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The Adolescent Brain

By Katie Jerstad

Editor's Note: Juvenile Justice Update is very pleased to publish this contribution from the NDAA's forthcoming "Juvenile Prosecution Handbook," following on "What Juvenile Court Prosecutors Need To Know about Risk Assessment Instruments," also adapted from the handbook, in the Summer 2023 issue of JJU. Both articles were written by Katie Jerstad, senior attorney with the National District Attorney's Association. She received significant input and guidance from Susan Broderick, profiled in this issue on page 1, in the development of "Risk Assessment," and from Michele Linley and Stacy Miller in "Brain Science." The author and NDAA want to emphasize that she is an attorney, not a neuroscientist, and that the material here, while grounded in current science, is written for and by attorneys serving the juvenile courts.

Introduction

Society has known for a long time that child and adolescent brains are different than those of adults. This difference was the reason for the creation of the juvenile justice system in Chicago in the late 1890s.[1] Even before advances in brain science explained these behavioral differences between teens and adults, states legislated an 18-year-old threshold for "adulthood"—the right to vote, the right to join the military, the right to marry without parental consent, etc. On the one hand, some laws are designed to protect the young and society from youth's immaturity, such as setting the legal age for alcohol consumption at 21. On the other hand, many states' juvenile court jurisdiction has no floor and children ten years of age or younger can be brought before a juvenile court judge. Most states allow for youth as young as fourteen to be prosecuted as adults for the most serious crimes. During this period of brain growth, American adolescents live in a "precarious middle ground" (and thus legal status) between innocence and immaturity, and responsibility and accountability.[2]

With the advancements in brain science, society has come to accept that, while most young adults may stop growing vertically by age 17 or 18, their brains continue to develop into their mid-to-late 20s. Advancements in science in the last 20 years, particularly research

[1] *In re. Gault*, 387 U.S. 1, 15, 87 S. Ct. 1428, 1437 (1967) ("The Juvenile Court movement began in this country at the end of the last century. From the juvenile court statute adopted in Illinois in 1899, the system has spread to every State in the Union, the District of Columbia, and Puerto Rico." However, it was lacking in expertise and legal resources. As the *Gault* court included in a footnote, see Harvard Law Review Note, p. 809; and also McCune, Profile of the Nation's Juvenile Court Judges (monograph, George Washington University, Center for the Behavioral Sciences, 1965.)

[2] ACT4JuvenileJustice, *Adolescent Brain Development & Juvenile Justice Fact Sheet*, JJDPA Fact Book, accessed August 7, 2023, https://tinyurl.com/3h3hnwt7

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Remembering Susan Broderick

By Katie Jerstad, NDAA

Juvenile justice professionals lost an advocate and champion with the passing of Susan Broderick to cancer in December of 2022, just a couple months shy of her 60th birthday. A longtime Manhattan prosecutor, Susan became well-known for her leadership training and mentoring of juvenile court prosecutors. She was also an expert on addiction and recovery. She founded Bridges to Recovery, through which she provided private recovery coaching, keynote presentations and training workshops about the latest recovery research, innovative programs, and strategies to achieve both accountability and positive change in the criminal justice system. Susan recognized that doing justice required an understanding of the forces that drive people to criminality, and she worked constantly to understand and educate others about those forces. Family, friends and colleagues all agree that Susan was a dedicated and compassionate advocate who made a difference.

Susan started her legal career in the Manhattan DA's Office in 1989, where she served as a prosecutor for 14 years and handled family violence, sex crimes, and homicide cases. During her time there, she supervised the Child Abuse Bureau and became known for her work on cases involving children. One early example was a particularly horrific case involving the starvation of a child, resulting in death, which she tried before a

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involving MRIs and functional MRIs[3], have enhanced our knowledge about the differences not only in the architecture of adolescents' and adults' brains but the functional pathways.

Some of these differences, such as lack of maturity, undeveloped sense of responsibility, and higher levels of risk-taking, were the basis for legislative changes as well as expansion of Eighth Amendment protections for juveniles by the United States Supreme Court. Some state legislatures have determined 17-year-olds are adults for criminal proceedings while other states are raising the age to 19 or 20 for adult prosecution to enable emerging adults the benefits of the juvenile justice system for certain types of offenses. Some jurisdictions have already enacted legislation or are considering legislation that would raise the floor of juvenile justice prosecution to 12 or 13 so as to prevent younger children from becoming "system-involved." The U.S. Supreme Court, in a series of cases, considered the appropriate sentences and sentencing procedure for crimes committed by youth in light of brain science advancements; we'll discuss these cases, including *Roper, Graham, Montgomery,* and *Jones,* in the next issue of JJU. Adolescent brain science is influencing these changes to some degree, but prosecutors must be cautious about what assumptions are being made about brain science in court.

This article covers what prosecutors need to know about adolescent brain science. Since the U.S. Supreme Court decided *Miller v. Alabama* in 2012, study of the brain's development throughout late adolescence has appeared in more than one hundred new publications.[3] Of over 1,000 legal cases referencing the same or similar neuroscience discussed in *Miller*, roughly half concerned individuals who were 18 years old or older at the time of the offense for which they are charged.[4] Almost 40% of those serving the longest prison sentences in the U.S. were incarcerated before the age of 25.[5] The implications of brain science research could alter the U.S. judicial and correctional systems significantly and some vocal proponents are advocating for that.

The implications of brain science research could alter the U.S. judicial and correctional systems significantly.

This article will also aim to answer the following questions:

- How have generalities about adolescents' brains affected specific decisions involving juvenile offenders?
- And how, when applied to a specific case, can one tell how likely it is that a particular youth will be rehabilitated when their behavior shocks the conscience and carries some of the harshest penalties?
- If all adolescents have undeveloped parts of their brains, why aren't all adolescents committing crimes? Do the brains of teens committing crimes look different from their peers who are staying out of trouble?
- What can a brain science expert testify to and what can't they testify to? What are the limits on their knowledge? Expertise? What don't we know yet?

Within the adolescent brain science field, neuroscientists have learned through their studies that complex interactions between biology and environment influence brain development. Neuroscientists recognize that both positive and negative experiences and environments affect child and adolescent development and life outcomes. Advanced research has helped us better understand the parts of the adolescent brain that control or influence youth decision-making, impulsivity, and risk-taking. The research has led to changes in laws, policies, and juvenile justice systems across the country

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[3] Center for Law, Brain & Behavior at Massachusetts General Hospital, White Paper on the Science of Late Adolescence: A Guide for Judges, Attorneys, and Policy Makers (January 27, 2022), p. 7, https://tinyurl.com/4pu3uv48.

[4] *Id.*

[5] *Id.* at p. 8.

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that embrace a youth's ability to correct criminal behavior as compared to an adult offender whose brain is no longer growing. This article will discuss that research and what has been learned as well as how the courts have taken that research into consideration in reaching decisions on specific youth cases.

How this general population research is applied to specific case facts is a matter of significant importance to the Youth Court and Adult Court Prosecutors. Juvenile Prosecutors have the dual task of advocating for community safety while also considering the rehabilitative needs of the juvenile involved, taking into account the emotional and psychological development of the youth. To some degree, adolescent brain science and the ACES study (discussed below) will inform that dual task.

Brain Science

A. Areas of the Brain

The central nervous system is made up of the brain and spinal cord, which are interconnected with nearly every other part of your body with the help of ***nerves***.[6] The brain can be divided into three basic units: the **forebrain**, the **midbrain**, and the **hindbrain**.

The forebrain is the largest part of the brain and consists primarily of the ***cerebrum*** and the structures hidden beneath it (the "***inner brain***"). The *cerebrum* holds memories, allows you to plan, imagine, think, recognize friends, read books, and play games. The *cerebrum* is split into two halves by deep fissures. The ability to form words seems to lie primarily in the left hemisphere, while the right hemisphere seems to control many abstract reasoning skills. These hemispheres communicate with each other through a thick tract of nerve fibers called the ***corpus callasum***. During adolescence, the *corpus callosum* begins to thicken, "making stronger connections between different parts of your brain, so suddenly things like abstract math start to click."[7]

The midbrain contains the uppermost part of the brain stem, which controls reflex actions and circuitry controlling eye movement and other voluntary movements.[8]

The hindbrain includes the upper part of the spinal cord, the brain stem and the ***cerebellum***. The hindbrain controls respiration and heart rate.[9] The ***cerebellum*** coordinates movement and motor control.[10] This includes balance, coordination, fine motor learning upon repetition, integration of muscle groups to provide smooth body movements and posture.[11] Recent testing shows this area is also responsible for some cognitive functions relating to emotional processing, language, attention, fear, and pleasure.[12]

Adolescence is "like driving a car with a sensitive gas pedal and bad brakes."

The **Cerebral Cortex:** this is a vital layer of tissue, like bark, that surrounds or coats the cerebrum and the cerebellum.[13] Often referred to as "gray matter" in the brain, the nerves in this area have less insulation causing a slightly darker appearance than other whiter parts of the brain.[14]

> The term "**gray matter**" is also used to describe the unmyelinated (insulated) neurons in the brain, the density of which appear to increase as a child develops into early adulthood.[15]

The cerebrum, each of its two hemispheres, contain lobes each specializing in a distinct function: the *Occipital Lobes*, *Temporal Lobes, Parietal Lobes*, and *Frontal Lobes* (which contains the *Pre-Frontal Cortex (PFC)*, thought of as the seat of executive functioning).

Occipital Lobes: The occipital lobes are two areas at the back of the brain that are primarily responsible for image and visual processing, linking what we see with images stored in memory.

Temporal Lobes: The temporal lobes process sensory input for hearing and assists with language and sound recognition. It is located just above the spinal cord. At the top of the temporal lobes is an area responsible for receiving information from the ears.[16] In the left temporal lobe, a region important for memory and language, gray matter density continues to grow until age 30, according to MRI studies.[17]

The Temporal Lobes contain a ***limbic system*** which handled emotions, instincts, goal-directed behavior such as thirst, appetite for food, and other things like social interaction.[18] The limbic system activates when one experiences survival instincts and reward/pleasure. The limbic system is a powerful brain region responsible for motivation, fear, fight or flight, anger, and pleasure. The limbic system can overtake the frontal lobes executive functions in a teen, especially when stressors are involved. It can cause teens to experience higher "highs," lower "lows" and makes a teen especially sensitive to emotional cues, information, and rewards.[19]

The **Amygdala** is a crucial part of the limbic system connected to the **ventral Anterior Cingulate Cortex** (vACC). It is activated when we experience basic emotions like fear, anger and pleasure.[20] It is also involved in binding

6 Deak, JoAnn & Terrence Deak, *The Owner's Manual for Driving your Adolescent Brain*, Little Pickle Press, San Francisco, CA p. 13 (2013).

7 *Id.*

8 National Institute of Neurological Disorders and Stroke, "Brain Basics: Know Your Brain," last reviewed on March 17, 2023 https://tinyurl.com/b5kjkcj9.

9 *Id.*

10 *Id.*

11 *Id.* & Olivia Guy Evans, "Cerebellum: Functions, Structure, and Location," Simply Pscychology, last updated July 3, 2023, https://tinyurl.com/56j7ssaa

12 Jill Seladi-Schulman, "What Is the Cerebellum and What Does It Do?", Healthline, last reviewed February 11, 2020, www.healthline.com/health/cerebellum#function

13 *Id.*

14 *Id.*

15 Efstathios D. Gennatas et al., "Age-Related Effects and Sex Differences in Gray Matter Density, Volume, Mass, and Cortical Thickness from Childhood to Young Adulthood," Journal of Neuroscience 37, no. 20 (May 17, 2017): 5065–5073, doi.org/10.1523/JNEUROSCI.3550-16.2017

16 *Id.*

17 Lindzi Wessel, "The Teen Years," BrainFacts.org, September 26, 2019, www.brainfacts.org/thinking-sensing-and-behaving/childhood-and-adolescence/2019/the-teen-years-092619

18 Deak, *The Owner's Manual*, 15.

19 Harvard Health Publishing, "The adolescent brain: Beyond raging hormones," March 7, 2011, www.health.harvard.edu/mind-and-mood/the-adolescent-brain-beyond-raging-hormones.

20 PracticalPie, "Anterior Cingulate Cortex," August 9, 2022, practicalpie.com/anterior-cingulate-cortex/.

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individual memories with particular emotions.[21] It "becomes activated when you feel a very strong emotion, especially in response to a fearful situation, and files that intense emotion in your memory bank."[22]

Parietal Lobes: The parietal lobe is on the top of the brain and integrates information from sensory input like touch, taste, aroma, pain, and temperature. Reading and arithmetic are also functions of each parietal lobe.[23] Rewards circuits to the parietal cortex help with attention.[24]

Somatosensory cortex is the front part of the parietal lobes and receives information about "temperature, taste, touch, and movement from the rest of the body."[25]

Frontal Lobes: The frontal lobe is at the front of your brain behind the forehead. Functions of the frontal lobe include short-term storage site for ideas, attention, abstract thinking, emotional and behavioral control, long term planning, motivation, goal directed behavior, and understanding and evaluating consequences. The frontal lobes are the last area of the brain to fully develop. <u>This late maturation of the frontal lobe might explain some of the characteristics of a "typical teenager" such as short attention span, impulsive behavior, and forgetting homework.</u>[26]

Special areas within the frontal lobe are the **motor cortex** (which helps plan, control and execute voluntary body movement, like moving your arm or kicking a ball), the **prefrontal cortex** (the "conductor"[27] for "executive functions" such as thinking, problem-solving, reasoning, impulse-control) and **Broca's area** (involved in speech production). The prefrontal cortex supervises and directs other areas of the brain.[28]

The prefrontal cortex is also the final area of the human brain to mature.[29]

Disruption of functions associated with the frontal lobe may lead to impairments of foresight, strategic thinking, and risk management.[30] One "hallmark of frontal lobe dysfunction is difficulty in making decisions that are in the long-term best interests of the individual."[31] How do disruptions or dysfunction of the frontal lobe occur? As discussed below, disruptions or dysfunction may result from traumatic events (both physical or emotional trauma), chronic toxic stress (discussed in more depth below) or substance abuse.

Inner Brain: deep in the brain are the parts that act as gatekeepers between the spinal cord and cerebral hemispheres. Like lobes, these come in pairs, duplicated in both cerebral hemispheres. These parts are the hypothalamus, thalamus, hippocampus, and basal ganglia.

Hypothalamus—part of the limbic system; mediates between the endocrine and central nervous systems[32] (wakes you up in the morning, gets adrenaline flowing, important emotional center, controlling molecules that make you feel exhilarated, angry or unhappy). According to a 1972 study by psychologist Donald Hebb, the hypothalamus contains from the time of birth "the anatomical circuitry of instinctual violence."[33] Contains a section called the **nucleus accumbens** which is part of reward system and is associated with motivation and behavioral reinforcement.[34]

Thalamus—center of communication between spinal cord and cerebrum.

Hippocampus—part of limbic system, acts as a memory indexer—sending memories out to appropriate parts of the brain for long term storage and retrieval when necessary. Working with the amygdala, the hippocampus ensures that you remember where and how you were previously hurt or injured and other important environmental cues to predict where danger might be lying in wait and effectively protect you.[35]

Basal Ganglia—cluster of nerve cells surroundings thalamus. Responsible for initiating and integrating movements.[36]

No parts of the brain would work without many different cell types doing their job, but the primary functional cell in the brain is called the ***<u>neuron</u>***.[37] Neurons are different from other cells in the body because they are electrically charged and process electrical information.[38] "Groups of neurons in one brain structure send their **axons** together to other brain structures, forming a **neural pathway**."[39] "Specialized sensory neurons translate messages from the environment into **electrical impulses—**the language of the brain to form a **sensation.**"[40]

Neurons require the support of glial cells, or ***glia***, which provide nourishment by releasing proteins that act like fertilizer

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[21] *Id.*

[22] Deak, *The Owner's Manual*, 43.

[23] National Institute of Neurological Disorders and Stroke, "Brain Basics: Know Your Brain."

[24] Emily Underwood, "Teens can have excellent executive function—just not all the time," Knowable Magazine, April 20, 2023, knowablemagazine.org/article/mind/2023/executive-function-in-teen-brains.

[25] National Institute of Neurological Disorders and Stroke, "Brain Basics: Know Your Brain."

[26] Lindzi Wessel, "The Teen Years."

[27] Underwood, "Teens can have excellent executive function."

[28] Cleveland Clinic, "Cerebral Cortex," last reviewed May 23, 2022, https://my.clevelandclinic.org/health/articles/23073-cerebral-cortex.

[29] ACT4JuvenileJustice, Adolescent Brain Development & Juvenile Justice, citing Paul Thompson, "Time-Lapse Imaging Tracks Brain Maturation From Ages 5 to 20," National Institutes of Mental Health and the University of California Los Angeles, May 2004; also author interview with Robin Jenkins, June 2006. Coalition for Juvenile Justice, What Are the Implications of Adolescent Brain Development for Juvenile Justice? (Washington, DC: Coalition for Juvenile Justice, 2006), 3, accessed January 13, 2016, www.juvjustice.org/sites/default/files/resource-files/resource_134.pdf.

[30] See M.-Marsel Mesulam, "Behavioral Neuroanatomy," in *Principles of Behavioral and Cognitive Neurology*, 2nd ed., ed. M.-Marsel Mesulam (Oxford University Press, 2000), 47–48.

[31] See Antonio R. Damasio and Steven W. Anderson, "The Frontal Lobes," in *Clinical Neuropsychology*, 4th ed., ed. Kenneth M. Heilman and Edward Valenstein (Oxford University Press, 2003), 404, 434.

[32] PracticalPie, "Anterior Cingulate Cortex."

[33] Chris Murphy, *The Violence Inside Us: A Brief History of an Ongoing American Tragedy* (New York: Random House, 2020), 38.

[34] PracticalPie, "Anterior Cingulate Cortex."

[35] Deak, *The Owner's Manual*, 43.

[36] National Institute of Neurological Disorders and Stroke, "Brain Basics: Know Your Brain."

[37] Deak, *The Owner's Manual*, 16.

[38] *Id.* at 17.

[39] *Id.* at 17.

[40] *Id.* at 20.

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to help neurons thrive and remove waste material from neurons.[41]

All sensations, movements, thoughts, memories, and feelings are the results of signals passed through neurons. This activation takes place with the help of ***vesicles*** that release ***neurotransmitters*** from the end of its axon (which can be up to a meter long) that carry a signal through the ***synapse*** (the place where a signal passes from the neuron to another cell) to a receptor on a neighboring cell.[42]

Different types of neurotransmitters can activate or dampen a cell's activity level. "There are two types of neurotransmitters: **inhibitory neurotransmitters** send a STOP signal to the next neuron (like hitting the brakes) and **excitatory neurotransmitters** send a signal for the next neuron to GO (like stepping on the gas)."[43] Scientists have learned that certain diseases stem from over-production or under-production of certain types of neurotransmitters.[44]

Dopamine, a neurotransmitter (and hormone) that influences memory, concentration, problem-solving and other mental functions, is not at its most effective level in adolescence.[45] "Dopamine is critical to the brain's reward system—creating a neurochemical loop that links a stimulus with pleasure and satisfaction."[46] One theory on the bio-chemistry of violence posits that when dopamine levels are off-kilter, the brain may offer higher reward signals to violence and aggression than in brains where the levels are more stable.[47]

Much knowledge of brain development and many of the studies rely on the use of MRIs and functional MRIs (fMRI). An fMRI uses the same equipment as an MRI, however, in an fMRI a task or stimulus is introduced. The fMRI measures blood flow that results from or is indicative of an increase in neuronal connectivity, ie. brain activity, resulting from the stimuli.[48] Researchers infer that the part of the brain with increased blood flow resulted from the stimulus or was used in the task. Where an MRI provides a static structural view of the brain, the fMRI can show how those structures react to a stimuli.

Past studies have guided newer neuroimaging studies to look at

> the role of a relatively small number of brain regions in mediating social-affective behavior. Specifically, much attention has been given to the **amygdala**, **striatum**, **insula**, and **anterior cingulate cortex** (ACC), and a number of regions within the **prefrontal cortex** (PFC). These regions work together to assign salience, promote learning, monitor conflict, compute relative valence of social stimuli, and integrate this information to generate and guide affective behaviors toward wider goals and within the contexts in which they occur.[49]

Where there was once a focus on the "regional activation" with certain stimuli, more recent studies are looking at the "functional interconnection" between and among these brain regions and areas by looking at neural substrates and networks.[50]

B. How the Brain Develops and Why that Leads to Risky and Other Behavior

The brain develops through a combination of our genes, environment, experiences, and interpersonal relations. By age three, the brain has grown to almost ninety percent of its adult size.[51] "During adolescence the brain gets larger and heavier overall, ridges (**gyri**) and folds (**sulci**) in the cortex become more pronounced and the brain takes on a more cauliflower-like shape."[52] Aside from its physical appearance or growth in size, the brain becomes more complex and efficient during this adolescence in part because of the strengthening of neural pathways and increased effectiveness of glia protecting and nourishing of neurons.[53]

Adolescence is a tricky time because of this variable rate of growth across different regions of the brain. The growth period referred to as "adolescent brain development" typically begins at puberty and is roughly defined as lasting from age 10 to 25.[54] The functions of the brain continue to develop into the mid-20s and for some parts, the early 30s.[55] Development of each area of the brain is generally completed at different rates and times[56] rather than linearly like height. "The hindbrain structures are more mature at birth than structures of the forebrain."[57] The forebrain structures, like the cerebral cortex, are not fully developed until adulthood.[58]

There are **critical periods** for developing certain abilities. The critical period for learning a language, for example, is from birth to age eight. Once a critical period passes, the brain begins to fossilize. At that point, you could still learn a language, but it will take more time and effort.[59]

This doesn't mean that the brain stops growing at age eight—the brain will continue to produce new neurons throughout a lifetime in a process called ***neurogenesis.*** "This happens mostly in brain structures that help with ***plasticity***, or learning." Regular exercise has been shown to increase neurogenesis.[60] The more a teen stimulates, challenges, and stretches their mind, the more ***neurotrophins*** the brain will produce. Neurotrophins are proteins produced by glial cells that act like fertilizer for the brain, stimulating neurogenesis

[41] *Id.* at 18.

[42] *Id.* at 19.

[43] *Id.* at 18.

[44] National Institute of Neurological Disorders and Stroke, "Brain Basics: Know Your Brain."

[45] ACT4JuvenileJustice, *Adolescent Brain Development & Juvenile Justice*, citing Linda Patia Spear, "Neurodevelopment During Adolescence," in *Neurodevelopmental Mechanisms in Psychopathology*, ed. Dante Cicchetti and Elaine F. Walker (Cambridge University Press, 2003); Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development.*

[46] Murphy, *The Violence Inside Us,* 40.

[47] *Id.*

[48] John C. Gore, "Principles and practice of functional MRI of the human brain," *The Journal of Clinical Investigation* 112, no. 1 (July 2003): 4–9, doi.org/10.1172/JCI19010

[49] Amanda E. Guyer, Jennifer S. Silk, and Eric E Nelson, "The neurobiology of the emotional adolescent: From the inside out," *Neuroscience & Biobehavioral Reviews* 70 (November 2016): 74–85, doi.org/10.1016/j.neubiorev.2016.07.037.

[50] *Id.*

[51] Child Welfare Information Gateway, *Child Maltreatment and Brain Development: A Primer for Child Welfare Professionals* (U.S. Department of Health and Human Services, Administration for Children and Families, Children's Bureau, 2023), www.childwelfare.gov/pubs/issue-briefs/brain-development/.

[52] Deak, *The Owner's Manual,* 25.

[53] *Id.*

[54] ACT4JuvenileJustice, *Adolescent Brain Development & Juvenile Justice.*

[55] National Juvenile Justice Prosecution Center in partnership with NDAA, OJJDP, DOJ, Juvenile Prosecutor Training Curriculum, Instructor Manual, Module 2, Child and Adolescent Development, 28, citing Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development.*

[56] Deak, *The Owner's Manual,* 25.

[57] *Id.*

[58] *Id.*

[59] *Id.* at 27.

[60] *Id.*

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and increasing resiliency to stress and capability of handling new experiences.[61]

Three processes occur simultaneously in the brain of a teen at a greater rate than at any other time of brain development. These are *cell proliferation, pruning* and *myelination.*

Cell proliferation is a growth spurt of neurons and connections, mainly in the frontal lobe, which generally begins at the onset of puberty.

Synaptic Pruning of neuronal connections eliminate those connections that are not being used as often. Pruning is a fine tuning of the brain through one's environment and experiences. By pruning away irrelevant synapses, neural signals can travel and transmit information more efficiently.

Finally, **Myelination** is the insulation of axons of the neurons to enable fast and efficient transmission of electrical and chemical impulses.[62] Myelination takes place from birth through late adolescence but different brain structures achieve a fully myelinated state at different ages. "As myelination becomes more extensive, the brain becomes more capable of complex skills."[63]

With the three processes working at their busiest rate, adolescence is a distinct, transient period of tremendous neuroplasticity. "Because many of the brain circuits involved in social information processing continue to develop throughout the teenage years, adolescence may represent a sensitive period for the long-term organization of social behavior."[64]

One component of social behavior that makes humans unique is **empathy**. Scientists believe that the **right temporal parietal junction (RTPJ)** is particularly important for developing empathy and that a critical period of its development happens during adolescence. The **medial prefrontal cortex** is strongly engaged when you think about yourself and others as well, but is more active in adolescents than in adults.[65] The **temporoparietal junction** becomes active when you switch your perspective between yourself and others. Some research on adolescents with a history of delinquent behavior found that the temporoparietal junction showed less variation in activity across different social situations in adolescents with a history of delinquency, compared with others.[66] One potential explanation is that they are not as successful in switching from their own perspective to others', but other explanations are possible.

Face-to-face human interaction activates the temporoparietal junction of the brain and the more activation, the more positive social interactions one will have. Researchers are concerned about decreased use of this area of the brain by adolescents today who are communicating mostly electronically.

Researchers have concluded that face to face human interaction activates this part of the brain and the more activation, the more positive social interactions one will have (suggesting more empathy). Researchers are concerned, however, about decreased use of this area of the brain by adolescents today who are communicating mostly electronically and certainly did so during the Covid 19 pandemic. Rodent studies have shown that when contact with other rodents was restricted, the rodents failed to develop normal social interactions. "These effects are particularly pronounced when social interaction is restricted during adolescent, suggesting that this is a critical/sensitive period for social interaction."[67]

On the other side of the spectrum from empathy is **rage, aggression**, hate, violence or antipathy. Young children often exhibit violent tendencies—and studies of twin toddlers supported this observation. "The children generally were able to unlearn violence, suggesting that while violence may be part of our nature, nurture plays an increasingly influential role as children gain more exposure to alternative methods of conflict and rage resolution."[68] The study suggests that "[v]iolence may be a part of human biology, but it is not destiny."[69] "As children grow, they learn to manage their emotions, communicate with others and deal with conflict."[70]

Kent Kiehl, a neuroscience professor at the University of New Mexico, is developing a database of brains of hardened criminals and found that they have, in adulthood, different brains. There is less gray matter; the amygdala is smaller; and there are defects in limbic and paralimbic cortex.[71] This study is backed up by other studies that show brain scans of those prone to violence look different from those who are not.[72] Scientists are trying to understand the role that not only genetics but also brain chemicals play in the brain architecture of this one percent of the population (brain chemicals/neurotransmitters such as norepinephrine, dopamine, and serotonin for instance).[73]

It would be an oversight to not mention ***puberty***, also taking place during adolescence and causing rapid growth and maturation of body parts. Puberty starts in the brain when a small group of neurons in the hypothalamus begin to produce a protein called **kisspeptin**.[74]

61 *Id.* at 41.

62 Child Welfare Information Gateway, *Child Maltreatment and Brain Development.*

63 Deak, *The Owner's Manual*, 29.

64 Guyer, "The neurobiology of the emotional adolescent," 2.1

65 Tim Vernimmen, "Inside the adolescent brain," *Knowable Magazine*, June 30, 2022, knowablemagazine.org/article/mind/2022/inside-adolescent-brain.

66 Wouter van den Bos et al., "Neural correlates of social decision-making in severely antisocial adolescents," *Social Cognitive and Affective Neuroscience* 9, no. 11 (December 2014): 2059–2066, doi.org/10.1093/scan/nsu003

67 Deak, *The Owner's Manual*, 44–45.

68 Murphy, *The Violence Inside Us*, 38, referencing a 2014 University of Montreal study.

69 *Id.*

70 *Id.*

71 Murphy, *The Violence Inside Us*, 40.

72 *Id.*

73 *Id.*

74 Deak, *The Owner's Manual*, 33-34.

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When sufficient kisspeptin is produced, a specific hormone called **gonadotropin-releasing hormone** (GnRH) is released, which stimulates the release of **testosterone** (in males) and **estrogen** (in females) that surge around the body during puberty.[75] Animal studies have contributed to our knowledge of the influence of puberty and specific hormones on adolescent behavior, brain development and emotionality.[76]

Unlike popular belief, hormones and sex drive are not the only source of **risky behavior** for this age group. Adolescent brains' cognitive processes are mature by mid-teens, but self-regulation and other socio-emotional processes are not complete until early adulthood. The neural circuitry needed to produce an executive response is already there in adolescence, but an adolescent's ability to access these systems in a sustained and reliable way is variable.[77] Without consistent access to that system, teens use a different area of the brain to assist in making decisions than adults.[78] This is a time when synaptic pruning in the PFC is occurring.[79] Studies have shown that adolescents' greater involvement than adults in risk taking does not stem from ignorance, irrationality, delusions of invulnerability, or faulty calculations.[80] Because the frontal cortex is the last to develop, teens rely heavily on parts of the brain that house their emotional centers (the **limbic system** of the temporal lobe) when making decisions.[81]

Perhaps this is the reason one author and scientist described adolescence as "like driving a car with a sensitive gas pedal and bad brakes."[82] More recent research indicates that adolescence is more like driving a car that is generally smooth and well-functioning, except, in highly emotionally charged situations, the gas pedal becomes more sensitive and the brakes go bad temporarily. Studies have shown that adolescents can make well-reasoned decisions when things are calm but struggle with activating their PFC when emotions are high.[83]

"Recent research has shown that adolescents often act impulsively or engage in risky behaviors in part because the PFC is not yet fully mature, and not yet capable of effectively reigning in impulsive actions. This may be because adolescents don't have as much GABA, a key inhibitory neurotransmitter, in their PFC as adults."[84] A small percentage of youth engage in extremely risky behavior, which is a problem for juvenile justice systems, but according to researchers, "a side effect of the helpful, adaptive function of risk-taking that propels teens into adulthood."[85]

When compared to adults' cognitive control, adolescents' is not as good unless there is a **short-term reward** involved. Kids with higher levels of dopamine, the neurotransmitter involved in reward, in neurons in the basal ganglia exhibited cognitive control at levels of an adult when a short-term reward was offered for following the rule ("don't look at the light").[86]

This is consistent with another study looking at adolescents' lack of impulse control and their lower level of **dopamine** than adults. In one study, adolescents with higher dopamine levels could control their impulsive responses better than those with less dopamine when there was a reward involved.[87]

Due to fluctuating dopamine levels in adolescents and the reality that short-term rewards are not always available, cognitive control is inconsistent for this age group. Due to teens' excitement to pursue short-term rewards, some think that teens are naturally and chemically geared to seek greater risks for social, emotional, and physical reasons.[88] Some think that, at this point in their brain development, teens are naturally attracted to risky activities.[89]

Some theorize that adolescents experience "reward-deficiency syndrome" that occurs when youth are no longer stimulated by activities that thrilled them when they were younger, and they engage in

Recent research has shown that adolescents often act impulsively or engage in risky behaviors in part because the PFC is not yet fully mature, and not yet capable of effectively reigning in impulsive actions.

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[75] *Id.*

[76] National Juvenile Justice Prosecution Center in partnership with NDAA, OJJDP, DOJ, Juvenile Prosecutor Training Curriculum, Instructor Manual, Module 2, Child and Adolescent Development, 28, citing Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development.*

[77] Underwood, "Teens can have excellent executive function."

[78] ACT4JuvenileJustice, Adolescent Brain Development & Juvenile Justice; Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development.*

[79] Underwood, "Teens can have excellent executive function."

[80] Valerie Reyna and Frank Farley, "Risk and Rationality in Adolescent Decision Making," *Psychological Science in the Public Interest* 7, no. 1 (2006): 1–44, doi.org/10.1111/j.1529-1006.2006.00026.x; Valerie Reyna and Frank Farley, "Is the Teen Brain Too Rational?" *Scientific American Mind* 17, no. 6 (June 2007), www.scientificamerican.com/article/is-the-teen-brain-too-rational/.

[81] Child Welfare Information Gateway, *Child Maltreatment and Brain Development.*

[82] Juvenile Prosecutor Training Curriculum, Instructor Manual. Module 2. Child and Adolescent Development, National Juvenile Justice Prosecution Center in partnership with NDAA, OJJDP, DOJ. Page 28, citing Age of Opportunity, Laurence Steinberg, Ph.D.

[83] B. J. Casey, "Beyond Simple Models of Self-Control to Circuit-Based Accounts of Adolescent Behavior," *Annual Review of Psychology* 66, no. 1 (2015): 295–319, doi.org/10.1146/annurev-psych-010814-015156.

[84] Deak, *The Owner's Manual*, 50.

[85] Vernimmen, "Inside the adolescent brain."

[86] Underwood, "Teens can have excellent executive function."

[87] Daniel Siegel, "Dopamine and Teenage Logic," *The Atlantic*, January 24, 2014, www.theatlantic.com/health/archive/2014/01/dopamine-and-teenage-logic/282895/. Also discussed in National Juvenile Justice Prosecution Center in partnership with NDAA, OJJDP, DOJ, Juvenile Prosecutor Training Curriculum, Instructor Manual, Module 2, Child *and Adolescent Development, 28, citing Coalition for Juvenile Justice, What Are the Implications of Adolescent Brain Development.*

[88] National Juvenile Justice Prosecution Center in partnership with NDAA, OJJDP, DOJ, Juvenile Prosecutor Training Curriculum, Instructor Manual, Module 2, Child and Adolescent Development, 28, citing Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development.*

[89] *Id.*

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activities involving greater risk and higher stimulation in order to achieve similar level of excitement.[90] These theories contemplate the adolescent actor choosing risk or reward over reason as purposeful or volitional behavior when the biological explanation (though perhaps not a justification) makes it more complicated than that.

As an example, in one study it was determined, through imaging, that two networks in the frontal lobe of the brain impact adolescent behavior and choices. In this study exploring contraceptive use and pregnancy prevention, it was found that the emotional network dominates the cognitive network and impacts planning and risk assessment.

> Under normal conditions, the cognitive network can regulate the social/emotional network. However, when the social/emotional network is highly activated, they do not work together. The emotional network dominates the cognitive network. The result is that emotion, rather than reason, often influences adolescent decision-making.[91]

It is probably not a surprise to anyone that a teenager could be emotionally overwhelmed by sexual activity to the point of losing cognitive control. What might come as a surprise is the extent to which not just paramours but **peers** can cause the emotional network to dominate over the PFC.[92] Peers act like a form of reward that can overwhelm cognitive control.[93] Peer acceptance is extremely important to an adolescent.[94] This makes sense from an evolution standpoint—at a time when humans are getting ready to leave the safety of their family, they want to ensure safety and protection provided by the peer group, find a partner, and reproduce.[95] **Peer rejection, pressure and influence** greatly impact teens emotions and therefore decision-making, but even the mere **presence** of peers can greatly influence an adolescent's decision-making.[96] On the other hand, a calm atmosphere helps teens' brains focus on frontal lobe functions when making decisions instead of only reacting to limbic system impulses.[97] There are numerous studies in the area of peer rejection, acceptance, and presence, but one take away from some studies is that anxious and depressed adolescents may have less access to the parts of the brain that can reduce distress from peer rejection, creating a never-ending cycle of negative feelings.[98] Many major mental illnesses emerge during adolescence—that is why psychiatrists and neurologists have been using these studies to map typical trajectories in a pediatric growth chart to identify risk and fortify weaknesses in certain brain functions.[99] Cognitive Behavioral Therapy (CBT) trains the brain to start to observe emotional reactions and activate the PFC executive system with the goal that overtime the cognitive control will get stronger, and neural pathways that reinforced the illness will grow weaker due to infrequent use.[100]

Peer acceptance is extremely important to an adolescent. Peers act like a form of reward that can overwhelm cognitive control.

In addition to anxiety and depression, other illnesses like **substance abuse** can threaten brain responses, executive functioning, and development during adolescence. A neural pathway activated by natural rewards such as social interaction, tasty food, and sexual activity, becomes even more activated when a teen consumes **alcohol or drugs**, causing the teen to seek out those substances over and over again.[101] If this behavior becomes pathological, it can result in **addiction**, which takes over your life's priorities and can lead to devastating consequences. Alcohol use reduces neurogenesis and reduces how much a teen can learn later in life. Adolescents metabolize alcohol faster than adults so they can consume more without showing signs of impairment and are less likely to suffer hangover effects.

While the adolescent brain is developing, it is a time of great emotional, social, and moral development. Often the intensity of a teen's emotions can be overwhelming. Pursuing important passions, like pastimes such as music, sports, or writing, can hold a teen steady when they are feeling overwhelmed. These activities or pursuits are sometimes referred to a **North Star**.[102]

[90] ACT4JuvenileJustice, *Adolescent Brain Development & Juvenile Justice*, citing Linda Patia Spear, "Neurodevelopment During Adolescence," in *Neurodevelopmental Mechanisms in Psychopathology*, ed. Dante Cicchetti and Elaine F. Walker (Cambridge University Press, 2003); Coalition for Juvenile Justice, *What Are the Implications of Adolescent Brain Development*.

[91] Youth.gov, "Adolescent Decision-Making Research," August 7, 2023, youth.gov/youth-topics/adolescent-health/adolescent-decision-making.

[92] See Kerry E. Bolger and Charlotte J. Patterson, "Developmental Pathways from Child Maltreatment to Peer Rejection," *Child Development* 72, no. 2 (March/April 2001): 549–568, doi.org/10.1111/1467-8624.00296; Laura R. Stroud et al., "Sex differences in biological response to peer rejection and performance challenge across development: A pilot study," *Physiology & Behavior* 169 (February 2017): 224–233, doi.org/10.1016/j.physbeh.2016.12.005.

[93] Underwood, "Teens can have excellent executive function."

[94] Berna Güroğlu, "Adolescent brain in a social world: Unravelling the positive power of peers from a neurobehavioral perspective," *European Journal of Developmental Psychology* 18, no. 4 (2021): 471–493, doi.org/10.1080/17405629.2020.1813101.

[95] Underwood, "Teens can have excellent executive function."

[96] Guyer, "The neurobiology of the emotional adolescent."

[97] Ken Ginsburg, "How Teens Make Decisions: The Developing Adolescent Brain," Center for Parent and Teen Communication, September 4, 2018, parentandteen.com/how-teens-make-decisions/; Jay N. Giedd, "The Amazing Teen Brain," Scientific American, May 1, 2016, www.scientificamerican.com/article/the-amazing-teen-brain/.

[98] Carrie L. Masten et al., "Neural correlates of social exclusion during adolescence: understanding the distress of peer rejection," *Social Cognitive and Affective Neuroscience* 4, no. 2 (June 2009): 143–157, doi.org/10.1093/scan/nsp007.

[99] Underwood, "Teens can have excellent executive function."

[100] *Id.*

[101] Deak, *The Owner's Manual*, 48.

[102] *Id.*, 37.

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Ideally, during this period of social and brain development adolescents move from being totally reliant on their families to being reliant on their peer group's influence to becoming reliant on themselves and more independent. Like addiction, other external influences like stress and adverse childhood experiences can impact adolescent brain development. Although certain neural pathways might be impacted, therapeutic interventions can help get the brain back on track.

C. Stress

Stress is the internal response the mind-body system creates when experiencing something that the survival brain **perceives** as pressure, a challenge, or a threat. The perception starts in the brain with eyes and ears sending information to the amygdala, which send a distress signal to the hypothalamus, which sends signals to the adrenal glands, which pumps adrenaline into the bloodstream, which raises heart rate, pulse, and blood pressure, and releases blood sugar (energy) into the body.[103]

Although normally thought of in negative terms, stress is simply our system mobilizing energy to respond to the challenge or threat. A stress response temporarily disrupts our internal equilibrium so we can successfully respond. When our inner equilibrium is perturbed and comes back to baseline, this is called ***Allostasis*** (the return to homeostasis after acute stress with the help of stress hormones).[104] Our bodies are wired for this response as a means of survival. A certain level of stress is necessary for brain development while certain types of stress or prolonged periods of stress can interrupt it.[105]

The effect of stress mainly depends on an individual's tolerance to stress, not the actual event causing the stress. Where a person finds themselves on the stress continuum has everything to do with how their system (conscious and unconscious) perceives the situation. Although stress can influence the brain and brain development, it largely depends on several factors including what type of stress an adolescent is experiencing.

The three types of stress are *positive stress*, *tolerable stress*, and *toxic stress*. How these types of stress affect an adolescent's brain development depend on the child's *resilience*.[106]

Positive stress briefly increases the heart rate and causes mild elevations in stress hormones. Positive stress is a normal and essential part of health and human development.

Adverse childhood experiences (ACEs) are a pathway to negative neuro-developmental consequences and social problems.

Tolerable Stress: Tolerable stress causes serious but temporary stress responses. This causes a body's alert systems to be activated and it is usually a result of a more severe and/or longer lasting difficulty such as loss of a loved one or a natural disaster. When tolerable stress activation is for a limited time and buffered by caring adults the brain and organs can recover.[107]

Toxic Stress: Toxic stress, on the other hand, causes prolonged activation of stress response systems in the absence of protective relationships. Toxic stress occurs with strong, frequent and/or prolonged adversity such as physical or emotional abuse, chronic neglect, and addiction. Prolonged activation of the body's natural stress response can rewire parts of the brain, altering activity and influence over emotions and the body.[108] The issue with chronic or prolonged stress is that the brain does not completely recovery and remains in an activated state—it can "disrupt the development of brain architecture and other organ systems, and increase the risk for stress-related disease and cognitive impairment, well into adult years."[109] The good news is that it is possible to develop and build tolerance to stress.[110]

Resilience: A growing body of science and respected research supports the belief that children are both vulnerable and resilient. Even youth and families who face extraordinary stresses, as detailed above, have the capacity for resilience. Research shows that supportive, responsive relationships with caring adults as early in life as possible can prevent or reverse the damaging effects of the toxic stress response. Family conflict and cohesion affected resilience far more than the length or type of abuse people had suffered. The faith community, when assisting in building stronger family dynamics, is trying to build resilience.[111]

103 Harvard Health Publishing, "Understanding the stress response," July 6, 2020, www.health.harvard.edu/staying-healthy/understanding-the-stress-response.

104 Bruce S. McEwen, "Allostasis and Allostatic Load: Implications for Neuropsychopharmacology," Neuropsychopharmacology 22 (2000): 108–124, doi.org/10.1016/S0893-133X(99)00129-3.

105 Harvard University Center on the Developing Child, "Toxic Stress," accessed August 7, 2023, developingchild.harvard.edu/science/key-concepts/toxic-stress/.

106 National Scientific Council on the Developing Child, *Excessive Stress Disrupts the Architecture of the Developing Brain: Working Paper #3*, updated ed. (2005/2014), developingchild.harvard.edu/resources/wp3/.

107 Harvard University Center on the Developing Child, "Key Concepts," accessed August 7, 2023, developingchild.harvard.edu/science/key-concepts/.

108 Brainfacts.org, "Wired for Danger: The Effects of Childhood Trauma on the Brain," video created by Jasmine Purnomo, October 19, 2020, www.brainfacts.org/thinking-sensing-and-behaving/childhood-and-adolescence/2020/wired-for-danger-the-effects-of-childhood-trauma-on-the-brain-101920; Hillary A. Franke, "Toxic Stress: Effects, Prevention and Treatment," *Children* 1, no. 3 (November 2014): 390–402,doi.org/10.3390/children1030390.

109 Harvard University Center on the Developing Child, "Toxic Stress."

110 Harvard University Center on the Developing Child, "Key Concepts"; Celina M. Joos, Ashley McDonald, and Martha E. Wadsworth, "Extending the toxic stress model into adolescence: Profiles of cortisol reactivity," *Psychoneuroendocrinology* 107 (September 2019): 46–58, doi.org/10.1016/j.psyneuen.2019.05.002.

111 Ann S. Masten, "2019 Keynote: Ordinary Magic: Advances in Developmental Resilience Science," recorded February 22, 2019 at Miami International Child & Adolescent Mental Health Conference, video, 1:02:20, www.youtube.com/watch?v=YcfWZU2cfp8].

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D. ACEs - Adverse Childhood Experiences Study[112]

This discussion of brain development and stress naturally leads us to a discussion of the Adverse Childhood Experiences Study (ACES). ACES was conducted by Kaiser Permanente where they examined health and social effects of adverse childhood experiences on approximately 17,000 of their members. They asked participants to answer a series of questions about 10 types of adverse childhood experiences falling into three categories (abuse, neglect and household dysfunction). Participants were asked about three forms of abuse: physical, emotional, or sexual abuse; two types of neglect: physical or emotional neglect; and five types of "household dysfunction": witnessing domestic violence, growing up with substance abusing or mentally ill household members, parental separation or divorce, or having a household member sentenced to prison. What they found was that the higher the ACE score, the more likely the person would suffer negative health and social complications (smoking, chronic lung and kidney disease, shorter-lifetime/pre-mature mortality, alcoholism and drug addiction, teenage pregnancy and fertility complications, likelihood to be raped). Health consequences were found to include obesity, diabetes, depression, suicide attempts, STDs, heart disease, cancer, stroke, COPD, and broken bones. Higher ACEs scores led to behaviors like smoking, alcoholism, and drug use. Furthermore, high ACE scores correlated with low graduation rates, low academic achievement, and lost time from work. In summation, ACEs are a pathway to negative neuro-developmental consequences and social problems.

It is important not to conflate terms such as stress and trauma[113] and ACEs, while recognizing the overlap and interconnectedness of these events on brain function. Stress and trauma are not the same thing and don't affect the brain the same way unless and until the stress becomes toxic and chronic; once that happens, it can affect the region of the brain that helps with safe decision-making, making the person more prone to subsequent health and social problems, similar to a trauma response. Consider this statement from an article in the American Academy of Pediatrics:

> [T]oxic stress limits the ability of the hippocampus to promote contextual learning, making it more difficult to discriminate conditions for which there may be danger versus safety, as is common in posttraumatic stress disorder. Hence, altered brain architecture in response to toxic stress in early childhood could explain, at least in part, the strong association between early adverse experiences and subsequent problems in the development of linguistic, cognitive, and social-emotional skills, all of which are inextricably intertwined in the wiring of the developing brain.[114]

Why is ACES important and what can we learn from ACEs?

The first lesson learned is the importance of preventing ACEs from happening. Dr. Robert Anda summed it up best: "what is predictive is preventable."[115] If we prevent some or most adverse childhood experiences, we can prevent numerous adult health conditions and social problems.

Another lesson is that risky decision-making and lack of discrimination between danger and safety is not always a "bad choice" by a youth exercising free will but a neurological predisposition due to adverse childhood experiences, trauma, or chronic toxic stress.

A third lesson learned, and a positive finding in research, is that risk factors can be offset by protective factors. Safe, stable nurturing relationships are an example of a protective factor. The ABCD study conducted during the pandemic showed regular meal time or family time and open communication with parents were two buffers or protective factors reducing anxiety in adolescents.[116] The presence of one dependable and caring adult can make a difference.[117] This can include trauma-informed professionals working with youth crime victims or justice-involved youth. Safe, stable, and nurturing relationships and environments can have a positive impact on a broad range of health problems and on development of skills that help children reach their full potential.

Conclusion

If you read this article hoping to know when precisely a teenager's brain was sufficiently mature: I'm sorry. That answer is not available . . . yet. According to researcher Leah Somerville,

> "[t]here is little agreement among basic scientists on what properties of a brain should be evaluated when judging whether a brain is mature. This lack of consensus could reflect the fact that most neuroscientists are typically focused on the "journey"—the temporal unfolding of a particular development process—more than when a brain reaches a particular "destination."

It will not come as a surprise to learn that nurture and other experiences play a critical role in brain development.[118] Since brain development is strongly affected by interplay between the brain and the environment, teens are strongly affected by interactions with parents, peers, teachers, and community members. Juvenile justice partners, including prosecutors, can and must look for ways in which their communities can build and expand opportunities for teens to engage in activities that will positively impact their

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[112] National Center for Injury Prevention and Control, Division of Violence Prevention, "Adverse Childhood Experiences (ACEs)," last reviewed June 29, 2023, www.cdc.gov/violenceprevention/aces/; ACE Interface, Master TrainerEducation, www.aceinterface.com.

[113] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders*, 5th ed. (2013), psycnet.apa.org/record/2013-14907-000. The *Diagnostic and Statistical Manual of Mental Disorders* provides the following threshold definition of trauma as Criteria A of post-traumatic stress disorder: "The person was exposed to: death, threatened death, actual or threatened serious injury, or actual or threatened sexual violence, in the following way(s): direct exposure; witnessing the trauma; learning that a relative or close friend was exposed to trauma; indirect exposure to aversive details of the trauma, usually in the course of professional duties (e.g., first responders such as police or medics)."

[114] Jack P. Shonkoff et al., "The Lifelong Effects of Early Childhood Adversity and Toxic Stress," Pediatrics 129, no. 1 (2012): e232–e246, doi.org/10.1542/peds.2011-2663, citing National Scientific Council on the Developing Child, *Excessive Stress Disrupts the Architecture of the Developing Brain.*

[115] Tian Dayton, "ACE's Adverse Childhood Experiences: A Message from Dr. Robert Anda and Oprah Winfrey," Thrive Global, March 28, 2018, medium.com/thrive-global/aces-adverse-childhood-experiences-a-message-from-dr-robert-anda-and-oprah-winfrey-26654844ddc9.

[116] ABCD Research Consortium, "About the [Adolescent Brain Cognitive Development (ABCD)] Study," abcdstudy.org/about/.

[117] Dayton, "ACE's Adverse Childhood Experiences."

[118] Thumbs Down. Speak Up., "The Adolescent Brain, Neuroplasticity, and Social Media," September 15, 2022, tdsu.org/news/the-adolescent-brain-neuroplasticity-and-social-media/.

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growing brains, and re-examine each point of contact or interaction with adolescents to ensure that developmentally appropriate responses are in place.[119]

[119] ACT4JuvenileJustice, *Adolescent Brain Development & Juvenile Justice.*

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