibilities of young adulthood, teens have to contend with a brain that is destroying old neural connections and building new ones. Instead of battenning down the hatches to wait out some hormonal storm, teens are navigating a cerebral hurricane without a compass. This profound discovery will forever alter how educators and parents interpret the mysterious behaviors of adolescence.

Teenagers also notice the differences between their childhood days and their newfound adolescent interests. One girl said, "I go out more, hang out, talk on the phone." Another said, "I go to the mall, go to parties, dance, listen to music. . . . They're ways to have fun and spend more time with your friends." A middle school boy said simply, "I just chill." These are the same kids who, one year ago, were racing each other to the swings at recess, playing *Candy Land*, and letting Mom pick out their clothes.

POURING THE FOUNDATION

Understanding the complexity of how the brain grows during adolescence requires knowledge about how the brain is structured. It is composed of two types of cells, neurons and glial cells. Glial cells are the "glue" that binds cells together; they compose ninety percent of the cells in the brain. The other ten percent of brain cells are neurons, cells associated with learning. Neurons hold the secrets of the mind. They are the body's communicators and constantly strike up conversations all over the brain. They coordinate thoughts, ideas, and feelings at breakneck speeds. You can practically hear the neurons roar and rumble in a teenager's head as they fire, ignite, and spring into action!

Neurons are composed of a cell body, dendrites, and one axon. Dendrites, hairlike branches emerging from the plump cell body, receive information from other neurons. Every time an individual has a new experience or gains a bit of information, another connection is made. I once asked a group of middle school and high school students what they had learned in the last month. I was bombarded with responses: I started

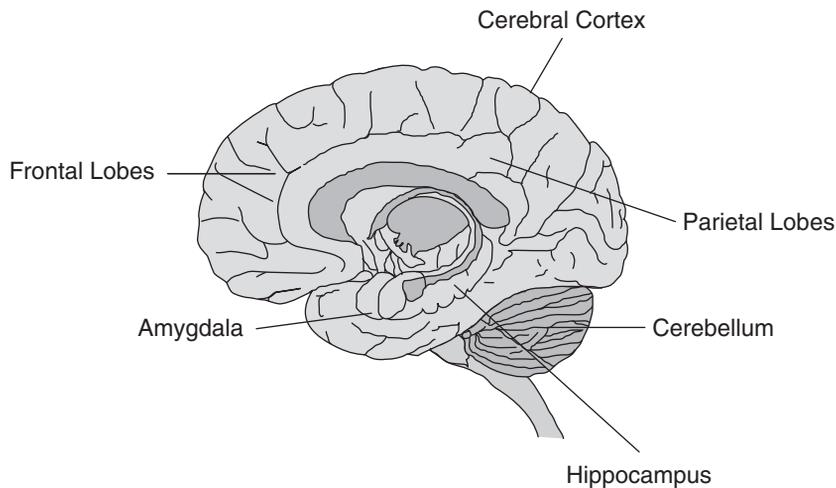
6 • Secrets of the Teenage Brain

to drive, I learned how to wait tables, I found out about mono, I learned how to calculate interest, I learned what *jugar* means in Spanish. What a burst of dendrite growth in their minds! Creating dendrites is an exciting proposition to educators; we want our students' brains to teem with them. The more dendrite receptors there are, the better the brain cells' ability to network with one another. And good news—there is plenty of room around the neuron table. Although neurons average about one thousand dendrites, one neuron can have many, many more.

Learning would not occur if neurons were isolated from each other. Each cell's single axon is a long extension from the cell body that sends information to another neuron's dendrite. The space between a dendrite and an axon (where communication between neurons takes place) is called a synapse. Messages sprint from neuron to neuron via the synapses. When the proverbial lightbulb flashes over a student's head in a moment of sudden comprehension, the synapses go wild. Neurons spark and fire across this entire network of cells in the brain. As synapses are strengthened through use, memories are reinforced and the ability to communicate with other neurons increases (Dahl, 2003).

UPGRADING THE HARD DRIVE

When we think of learning and memory, the cortex is often the first part of the brain to come to mind, but the hippocampus is also involved in learning. This small horseshoe-shaped part of the brain is capable of neurogenesis, the ability to give birth to new neurons. The hippocampus stands in stark contrast to the rest of the brain, which remains infertile. To a large degree, the 100 billion neurons you are born with tend to be your entire slice of the pie. A thought-provoking study of learning done by researchers at the University of Colorado revealed that the cortex finds patterns, integrates information, and attempts to give structure to information (the important stuff); the hippocampus deals with facts and details (rote memory). From this it is inferred that the hippocampus memorizes and the cortex learns (O'Reilly & Rudy, 2000). Like the rest of the brain, the hippocampus creates new dendrites and synapses during adolescence, which increases short-term memory in teenagers. Instead of just five to seven bits of information, teens may now be able to remember seven to nine bits (Woolfolk, 2006). They are better positioned to memorize that wistful sonnet or crucial math theorem.

Figure 1.1 Human Brain

SOURCE: Adapted from Sousa, D. A. (2003), *How the Gifted Brain Learns*, p. 18.

Secret Revealed



Remember Piaget's theory of cognition and the information processing model from your Ed Psych classes? They both state that the quality of short-term memory increases when students enter the teenage years, but neither explained why. Dr. Paul Thompson from the UCLA Laboratory of Neuro Imaging put adolescents into an MRI scanner to image their brains and actually witnessed the brains growing in size and power! (Thompson et al., 2000) The formation of new gray and white matter—through dendrites, synapses, and myelination—enables teens to remember more and remember it better. Now, Ed Psych professors can support Piaget's theory and the information processing model with hard data. Finally, teachers in the field and in training have the whole story.

The hippocampus is slow to develop; in fact, there isn't much evidence of activity until about age three. (This probably explains why we have trouble remembering anything in infancy.) The hippocampus is associated with short-term memory—it helps us remember the name and phone number of the person we just met or the location of our favorite pizza

8 • Secrets of the Teenage Brain

place. It acts as a switchboard connecting short- and long-term memory and constantly communicates between the two. This dialogue linking the hippocampus and the cortex helps give meaning to new information (Schacter, 1996).

The cerebral cortex, or neocortex, is the wrinkled outer covering of the brain, the site of higher-level thinking and self-awareness. The most developed part of the human brain, the cerebral cortex allows us to problem solve, think critically, and make decisions. “No, I don’t want a beer” or “Sure, I’ll have a cigarette” are decisions made in the cortex. Students who say, “Math is my favorite subject,” “I like Geography,” or “I enjoy my creative writing class” are referring to the content that dwells in the cerebral cortex.

Most mental tasks require communication between both hemispheres of the brain. The corpus callosum acts as a bridge between the two sides, allowing information to cross with ease. Even uncomplicated activities, such as comprehending a joke or singing a song, are not confined to one hemisphere but, rather, require complex connections between both sides of the brain. The more bells and whistles a task has, the more you use the entire brain to complete it (Weissman & Banich, 2000). During adolescence, the corpus callosum increases in size by creating more dendrites and synapses. As the adolescent brain becomes capable of more complex tasks, the corpus callosum becomes larger and thicker, better able to handle the job. Scientists were amazed to discover its long maturation cycle—it continues growing into young adulthood (Keshavan et al., 2002).

A relationship has recently been established between the corpus callosum and self-awareness (the ability to monitor one’s own thoughts). New neuroimaging technology has enabled researchers to study the process of self-awareness in the brain. The sense of self seems to be located in the right hemisphere of the brain, and the sense of others in the left (Kircher et al., 2001; Platek, Keenan, Gallup, & Mohammed, 2004). The strengthening corpus callosum enables teens to better understand themselves in relation to others—this budding awareness is part of what turns adolescents into adults.

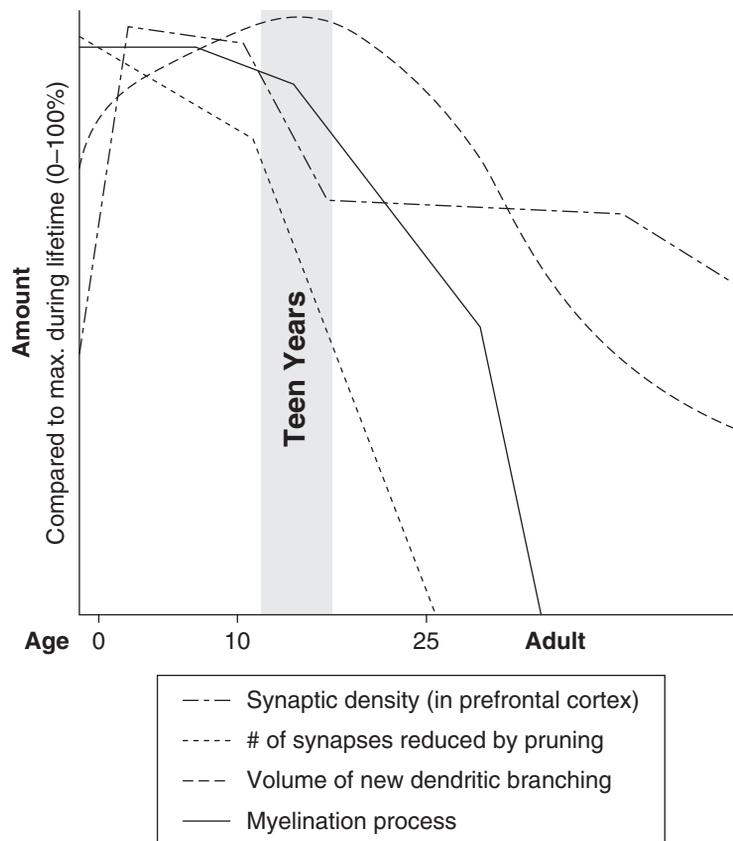
USE IT OR LOSE IT

Two processes occur as the human brain develops. The first is an overproduction of dendrites and synapses—gray matter—that results in an overload of dendrites from the cell bodies. Dendrites and synapses are multiplying like crazy in the brain! The second process, the pruning (or elimination) of brain cells, follows this overproduction. Which neurons survive or die is determined by survival of the fittest. The brain selectively

strengthens or prunes neurons based on activity. Synapses continually used will flourish; those that are not will wither away. It’s “use it or lose it” in action.

This overproduction of neurons, dendrites, and synapses begins at birth and continues until a child is approximately three years old; at this age, the average child has many more synapses than an adult. Obviously, an amazing amount of activity occurs in the brain during this time. From the moment of birth, however, synapses and neurons that are not being used begin to be pruned. This process is very efficient, allowing the brain to invest in strengthening the synapses that the individual finds most necessary and important.

Figure 1.2 Significant Brain Changes Occur During Teenage Years



SOURCES: Bourgeois (2001); Huttenlocher and Dabholkar (1997); Sampaio and Truwit (2001).

This period of neural growth has become the focus of popular attention in education, sparking a great deal of excitement from early childhood educators and parents. Research suggests that, as a result of the creation of gray matter, we are biologically primed for learning in the early years. Some individuals have taken this information about the young child to the extreme, claiming that preschoolers who “snooze” will lose the opportunity to grow any more brain cells—ever. This dire prediction places tremendous pressure on preschool children and their parents to fill childhood with as many educational and enrichment activities as possible (Puckett, Marshall, & Davis, 1999).

Secret Revealed



Did you go to your high school reunion? Were you surprised that the “Class Clown” was a prosperous salesperson or that “Most Likely to Succeed” did? You shouldn’t have been. The girl who spent all those science classes making students laugh when the teacher’s back was turned built her brain around the ability to make customers enjoy themselves—and buy products. The boy who spent his time reading, thinking, organizing his notes, and acing projects and exams built into his brain the ability to develop and grow his own business. Any information teens use and learn in school will be hardwired into the brain’s structure (good and bad), and anything they ignore will lose its priority. For parents and teachers of preschool children, this concept has been a no-brainer for quite some time. What no one realized until very recently was that teenage brains were still open to this kind of direction and input!

Such emphasis on the preschool brain has overshadowed the opportunities for growth and change in the brain during adolescence. This is known as *plasticity*. Brain plasticity refers to the brain’s ability to change as it experiences fresh phenomenon and learns new information. In essence, it means the brain is on a continual course of rewiring in order to make sense of its environment. Amazingly, due to plasticity, changes occur in both the brain’s physical structure and in the way it functions throughout our lifespan. This allows the sixty-year-old man to change his golf stroke or the forty-year-old woman to return to school for her master’s degree. It also gives special assistance to those with a brain injury, helping them depend more on their remaining brain functions.

Plasticity has promising implications for teachers and students alike. For instance, as a teacher your original course of study may have

been social studies, but due to hiring needs you find yourself teaching math. Being pragmatic you hone your math skills, enriching your brain. As a result, there will actually be more gray matter in your brain dealing with math; synapses are being generated. Even if you are not doing a dramatic switch of disciplines, education is an ever-changing field. Fortunately, our minds, and hopefully our spirits, are always up to the challenge. As for students, the same benefits apply; as they learn new information, their brain makes adjustments and grows (Doidges, 2007).

Neuroscience discovered that the brain remains quite malleable in cognitive and emotional development during adolescence and even into adulthood. In the early 1990s, Dr. Jay Giedd of the National Institute of Mental Health began doing MRIs on the brains of 145 healthy children from ages four to twenty-one. The participants selected for the study were scanned every two years to monitor possible anatomical changes occurring with maturation. He noted an undeniable overproduction of gray matter during adolescence (Giedd, Blumenthal, Jeffries, Castellanos, et al., 1999).

This overproduction gives teens the opportunity to excel in all kinds of areas; synapses spawn all over their brains. If teens do a lot of reading, they become better readers; if they are fond of and practice a lot of science, they will probably become scientists; kids who solve problems become great problem solvers. This is a neurological reason to involve adolescents in responsible activities and introduce them to all kinds of new experiences—teens who aren't involved in healthy activities may build their brains around the infamous sex, drugs, and rock 'n' roll! As Dr. Giedd said, "Teens are most likely to experiment with drugs and alcohol. I often show teens my data curve [and say], 'If you do this tonight, you may be affecting your brains not just this weekend but for the next eighty years of your life'" (Vedantam, 2001).

Just as important as the creation of additional gray matter to the adolescent is the process of pruning that follows. The use it or lose it theory pertains to adolescents as well as to ten-year-olds. The neural connections a teenager makes endure a lifetime, and unused connections are lost forever. If they aren't reading, doing science, or solving problems, the synapses for those activities will be pruned. It is hypothesized that pruning at this age permits the adolescent brain to organize its circuitry and refine its thinking processes (Thompson et al., 2000). It is a golden opportunity to build a better brain. It is also a golden opportunity to waste the brain's potential and water it down instead.



The mother of a seventh-grade boy who was getting ready for his first dance said, "His dad and I just could not believe it. He prepped for hours. Lifted weights that afternoon and then went on the treadmill. He took a selection of shirts and jeans into the bathroom—he never does that. He's always particular with his hair, but this time he was overly particular."

A supervisor at a middle school afterschool program said, "There's a group of sixth-grade girls really into boys. Two or three will follow a boy around for a day, take his pencil, that kind of thing. Eighth graders are more subtle. A boy and girl will sit close together, but if you look under the lunch table she'll have her leg over his."

Some scientists even speculate that adolescence is when people learn the mating ritual. Teenagers are very interested in the opposite sex and how to navigate this explosive social field. They commit an extensive amount of time and thought to mastering this particular learning opportunity. As luck would have it, hormones come into play at this very same time, inspiring a mating dance both painful and poetic. The chaos that ensues consumes the minds and lives of teens and everyone else they touch.

With all this restructuring, is it any wonder that the adolescent brain is at times unorganized, spontaneous, and prone to misinterpretations? They have a lot to adjust to. "I can literally stand right in front of my class and say that at 3:00 p.m. we are going to load the bus. The two kids right in front of me will come up one minute later and ask what time the bus will be loaded!" one teacher said. Eighth grader Jamiesha and her mother look at

the world from different angles. "Mom tells me I'm supposed to be in at a certain time. I come in late 'cause I decided to go to my friend's house for a little while. She gets all mad. I don't get it." To Jamiesha, being late is no big deal. So what if she changed her plans an hour one way or the other! She came home, didn't she?

THE INFORMATION SUPER HIGHWAY

After synapses are generated in the brain, myelin—a fatty substance made of glial—is produced to insulate the neurons. Myelin covers the axons of neurons and enables information to travel efficiently. Myelinated tissue is referred to as white matter. The more extensive the myelination of axons, the faster information flows between the cells. At the same time, the ability to use symbolism, metaphors, and analogies increases in older adolescents. They are able to appreciate irony and sarcasm; their sense of humor becomes more sophisticated, and teachers often find themselves the objects of this increased capability (Santrock, 2003). The adolescent is ready to

hypothesize, create abstractly, and comprehend complex math theorems. The rampant changes are dynamic and undeniable. The transition from the childhood brain to the adolescent brain is like paving a gravel road with asphalt; teens are on their way to becoming faster, sleeker thinking machines. Their steadfast memory, jaunty step, thinking processes, language skills, and emotions all benefit from this smoother ride.

Construction occurs throughout the teen brain. The parietal lobes (which process and desegregate sensory information like sights, sounds, and smells), temporal lobes (which process language and emotional behavior), occipital lobes (which processes visual information), cerebellum (which processes coordination and thinking skills), and hippocampus (seat of short-term memory) all benefit from the overproduction and pruning of synapses. Researchers at the UCLA Laboratory of Neuro Imaging discovered that the parietal lobes did not complete the creation of gray matter until about the age of twelve—and only then did they start pruning. Temporal lobes limped even further behind—they did not finish growing gray matter or begin the processes of pruning and myelination until the age of sixteen (Giedd, Blumenthal, Jeffries, Castellanos, et al., 1999)! In some areas, pruning and myelination follow even later.

The brain does not release myelin to all neurons at the same time but rather in stages. The timing of the release of myelin appears to be dependent upon the developmental age of the individual, environment, and genetics. One of the last parts of the brain to receive myelin is the frontal cortex, the area responsible for abstract thinking, language, and decision making (Fuster, 2002). As the brain's frontal lobes become myelinated during adolescence, teens develop the ability to hypothesize, look into the future, deduct, analyze, and logically reason.

Secret Revealed



There was a time when me and my best friend since first grade got into a fight. She told someone a secret I'd told her. I told her she was a liar; she said I was being paranoid. So I hit her.

—Kenisha, eighth grade

Have you ever felt like hitting your boss because of something he or she said about you? Did you? Why not? No matter how infuriated or exasperated adults become with each other, logic and reason usually prevail. Adults choose their words carefully and try to calmly discuss problems instead of rolling up their shirtsleeves and taking it outside. No matter how

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good it may feel to indulge in the wild emotions of the moment, adults think through the consequences and make decisions based on what might happen the next day and how their reactions affect things like income, family security, and personal relationships. Teens, however, are famous for not calmly assessing consequences and for making poor, on-the-spot decisions. Teens succumb to the temptation of hitting first and talking later.

In two separate studies, Dr. Deborah Yurgelun-Todd (Yurgelun-Todd, Killgore, & Young, 2002) of McLean Hospital and Dr. Elizabeth Sowell (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999) of the UCLA Laboratory of Neuro Imaging found out why. Until the frontal lobes, the seat of language and reason, are completely formed, teens rely overmuch on their amygdala—the seat of emotion. Not only do the wild emotions get first say about what teens will do next, their ability to negotiate their way out of a tense moment by using carefully chosen, diplomatic language is fledgling at best. Fortunately, the adults and adult brains that are often at the receiving end of adolescent outbursts can understand what is happening and de-escalate confrontations when they do occur.

The frontal lobes are in charge of taming the beast within us, humanizing our nature, and making us be the best we can be. They have an interesting relationship with the amygdala, an organ that controls our often tumultuous array of emotions. Pleasure, anger, and fear all spring from this small but mighty structure located a few inches from the ears in the lower center of the brain. When confronted with information, the adolescent brain reacts quite differently than the adult brain. Adults rely more on the frontal lobes of their brain and less on the amygdala, and therefore respond logically to the input they receive. The adolescent, on the other hand, tends to rely more on the amygdala than the frontal lobes and responds emotionally to stimuli (Baird et al., 1999). This explains the poor decisions they make, like going shopping (instead of doing homework) or having unprotected sex, and their highly emotional responses to ordinary requests, such as remarks like “I hate you!” or “Don’t tell me what to do!”

The frontal lobes are also the province of language. Frustrated teens answer frustrated adults with inarticulate expressions like “Whatever” and “I don’t know.” For years, educational psychologists have documented the vague and mumbled expressions of adolescents (Woolfolk, 2006), but it wasn’t until recently that neuroscientists examined the phenomenon. Dr. Elizabeth Sowell examined language production in adolescents and found that there is a shift in function as brains mature (Sowell et al., 1999). Young adolescents have more difficulty generating words

and expressing themselves than do older adolescents. By high school, teens start speaking in a more rational and logical manner.

MIRROR, MIRROR ON THE WALL

One of the most exciting new discoveries in neuroscience is that of mirror neurons. Evidence of mirror neurons was actually discovered in macaque monkeys during the mid-1990s, but not in humans until the early twenty-first century, when neuroimaging technology advanced to the point where studies could be done on humans. The very nature of mirror neurons is found in their name: Neuroscientists discovered that a network of neurons fired when they vicariously experienced something; it was as though another person's action was reflected in a mirror. The same parts of the human brain were activated in the observer as the neurons in the person doing the activity (Iacoboni, 2008; Sylwester, 2007).

Literally speaking, it means we actually experience another person's pain or joy. Early studies are suggesting that mirror neurons may help us understand how empathy, language, self-awareness, intentions, and altruism are developed. Individuals who have a burst of mirror neurons igniting in response to other's facial expressions are able to empathize with the sadness of failing a test or being rejected by a potential girlfriend and the happiness of scoring an A or getting that first date. These individuals develop a sense of caring, enabling them to share other's emotions and identify other's needs. In contrast, individuals with autism have few mirror neurons igniting in response to others, explaining their lack of social development. It may also add further support to learning through observation and imitation, a theory that Albert Bandura, the psychologist, promoted (see Woolfolk, 2006). There are possibilities for every content area, so stay tuned for exciting discoveries and educational implications in this neuron neighborhood.



ADOLESCENCE: THE FINAL FRONTIER

Innovations in brain technology have led to discoveries that spark the interest of educators and provide rich possibilities for instruction and assessment. But like the crew of the starship *Enterprise*, teachers and parents must go where no one has gone before—into the uniqueness of the brain that spans the abyss between childhood and adulthood. Teenagers seem

irresponsible and unreasonable only when they are compared to people older and younger. But viewed against the backdrop of the profound and rapid neurological and biological changes that are happening in their bodies, their behavior is much more understandable and logical.

Why do adolescents blurt out answers in class? Why do they fall asleep during third period? Why do they fight so bitterly over late homework assignments or missed points on a test? Take comfort in the fact that they do not plot their unruliness; they are just trying to cope in a school run and designed by adults from an adult perspective—adults with brains that are structured and that function in ways vastly different from their own. This book attempts to highlight the primary differences in teen and adult brains and behavior as well as offer suggestions for channeling these differences toward a more productive classroom, academically and emotionally.