Inside your teenager’s scary brain

New research shows incredible cognitive potential—and vulnerability—during adolescence. For parents, the stakes couldn’t be higher.

Tamsin McMahon

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Photo Illustration by Levi Nicholson and Richard Redditt.

As the head of a large university neurology department, Frances Jensen studies the mysteries of brain development for a living. But even she frequently found herself baffled by her two teenage sons.

When Jensen, then a Harvard neuroscientist and senior neurologist at two Boston hospitals, was transitioning to single motherhood after a divorce, her eldest son, Andrew, left his “cute little coat-and-tie” elementary school and began attending a liberal high school. Almost overnight, his grades fell. His new best friend wore platform

shoes and had blue hair—it wasn't long before Andrew wanted to dye his hair, too. "He just completely morphed in front of my eyes in a three- or four-month period," says Jensen, who now heads the neurology department at the University of Pennsylvania.

One day her otherwise well-behaved and studious younger son, Will, called to say he had smashed the car trying to squeeze an ill-conceived left turn through oncoming traffic into the high school parking lot.

Other parents might have had more primal reactions. But Jensen spends her days studying how the stages of brain development are associated with age-specific medical conditions—in particular, why some illnesses occur only in infants, while others emerge primarily in children, or older adults. So rather than get angry, she got reading.

The research into the medical mysteries of the teenage brain surprised even Jensen. Conventional wisdom has long held that our brains are largely developed by puberty. However, research in the past 10-15 years has shown that our brains continue to develop in fundamental ways through the teen years and even into the late 20s and 30s. In fact, Jensen argues in her new book, The Teenage Brain: A Neuroscientist's Survival Guide to Raising Adolescents and Young Adults, the teenage years comprise one of the brain's most critical periods for development—likely every bit as crucial as early childhood. "That seven years in their life is, in a way, as important as their first seven years of life," Jensen says. "It is probably one of the most important seven-year [periods] in their entire life."

Emerging brain development science is changing the way we view teen behaviour: why teens can seem so moody and disorganized, why they sometimes make such short-sighted decisions and why many serious mental illnesses begin to emerge in adolescence.

New discoveries are also revealing that teen brains are far more vulnerable than we thought, revelations that are destined to give rise to a new war over how parents, teachers and society should treat teenagers—with more freedom or more rules?

Recent scientific thinking on brain development underscores a fundamental shift, one that is poised to make adolescence, rather than childhood, the latest battleground in the fight to raise a generation of smart, healthy and independent adults.

Photograph by Kourosh Keshiri

The past year alone has seen the release of psychiatrist Daniel Siegel's bestselling book Brainstorm: The Power and Purpose of the Teenage Brain, along with Age of Opportunity: Lessons from the New Science of Adolescence by Temple University psychology professor Laurence Steinberg and the updated re-release of psychologist David Walsh's influential 2004 book on teen brains, Why Do They Act That Way? A Survival Guide to the Adolescent Brain for You and Your Teen.

Among the most popular misconceptions about brain development is the idea that the most important changes happen in the first three years of life. This "myth of three," has been the source of intense parental anxiety over the fear that "adults are in a race against time to provide stimulation to their infants before their synapses are lost," writes Paul Howard-Jones, a professor of neuroscience and

education at the University of Bristol in the journal Nature. While parents can breathe a sigh of relief and pack up some of the Baby Einstein toys, an improved understanding of the developing brain carries a growing acknowledgement that teenagers are uniquely susceptible to great risks. Behind the seemingly invincible teenage boy with the booming voice and adult body is a brain that is still incredibly vulnerable to everything from sports-related concussions to mental illness and addiction. New research is uncovering ways in which the activities that so often typify teenage years, such as experimenting with cigarettes and marijuana and alcohol, can lower a teen's IQ or increase susceptibility to mental illness later on. Chronic stress stemming from family violence, poverty or bullying has also been linked to changes in the teen brain that can raise the risk of mood disorders or learning disabilities. Scientists are only starting to explore those vulnerabilities—and the extent to which they may be permanent.

"The derailment of an adolescent may or may not be reversible and we have to understand it," Harvard psychobiologist Bertha Madras told a Boston medical research conference last summer, asking that a "significant" share of US$4.5 billion in recently announced government funding for brain research be set aside to study teen brain development. Science is only beginning to understand just how crucial the teen years are to the person we ultimately become. "This is an incredible reveal of how much capacity we have that we never really realized we had at this age," Jensen says. "But also that it has a price."

At the heart of our understanding of brain development are two basic concepts: grey matter and white matter. Grey matter consists of neurons, the brain cells that form the building blocks of the brain. White matter, axons, are the connections that form between grey matter, helping to move information from one area of the brain to the next.

While grey-matter growth is indeed almost completely finished by the age of six, white matter—the wiring between brain cells—continues to develop well into the 20s. In fact, says Jensen, that wiring is only about 80 per cent complete by the age of 18.

The last area of the brain to be hooked up with white matter is the prefrontal cortex, which controls insight, judgment, self-awareness and empathy—the brain's so-called "executive" functions.

Along with new wiring, the brains of teens and young adults are also undergoing a process called myelination, in which those white-matter connections are being coated in a protective fatty material. Myelin acts as a form of insulation, allowing signals to move faster between brain cells, helping to speed the flow of information in the brain. Since both the wiring to the prefrontal cortex, and the insulation, is incomplete, teens often take longer to access their prefrontal cortexes, meaning they have a harder time making accurate judgments and controlling their impulses. The process of myelination continues into the 30s, giving rise to questions about how old someone must be to be considered to have a fully developed "adult" brain.

At the same time that teens' brains are laying down connections and insulation, puberty has triggered pituitary glands to release hormones that are acting on the limbic system, the brain's emotional centre. The combination of heightened emotions and an underdeveloped prefrontal cortex explains why teens are often prone to emotional outbursts, says Jensen, and also why they seek out more emotionally charged situations, from sad movies to dangerous driving.

Hormones also appear to have a different effect in teens than they do in adults. The hormone THP, which is released by the body in response to stress, has a calming effect in adults, but actually seems to have the opposite effect in teens, increasing stress. It's one reason why teens are prone to anxiety and post-traumatic stress disorder. It's also a good reason, Jensen says, why parents and schools should be sensitive to the problem of bullying.

Along with new wiring, insulation and hormones, teen brains are highly sensitive to the release of dopamine, which plays on the areas of the brain that govern pleasure and helps explain why teens seem to take so many risks.

It’s not that they don’t know any better. In fact, reasoning abilities are largely developed by the age of 15 and studies have shown that teens are as accurate as adults when it comes to understanding if an activity is dangerous. Their brains are just more motivated by the rewards of taking a risk than deterred by its dangers. So even if they know something might be bad—speeding, drinking too much, trying new drugs—they get more pleasure from taking the risks anyway.

Central to our understanding of how teens learn is “pruning”—a period when the brain begins to shed some of the grey-matter cells built up in childhood to make room for the growth of white matter. A long period of grey-matter growth in childhood, followed by vigorous pruning in adolescence, has been linked to higher intelligence, Jensen says.

It’s for this reason that Jay Giedd, an expert in child and adolescent brain imaging at the U.S. National Institute of Mental Health, describes the teen years as a special period of “use it or lose it” for the brain. Brain cells grown in childhood that continue to get used in adolescence form new connections, while those that go unused wither away. It’s also another reason why parents should be anxious about what happens during the teen years—adolescence now appears to be a period that can make or break a child’s intelligence.

A significant consequence of pruning is that IQ, once thought to be fixed for life after childhood, can in fact change dramatically during the teen years.

Photograph by Kourosh Keshiri

British researchers at University College London tested the IQs of 33 teens aged 12 to 16 and then retested them four years later. They found some teens' IQs rose as much as 18 points, the difference between being average and being gifted. They attributed the changes to increases in grey matter in two areas of the brain that govern speech and language, as well as hand movements. In a follow-up study, the same researchers found that changes to verbal IQ were strongly linked to reading abilities in early adolescence, suggesting that changes weren't simply genetic. They recommended that children with dyslexia be given audiobooks so their verbal IQs don't deteriorate as they age.

A study published last year of Swedish teenagers linked a drop in IQ between ages 13 and 18 with a higher risk of developing a psychotic disorder, such as schizophrenia, as an adult.

Schizophrenia appeared to be closely related to a drop in verbal IQ, suggesting it may be related to problems in the brain's development during adolescence. Researchers concluded it was likely caused by genetic factors that affect adolescent brain development, rather

than social or environmental causes. (One common theory suggests that schizophrenia is linked to “overpruning” in the teenage brain.)

Just as teens’ brain development appears to make them highly sensitive to learning new skills, science is beginning to reveal just how vulnerable teens are to learning the wrong things.

Learning is a process of repeatedly exposing the brain to something that stimulates the production of dopamine, which strengthens connections in the brain’s reward centre and helps form new memories. Addiction, therefore, is simply a form of “overlearning” by the brain, Jensen says. That process can be controlled by the prefrontal cortex, but since teens are so primed for learning and have less of an ability to access the prefrontal cortex, they’re also more susceptible to addictions.

What’s more, substance abuse can interfere with brain development in ways that can make teens more vulnerable to mental illness or even lower their IQ. Researchers have shown that students with higher levels of cotinine, a byproduct of nicotine, in their bodies perform worse on cognitive tests. Smoking also seems to be related to less-active prefrontal cortexes in teens and appears to damage parts of the brain that produce serotonin, and lower levels of seratonin are linked to depression.

Other studies have linked smoking in teens to alcohol abuse, which itself has a devastating effect on both memory and intelligence. And it turns out smoking pot may be far worse for the teen brain than previously thought. Recent studies have linked regular marijuana use in adolescence to smaller brain volume and more damage to white matter. Smoking daily before the age of 17 has been shown to reduce verbal IQ and increase the risk of depression. This can be a particular problem for teens with ADHD, who researchers have found are far more likely to abuse both cigarettes and marijuana than other teenagers.

For teens who get a thrill from binge drinking and getting high, the consequences may be dire—and possibly, permanent.

Alcohol, for instance, can affect the developing teen brain in myriad negative ways: causing potentially permanent damage to the hippocampus, which helps the brain form long-term memories, a critical aspect of learning. American researchers have also found that teens who started drinking before the age of 15 were four times more likely to become alcoholics later in life than those who held off until age 21.

That research comes with a warning for parents who think that as long as their teenagers drink at home under supervision, they'll be safe from the temptation to abuse alcohol. Studies have found that the more teens drink at home, the more they will drink elsewhere and the higher their chances are of becoming an alcoholic. (It's one reason Jensen installed a lock on her liquor cabinet).

It's not just drugs and alcohol that can cause long-lasting damage to the teen brain. Chronic stress is also proving to permanently alter brain development, increasing the size of the amygdala, which governs emotions, and reducing the size of the hippocampus. The end result may be a brain that is hard-wired for anxiety, depression and learning disabilities.

As well, studies of video game addicts have shown their brains develop differently: excessive gaming appears to enlarge areas responsible for memory and visual-spacial skills, but shrink areas of the brain responsible for speech, memory, emotions, and areas responsible for inhibiting impulsive behaviour.

In an era marked by the ideological tug-of-war over how best to raise our teenagers, what's a parent to do with this new science of the teenage brain? More rules—an approach exemplified by Yale professor Amy Chua's 2011 Battle Hymn of the Tiger Mother? Or in intervening too much, do parents risk raising teens whose brains never learn how to become an adult—an approach typified by the backlash against "helicopter parenting" and movements like "slow parenting" and "free-range kids."

In Teenage Brain, Jensen puts herself squarely in the camp of the highly involved parent. She encourages parents to proof-read their teen's homework, help them make lists to prioritize their

assignments, watch them as they do schoolwork to see if they're getting distracted and to not be afraid to "sound like a broken record" in reminding teens over and over again about the dangers that could befall them (something Jensen did so often that her sons nicknamed her "Captain Obvious.")

She encourages parents to "be your teen's frontal lobes" and to "try to think for your teenage sons and daughters until their own brains are ready to take over the job."

Jensen argues that it's a parent's job to protect their teens from their own often short-sighted behaviour, while allowing them enough room for "safe failures."

"Your kid doesn't see the fact that if they fail all of their classes in 11th grade they won't be going to the kind of colleges they want to go to, or go to college at all," she says. "That's why you're a parent. That's why they're not off living by themselves. There is a point at which I think you have a moral responsibility to intervene."

In the quagmire of parental advice, it's no surprise that the counterargument to the neuroscience approach to parenting is robust, and passionate. Psychologist Robert Epstein, author of *The Case Against Adolescence: Rediscovering the Adult in Every Teen*, believes that adolescent rebellion has little to do with brain development and lots to do with how society treats teenagers. He argues scientists have it backward: teens don't act out because they have immature brains struggling to navigate an adult world, but because they have adult brains railing against a society that treats them like children. "Put yourself in their shoes," says Epstein. "Why they're stealing your stuff and why their room is a mess is because they have very limited ways in which they can demonstrate their power and their independence and some of them will demonstrate it in destructive and self-destructive ways."

Epstein has six children, including two teens and two adult children. He began changing his views on teen behaviour when he caught his second-oldest son, Justin, then 14, stealing his truck. Esptein hauled him down to the police station to scare him straight. "But inside my head I realized: Wait a minute, he's never gotten into an accident, he's never got a ticket, obviously he knows how to drive," he says. "Why isn't he allowed to drive?" He now parents his middle children differently than he did his eldest, leaving most of the decisions, from whether they're allowed to have dessert, to what courses they should take in school, entirely up to them. "I tell them 'you decide,' " he says, two words he says have completely transformed his relationship with his teenagers. His 16-year-old son now comes home from school and immediately starts doing chores without being asked.

Jensen agrees that the age limits society has placed on adolescents—such as why teens can drive as early as 15, join the military as young as 17, but not vote until 18 and in some provinces not drink until 19–have little to do with brain development science.

Although she prefers to avoid getting into politics, she thinks the trend toward more rules for teen drivers, such as curfews, or bans on cellphone use by teen drivers, but not adults, are heading in the right direction. "We have to understand what they're

developmentally capable of, and gradually introduce things in steps," she says.

Other research is challenging the notion that teens have a less mature and less connected prefrontal cortex and are therefore inherently more impulsive than adults.

At Temple University, Steinberg has used a car-racing video game to show that when teens are alone they perform as well as adults on tasks involving a tradeoff of risk and reward. But when other teens are in the room watching, adolescents tend to make far riskier decisions. Adults show no difference if other adults watch them, suggesting that teen risk-taking is likely social.

BJ Casey, director of the Sackler Institute for Developmental Psychobiology at Cornell University, found that teens could be less impulsive if they were offered rewards. The greater the reward, the longer teens took to make a decision, suggesting that parents trying to control a hot-headed teen might want to offer rewards for good decisions rather than punishing bad ones.

It worked for Jensen. For all of her worries about her own two sons, they survived. Andrew, her eldest, is doing a combined M.D. and Ph.D. at the University of Pennsylvania—his hair is a lovely natural shade of brown, with not a streak of red in sight. And Will is a business consultant with a degree from Harvard. After his car accident, Jensen bought him a "much bigger, safer, uglier car." He hasn't had so much as a fender-bender since. Her children, Jensen says, have started "to occupy the world that we find familiar."

But her happy ending may not belong to us all. "You look at the high school dropout rates and the people that fall off the curve not because of academic reasons, but because of peer pressure or drugs," Jensen says. "It's so sad because this is a time where you can actually make up for your innate weaknesses. We could get so much more out of our teenagers—and who they become later in life, in many cases—if we took a different approach to this window of time."