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# Juvenile Death Penalty Background Materials


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**Assembly Committee on Judiciary**

**State of Nevada Assembly**

**March 27, 2003**

AMERICAN ACADEMY OF CHILD & ADOLESCENT PSYCHIATRY

# POLICY STATEMENT

## JUVENILE DEATH SENTENCES

Approved by Council, October 24, 2000

The United States is one of the few countries in the world that executes juveniles, and, since 1990, it has executed 10 persons for crimes committed prior to age 18. Juveniles constitute approximately 2% of total death penalty sentences, and, as of June, 1999, there were 70 persons on death row for crimes committed at age 16 or 17. With the increasing trend of waiving juvenile offenders to the adult court and imposing harsher sentences than in the past, these numbers can be expected to rise. In 1988, the U.S. Supreme Court in Thomson v. Oklahoma decided that the Eighth Amendment prohibited the execution of persons younger than 16 years of age at the time of their crimes. The United States remains the only country in the world that has not yet ratified the UN Convention, Article 37a, which states that "Neither capital punishment nor life imprisonment without possibility of release shall be imposed for offenses committed by persons below eighteen years of age."

Our society recognizes that juveniles differ from adults in their decision-making capacities as reflected in laws regarding voting, driving, access to alcoholic beverages, consent to treatment, and contracting. For the following reasons, special consideration for crimes committed prior to age 18 should be made. Adolescents are cognitively and emotionally less mature than adults. They are less able than adults to consider the consequences of their behavior, they are easily swayed by peers, and they may show poor judgement. We also know that teens who have been victims of abuse or have witnessed violence may show increased levels of emotional arousal and a tendency to overreact to perceived threats. Victims of child abuse and neglect are overrepresented among incarcerated juveniles, including those on death row. Studies of this population consistently demonstrate a high incidence of mental disorders, serious brain injuries, substance abuse, and learning disabilities, which may predispose to aggressive or violent behaviors. In many instances, these juveniles have not received adequate diagnostic assessments or interventions. National statistics also indicate that African-American and Hispanic youth are disproportionately diverted into juvenile correctional facilities and waived to the adult criminal court system.

The pattern of the use of the death penalty indicates discrimination against the poor who do not have equal access to adequate legal representation. The death penalty is associated with an unavoidable risk of error, and its deterrent value has yet to be demonstrated. It is particularly unlikely to deter adolescents from crime, as they tend to live in the present, think of themselves as invincible, and have difficulty contemplating the long-term consequences of their behavior.

The philosophy of the juvenile court has always been rehabilitation. This goal is now made more attainable than ever by improved assessment tools, new effective community-intervention programs, and treatments for underlying psychiatric disorders. However, such efforts are often undermined by the diversion of scarce dollars into incarceration, long sentences, and the death penalty rather than into earlier intervention efforts and strengthening the juvenile justice system so that it can effectively respond to dangerous and/or repeat youth offenders to ensure public safety.

Therefore, the American Academy of Child and Adolescent Psychiatry strongly opposes the imposition of the death penalty for crimes committed as juveniles.

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# Juvenile Death Sentences
## POSITION STATEMENT

Approved by the Board of Trustees, June 2001

"Policy documents are approved by the APA Assembly and Board of Trustees...These are ... position statements that define APA official policy on specific subjects..." -- *APA Operations Manual.*

*This policy originated with the American Academy of Child and Adolescent Psychiatry. It was endorsed by APA Council on Children, Adolescents, and Their Families and revised by APA Council on Psychiatry and Law.*

The United States is one of the few countries in the world that executes juveniles, and, since 1990, it has executed 10 persons for crimes committed prior to age 18. Juveniles constitute approximately 2% of total death sentences, and, as of June, 1999, there were 70 persons on death row for crimes committed at age 16 or 17. With the increasing trend of waiving juvenile offenders to the adult court and imposing harsher sentences than in the past, these numbers can be expected to rise. Although the U.S. Supreme Court's decision in Thompson v. Oklahoma (1988) precluded execution of persons who were younger than 16 years of age at the time of their crimes, the Court ruled the following year (in Stanford v. Kentucky) that executing offenders who were 16 or 17 at the time of their crimes did not amount to cruel and unusual punishment under the Eighth Amendment. The United States remains the only country in the world that has not yet ratified the UN Convention, Article 37a, which states that "Neither capital punishment nor life imprisonment without possibility of release shall be imposed for offenses committed by persons below eighteen years of age."

For the following reasons, the harshest punishments, including the death penalty, should be precluded in cases involving offenders whose crimes were committed prior to age 18. Adolescents are cognitively and emotionally less mature than adults. They are less able than adults to consider the consequences of their behavior, they are easily swayed by peers, and they may show poor judgement. That juveniles differ from adults in their decision-making capacities is reflected in our nation's laws regarding voting, driving, access to alcoholic beverages, consent to treatment, contracting, and in the juvenile court itself. We also know that teens who have been victims of abuse or have witnessed violence may show increased levels of emotional arousal and a tendency to overreact to perceived threats. Victims of child abuse and neglect are over represented among incarcerated juveniles, including those on death row. Studies of this population consistently demonstrate a high prevalence of mental disorders, serious brain injuries, substance abuse, and learning disabilities, which may predispose to aggressive or violent behaviors. In many instances, these juveniles have not received adequate diagnostic assessments or interventions. National statistics also indicate that African-American and Hispanic youth are disproportionately diverted into juvenile correctional facilities and waived to the adult criminal court system.

Many psychiatrists oppose use of the death penalty in all cases due to concerns about its discriminatory application (including discrimination against poor offenders who do not have equal access to adequate legal representation) and about what appears to be an unavoidable risk of error. The deterrent value of capital punishment has yet to be demonstrated. However, whatever one may think about the overall deterrent effect of the death penalty, it is particularly unlikely to deter adolescents from crime, as they tend to live in the present, think of themselves as invincible, and have difficulty contemplating the long-term consequences of their behavior.

The American Psychiatric Association is a national medical specialty society, founded in 1844, whose 40,000 physician members specialize in the diagnosis and treatment of mental and emotional illnesses and substance use disorders.

**The American Psychiatric Association**
1400 K Street NW • Washington, D.C. 20005
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D 4 of 26

The traditional philosophy of the juvenile court has been rehabilitation. This goal is now made more attainable than ever by improved assessment tools, new effective community-intervention programs, and treatments for underlying psychiatric disorders. However, such efforts are often undermined by the diversion of scarce dollars into incarceration, long sentences, and carrying out the death penalty rather than into earlier intervention efforts and strengthening the juvenile justice system so that it can effectively respond to dangerous and/or repeat youth offenders to ensure public safety.

Therefore, the American Psychiatric Association strongly opposes the imposition of the death penalty for crimes committed as juveniles.



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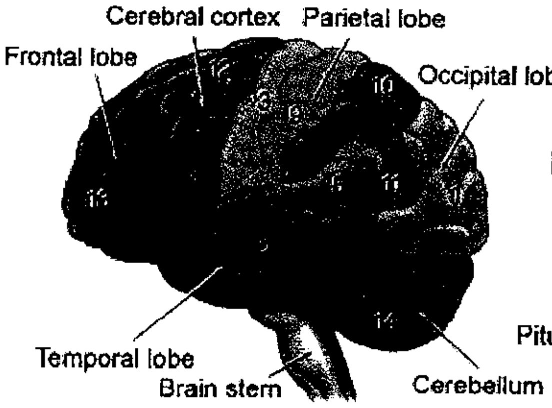
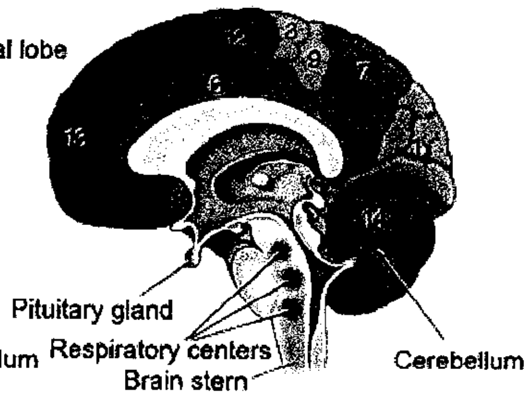
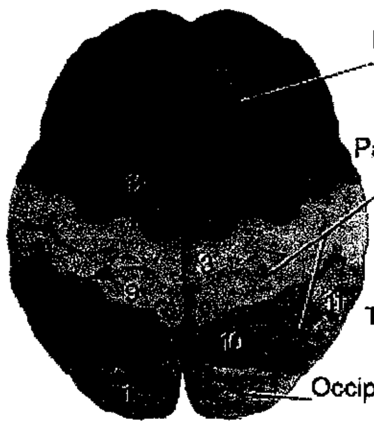
# Anatomy and Functional Areas of the Brain



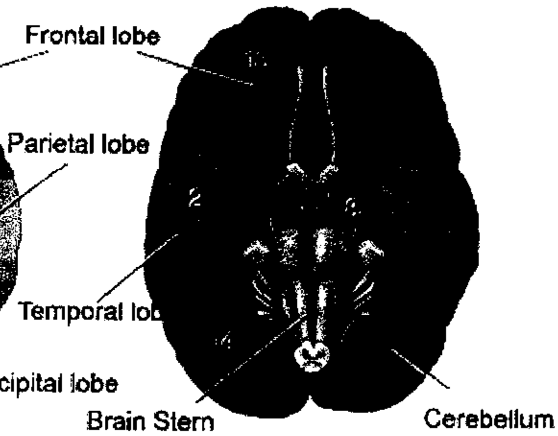

Lateral View




Sagitial View




Superior View




Inferior view

## Functional Areas of the Cerebral Cortex

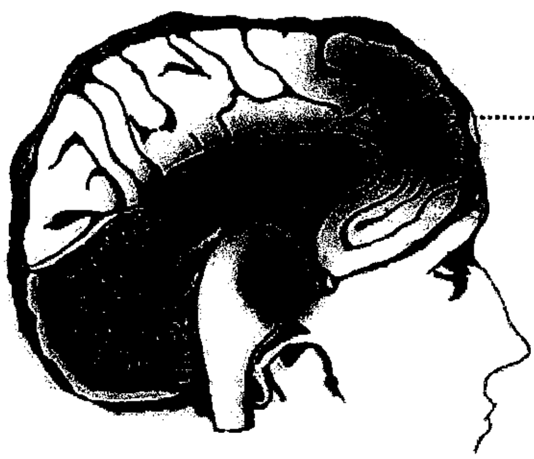
1. **Visual Area:**
   Sight
   Image recognition
   Image perception
2. **Association Area:**
   Short-term memory
   Equilibrium
   Emotion
3. **Motor Function Area:**
   Initiation of voluntary muscles
4. **Broca's Area:**
   Muscles of speech
5. **Auditory Area:**
   Hearing
6. **Emotional Area:**
   Pain
   Hunger
   "Fight or Right" response
7. **Sensory Association Area**
8. **Olfactory Area:**
   Smelling
9. **Sensory Area:**
   Sensation from muscles and skin
10. **Somatosensory Association Area:**
    Evaluation of weight, texture, temperature, etc. for object recognition
11. **Wemicke's Area:**
    Written and spoken language comprehension
12. **Motor Function Area:**
    Eye movement and orientation
13. **Higher Mental Functions:**
    Concentration
    Planning
    Judgment
    Emotional expression
    Creativity
    Inhibition

## Functional Areas of the Cerebellum

14. **Motor Functions:**
    Coordination of movement
    Balance and equilibrium
    Posture

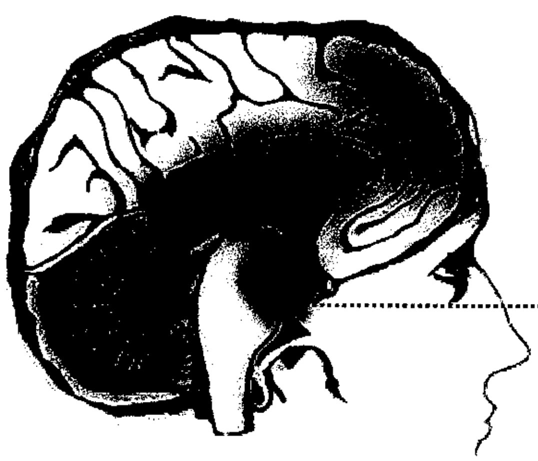
D 6 of 26

# Anatomy of a Teen Brain



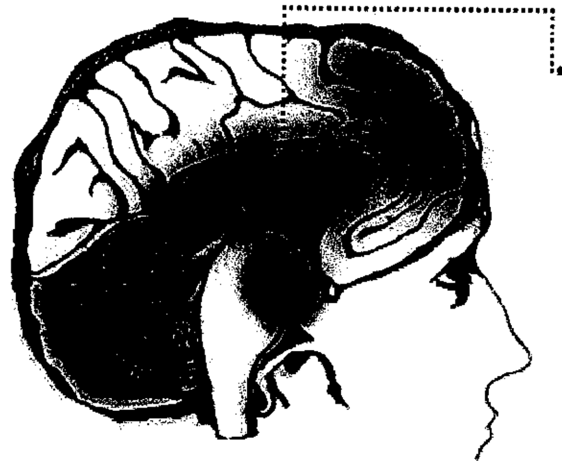
## Frontal Cortex

The frontal cortex is often refered to as the "CEO" of the brain, because it is the part responsible for planning, strategizing, and judgment. Recent research has shown that this area undergoes a growth spurt at around the ages of 11-12, followed by a period of pruning and organizing of the new neural connections during the teen years.



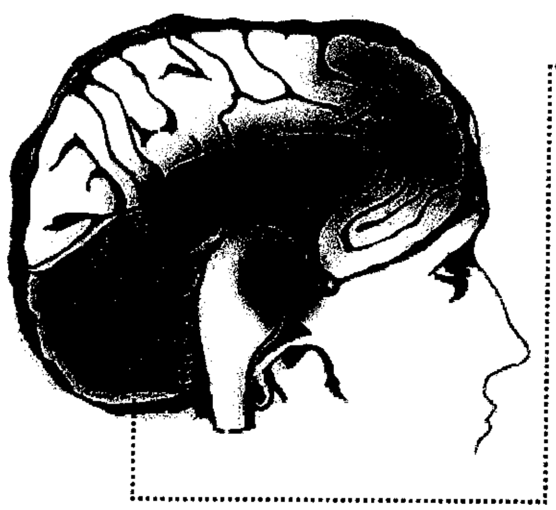
## Amygdala

This area of the brain is associated with emotional and gut responses. New imaging studies suggest that teenagers, when asked to interpret emotional information, use this reactive part of the brain rather than the more "thinking" region, the frontal cortex, while adults rely more heavily on the frontal cortex. Scientists speculate that this may be why teens have trouble modulating their emotional responses.



## Corpus Callosum

This is a cable of nerves that connects the two hemispheres of the brain, and is believed to be involved in creativity and problem solving. It appears to change and grow significantly through adolescence.



## Cerebellum

This part of the brain has long been thought to be involved with the coordination of muscles and physical movement. Recently, scientists have come to believe that it is involved in the coordination of thinking processes, as well. New research has shown that it is an area that undergoes dynamic growth and change during the teenage years.

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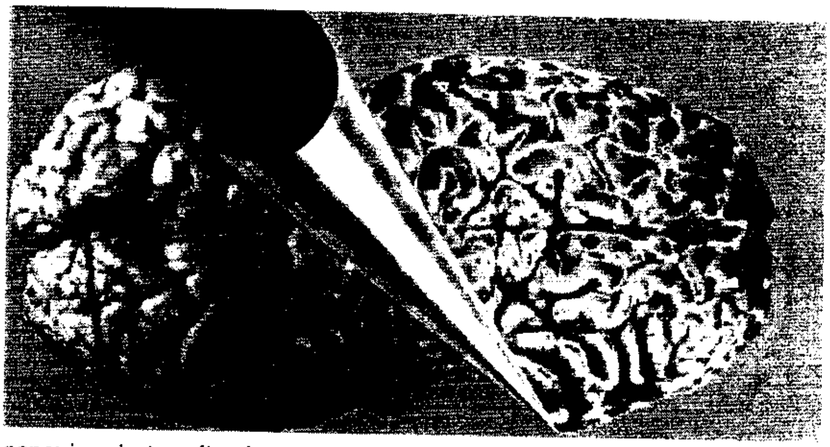
# Teenage brain:
## a work in progress

New imaging studies are revealing—for the first time—patterns of brain development that extend into the teenage years. Although scientists don't know yet what accounts for the observed changes, they may parallel a pruning process that occurs early in life that appears to follow the principle of "use-it-or-lose-it:" neural connections, or synapses, that get exercised are retained, while those that don't are lost. At least, this is what studies of animals' developing visual systems suggest. While it's known that both genes and environment play major roles in shaping early brain development, science still has much to learn about the relative influence of experience versus genes on the later maturation of the brain. Animal studies support a role for experience in late development, but no animal species undergoes anything comparable to humans' protracted childhood and adolescence. Nor is it yet clear whether experience actually creates new neurons and synapses, or merely establishes transitory functional changes. Nonetheless, it's tempting to interpret the new findings as empowering teens to protect and nurture their brain as a work in progress.



The newfound appreciation of the dynamic nature of the teen brain is emerging from MRI (magnetic resonance imaging) studies that scan a child's brain every two years, as he or she grows up. Individual brains differ enough that only broad generalizations can be made from comparisons of different individuals at different ages. But following the same brains as they mature allows scientists a much finer-grained view into developmental changes. In the first such longitudinal study of 145 children and adolescents, reported in 1999, NIMH's Dr. Judith Rapoport and colleagues were surprised to discover a second wave of overproduction of gray matter, the thinking part of the brain—neurons and their branch-like extensions—just prior to puberty.[1] Possibly related to the influence of surging sex hormones, this thickening peaks at around age 11 in girls, 12 in boys, after which the gray matter actually thins some.

Prior to this study, research had shown that the brain overproduced gray matter for a brief period in early development—in the womb and for about the first 18 months of life—and then underwent just one bout of pruning. Researchers are now confronted with structural changes that occur much later in adolescence. The teen's gray matter waxes and wanes in different functional brain areas at different times in development. For example, the gray matter growth spurt just prior to puberty predominates in the frontal lobe, the seat of "executive functions"—planning, impulse control and reasoning. In teens affected by a rare, childhood onset form of schizophrenia that impairs these functions, the MRI scans revealed four times as much gray matter loss in the frontal lobe as normally occurs.[2]

b 9 of 26

Unlike gray matter, the brain's white matter—wire-like fibers that establish neurons' long-distance connections between brain regions—thickens progressively from birth in humans. A layer of insulation called myelin progressively envelops these nerve fibers, making them more efficient, just like insulation on electric wires improves their conductivity.

Advancements in MRI image analysis are providing new insights into how the brain develops. UCLA's Dr. Arthur Toga and colleagues turned the NIMH team's MRI scan data into 4-D time-lapse animations of children's brains morphing as they grow up—the 4th dimension being rate-of-change.[3] Researchers report a wave of white matter growth that begins at the front of the brain in early childhood, moves rearward, and then subsides after puberty. Striking growth spurts can be seen from ages 6 to 13 in areas connecting brain regions specialized for language and understanding spatial relations, the temporal and parietal lobes. This growth drops off sharply after age 12, coinciding with the end of a critical period for learning languages.

While this work suggests a wave of brain white matter development that flows from front to back, animal, functional brain imaging and postmortem studies have suggested that gray matter maturation flows in the opposite direction, with the frontal lobes not fully maturing until young adulthood. To confirm this in living humans, the UCLA researchers compared MRI scans of young adults, 23–30, with those of teens, 12–16.[4] They looked for signs of myelin, which would imply more mature, efficient connections, within gray matter. As expected, areas of the frontal lobe showed the largest differences between young adults and teens. This increased myelination in the adult frontal cortex likely relates to the maturation of cognitive processing and other "executive" functions. Parietal and temporal areas mediating spatial, sensory, auditory and language functions appeared largely mature in the teen brain. The observed late maturation of the frontal lobe conspicuously coincides with the typical age-of-onset of schizophrenia—late teens, early twenties—which, as noted earlier, is characterized by impaired "executive" functioning.

Another series of MRI studies is shedding light on how teens may process emotions differently than adults. Using functional MRI (fMRI), a team led by Dr. Deborah Yurgelun-Todd at Harvard's McLean Hospital scanned subjects' brain activity while they identified emotions on pictures of faces displayed on a computer screen.[5] Young teens, who characteristically perform poorly on the task, activated the amygdala, a brain center that mediates fear and other "gut" reactions, more than the frontal lobe. As teens grow older, their brain activity during this task tends to shift to the frontal lobe, leading to more reasoned perceptions and improved performance. Similarly, the researchers saw a shift in activation from the temporal lobe to the frontal lobe during a language skills task, as teens got older. These functional changes paralleled structural changes in temporal lobe white matter.

While these studies have shown remarkable changes that occur in the brain during the teen years, they also demonstrate what every parent can confirm: the teenage brain is a very complicated and dynamic arena, one that is not easily understood.

## For More Information

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Media Inquiries: (301) 443-4536
E-mail: nimhinfo@nih.gov
Web site: http://www.nimh.nih.gov

Child and adolescent mental health information: http://www.nimh.nih.gov/publicat/childmenu.cfm



## References

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[2] Rapoport JL, Giedd JN, Blumenthal J, et al. Progressive cortical change during adolescence in childhood-onset schizophrenia. A longitudinal magnetic resonance imaging study. *Archives of General Psychiatry*, 1999; 56(7): 649-54.

[3] Thompson PM, Giedd JN, Woods RP, et al. Growth patterns in the developing brain detected by using continuum mechanical tensor maps. *Nature*, 2000; 404(6774): 190-3.

[4] Sowell ER, Thompson PM, Holmes CJ, et al. In vivo evidence for post-adolescent brain maturation in frontal and striatal regions. *Nature Neuroscience,* 1999; 2(10): 859-61.

[5] Baird AA, Gruber SA, Fein DA, et al. Functional magnetic resonance imaging of facial affect recognition in children and adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry,* 1999; 38(2): 195-9.

# One Reason Teens Respond Differently to the World: Immature Brain Circuitry

by FRONTLINE producer Sarah Spinks

We used to think that teens respond differently to the world because of hormones, or attitude, or because they simply need independence. But when adolescents' brains are studied through magnetic resonance imaging (MRI), we see that they actually work differently than adult brains.

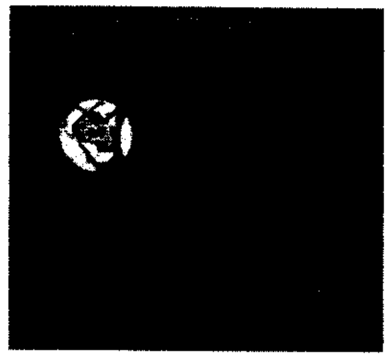
Many teen subjects failed to interpret the emotion in faces like this one as fear.

At the McLean Hospital in Belmont, Mass., Deborah Yurgelun-Todd and a group of researchers have studied how adolescents perceive emotion as compared to adults. The scientists looked at the brains of 18 children between the ages of 10 and 18 and compared them to 16 adults using functional magnetic resonance imaging (fMRI). Both groups were shown pictures of adult faces and asked to identify the emotion on the faces. Using fMRI, the researchers could trace what part of the brain responded as subjects were asked to identify the expression depicted in the picture.

The results surprised the researchers. The adults correctly identified the expression as fear. Yet the teens answered "shocked, surprised, angry." And the teens and adults used different parts of their brains to process what they were feeling. The teens mostly used the amygdala, a small almond shaped region that guides instinctual or "gut" reactions, while the adults relied on the frontal cortex, which governs reason and planning.

As the teens got older, the center of activity shifted more toward the frontal cortex and away from the cruder response of the amygdala.

Yurgelun-Todd, director of neuropsychology and cognitive neuroimaging at McLean Hospital believes the study goes partway to understanding why the teenage years seem so emotionally turbulent. The teens seemed not only to be misreading the feelings on the adult's face, but they reacted strongly from an area deep inside the brain. The frontal cortex helped the adults distinguish fear from shock or surprise. Often called the executive or CEO of the brain, the frontal cortex gives adults the ability to distinguish a subtlety of expression: "Was this really fear or was it surprise or shock?" For the teens, this area wasn't fully operating.



When reading emotion, teens **(left)** rely more on the amygdala, while adults **(right)** rely more on the frontal cortex.

Reactions, rather than rational thought, come more from the amygdala, deep in the brain, than the frontal cortex, which led Yurgelun-Todd and other neuroscientists to suggest that an immature brain leads to impulsivity, or what researchers dub "risk-taking behavior." Although it was known from animal studies and brain-injured people that the frontal cortex matures more slowly than other brain strucures, it has only been with the advent of functional MRI that researchers have been able to study brain activity in normal children.

The brain scans used in these studies are a valuable tool for researchers. Never before have scientists been able to develop data banks of normal, healthy children. Outlining the changes in normal function and development will help researchers determine the causes of psychiatric disorders that afflict children and adolescents.

home + introduction + from zzzs to a's + work in progress + seem like aliens? + science

Home

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Teens are Terrific!

The Teen Side of Things

Who's that Stranger in My House?

Books and Resources

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Here come the Experts

About those Touchy Topics

Why I write about Teens

# Articles

# Teen Brains Are Different For SURE!

**By Barbara Cooke © Pioneer Press, August 3, 2000**

So your teenager forgot to write down an important phone message for you, causing you to show up for lunch at the wrong place and severing a 10-year friendship with your best friend who now thinks you're thoughtless and selfish?

It's a sure bet he was on the phone with a friend and call waiting beeped and he answered and the call was for you ( how annoying) and he promised to tell you about the change of restaurants, but then he clicked back to his phone call where they were debating who will be the winning Survivor cast member and what the team name should be for the Chicago XFL league. And your urgent phone message drifted into forgotten, discarded phone message heaven.

*BLAME IT ON THE AMYGDALA!*

Now you have to run to the store for some Starbucks and your teen's car is blocking you in the driveway, so you decide to borrow it for a minute. You get in, slam the door, turn the key, and are assaulted by music so loud the windows are reverberating and you can feel the celia in your ears slowly wilting and dying. The driver's seat is in the lounging position. Wrappers from gum, straws and McDonalds, empty water and Gatorade bottles roll around in the back seat. CDs and tapes clutter the dashboard. A vanilla-scented cardboard deodorizer dangles from the rear-view mirror, blocking your view. Clothes from two meteorological seasons ago are on the floor.

*BLAME IT ON THE AMYGDALA!*

On record-breaking frigid days when you're worrying about the pipes bursting, you suddenly notice that teens have all sworn off hats, scarves, boots or gloves. They'll hop up and down, trying inconspicuously to keep warm, demonstrating that a teenager's self-esteem is defined by the least amount of cold weather paraphernalia that can be worn without suffering frostbite while, most importantly, still looking cool. As your high schoolers sweep out of the kitchen on their way to school, wearing maybe a sweater or a few cotton T-shirts layered with a flannel shirt., you will probably ask, "Where's your jackets?" . And you'll invariably get a blank look, then, "Oh, yeah, it's in the car" or "It's in my locker" or "It's at Andi's house."

*YEP, BLAME IT ON THE AMYGDALA!*

Now, confess. You think the amygdal is a new kind of club drug, maybe a cousin of Ecstasy, don't you? No, the amygdala is an almond-shaped part of the brain, nestled deep in the back, that pretty much controls the way teens act for their middle school and high school years. So before you once again bellow, "WHAT in the world were you thinking when you did that?," remember this intriguing fact:

They're NOT thinking the way adults think because they absolutely, positively can't do it yet. Adolescent brains just aren't "hard wired" like adult brains.

Researchers at Harvard Medical School's Brain Imaging Center, the National Institute of Mental Health, and the University of California at Los Angeles recently looked at teens' brains in magnetic resonance imaging (MRI) scans. They discovered that adults think with the rational part of the brain, or the prefrontal cortex, while teens process information in the limbic system with the amygdala, or the instinctual, emotional part of the brain. In other words, gut reactions rather than critical thinking drive teens to do most of the things they do. So they're not thinking, "My house will get trashed and the neighbors will call the police if I have a party." They're hyperventilating: "Party! Party time at my house! My parents are so clueless they'll never know!"

The newest studies followed children ranging from as young as three years old to teenagers for nine years and scanned their brains every two years. Dr. Jay Giedd, chief of child psychology at the National Institute of Mental Health, and Elizabeth Sowell, a neuroscientist at UCLA, found that the brain has a huge explosion in growth around the ages of 12 and 13 as puberty comes to life. This discovery shatters the conventional thinking set forth in a 1997 White House Conference on Early Learning and Childhood Development that the greatest time of brain growth occurred before the age of 18 months, and was set forever by the age of three.

They were shocked to discover that teenage brains are in the kiddie category when it comes to abstract thinking, learning behavior and information, memory retention, rationalizing cause and effect, judgment , planning and organization.

The prefrontal cortex acts like a stern disciplinarian, sprinkling insight, reasoning and judgment upon the excitable amygdala. It's the cortex, in fact, that makes people "act like an adult." But this part of the brain is not fully developed in a teenager until after the age of 18.

Meanwhile, teens are whizzing through life manipulated by the wild whims of the amygdala, home to primal feelings such as fear, rage and impulse. And to complicate things even more, the agygdala gangs up with all kinds of hormones, and pumps them through puberty-ravaged bodies, making them moody, unpredictable and seemingly irrational. It's a struggle 24/7 to see if the still-developing prefrontal cortex can step in front of the amygdala and shout, "Halt! Use good judgment on this one! Remember what happened last time? Please stop? Hey, come back here NOW....."

So teens parade through adolescence doing all those things that keep parents up at night. Sneaking out late at night. Moving from hysterics to hugs in wharpspeed. Snorting heroin. Flaunting purple hair. Having unsafe safe with multiple partners. Binge drinking. Smoking cigarettes. Being totally, completely unorganized. Waiting until the last minute to do the term paper. Asking for another, and another, body pierce. Following Phish throughout the summer. Throwing a party for hundreds while you're out of town. Leaving expensive golf clubs in the open trunk in your driveway. Never seeing things from someone else's view. Getting in a car with friends who are drunk. Quitting the sport they loved for 10 years. Forgetting to turn the water off in the sink. Leaving the gas tank on empty. Overreacting to fights with boyfriends and girlfriends. Lending your best sweater to her best friend...and the list goes on and on.

"Adolescence is the time when everything is out of kilter, and nothing is stable in the body or mind. It's the second time that kids act like they're two years old, " laughs Ruth Kraus, PhD, assistant professor of clinical psychology at the University of Chicago's Child Psychiatry Clinic in Arlington Heights. "The difference is that when they're young you say, 'They're only kids. Give them a break.' But when they're teens you expect them to act like adults...and they're not."

So the next time your teen acts strange (today), don't give it another thought.

Just BLAME IT ON THE AMYGDALA.

# Getting Inside a Teen Brain



Newsweek

*By Sharon Begley*
*February 28, 2000*

**Hormones aren't the only reason adolescents act crazy. Their gray matter differs from children's and adults'.**

You probably recognize the species: it's known for making stupid decisions... barely able to plan beyond the next minute... clueless when it comes to reading parents' facial expressions... exhibits poor self-control... seems to think with its hormones more than its brain... all thumbs when juggling several tasks. Such is Homo teenageris.

But while the adolescent mind has been well documented, the reason kids passing through and just beyond puberty seem to be members of a different species has been a puzzle, though raging hormones and simple rebellion are handy scapegoats. It turns out there's a good reason adolescent brains seem different: they are. Contrary to the notion that the brain has fully matured by the age of 8 or 12, with the truly crucial wiring complete as early as 3, it turns out that the brain is an ongoing construction site. "Maturation does not stop at age 10, but continues into the teen years and even the 20s," says Jay Giedd of the National Institute of Mental Health. "What is most surprising is that you get a second wave of overproduction of gray matter, something that was thought to happen only in the first 18 months of life."

The brain reaches about 95 percent of its adult volume by the age of 5 or so. To get beyond such crude measures, in the early 1990s Giedd and colleagues began snapping images of the brains of healthy kids with magnetic resonance imaging (MRI) every two years. The first surprise came last May, with the discovery that the corpus callosum, the cable of nerves that connects the right half of the brain to the left, "continues growing into your 20s," says Giedd. Although the effect of an immature corpus callosum is not crystal clear, let us simply note that this structure has been implicated in intelligence, consciousness and self-awareness.

Until now, studies of the brains of children and adolescents have shown that their gray matter decreases with age. The rule seems to be "use it or lose it": connections among neurons that are not used wither away, a process called pruning. But neuroscientists led by Elizabeth Sowell of UCLA's Lab of Neuro Imaging found that the story is not so simple. They used MRI to compare the brains of 12- to 16-year-olds to those of twentysomethings. What they found will surprise no one who has a teen or is a teen or just remembers being a teen: the frontal lobes, responsible for such "executive" functions as self-control, judgment, emotional regulation, organization and planning, undergo the greatest change between puberty and young adulthood. They grow measurably between 10 and 12 (with girls' growth spurt generally coming a little earlier than boys'), then shrink into the 20s as extraneous branchings are pruned back into efficient, well-organized circuitry. Giedd's team, using MRI to scan the brains of 145 healthy 4- to 21-year-olds, also "found that the grey matter in the frontal lobes increased through age 11 or 12," as they reported in the journal Nature Neuroscience. "Then there is a noticeable decline. It looks like there is a second wave of creation of gray matter at puberty, probably related to new connections and branches, followed by pruning." Neuronal connections that underlie cognitive and other abilities stick around if they're used, but wither if they're not.

Toddlers are pretty much at the mercy of their parents when it comes to the kind and amount of environmental stimulation they get, and thus which connections remain. Teenagers, however, create their own world. "Teens thus have the power to determine their own brain development, to determine which connections survive and which don't," says Giedd. "Whether they do art, or music, or sports, or videogames, the brain is figuring out what it needs to survive and adapting accordingly."

Things get even more interesting once neuroscientists look beyond the frontal lobes. When the UCLA team scanned the brains of 19 normal children and adolescents, ages 7 and 16, they found that the parietal lobes (which integrate information from far-flung neighborhoods of the brain, such as auditory, tactile and visual signals) are still maturing through the midteens. The long nerve fibers called white matter are probably still being sheathed in myelin, a fatty substance that lets nerves transmit signals faster and more efficiently. As a result, circuits that make sense of disparate information are works in progress through age 16 or so. The parietal lobes reach their gray-matter peak at 10 (girls) or 12 (boys), and are then pruned. But the seats of language, as well as emotional control, called the temporal lobes, do not reach their gray-matter maximum until age 16, Giedd finds. Only then do they undergo pruning. If teens are hardly models of emotional maturity, at least they have a good excuse.

Studies at McLean Hospital outside Boston find that many teenagers are unable to read emotions in people's faces. Brain regions that light up with activity when adults read "fear" in faces are nearly dark in these teens. Their brains' emotional centers light up. But the thinking regions stay dark, as if they are unable to integrate visual, emotional and cognitive information. No wonder looking daggers at a teen hardly gets a rise out of him.

Might hormones be responsible for the changes the brain undergoes during and after adolescence? Research into this question is only in its infancy. But in one suggestive finding, Giedd reports that in girls the hippocampus, which responds to estrogen, grows faster than in boys. The hippocampus forms memories. In boys, the amygdala, which responds to androgen, grows faster than in girls. The amygdala is in charge of emotions like fear and anger.

Together, the experiments suggest that the teen brain reprises one of its most momentous acts of infancy, the overproduction and then pruning of neuronal branches. "The brain," says Sowell, "undergoes dynamic changes much later than we originally thought." Maturity is not simply a matter of slipping software (learning) into existing equipment. Instead, the hardware changes. Those changes partly reflect signals from the world outside, and seem to be a peculiarly human adaptation. Think of it as nature's way of giving us a second chance.



Top ↑

Behavior can be baffling when young minds are taking shape

**BY SHANNON BROWNLEE**

One day, your child is a beautiful, charming 12-year-old, a kid who pops out of bed full of good cheer, clears the table without being asked, and brings home good grades from school. The next day, your child bursts into tears when you ask for the salt and listens to electronic music at maximum volume for hours on end. Chores? Forget it. Homework? There's little time, after talking to friends on the phone for five hours every night. Mornings? Your bluebird of happiness is flown, replaced by a groaning lump that can scarcely be roused for school. In short, your home is now inhabited by a teenager.

The shootings in Littleton, Colo., focused the nation's attention on aberrant adolescent behavior, but most teens never come close to committing violent acts. Still, even the most easygoing teenagers often confound their elders with behavior that seems odd by adult standards.

For most of this century, the assumption has been that teenage *sturm und drang,* the insolence and the rages, are all directed at parents. Teens turn against authority figures, went the conventional wisdom, in an effort to define who they are and to assert their independence–a view that spawned the teenage rebel, that quintessential American icon. The alternative explanation was that hormones, those glandular bringers of sexual stirrings and pimples, were to blame.

The true source of teenage behavior lies north of the gonads. It's that 3-pound blob of gray and white matter known as the brain.

Yes, teenagers do have brains, but theirs don't yet function like an adult's. With the advent of technologies such as magnetic resonance imaging, neuroscientists have discovered that the adolescent brain is far from mature. "The teenage brain is a work in progress," says Sandra Witelson, a neuroscientist at McMaster University in Ontario, and it's a work that develops in fits and starts.

Until the past decade, neuroscientists believed that the brain was fully developed by the time a child reached puberty and that the 100 billion neurons, or nerves, inside an adult's skull–the hardware of the brain–were already in place by the time pimples began to sprout. The supposition was that a teenager could think like an adult if only he or she would cram in the necessary software–a little algebra here, some Civil War history there, capped by proficiency in balancing a checkbook. But the neural circuitry, or hardware, it turns out, isn't completely installed in most people until their early 20s.

And just as a teenager is all legs one day and all nose and ears the next, different regions of his brain are developing on different timetables. For instance, one of the last parts to mature is in charge of making sound judgments and calming unruly emotions. And the emotional centers in the teenage brain have already been revving up, probably under the influence of sex hormones.

This imbalance may explain why your intelligent 16-year-old doesn't think twice about getting into a car driven by a friend who is drunk, or why your formerly equable 13-year-old can be hugging you one minute and then flying off the handle the next.

Indeed, the brain inside a teenager's skull is in some ways closer to a child's brain than to an adult's. Still being forged are the connections between neurons that affect not only emotional skills but also physical and mental abilities. That means that it might be unreasonable to expect young teenagers to organize multiple tasks or grasp abstract ideas. And these still-developing neural links leave a teenager vulnerable: Depression in adolescence may set up circuits in the brain that will make it much harder to treat the illness later in life.

But these changes aren't all for the worse. The brain's capacity for growth through adolescence may also indicate that even troubled teenagers can still learn restraint, judgment, and empathy. "Adolescence is a time of tumultuous change in the brain," says Jay Giedd, a child psychiatrist at the National Institute of Mental Health in Bethesda, Md. "Teenagers are choosing what their brains are going to be good at--learning right from wrong, responsibility or impulsiveness, thinking or video games."

If there's one thing that drives parents nuts about their teenagers, it's moodiness. "It's hot and cold, nasty and nice," says Vicki Sasso, 34, the mother of 13-year-old Angelo, a ninth grader from Staten Island, N.Y. "One minute loving me, one minute hating me." Don't blame Angelo; blame the parts of his brain that process emotions and make decisions. His prefrontal cortex, where judgments are formed, is practically asleep at the wheel. At the same time, his limbic system, where raw emotions such as anger are generated, is entering a stage of development in which it goes into hyperdrive.

**Brain police.** The limbic system, located deep in the brain's interior, is associated with gut reactions, sparking instant waves of fear at the sight of a large snake or elation at a high SAT score. In adults, such emotional responses are modulated by the prefrontal cortex, the part of the brain that lies just behind the forehead and that acts as a sort of mental traffic cop, keeping tabs on many other parts of the brain, including the limbic system.

Indeed, the brain works something like a loosely organized team, with various parts carrying out different tasks and more or less cooperating with one another. The prefrontal cortex, says Karl Pribram, director of the Center for Brain Research and Informational Sciences at Radford University in Virginia, is in charge of "executive functions."

These include the brain's ability to handle ambiguous information and make decisions, to coordinate signals in different regions of the brain, and to tamp down or prolong emotions generated in the limbic system. In an adult, for instance, an overheard insult might arouse a murderous rage, until the prefrontal cortex figures out that the comment was meant for somebody else and tells the limbic system to pipe down. As Pribram puts it, "The prefrontal cortex is the seat of civilization."

Something very different happens in teenagers, according to Deborah Yurgelun-Todd, a neuropsychologist at McLean Hospital in Belmont, Mass. In recent experiments, Yurgelun-Todd and graduate student Abigail Baird showed adults and teenagers photographs of people's faces contorted in fear. When the researcher asked her subjects to identify the emotion being expressed, all of the adults got it right. Many of the teens, however, were unable to correctly identify the expression.

Then the researchers used functional magnetic resonance imaging, a technology that takes a picture of brain activity every three seconds or so in order to see which parts are being used during processing. Adult brains, the scientists discovered, light up in both the limbic areas and the prefrontal cortex when looking at expressions of fright. In teenagers, however, the prefrontal cortex was almost dark while the limbic system lit up.

These results suggest to Yurgelun-Todd that kids may not be as good as we think they are at interpreting facial expressions, in part because the prefrontal cortex is not yet lending the limbic system a hand. Teenagers are not adept readers of social signals, such as facial expressions, even if they seem to do nothing but socialize. "You have to actually learn how to read emotions," says Yurgelun-Todd. "We may think anger is pretty obvious to our kids, but they may not."

**Map makers.** Yurgelun-Todd's research reinforces other new findings suggesting that the average teenager's prefrontal cortex isn't ready to take on the role of brain CEO. At NIMH, Giedd and colleagues are using another type of MRI, which captures brain structure rather than activity, to chart for the first time normal brain development from childhood through adolescence.

Since 1991, Giedd and his colleagues have mapped the brains of nearly 1,000 healthy children and adolescents ranging in age from 3 to 18. Each child must lie inside a claustrophobically narrow tube surrounded by the giant, humming machine, holding perfectly still for 10 minutes at a stretch while a computerized brain image is built.

The researchers expected to find that after puberty, the brain looks like an adult's. Instead, they found that the prefrontal cortex undergoes a growth spurt at around age 9 or 10, when neurons begin sprouting new connections, or synapses. Most of these connections subsequently die off, starting at about age 12, in a process called pruning–a sort of "use it or lose it" system for ensuring that the brain nourishes only the neurons and synapses that are useful. Pruning, which occurs in different parts of the brain at different times, also appears to allow the brain to think more efficiently.

Until the prefrontal cortex has been pruned, most young teenagers don't yet have all the brain power they need to make good judgments. Researchers suspect that the excess of synapses means the young adolescent mind can't easily keep track of multiple thoughts, and it can't gain instant access to critical memories and emotions that allow grown-ups to make judicious decisions.

"Good judgment is learned, but you can't learn it if you don't have the necessary hardware," says Yurgelun-Todd. An unfinished prefrontal cortex also means that young teenagers may also have trouble organizing several tasks, deciding, for example, which to do first: call a friend, wash the dishes, or read the book for a report that's due in the morning.

The teenage tendency to leap before looking is compounded by the fact that adolescence is a time for seeking out new experiences, including some that are dangerous. "I think all people do stupid things sometimes. It just seems like teenagers do it more often," says Rachael Fisher, an 18-year-old senior from Lakewood, Colo. That's an understatement. Driving without a seat belt, getting tattooed, smoking cigarettes, shoplifting–the list of foolish things kids do is longer than most parents really want to know.

Parents can relax a little, says Lynn Ponton, a child psychiatrist at the University of California-San Francisco and author of *The Romance of Risk*. "Risk taking is normal." But not all of it, she adds, is safe. Other research suggests that about 60 percent of a teenager's tendency to act impulsively and misjudge potential danger is genetic, a trait that is shared with other family members and is probably the result of differences in brain chemicals among individuals.

**Mental mosh pit.** Researchers also think that new experiences, especially those with a *frisson* of danger or the thrill of the new, tap into a teenager's so-called reward system, a set of neurons that link emotional centers to many other parts of the brain and that can produce feelings of intense pleasure. This is the same set of neurons affected by certain illicit drugs, such as cocaine, that release dopamine, one of the brain chemicals, or neurotransmitters, that are responsible for arousal and motivation.

Marvin Zuckerman, a professor of psychology at the University of Delaware, and others suspect that thrills–like sneaking out at night or jumping into the mosh pit at a heavy-metal concert–stimulate the teenage brain's dopamine system, for reasons that are not yet fully understood. The result, however, is clear: Teenagers are far more interested in novelty than children or adults are, probably because it makes them feel good. Other research has shown that at the same time, levels of another neurotransmitter, serotonin, appear to decline temporarily in most adolescents, making them more likely to act impulsively.

Added to this brew of neurotransmitters are the sex hormones, which not only turn on an interest in sex but also change the brain's architecture. Giedd and his colleagues recently reported for the first time that, in both sexes, surges of testosterone at puberty swell the amygdala, an almond-shaped part of the limbic system that generates feelings of fear and anger. (Girls' bodies make testosterone by breaking down estrogen, while boys' bodies transform testosterone into an estrogen-like hormone called estradiol.) This blossoming of the amygdala is especially pronounced in boys, but it may account for the rise in aggressiveness and irritability seen in both sexes at adolescence. Increased levels of estrogen at puberty are responsible for the sudden growth of the hippocampus, the part of the brain that processes memory. The larger the hippocampus, the better the memory, at least in animals. The hippocampus in girls grows proportionally larger than it does in boys, a finding that may help explain why women are better than men are at remembering complex social relationships and are likely to suffer less from the memory loss that accompanies Alzheimer's.

Estrogen and testosterone may not alter the brain at puberty so much as flip neurological switches, which were set by hormonal levels while a child was still in his mother's womb. Once flipped, these switches have a profound effect on a teenager's sex drive and moodiness.

Shifts in prenatal hormones also affect mental skills in ways that may not become apparent until later in life. Testosterone, for example, appears to shape centers in the brain that process spatial information. Evidence for this comes from a study of girls with congenital adrenal hyperplasia, or CAH, a condition that causes their adrenal glands to pump out excess androgen, a testosterone-like hormone, during prenatal development. Once the girls are born, they are given cortisone, to keep the body from producing too much androgen.

Their brains, however, have already been molded. Sheri Berenbaum, a psychologist at Southern Illinois University medical school, and others have found that as teenagers, girls with CAH report they are more aggressive than their sisters, and they have better spatial skills–the ability to rotate an object in their minds, for instance, or to imagine how pieces of a shape fit together. They are also more interested than their sisters in becoming engineers and pilots, traditionally masculine professions. But researchers don't yet know precisely how testosterone molds the brain's ability to imagine all the facets of an object, or why it would make girls (or boys, for that matter) want to become engineers.

One of the last steps in making an adult brain is the coating of nerves in white matter, fatty cells that spiral around the shaft of nerves like vines around a tree. The white matter, also known as myelin, acts like the insulation on an electric cord, allowing electrical impulses to travel down a nerve faster and more efficiently. This is one reason a toddler is less coordinated than a 10-year-old. It now appears that many of the nerves connecting different processing centers in the brain don't finish myelinating until the early 20s.

Some of the nerves that become sheathed during adolescence connect areas of the brain that regulate emotion, judgment, and impulse control. Francine Benes, a neuroscientist at McLean Hospital, says that these nerves myelinate in girls earlier than in boys, which may help explain why teenage girls seem more emotionally mature than boys, whose myelin levels may not equal girls' until age 30.

The myelination process also has been implicated in schizophrenia, which often becomes apparent in late adolescence. Benes believes the faster transmissions overload defective nerves in schizophrenics. "If the circuit starts to have too much information coming in too rapidly, it may become overwhelmed."

**Laying foundations.** Researchers feel they have only begun to probe the workings of the adolescent brain, but their findings already offer some new ways for parents to deal with teenagers. During adolescence, many higher mental skills will become automatic, just the way playing tennis and driving do. Kids who exercise their brains, in effect, by learning to marshal their thoughts, to measure their impulses, and to understand abstract concepts, are laying the neural foundations that will serve them for the rest of their lives.

"This argues for doing a lot of things as a teenager," says the NIMH's Giedd. "You are hard-wiring your brain in adolescence. Do you want to hard-wire it for sports and playing music and doing mathematics–or for lying on the couch in front of the television?" This hard-wiring also provides yet another reason for teens not to take drugs or alcohol, because they may permanently alter the balance of chemicals in their brains.

Parents can take comfort in knowing that searching for new experiences is a normal part of growing up. The trick, say experts, is helping kids find healthy sources of stimulation. For one child, being in the school play or volunteering in the community may provide plenty of excitement. For another, it could take hang-gliding lessons. The problem, of course, is that safe risks are not always available to the kids who need them. "Middle-class kids can go skiing and scuba diving," says the University of Delaware's Zuckerman. "But for many kids, there's just crime, sex, drugs, and rock-and-roll."

The best news for parents is that the vast majority of kids will make it through adolescence with few permanent scars, except perhaps the occasional hole through a bellybutton. New research shows that most children emerge from adolescence physically and emotionally intact–although their parents will probably never be the same. Mary Scott, 48, of Port Jefferson, N.Y., is a veteran of teenage wars: She's the mother of two adolescents and a 22-year-old. "Occasionally they do things that are so incredibly selfish, it's unbelievable," she says. On the other hand, Scott adds, "If they didn't drive you crazy, they'd never leave [the nest]." Maybe adolescence is nature's way of forcing children to grow up.

*With Roberta Hotinski, Bellamy Pailthorp, Erin Ragan, and Kathleen Wong*

**MISSED SIGNALS**

## You were angry?

When grown-ups and teens don't see eye to eye, the problem might be in the brain. Neuropsychologists studying brain development showed standardized pictures of fearful faces to 15 adults and 15 teenagers. All the adults correctly identified the emotion, but 11 of the teens guessed wrong at least once, picking emotions such as anger or discomfort instead. The researchers, at McLean Hospital in Belmont, Mass., say teenagers relied more on the primitive emotion center of the brain and less on the region tied to judgment than adults did. Teens literally think differently than adults, so their baffling behavior may reflect cluelessness, not stubbornness. *-Roberta Hotinski*

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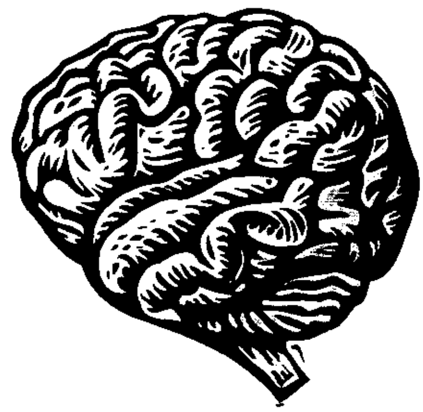
# Adolescent Brain Development

Research now supports what parents have *long* suspected—that the teenager's brain is different than the adult brain. Recent research by scientists at the National Institute of Mental Health (NIMH) using magnetic resonance imaging (MRI) has found that the teen brain is not a finished product, but is a work in progress. Until recently most scientists believed that the major "wiring" of the brain was completed by as early as three years of age and that the brain was fully mature by the age of 10 or 12. New findings show that the greatest changes to the parts of the brain that are responsible for functions such as self-control, judgment, emotions, and organization occur between puberty and adulthood. This may help to explain certain teenage behavior that adults can find mystifying, such as poor decision-making, recklessness, and emotional outbursts.

*The brain is still developing during the teen years* Dr. Jay Giedd of the NIMH has reported that brain "maturation does not stop at age 10, but continues into the teen years and even into the 20's. What is most surprising is that you get a second wave of overproduction of gray matter, something that was thought to happen only in the first 18 months of life (Begley, 2000)." Following the overproduction of gray matter, the brain undergoes a process called "pruning" where connections among neurons in the brain that are not used wither away, while those that are used stay—the "use it or lose it" principle. It is thought that this pruning process makes the brain more efficient by strengthening the connections that are used most often, and eliminating the clutter of those that are not used at all.

*What does this mean for teens?* According to Dr. Giedd, this is exciting news for teens. "...unlike infants whose brain activity is completely determined by their parents and environment, the teens may actually be able to control how their own brains are wired and sculpted." Kids who "exercise" their brains by learning to order their thoughts, understand abstract concepts, and control their impulses are laying the neural foundations that will serve them for the rest of their lives. "This argues for doing a lot of things as a teenager," says Dr. Giedd. "You are hard-wiring your brain in adolescence. Do you want to hard-wire it for sports and playing music and doing mathematics-or for lying on the couch in front of the television?"



*Alcohol use and the developing teen brain* Recent research suggests that alcohol use affects adolescents and adults differently, which makes sense given what we now know about the changes going on in the teen brain. While more research needs to be done in this area, Duke University scientists say "the available research suggests that adolescents are more vulnerable than adults to the affects of alcohol on learning and memory (White, 2001). Not only do they react differently to the initial affects of alcohol, studies suggest that teens who repeatedly use alcohol can suffer long-term effects. Preliminary studies using rats have shown that those with repeated alcohol exposure during adolescence are more sensitive to alcohol-induced impairments later in life (White, 2001).

Research on humans by Brown, et al. (2000) has shown the first concrete evidence that heavy, on-going alcohol use by adolescents can impair brain functioning. Brown's research on 15 and 16 year olds showed cognitive impairments in teen alcohol abusers, compared with non-abusing peers, even weeks after they stop drinking. This suggests that abuse of alcohol by teens may have long-term negative effects on the make up of their brains.

*Teens and understanding emotions* Teens also differ from adults in their ability to read and understand emotions in the faces of others. Recent research shows that teens and adults actually use different regions of the brain in responding to certain tasks. In a study conducted at Boston's McLean Hospital, psychologist Deborah Yurgelun-Todd and colleagues showed pictures of people wearing fearful expressions to teenagers between the ages of 11 and 17 while the teens had their brains scanned using functional magnetic resonance imaging (fMRI). She found that compared to adults the teens' frontal lobes (the seat of goal-oriented rational thinking) are less active and their amygdala (a structure in the temporal lobe that is involved in discriminating fear and other emotions) is more active. The teens often misread facial expressions, with those under the age of 14 more often seeing sadness or anger or confusion instead of fear. Older teenagers answered correctly more often and exhibited a progressive shift of activity from the amygdala to the frontal lobes. The results suggest that "in teens, the judgment, insight and reasoning

**Brain Regions and functions**

**Frontal lobe**—self-control, judgment, emotional regulation; restructured in teen years

**Corpus callosum**—intelligence, consciousness and self-awareness; reaches full maturity in 20's

**Parietal lobes**—integrate auditory, visual, and tactile signals; immature until age 16

**Temporal lobes**—emotional maturity; still developing after age 16

D 25 of 26

power of the frontal cortex is not being brought to bear on the task as it is in adults. Teens just process information differently from adults. (Yurgelun-Todd, 2002)"

*Implications* It is important to note that experts caution careful interpretation of this new information about adolescent brain development, as it is still very early in the analysis and understanding of what it all means. Yet it is also true that these findings add new dimensions to issues facing young people, as well as their parents and teachers, and they pose a challenge to policy makers (NIH, 2000). If the choices adolescents make about using drugs and alcohol and engaging in or avoiding challenging learning tasks have long-term and irreversible consequences for the development of their brains, then discouraging harmful choices and encouraging healthy ones is all the more urgent. This new research may also provide a compelling explanation for why adolescents often fail to heed adults' warnings about such choices; they may simply not be able to understand and accept arguments that seem logical and decisive to adults. It is also possible that teens are misperceiving or misunderstanding the emotions of adults, leading to miscommunication both in terms of what the teen thinks the adult is feeling and in terms of the teen's response.

Perhaps most importantly, teenagers are empowered with opportunities to develop their brains through the activities in which they choose to participate.

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D 26 & 26