Adolescents

Phineas Gage

The cerebral cortex consists of four regions called lobes. These lobes control many of your body's functions—from physical activities such as running, to mental tasks such as remembering facts.

The **frontal** lobe is the largest part of the cerebral cortex. As its name suggests, it is located at the front of the brain. Some of the most important functions that your body performs—speech formation, movement, and reasoning—are controlled by the frontal lobe. Your personality traits (the characteristics that make you who you are) and the controls that influence decision making are found in this lobe. Damage to the frontal lobe can lead to changes in social and emotional behaviors.

Just behind the frontal lobe is the **parietal** lobe. The parietal lobe helps you process sensory information, particularly your sense of touch. This can include a physical touch, such as a pat on the back or the warm feeling of the sun on your face. The parietal lobe also enables you to react to the pain of a hot flame touching your finger or stubbing your toe on a rock.

The **occipital** lobe is located at the rear of the brain. It helps you understand and react to what you are seeing. You are able to recognize and identify the things that you see because of your occipital lobe.

The fourth lobe of the cerebral cortex is the **temporal** lobe. It is located in the lower part of the cortex, near your ears. When it's time to listen to spoken words or to any other sounds, you use your temporal lobe to understand what you are hearing. And don't forget that many memories are stored away in a part of the temporal lobe.

Adolescence isn’t an aberration

by Sarah-Jayne Blakemore

1x When I tell people I study the adolescent brain, the immediate response is often a joke—something along the lines of: “What? Teenagers have brains?” For some reason, it’s socially acceptable to mock people in this stage of their lives. But when you think about it, this is strange: we wouldn’t ridicule other age groups in the same way. Imagine if we went around openly sneering at the elderly for their poor memory and lack of agility.

2x Perhaps part of the reason why adolescents are mocked is that they do sometimes behave differently from adults. Some take risks. Many become self-conscious. They go to bed late, get up late. They relate to their friends differently.

3x We now know that all these characteristics are reflections of an important stage of brain development. Adolescence isn’t an aberration; it’s a crucial stage of our becoming individual and social human beings. I find teenage behavior fascinating, but not because it’s irrational, inexplicable—quite the opposite: because it gives us an insight into how natural changes in the physiology of our brains are reflected in the things we do, and determine who we will become as adults.

4x In this book, I want to tell you what we know about the adolescent brain. I will show you how we study the way the brain develops during these years, how that development shapes adolescent behavior, and how it ultimately goes on to define the people we become. This is the time during which much of our sense of ourselves, and of how we fit in with others, is laid down. The development that adolescents go through is central to human experience.

5x So what is adolescence? It’s not a straightforward question to answer. Some people think of adolescence as equivalent to the teenage years. Scientific studies often define it as simply as the second decade of life—this is the World Health Organization definition. On the other hand, many people believe that adolescence should not be tied to a particular chronological age range. The first psychologist to study adolescence as a period of development was Stanley Hall, who at the beginning of the twentieth century defined adolescence as starting at puberty, around 12 or 13 years, and ending between 22 and 25 years. Many researchers today define adolescence as the interval between the biological changes of puberty and the point at which an individual attains a stable, independent role in society. In this definition, the start of adolescence is measured biologically while the end is described socially, and is rather arbitrary. In many industrialized cultures the end of adolescence, defined in this way, is constantly being extended as it has become acceptable for young people to stay in full-time education, and live with their parents, into their twenties or even later. Thus, adolescence in the West is often defined as beginning at puberty, now roughly around age 11 or 12, and ending at some point between the late teens and the mid-twenties. In other cultures, things are very different, and children are expected to become financially and socially independent as soon as they reach puberty. In some of these cultures, adolescence isn’t seen as a period of development and there’s no word for it. Indeed, people often ask whether the concept of adolescence is a recent, Western invention. But it isn’t.

6x There are three main reasons why we can confidently say that adolescence is an important, distinct biological period of development in its own right, in all cultures. First, you can see behaviors that we typically associate with adolescence, such as risk-taking, self-consciousness and peer influence, in many different human cultures, not just those in the West.

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7x A study led by Laurence Steinberg from Temple University in Pennsylvania, and involving scientists from around the world, investigated sensation-seeking and self-regulation in more than five thousand young people from eleven different countries (China, Colombia, Cyprus, India, Italy, Jordan, Kenya, the Philippines, Sweden, Thailand and the United States). Participants aged between 10 and 30 years completed a number of experimental tasks and filled in questionnaires. Two tasks were combined with a questionnaire to provide a measure of sensation-seeking, the desire to seek out novel experiences, which often involves risk-taking. A measure of self-regulation was also taken—that is, the ability to control yourself and make decisions. Not all cultures showed identical developmental trajectories, but there was remarkable similarity across them. Sensation-seeking increased between age 10 and the late teens (peaking at age 19), and then fell again during the twenties. In contrast, self-regulation increased steadily between 10 and the mid-twenties, after which it leveled out. So, while societal expectations differ between cultures, adolescent-typical behaviors can be seen across cultures.

8x The second reason why we can consider adolescence a unique period of biological development is that there is also evidence of adolescent-typical behavior in non-human animals. All mammals undergo a period of development that we can think of as adolescence. There’s a lot of research on this period in mice and rats, which are “adolescent” for about thirty days. Research has shown that, during the month or so of adolescence, these animals take more risks and are more inclined to seek out novel environments than either before puberty or in adulthood. A study published in 2014, carried out by Steinberg and his colleagues, showed that, if given access to alcohol, adolescent mice drink more of it when they are with other adolescent mice; this isn’t the case for adult mice.

9x We come across adolescent-like behavior in animals in all sorts of settings. A newspaper article in August 2016 described an incident in which a woman was attacked by an adolescent wombat. In an interview with the Guardian, Martin Lind, from the Australian wildlife service, had this to say about the creatures:

10x As babies, they’re clingy, they’re adorable, they’re with mum 24 hours a day, they’re in a soft, snuggly sleeping bag all the time listening to a heart beat. When they start to mature and hit puberty, they just hate everybody and everything. They go from running between your legs and cute as a button to being absolute little—can I swear?—little devils They nip you, they wreck, they bite. I won’t look after wombats because you kiss goodbye to your flooring and everything. They just destroy everything.

11x So, adolescent-typical behavior is present across human cultures and across species. And, third, such behavior is also typical across history. One of the earliest descriptions of adolescents I’m aware of is said to come from Socrates (469–399 BC): “The children now love luxury. They have bad manners, contempt for authority; they show disrespect for elders and love chatter in place of exercise.” A hundred years or so later, Aristotle described “youth” as “lacking in self-restraint, fickle in their desires, passionate and impulsive.”

“Horrible Accident” in Vermont

by John Fleischman

1x Ten weeks after the accident, Dr. Harlow declares Phineas fully recovered from his wounds. He puts Phineas in a closed carriage and sends him home to his mother in New Hampshire. Phineas is very weak, but he can walk short distances. He can count, feed and dress himself, and sing. He can speak clearly and make sense of what he hears. Yet there is something odd about the “recovered” Phineas. Just before he leaves Cavendish, Dr. Harlow gives Phineas a little test. The doctor offers Phineas $1,000 for the pocketful of pebbles that Phineas has collected walking along the Black River near town. Dr. Harlow knows that Phineas can add and subtract, yet Phineas angrily refuses the deal. Dr. Harlow tells himself that a man who was so badly hurt is going to need time to regain his full powers

2x As soon as Phineas leaves for home, Dr. Harlow writes a short report for the Boston Medical & Surgical Journal. Most doctors ignore Dr. Harlow’s article. The few who read it don’t believe it. How could a man survive such an injury, let alone make a “complete recovery”? But one Boston doctor is intrigued. He writes to Harlow for information and urges the Vermont doctor to back up his case by collecting formal statements from eyewitnesses in Cavendish. The letter is from Henry J. Bigelow, professor of surgery at the Harvard Medical College.

3x In the spring, Phineas is back in Cavendish, carrying his tamping iron. He never goes anywhere without it these days. Phineas has come for a final examination by Dr. Harlow and to reclaim his old job on the railroad. His left eye looks intact, but the vision has gradually faded away. Phineas has a huge scar on his forehead and a small scar under his cheekbone, but otherwise he is physically healed. Yet Dr. Harlow has private doubts about Phineas’s mental state. Phineas is just not his old self.

4x His old employers on the railroad quickly come to the same conclusion. The new Phineas is unreliable and, at times, downright nasty. He insults old workmates and friends. He spouts vulgar language in the presence of women. He changes his mind and his orders from minute to minute. The railroad contractors let him go. Dr. Harlow, who is keeping confidential notes on Phineas, sadly writes, “His contractors, who regarded him as the most efficient and capable foreman in their employ previous to his injury, considered the change in his mind so marked that they could not give him his place again.”

5x Phineas’s old friends also wash their hands of him. Dr. Harlow writes: “He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires.” Phineas comes up with all sorts of new plans, the doctor writes, but they are no sooner announced than he drops them. Phineas is like a small child who says he is running away from home after lunch and then comes up with a new idea over his sandwich. Dr. Harlow writes, “A child in his intellectual capacities and manifestations, he has the animal passions of a strong man.” A doctor is bound by his oath not to reveal the details of a patient’s condition without permission, so Dr. Harlow will keep his observations to himself for twenty years.

6x Meantime, Dr. Harlow has another letter from Dr. Bigelow at Harvard, who thanks him for

Putting Phineas Together Again

by John Fleischman

1x Unfortunately, Phineas is not the only person to have suffered damage to the frontal cortex. Antonio and Hanna Damasio, a husband-and-wife team of doctors, regularly see people who remind them of Phineas Gage. The Damasios are renowned brain researchers at the University of Iowa Hospitals & Clinics in Iowa City and treat patients with the same kind of frontal lobe damage that afflicted Phineas. Like Phineas, these patients with frontal lobe damage have trouble making decisions. Like Phineas with his $1,000 pebbles, they perform well on logic and math tests but make strange choices in trading situations. Their emotional responses are unpredictable. They seem out of step emotionally with the rest of the world.

2x The patients who come to the Damasios' clinic are not victims of blasting accidents. Their brain injuries usually follow surgery to remove a tumor from deep inside the frontal cortex. This kind of brain surgery is strictly a last resort to save a patient's life, because even if the operation goes well, the risk of side effects is high. Any damage to the frontal cortex can change behavior and personality forever, as the case of Phineas Gage demonstrates. Sometimes, cancer surgeons have no other choice. These cases are not common, but the Damasios have seen a dozen patients with many of the same symptoms as Phineas. All have frontal cortex damage. All have trouble making decisions on personal or social matters. All react with little empathy and seem to find emotion a foreign language.

3x To study these modern-day Phineases, the Damasios have far more sophisticated equipment than Dr. Harlow did. They have the full arsenal of CTs and MRIs—noninvasive brain scanners that can electronically "slice up" a brain and lay it out, level by level, like the floor plan of a house. But the Damasios also do simpler tests. Emotional response is difficult to measure, but there is one usually reliable sign of how you are feeling—sweaty palms. When your emotions are "aroused," your skin (all over and not just your palms) gets slightly warmer and slightly sweatier. Your sweat contains salts, which increase electrical conductivity. A person having a strong emotional reaction is going to "spike" a conductivity meter. It's the same principle used in the police "lie detector" test, only the Damasios are interested in a different sort of truth.

4x Hooked to a skin response machine, the modern-day Phineases are shown a series of emotionally charged pictures—a tranquil landscape, a beautiful woman, a severed foot. Their skin reactions are usually the same—nearly flat. The emotional colors of their world seem to have drained away. Another Damasio experiment involves a computer "gambling" game. There are four decks: A, B, C, and D. The decks are rigged. Normal subjects who play the game soon figure out that the C and D decks are better risks than A and B. The modern-day Phineases keep playing A and B, though they can explain to the experimenters mathematically exactly why C and D are better risks. They realize the game is rigged to favor a "slow but steady" strategy against a "risk-all" strategy, but they still play "risk-all." Call them Phineas's rules.

5x So what part of the brain controls this behavior? Dr. Harlow thought he had found the precise location of Phineas's troubles once he had the skull. By then, Phineas's actual brain was long gone, but Dr. Harlow knew enough gross anatomy to calculate that the iron had passed through the very front of the left frontal cortex. His answer was good enough for 1868. It isn't good enough today.

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6x Studying the brain scans of these Phineas-like patients, the Damasios wonder what a brain scan of Phineas Gage himself would have shown. In 1994, Hanna Damasio has an idea of how to construct one retroactively. First she asks Dr. Albert Galaburda at the Harvard Medical School to have another look at Phineas's skull in the Harvard medical museum. Under the careful eye of the curators, Dr. Galaburda x-rays, photographs, and remeasures the skull. The results are digitized so the specifics of Phineas's skull can be overlaid onto a three-dimensional computer image of a generic human skull. Back in her lab in Iowa, Hanna Damasio carefully plots the entrance and exit wounds. A line is drawn between their center point to lay out a hypothetical path for the tamping iron. The generic electronic skull is then adjusted to Phineas's specifications. Now Dr. Damasio has Phineas's skull on a computer screen. She can tilt and rotate it in any direction exactly as if she were holding it in her hand.

7x Then she adds the tamping iron electronically. The real one tapers, but the electronic one is represented as a cylinder as big around as the fat end of the tamping iron. Now Dr. Damasio turns to a computer program called Brainvox that is used to reassemble brain scan "slices" into a three-dimensional model. Brainvox fits this electronically scanned brain inside Phineas's electronic skull.

8x The brain is a very small place, and a very small change in the path of the iron would have had very different results. Brainvox calculates sixteen possible paths for the iron to follow through Phineas's head. The anatomical evidence from Phineas rules out nine of these. Dr. Damasio knows that the iron missed his jawbone, lightly clipped the interior arch of his brow, and knocked out one molar but didn't destroy the socket. Any path that falls outside those landmarks is out of bounds. Of the remaining seven routes, two would have cut important blood vessels and would have killed Phineas instantly. Brainvox lays out the last five routes. The Damasio team whittles it down to one.

9x Brainvox plots it as a red cylinder passing through the animated computer skull. The top of the skull is open to show the rod emerging from the frontal cortex. It is a riveting image. The scientific journal Science puts Brainvox's images of the pierced skull on its cover and it causes a sensation. Whether you're a brain surgeon or a sixth-grader, the first time you see the Brainvox image of Phineas's head with that red bar through it, you wince.

10x If you study the animated skull from different angles, you can see Phineas's incredible luck. The iron passes through his head at a very steep angle. That's both his salvation and his ruin. It misses a number of key areas on the side and top of the brain. On the left temple, it misses Broca's area for speech. On top, it misses two key sections of the cortex, the motor and somatosensory strips. These areas integrate your sensory input and muscle actions so you keep oriented in space and in motion. Thus Phineas is left with the ability to keep his balance, to focus his attention, and to remember both old and new events.

11x The tamping iron, however, plows on through his frontal lobes, passing through the middle, where the two hemispheres face each other. The iron damages the left hemisphere more than the right, the front of the frontal cortex more than the back, the underside more than the top. Dr. Damasio recognizes the pattern. Phineas's reconstructed brain matches brain scans of her patients who had