Spectrum of Change

esearch using many different approaches is showing that nore than gray matter is changing:

- 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.

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 underlying these patterns involve brain centers and 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.

- Enormous hormonal changes take place 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.

- 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. At the same time, behavioral tests, sometimes combined with functional brain imaging, suggest differences in how adolescents and adults carry out mental tasks. Adolescents and adults seem to engage different parts of the brain to different extents during tests requiring calculation and impulse control, or in reaction to emotional content.

- 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 report finding that it is a factor in delinquency. Adequate sleep is central to physical and emotional health.

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, or even more active than in adults, while the parts of the brain involved in keeping emotional, impulsive responses in check are still reaching maturity. Such a changing balance 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 to 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 many other factors, among them inborn traits, personal history, family, friends, community, and culture.

SOURCE 1

http://www.nimh.nih.gov/health/publications/the-teen-brain-still-under-construction/teen-brain.pdf

SOURCE 2

How the Brain Matures

- Birth through age 6: rapid growth; brain reaches 95 percent of its full size
- *Ages 6–10:* connections between different parts of the brain grow stronger
- Ages 10–12: second "growth spurt" of brain and skull
- Teen years:
  - —brain changes dramatically; reorganizes itself
  - —strengthens some connections and eliminates others
  - —parts that control physical movements mature first
  - —parts that control mental processes mature last
- Early 20s: brain begins to look like and function like that of an adult

The human brain changes throughout life. We are born with roughly 100 billion neurons. Connections, or synapses, adapt to include or eliminate connections that are or are no longer useful to us.

SOURCE 3

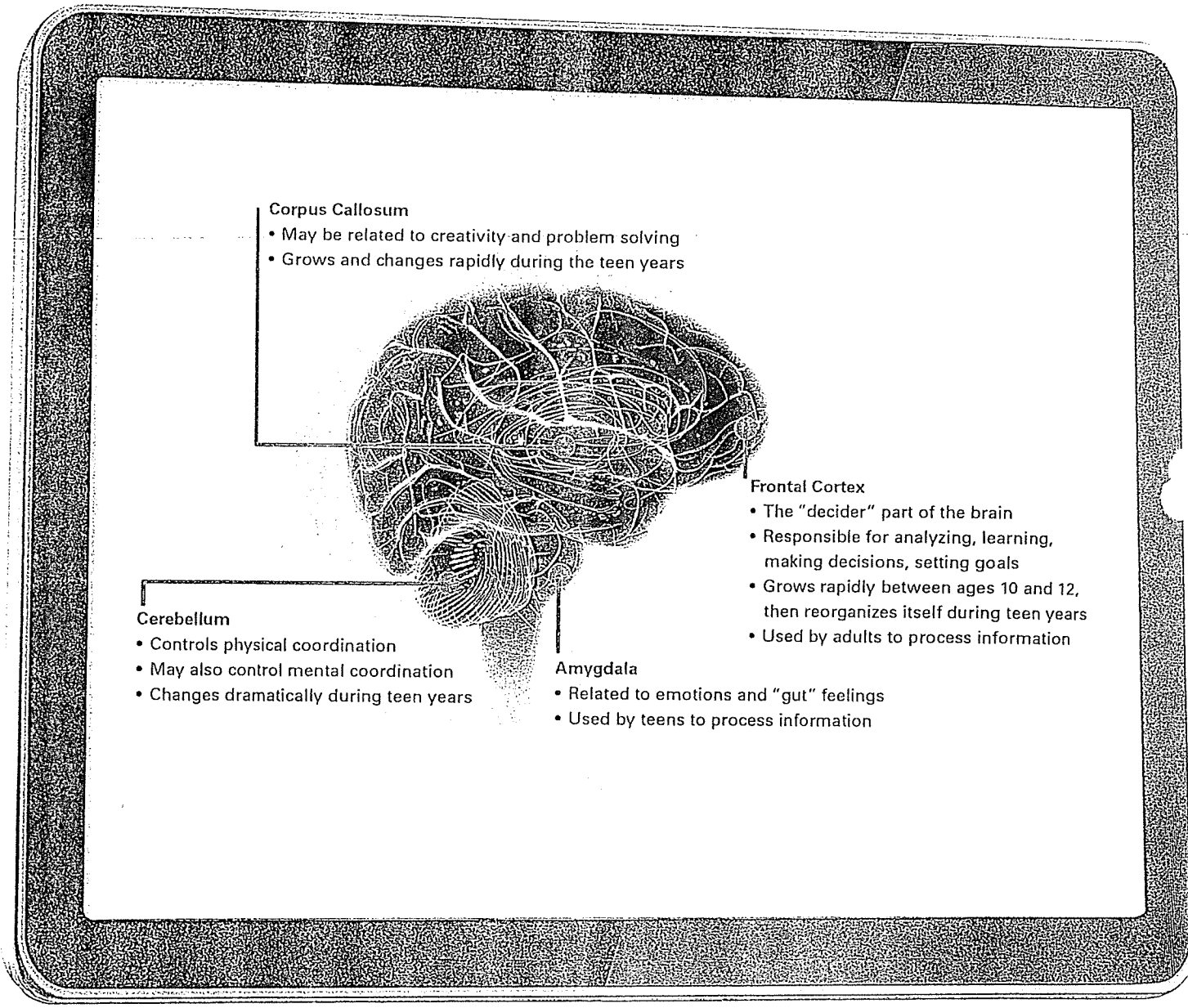
In one study, 10-year-olds, teenagers, and adults were asked to look at a screen while brain scans called MRIs were being taken. When a flickering light appeared on one side of the screen, the subjects were instructed to look in the opposite direction, at the other side of the screen.

The 10-year-olds failed miserably. The teens did better, sometimes as well as the adults. However, the brain scans showed something interesting. It showed that the teens made less use of the part of the brain that manages higher-order thinking. If they were highly disciplined, they could resist the temptation to look at the flashing light. But many gave in.

In the same way, teens are less able to resist looking at a cell phone while driving—or say "no" to a range of other temptations—than adults are. Their brains aren't finished yet.

This isn't necessarily a bad thing. Some scientists point out that the teen's brain-in-progress is the perfect tool for adapting to the big, complicated world into which teens are moving as they gain independence. Taking risks is necessary during this period of life. If the brain adapts to healthy risks, such as learning new skills and meeting new people, the results are happiness, success, and good health. But if the brain adapts to dangerous risks, the opposite results occur.

SOURCE 4



SOURCE 5

GLOSSARY

gray matter material that covers the outer layer of the brain; made up of nerve cells connected by synapses (p. 913)

hippocampus a brain structure that is involved in learning and memory (p. 704)

homeostasis the process of keeping the internal environment of the body stable by making adjustments to changes in the e[illegible]environment (p. 924)

SOURCE 6

INDEX

Your Teen's Brain

By Melissa Brown, M.D.

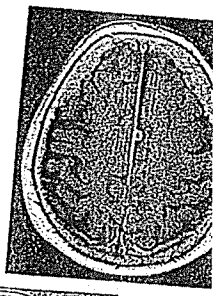
Scientists have long known that before a baby is born and for the first months of life, the brain grows rapidly. But with the help of new brain-imaging technology, scientists have recently learned something else about the brain: between the ages of about 11 and 24, the brain reorganizes itself in major ways. It isn't growing, but it's getting remodeled and rewired. It strengthens the synapses, or connectors, that are used more often and gets rid of those that aren't.

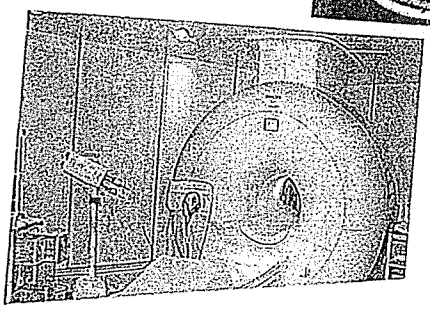
These facts suggest that teens take risks because their brains are "in process." They also suggest that how teenagers use their brains may shape their brains for life. Scientists agree, however, that the best thing for teen mental health is strong, loving relationships with parents and friends.

SOURCE 8

How MRIs Work

Scientists learned what they know about the teen brain from a technology called Magnetic Resonance Imaging (MRI). In an MRI, special machines scan the brain and make images. In the images, parts of the brain that are performing certain tasks "light up." Scientists can take images of the same brain over time and compare the images with each other. These comparisons show what parts of the brain are more or less active at different ages and times.





SOURCE 7

Wavesandlequeeesneg.com

"OUR LEADING HYPOTHESIS . . . IS THE 'USE IT OR LOSE IT' PRINCIPLE . . . . IF A TEEN IS DOING MUSIC OR SPORTS OR ACADEMICS, THOSE ARE THE CELLS AND CONNECTIONS THAT WILL BE HARDWIRED. IF THEY'RE LYING ON THE COUCH OR PLAYING VIDEO GAMES . . . , THOSE ARE THE CELLS AND CONNECTIONS THAT ARE GOING TO SURVIVE."

—DR. JAY GIEDD, NATIONAL INSTITUTE OF MENTAL HEALTH

SOURCE 9

SOURCE 10

When mother Jan Hernandez walked in the door one evening, she encountered a stranger. He had dark blue hair and a stud in his nose. He was also wearing black eyeliner.

On closer inspection, she realized this "stranger" was her son, Jace. Over the past month or so, Jace had begun sulking and spending time locked in his room. But Jan hadn't begun to worry. She'd thought all teenagers were moody.

But when she saw Jace's new "look," alarms went off in her mind. What kind of trouble was her son in? Why was he acting so strange?

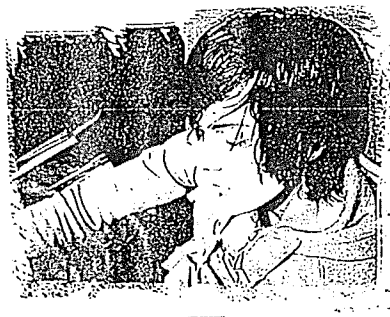
On her lunch break that day, Jan did some online research. She learned that the logical part of the brain—the part that asks, "Is this a good choice? How will it affect me and other people?"—is still developing during the teen years. The connections between that part of the brain and the other parts are not fully formed. Nerve signals travel more slowly and have a greater chance of getting lost or fizzling out. Teens tend to make decisions out of a different part of the brain—the emotional part.

Jan learned that this is why some teens drive too fast or take other dangerous risks. It is also why their actions may seem rude or selfish. Their brains are not wired to think through the possible consequences of a choice on themselves or on others.

Jan also learned that during adolescence, the brain is highly adaptive to both the teen's behavior and his or her environment. If a teen develops a new habit, the brain will strengthen the parts of itself that are needed for that habit. So, if a teen is learning to play an instrument, the parts of the brain related to music will grow stronger. If a teen develops harmful habits, other parts of the brain will strengthen, and an addiction may form.

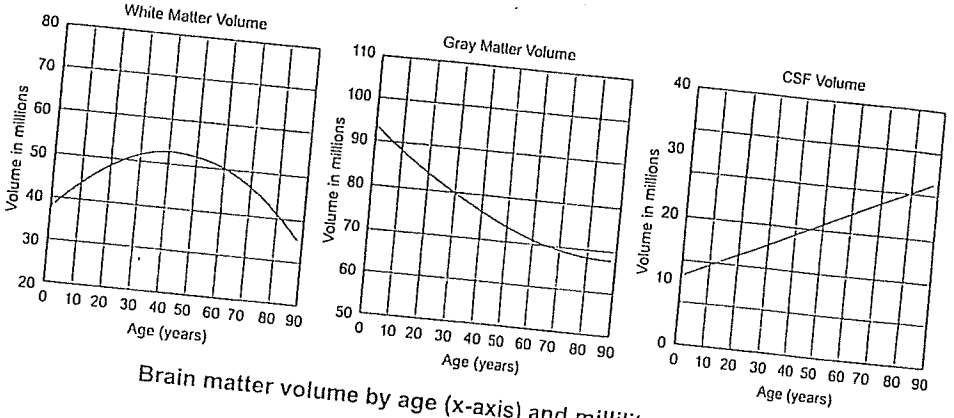
That evening, Jan invited Jace to sit down with her and have a talk. She thought it might help him to know what was going on in his brain. First, she told him that she loved him, no matter what choices he made . . . .

continued on page 82



Teenagers tend to make choices without thinking through the consequences.

SOURCE 12



Brain matter volume by age (x-axis) and milliliters (y-axis)

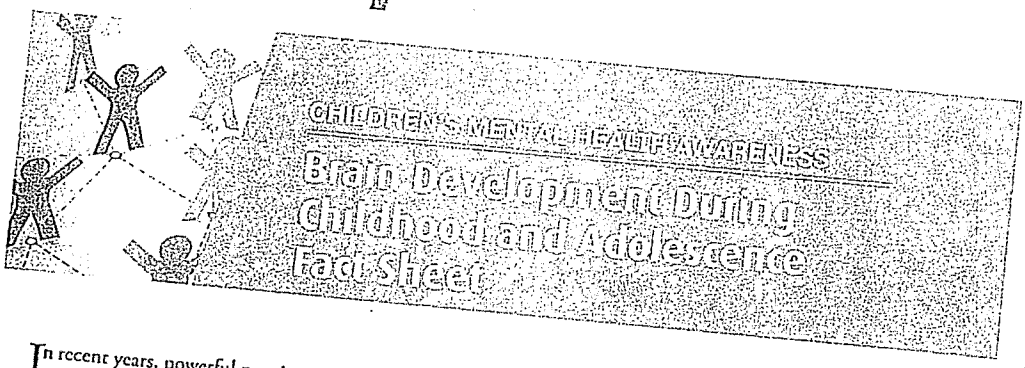
SOURCE 11

SOURCE 14

GLOSSARY

white matter bundles of axons, or long nerve fibers that carry impulses away from cells, that connect the outer layer of the brain with the brain stem; the brain stem, in turn, connects the brain to the spinal cord (p. 913)

SOURCE 13



In recent years, powerful new imaging technologies and other approaches have allowed scientists to track the development of the brain during childhood. These studies offer a way to understand how the intellectual abilities and behavioral maturity of children at various ages are rooted in the developing brain. Studies of the developing brain also offer the best possibility for understanding the origins of mental illnesses. Research suggests that vulnerability to mental illness—and resilience—is rooted in development. Both risk and resilience are shaped by genes and environment interacting together, through childhood and adolescence. Research can show how.

YESTERDAY

- Thirty years ago, it was thought that children did not experience mood disorders like depression.
- In the 1980s and 1990s, national surveys revealed that many adults with mental illness recall having had their first symptoms in youth. Subsequent work confirmed that early signs of psychiatric disorders are often present years before a diagnosis is made.
- Studies tracking the maturation of the brain showed that different parts of the brain grow at different times. There are growth spurts as well as periods of more gradual growth. Imaging studies have also shown that youth diagnosed with mental disorders show patterns of development different than in unaffected youth.
- Research in animals has shown that early experience, including the quality of early parental nurturing, has measurable effects on the brain and later behavior. Early experiences shape how the brain-based stress response system develops and can influence later stress resilience.

TODAY

- Scientists are continually refining imaging techniques to provide more detailed information on brain development, even in very young children. Researchers are tracing how changes in the developing brain underlie milestones in a child's mental and physical abilities and behavior.
- Scientists are conducting studies to determine what individual genes do in the brain and how changes in genes disrupt brain function. Already this work has led to the identification of candidate compounds to correct deficits associated with neurodevelopmental disorders like Fragile X syndrome; clinical trials are underway.
- Research on early childhood stress is showing how early trauma can alter the brain's stress response system and contribute to future risk of anxiety and mood disorders.
- Scientists are also studying how genes that convey vulnerability to stress may increase risk.
- Studies of how the environment can turn genes on and off—a field called epigenetics—are providing clues to how early experience can have lasting effects on behavior, even across generations. Epigenetic changes are likely to be involved in the effects of the environment on development of the nervous system. Knowledge of epigenetic processes may offer targets for the development of new medications.