

The Wild World of a Teen Brain

Adolescence can be a volatile time, but the storms that play out in the home are nothing compared with what's going on in the heads of the teens themselves

BY CLAUDIA WALLIS

FIVE YOUNG MEN IN SNEAKERS and jeans troop into a waiting room at the National Institutes of Health Clinical Center in Bethesda, Md., and drape themselves all over the chairs in classic collapsed-teenager mode. It's midafternoon, and they are, of course, tired, but their presence adds a jangly, hormonal buzz to the bland, institutional setting. The teens are here to have their heads examined. Literally. They are participants in a giant study that's been going on in this building since 1991. Its goal: to determine how the brain develops from childhood into adolescence and on into early adulthood.

It is the project of Dr. Jay Giedd, chief of brain-imaging in the child-psychiatry branch at the National Institute of Mental Health. Giedd uses magnetic resonance imaging (MRI) to peek at kids' brains over the years and find physiological changes that might account for the adolescent behaviors so familiar to parents: emotional outbursts, recklessness, rule-breaking and the impassioned pursuit of sex, drugs and rock 'n' roll.

One reason scientists have been so intrigued by the ferment in the teenage brain is that the brain grows very little over the course of childhood. By the time a child

is 6, the brain is 90% to 95% of its adult size. As a matter of fact, we are born equipped with most of the neurons our brain will ever have—and that's fewer than we have in utero. What Giedd's long-term studies are documenting is that there is a second wave of neuron proliferation and pruning that happens later in childhood and that the final, critical part of this second wave, affecting some of our highest mental functions, occurs in the late teens.

No matter how a particular brain turns out, its development proceeds in stages, generally from back to front. Some of the regions that reach maturity earliest are those in the back of the brain that mediate direct contact with the environment by controlling such sensory functions as vision, hearing, touch and spatial processing. Next are areas that coordinate those functions. The very last part of the brain to be shaped to its adult dimensions is the prefrontal cortex, home of the so-called executive functions—planning, prioritizing, organizing thoughts, suppressing impulses, weighing consequences.

"Scientists attributed the bad decisions teens make to hormones," says Elizabeth Sowell, a UCLA neuroscientist who has done seminal MRI work on the developing brain. "But once we started mapping brain changes, we could say, Aha, the part of the brain that makes teenagers more responsible is not finished maturing."

Hormones, however, do remain an important part of the teen-brain story. At puberty, the ovaries and testes



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begin to pour estrogen and testosterone into the bloodstream. At the same time, testosterone-like hormones released by the adrenal glands, located near the kidneys, begin to circulate. Recent discoveries show that these hormones are extremely active in the brain, especially in the emotional center—the limbic system. This creates a “tinderbox of emotions,” says Dr. Ronald Dahl, a psychiatrist at the University of Pittsburgh. Not only do feelings reach a flash point more easily, but adolescents also tend to seek out situations that allow their emotions and passions to run wild. “Adolescents are actively looking for experiences to create intense feelings,” says Dahl.

Psychologists are investigating the brain to explain other kinds of wacky adolescent behavior. At McLean Hospital in Belmont, Mass., Harvard neuropsychologist Deborah Yurgelun-Todd did an elegant series of functional MRI experiments in which both kids and adults were asked to identify the emotions displayed in photographs of faces. “In doing these tasks,” she says, “kids and young adolescents rely heavily on the amygdala, a structure in the temporal lobes associated with emotional reactions. Adults rely less on the amygdala and more on the frontal lobe.”

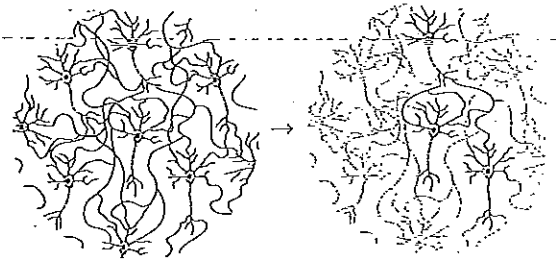
And what about why it’s so hard to get a teenager off the couch? You might blame that on an immature nucleus accumbens, a brain region that directs motivation to seek rewards. James Bjork at the National Institute on Alcohol Abuse and Alcoholism used brain scans to study motivation in a challenging gambling game. He found that teenagers have less activity in this region than adults do. “If adolescents have a motivational deficit, it may mean that they are prone to engaging in behaviors that have either a really high excitement factor or a really low effort factor, or both,” he says. Sound familiar?

In light of what’s being learned, it seems almost arbitrary that our culture has decided that a young American is ready to drive a car at 16, vote and serve in the military at 18 and drink alcohol at 21. Giedd says the best estimate for when the brain is truly mature is 25. Some legal scholars and children’s advocates also argue that minors should never be tried as adults and should be spared the death penalty. In 2003 the American Bar Association urged all state legislatures to ban the death penalty for juveniles “for social and biological reasons.”

Most parents, of course, know instinctively about the limited nature of the teen brain. What bears remembering is that there’s only so much even the best child-rearing practices can do about it. “You can tell [teens] to shape up or ship out,” Giedd says, “but making mistakes is part of how the brain grows.” It might be more useful for parents to help kids make up for what the brain still lacks by providing structure and guidance and applying those time-tested virtues: patience and love.

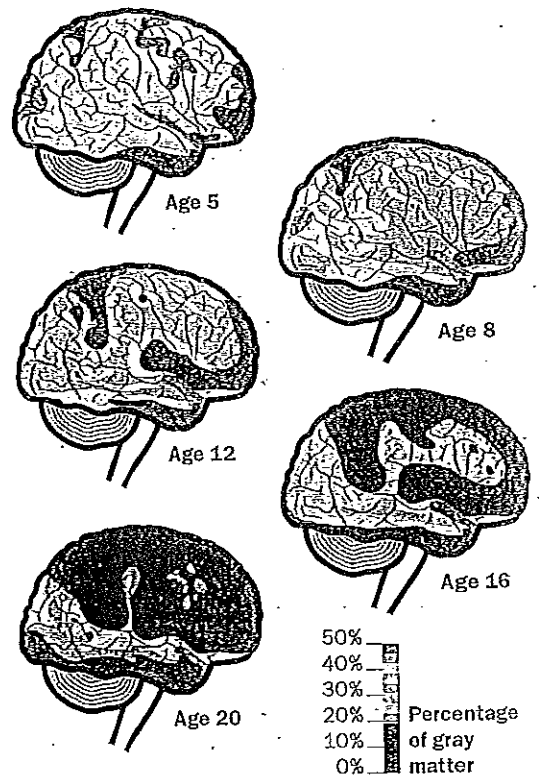
Inside the Adolescent Brain

The brain undergoes two major developmental phases, one in the womb and a second that takes place from childhood through the teen years. The maturation occurs in a predictable pattern, spreading from the back of the brain to the front



Nerve Proliferation and Pruning

By age 11 for girls and 12½ for boys, the neurons in the front of the brain have formed thousands of new connections. Over the next few years, many of these links will be pruned. Those that are used and reinforced—the pathways involved in language, for example—will be strengthened, while the ones that aren’t used will die out

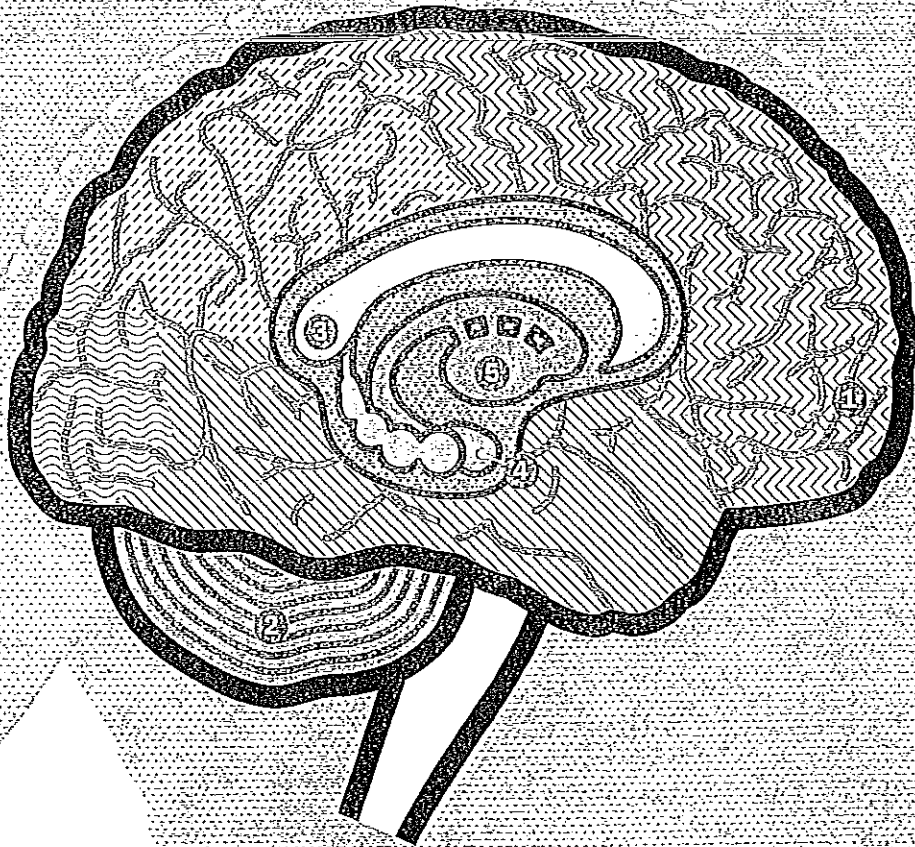


Time-Lapse Brain

Gray matter wanes as the brain matures. Here, 15 years of brain development are compressed into five images showing a shift from red (least mature) to purple (most mature)

Sources: Dr. Jay Giedd, chief of brain-imaging, child-psychiatry branch, NIMH; Paul Thompson, An Lee, Kuzel Hayashi and Arthur Toga, UCLA Lab of Neuro Imaging; Mitha Gogtay and Judy Rapoport, child-psychiatry branch, NIMH. Text by Kristina Dell

GRAPHIC BY ROBERT A. DIZEO JR.



Direction
of brain
development

1. Prefrontal Cortex

The CEO of the brain, also called the area of sober second thought, is the last part of the brain to mature—which may be why teens get into so much trouble. Located just behind the forehead, the prefrontal cortex grows during the preteen years and then shrinks as neural connections are pruned during adolescence.

2. Cerebellum

Long thought to play a role in physical coordination, this area may also regulate certain thought processes. More sensitive to the environment than to heredity, the cerebellum supports activities of higher learning like mathematics, music and advanced social skills. New research shows that it changes dramatically during adolescence.

3. Corpus Callosum

Thought to be involved in problem-solving and creativity, this bundle of nerve fibers connects the left and right hemispheres of the brain. During adolescence, the nerve fibers thicken and process information more and more efficiently.

4. Amygdala

This region is the emotional center of the brain, home to such primal feelings as fear and rage. When they are processing emotional information, teens tend to rely more heavily on the amygdala, whereas adults depend more on the rational prefrontal cortex, which is underdeveloped in teens. The impulsive decisions, arguments and door slams of the adolescent are the amygdala at work.

5. Basal Ganglia

Larger in females than in males, this part of the brain acts like a manager for the prefrontal cortex by helping it prioritize information. The basal ganglia and prefrontal cortex are tightly connected: at nearly the same time, they both grow and prune neuronal connections. This area is also active in directing and coordinating small and large motor movements, so it may be important to expose preteens to music and sports while it is growing.

