The Teen Brain: Still Under Construction

NATIONAL INSTITUTE OF MENTAL HEALTH
The research has turned up some surprises, among them the discovery of striking changes taking place during the teen years. These findings have altered long-held assumptions about the timing of brain maturation. In key ways, the brain doesn’t look like that of an adult until the early 20s. An understanding of how the brain of an adolescent is changing may help explain a puzzling contradiction of adolescence: young people at this age are close to a lifelong peak of physical health, strength, and mental capacity, and yet, for some, this can be a hazardous age. Mortality rates jump between early and late adolescence. Rates of death by suicide, for example, are highest among 15- to 19-year-olds, and once death by self-inflicted injury occurs, the rate is highest among boys. These findings are among many more surprising discoveries to emerge from the scanning of the human brain. The “Visible” Brain

About the degree of change taking place in the teen brain came from studies in which scientists did brain scans of children as they grew from early childhood through age 20. The scans revealed unexpected late changes in the volume of gray matter, which forms the thin, folding outer layer or cortex of the brain. The cortex is where the processes of thought and memory are based. Over the course of childhood, the volume of gray matter in the cortex increases at a very rapid rate. A decline is expected later on, but the rate of decline in many synapses as an adult. (For an idea of the complexity of the brain, a cube of brain matter, 1 millimeter on each side, can contain between 35 and 70 million neurons and an estimated 500 billion synapses.) Scientists believe that the loss of synapses as a child matures is part of the process by which the brain becomes more efficient. Although genes play a role in the decline in synapses, animal research has shown that experience also shapes the decline. Synapses “exercised” by experience survive and are strengthened, while others are pruned away. Scientists are working to determine to what extent the changes in gray matter on brain scans during the teen years reflect growth and pruning of synapses.

The Changing Brain and Behavior in Teens

One interpretation of all these findings is that in teens, the parts of the brain involved in emotional responses are fully online, and some even more active than in adults, which can part the brain involved in keeping emotional, impulsive responses in check. Sleep is central to physical and emotional health. Night. Along with the obvious effects of sleep deprivation, some researchers report that sleep deprivation can increase impulsive behavior; some researchers find that if a factor in the frequency of sleep, adequate sleep is central to physical and emotional health. and as a result, behavior.

Connections between different parts of the brain increase throughout childhood and well into adult- hood. As the brain develops, the fibers connecting nerve cells are wrapped in a protein that increases the speed with which they can transmit impulses from cell to cell. The resulting increases in speed and efficiency of connections little—like providing a growing city with a fast, integrated communica- tion system—shapes how different parts of the brain work in tandem. Research is finding that the extent of connectivity is related to growth in intellectual capaci- ties such as memory and reading ability. Several lines of evidence suggest that the brain circuitry involved in emotional responses is changing during the teen years. Functional brain imaging studies, for example, suggest that the response to a stressor varies with age; a decline in response amplitude (measured in millimeters on scans) over time is expected in early adolescence. The scans also suggest that different parts of the cortex are involved at different ages. Adolescents involved in more basic functions mature first; those involved, for example, in the processing of information from the senses, and in controlling movement. The parts of the brain responsible for more “top-down” control, controlling impulses, and planning ahead—the hallmarks of adult behavior—are among the last to mature.

What’s Gray Matter?

The details of what behind the increase in gray matter are not yet clear. Gray, or neuronal, matter makes up the cell bodies of neurons, the nerve fibers that project from them, and support cells. One of the features of the brain’s growth in early life is that there is an early blooming of synapses—the connections between brain cells or neurons—followed by pruning as the brain matures. Synapses are the relay stations through which messages communicate with each other and are the basic bricks in the work commuting system of the brain. Already more numerous than an adult at birth, synapses multiply rapidly in the first months of life, numbers peak by about 2 to 3 years, and then many synapses as an adult. (For an idea of the complexity of the brain, a cube of brain matter, 1 millimeter on each side, can contain between 35 and 70 million neurons and an estimated 500 billion synapses.) Scientists believe that the loss of synapses as a child matures is part of the process by which the brain becomes more efficient. Although genes play a role in the decline in synapses, animal research has shown that experience also shapes the decline. Synapses “exercised” by experience survive and are strengthened, while others are pruned away. Scientists are working to determine to what extent the changes in gray matter on brain scans during the teen years reflect growth and pruning of synapses.

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The Visible Brain

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The more we learn, the better we may be able to understand the abilities and vulnerabilities of teens, and the significance of this stage for lifelong mental health.

The fact that so much change is taking place beneath the surface may be something for parents to keep in mind during the ups and downs of adolescence.

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A clue to the degree of change taking place in the teen brain came from studies in which scientists did brain scans of children as they grew from early childhood through adolescence. The scans revealed some unexpected late changes in the volume of gray matter, which forms the thin, folding outer layer of the brain. The cortex is where the processes of thought and memory are based. Over the course of childhood, the volume of gray matter in the cortex increases, but the increases are not linear. Gray matter in the brain doesn’t look like that of an adult until the early 20s. An understanding of how the brain of an adolescent is changing may help explain a puzzling contradiction of adolescence: young people at this age are close to a lifelong peak of physical health, strength, and mental capacity, and yet, for some, this can be a hazardous age. Mortality rates jump between early adolescence and young adulthood. Injuries from accidents account for most of the deaths of children between age 10 and 14. Crime rates are highest among 15-19 year olds. Suicide rates in the early 20s.

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In terms of sheer intellectual power, the brain of an adolescent is a match for an adult’s. The capacity of a person to learn will never be greater than during adolescence. Reproductive hormones shape not only sex-related growth and behavior, but overall social behavior. Hormone systems involved in the brain’s response to stress are also changing during the teens. As with reproductive hormones, stress hormones can have complex effects on the brain, and as a result, behavior.

One interpretation of all these findings is that in teens, the part of the brain involved in emotional impulsivity is in check as are other longstanding changes such as the build-up of gray matter in the cortex.

Connections between different parts of the brain increase throughout childhood and well into adulthood. As the brain develops, the fibers connecting nerve cells are wrapped in a protein that greatly increases the speed with which they can transmit impulses from cell to cell. The resulting increase in connectivity—a little like providing a growing city with a fast, integrated communication system—shapes how well different parts of the brain work in tandem. Research is finding that the extent of connectivity is related to growth in intellectual capacities such as memory and reading ability.

The details of what is behind the increase in gray matter are still not completely clear. Gray matter is made up of the cell bodies of neurons, the nerve fibers that project from them, and support cells. One of the features of the brain’s growth in early life is that there is an early blooming of synapses—the connections between brain cells or neurons—followed by pruning as the brain matures. Synapses are the relay stations that connect neurons. Synapses “exercised” by experience survive and are strengthened, while others are pruned away.

A spectrum of change.

Connections to brain ever labs in the regulation of sleep that may contribute to teens’ tendency to stay up late at night. Along with the obvious effects of sleep deprivation, such as fatigue and difficulty maintaining attention, inadequate sleep is a powerful contributor to irritability and depression. Studies of children and adolescents have found that sleep deprivation can increase impulsive behavior; some researchers report finding that it is a factor in inadequate sleep is central to physical and emotional health.

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Several lines of evidence suggest that the brain circuitry involved in emotional responses is changing during the teen years. Functional brain imaging studies, for example, suggest that the responses of teens to emotionally loaded images and situations are heightened relative to younger children and adults. The brain changes under- lying these patterns of activity and the signaling molecules that are part of the reward system with which the brain motivates behavior. These age-related changes shape how much different parts of the brain are activated in response to experience, and in terms of behavior, the urgency and intensity of emotional reactions.

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These findings have altered long-held assumptions about the timing of brain maturation. In key ways, the brain doesn’t look like that of an adult until the early 20s. An understanding of how the brain of an adolescent is changing may help explain a puzzling contradiction of adolescence: young people at this age are close to a lifelong peak of physical health, strength, and mental capacity, and yet, for some, this can be a hazardous age. Mortality rates jump between early adolescence and early adulthood. Injuries between ages 15 to 19 are about six times that of the age 20. The scans revealed unexpectedly late changes in the volume of gray matter, which forms the thin, folding outer layer or cortex of the brain. The cortex is where the processes of thought and memory are based. Over the course of childhood, the volume of gray matter in the cortex increases more quickly than the response time of individuals. A decline in volume is normal at this age and is in fact a necessary part of maturation. The assumption for many years had been that the volume of gray matter was highest in very early childhood, and gradually fell as a child grew. The more recent scans, however, revealed that the high point of the volume of gray matter occurs during early adolescence. 

While the details behind the changes in volume on scans are not completely clear, the results push the timeline of brain maturation into adolescence and young adulthood. In terms of the volume of gray matter seen in brain images, the brain does not begin to resemble that of an adult until the early 20s. The scans also suggest that different parts of the cortex mature at different rates. Adolescents involved in more basic functions mature first: those involved, for example, in the processing of information from the senses, and in controlling movement. The parts of the brain responsible for more “top-down” control, controlling impulses, and planning ahead—the hallmarks of adult behavior—are among the last to mature.

The details of what is behind the increase in gray matter are not yet clear. Genes are not the only ones made up of the cell bodies of neurons, the nerve fibers that project from them, and support cells. One of the features of the brain’s growth in early life is that there is an early pruning of synapses—the connections between brain cells or neurons—followed by pruning as the brain matures. Synapses are the rheas through which neurons communicate with each other and are the basic elic in working circuitry of the brain. Already more numerous than an adult’s at birth, synapses multiply rapidly in the first months. At age 2, the human brain already contains many, many synapses as an adult. (For an idea of the complexity of the brain: a cube of brain matter, 1 millimeter on each side, contains an estimated 100 billion synapses.) Scientists believe that the loss of synapses as a child matures is part of the process by which the brain becomes more efficient. Although a good game of checkers at the age of 2 is as good as an adult can do, at the age of 14, about half of the billions of synapses are pruned. Synapses “exercised” by experience survive and are strengthened, while others are pruned away. Scientists are working to determine to what extent the changes in gray matter are unique to adolescents during the teen years. Functional brain imaging studies, for example, suggest that the response time of individuals. A decline in volume is normal at this age and is in fact a necessary part of maturation. The assumption for many years had been that the volume of gray matter was highest in very early childhood, and gradually fell as a child grew. The more recent scans, however, revealed that the high point of the volume of gray matter occurs during early adolescence. 

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This chapter is an attempt to explore the connections between brain function, development, and behavior. It is not intended to be a prescription or guide for parents, but rather a description of some of the most significant changes that occur during adolescence.

What’s the impact of genetics?

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The details of what is behind the increase and decline in gray matter are too complex to cover adequately here. Gray matter is made up of the cell bodies of neurons, the nerve fibers that project from them, and support cells. One of the features of the brain’s growth in early life is that there is an early pruning of synapses—the connections between brain cells or neurons—followed by pruning as the brain matures. Synapses are the tiny streets on which neurons communicate with each other and are the basic block in working circuitry of the brain. Already more numerous than an adult’s at birth, synapses multiply rapidly in the first few years in all parts of the brain. If you multiply the number of synapses by an estimated 500 billion (500 billion synapses), you reach the number of connections between brain cells that is considered normal in an adult and in a necessary part of maturation.

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The research suggests that adolescence brings with it brain-based changes in the regulation of sleep that may contribute to teens’ tendency to stay up late at night. Along with the obvious effects of sleep deprivation, such as fatigue and difficulty maintaining attention, inadequate sleep is a powerful contributor to irritability and depression. Studies of children and adolescents have found that sleep deprivation can increase impulsive behavior; some researchers find that it is a factor in Attention Deficit Hyperactivity Disorder or ADHD.

One interpretation of all these findings is that in teens, the parts of the brain involved in emotional responses are fully online, or even more active than in adults, while some parts of the brain involved in keeping emotional, impulsive responses in check are still reaching maturity. Such a relationship might provide clues to a youthful appetite for novelty, and a tendency to act on impulse—without regard for risk.

While much is being learned about the teen brain, it is not yet possible to know what extent a particular behavior or ability is the result of a feature of brain structure—or a change in brain structure.

Changes in the brain take place in the context of other factors, among them, inborn traits, personal history, family, friends, community, and culture.
The Adolescent and Adult Brain

It is not surprising that the behavior of adolescents would be a study in change, since the brain itself is changing in such striking ways. Scientists emphasize that the fact that the teen brain is in transition doesn’t mean it is somehow not up to par. It is different from both a child’s and an adult’s in ways that may equip youth to make the transition from dependence to independence. The capacity for learning at this age, an expanding social life, and a taste for exploration and limit testing may all, to some extent, be reflections of age-related biology.

Understanding the changes taking place in the brain at this age presents an opportunity to intervene early in mental illnesses that have their onset at this age. Research findings on the developing brain should help explore and experiment while helping them avoid behavior that is destructive to themselves and others.

Alcohol and the Teen Brain

Adults drink more frequently than teens, but when teens drink they tend to drink larger quantities than adults. There is evidence to suggest that the adolescent brain responds to alcohol differently than the adult brain, perhaps helping to explain the elevated risk of binge drinking in youth. Drinking in youth, and intense drinking are both risk factors for later alcohol dependence. Findings on the developing brain should help clarify the role of the changing brain in youthful drinking, and the relationship between youth drinking and the risk of addiction later in life.

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The Teen Brain:

Teens and the Brain: More Questions for Research

Scientists continue to investigate the development of the brain and the relationship between the changes taking place, behavior, and health. The following questions are among the important ones that are targets of research:

- How do experience and environment interact with genetic preprogramming to shape the maturing brain, and as a result, future abilities and behavior? In other words, to what extent does what a teen does and learns shape his or her brain over the rest of a lifetime?
- In what ways do features unique to the teen brain play a role in the high rates of illicit substance use and alcohol abuse in the late teen to young adult years? Does the adolescent capacity for learning make this a stage of particular vulnerability to addiction?
- Why is it so often the case that, for many mental disorders, symptoms first emerge during adolescence and young adulthood?

This last question has been the central reason to study brain development from infancy to adulthood. Scientists increasingly view mental illnesses as developmental disorders that have their roots in the processes involved in how the brain matures. By studying how the circuitry of the brain develops, scientists hope to identify when and for what reasons development goes off track. Brain imaging studies have revealed distinctive variations in growth patterns of brain tissue in youth who show signs of conditions affecting mental health. Ongoing research is providing information on how genetic factors increase or reduce vulnerability to mental illness or protect against it.
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Understanding the changes taking place in the brain at this age presents an opportunity to intervene early in mental illnesses that have their onset at this age. Research findings on the brain may also serve to help adults understand the importance of creating an environment in which teens can explore and experiment while helping them avoid behavior that is destructive to themselves and others.

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STILL UNDER CONSTRUCTION
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Why is it so often the case that, for many mental disorders, symptoms first emerge during adolescence and young adulthood? This last question has been the central reason to study brain development from infancy to adulthood. Scientists increas- ingly view mental illnesses as developmental disorders that have their roots in the processes involved in how the brain matures. By studying how the circuitry of the brain develops, scientists hope to identify when and for what reasons development goes off track. Brain imaging studies have revealed distinctive variations in growth patterns of brain tissue in youth who show signs of conditions affecting the brain. It is not surprising that the behavior of adolescents would be a study in change, since the brain itself is changing in such striking ways.
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