



## Putting Phineas Together Again

**I**n our time, Phineas Gage is a textbook case. Students of neurology or psychology study his case because it illustrates how the lobes of the frontal cortex—the two halves of your brain that meet in your forehead—are the seat of “executive functions.” Those are your abilities to predict, to decide, and to interact socially.

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

At last, the true story of Phineas Gage is out in the open. The scientific debate about the brain, though, has moved on. The theories of the Localizers and Whole Brainers are being replaced by a new experimental brain science. In time, the pinpointing of control areas will become more and more detailed. Knowledge of cells in general and neurons in particular will transform understanding of the brain. Yet the truth about Phineas poses a question that no one seems eager to answer. If there are exact locations in the brain that allow for the ability to hear or to breathe, is there a place that generates human social behavior? If that place is damaged, do you stop acting human?

people who remind them of Phineas Gage. The Damasio's 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.

The patients who come to the Damasio's 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 Damasio's 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.

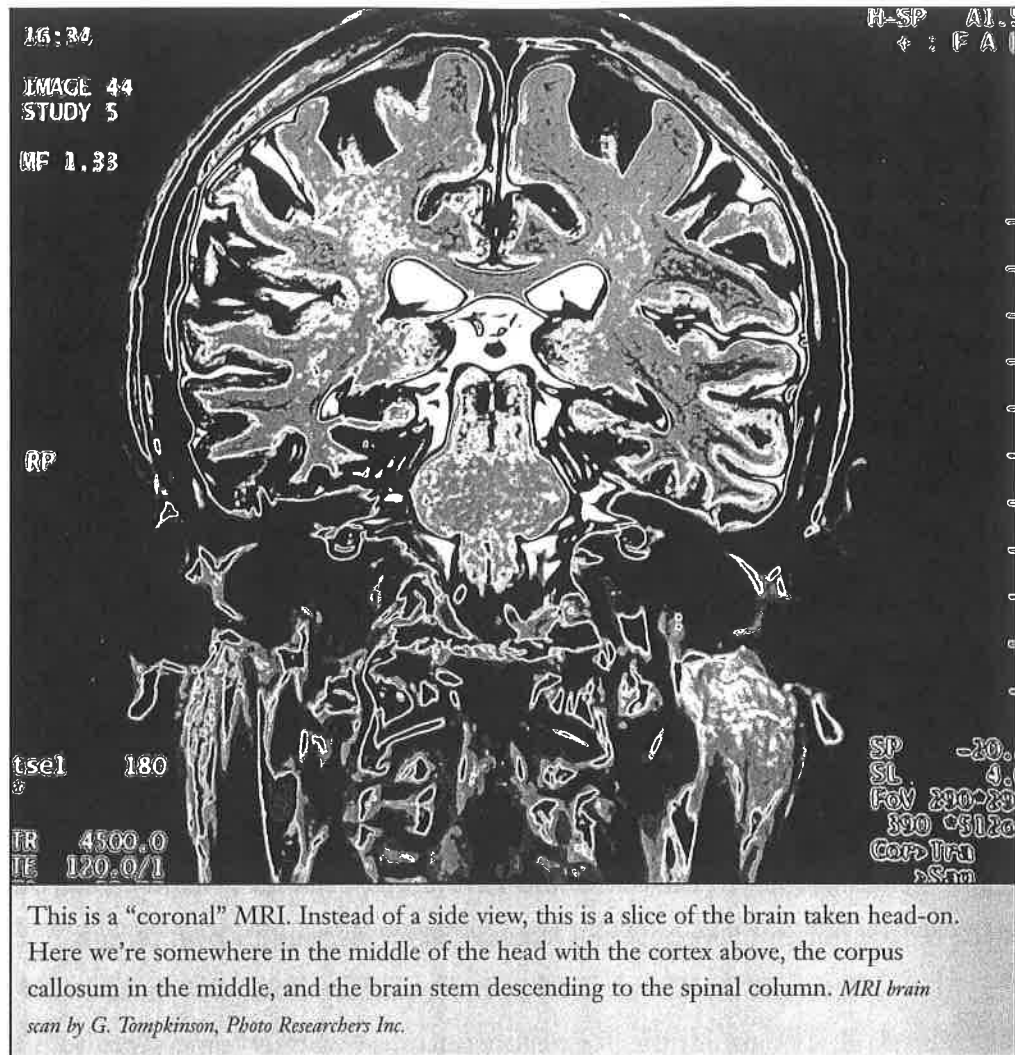
To study these modern-day Phineases, the Damasio's have far more sophisticated equipment than Dr. Harlow did. They have the full arsenal of CTs and MRIs—noninvasive brain scanners that can electronically “slice up” a brain and lay it out, level by level, like the floor plan of a house. But the Damasio's 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 Damasio are interested in a different sort of truth.

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.

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.

Studying the brain scans of these Phineas-like patients, the Damasio 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.

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.

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.

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.

If you study the animated skull from different angles, you can see Phineas's

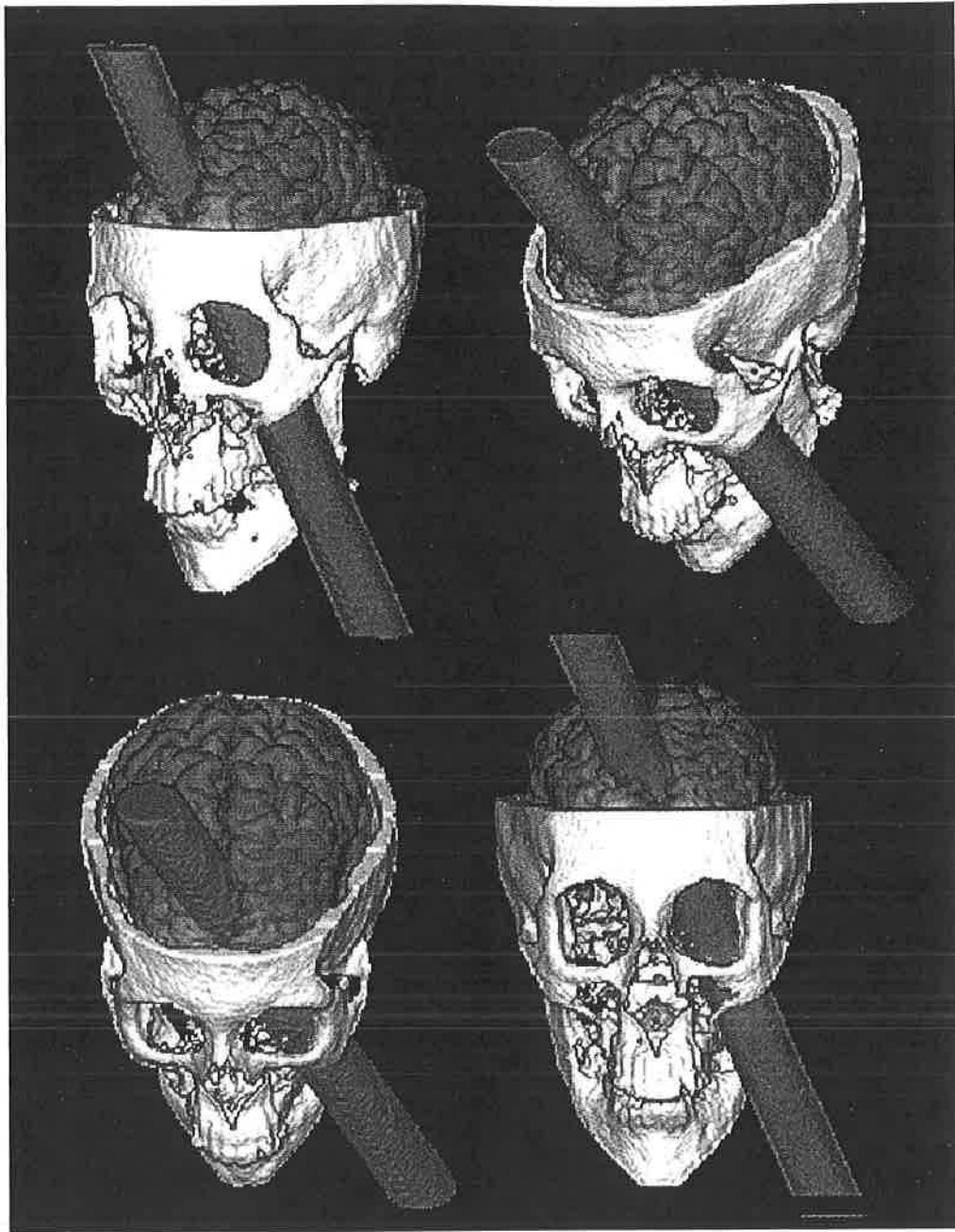
incredible luck. The iron passes through his head at a very steep angle. That's both his salvation and his ruin. It misses a number of key areas on the side and top of the brain. On the left temple, it misses Broca's area for speech. On top, it misses two key sections of the cortex, the motor and somatosensory 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.

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 cortex tumor surgery.

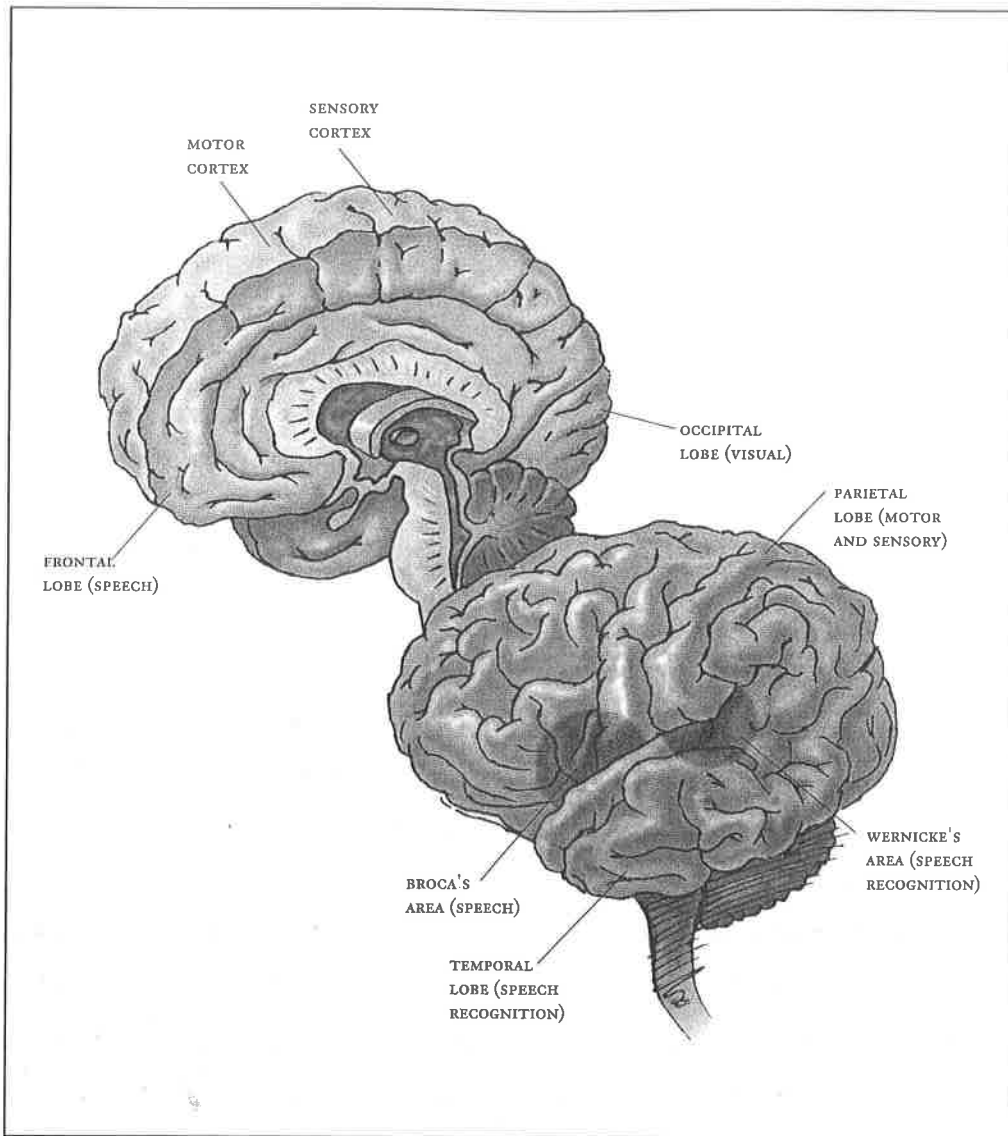
Humans have always argued about what makes us human. Is it our ability to walk on two feet? To hold tools in our hands? To speak and hear language? To worship a supreme being? The case of Phineas Gage suggests that we are human because our frontal lobes are set up so we can get along with other humans. We are "hard wired" to be sociable. When we lose that ability, we end up like Phineas. His closest companion was an iron rod.

The tamping iron and skull of Phineas have a new home at Harvard Medical

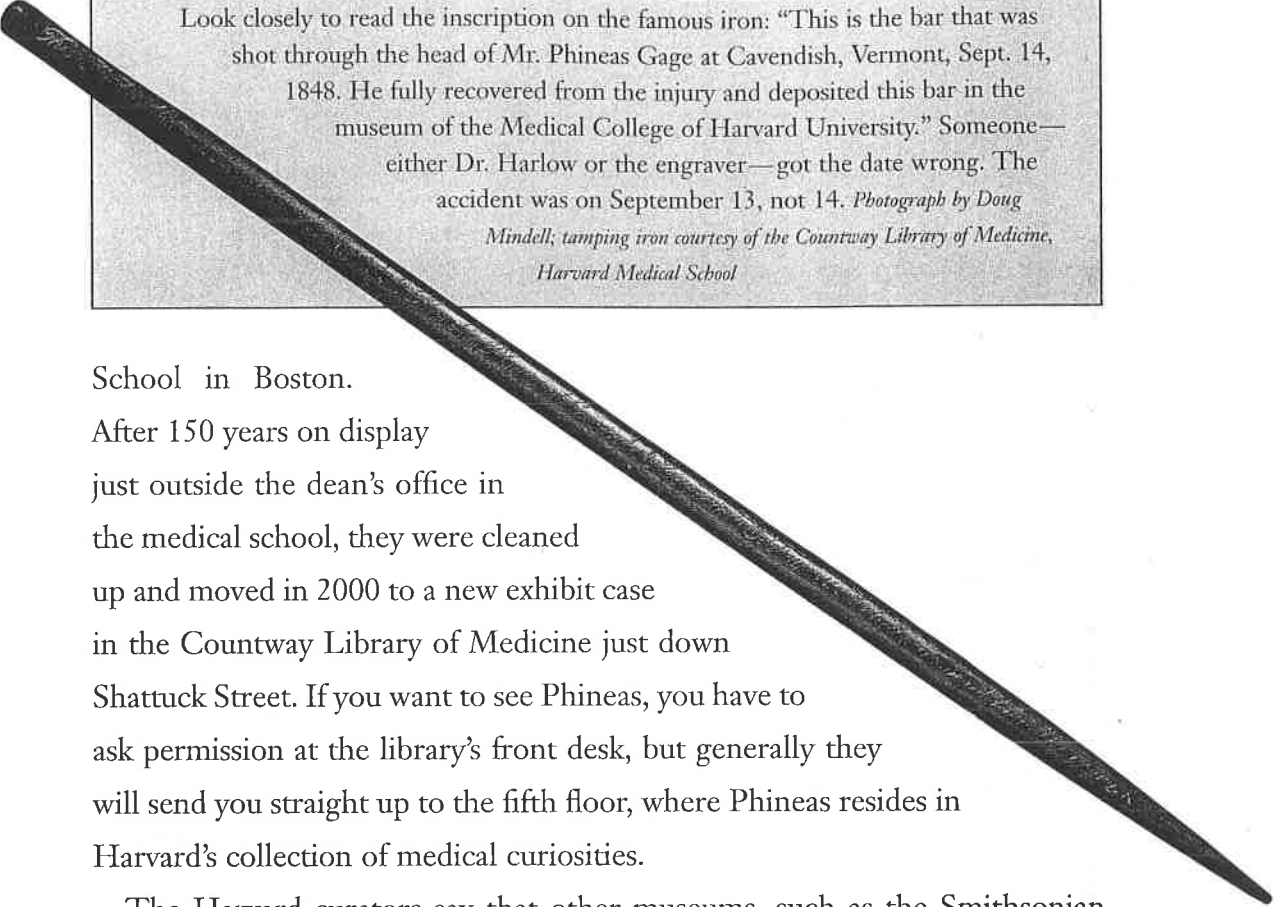
The skull of Phineas Gage appeared on the cover of the journal *Science*. Generated by computer, the red bar plots the exact path of the tamping iron through his frontal cortex. From Damasio, H., Grabowski, T., Galaburda, A. M., "The return of Phineas Gage: Clues from the brain of a famous patient," *Science*, 264:1102-1156, 1994. Department of Image Analysis Facility, University of Iowa. Reprinted with permission of the American Association for the Advancement of Science, copyright 1994







What is so remarkable about Phineas Gage's injury is not only where the rod went in his head but where it did *not* go. The tamping iron missed a number of key areas on either side of the brain that control important functions, including Broca's and Wernicke's areas, plus the motor strip and the somatosensory strip. *Illustration by Jerry Malone*



Look closely to read the inscription on the famous iron: "This is the bar that was shot through the head of Mr. Phineas Gage at Cavendish, Vermont, Sept. 14, 1848. He fully recovered from the injury and deposited this bar in the museum of the Medical College of Harvard University." Someone—either Dr. Harlow or the engraver—got the date wrong. The accident was on September 13, not 14. *Photograph by Doug Mindell; tamping iron courtesy of the Countway Library of Medicine, Harvard Medical School*

School in Boston.

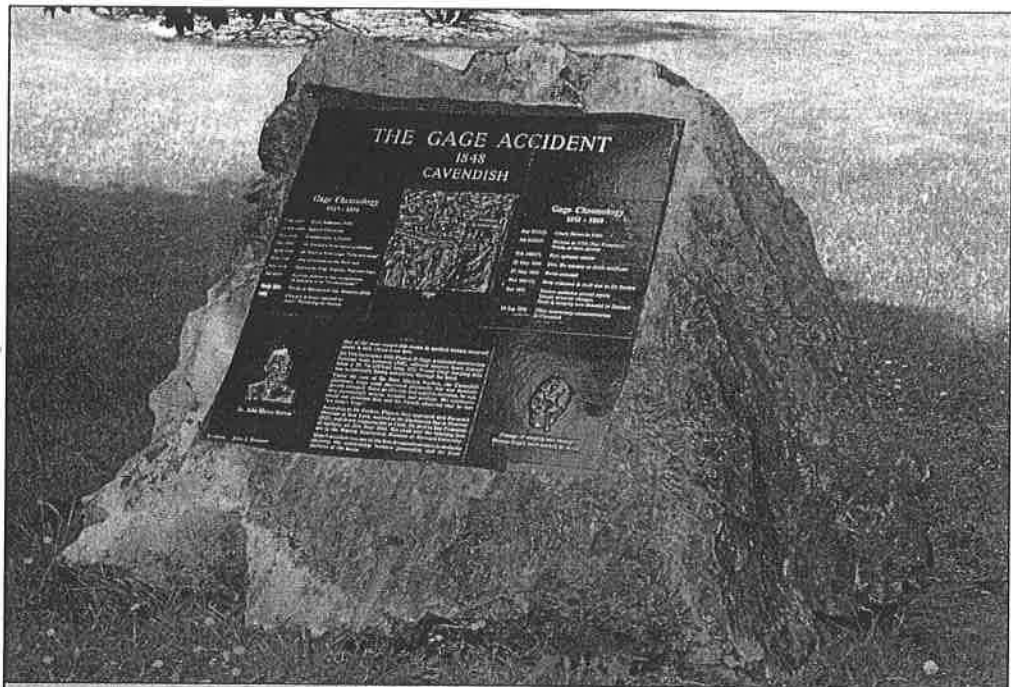
After 150 years on display just outside the dean's office in the medical school, they were cleaned up and moved in 2000 to a new exhibit case in the Countway Library of Medicine just down Shattuck Street. If you want to see Phineas, you have to ask permission at the library's front desk, but generally they will send you straight up to the fifth floor, where Phineas resides in Harvard's collection of medical curiosities.

The Harvard curators say that other museums, such as the Smithsonian Institution, are constantly asking to borrow Phineas's skull and iron, but his traveling days are over. The last time he was lent for exhibit in 1998, he came back with a loosened tooth. That year, Phineas went in the back seat of a limousine to Cavendish, Vermont, for a festival and medical seminar to mark the 150th anniversary of his terrible accident. Psychologists, surgeons, and neurologists came from all over the world to present scientific papers on frontal cortex injuries. Also on hand were men and women in wheelchairs who suffer

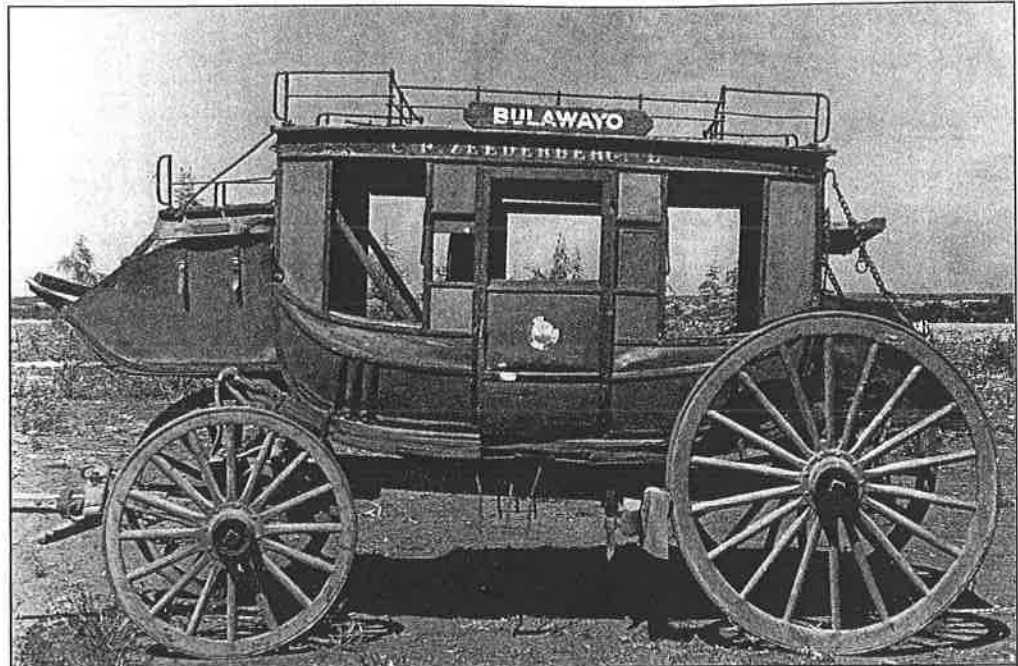
from cortex injury or disease. To these special attendees, Phineas was no specimen or historical curiosity. He was a fellow sufferer.

At the end of the celebration, the town unveiled a boulder of Vermont granite on the village green with a bronze plaque as a permanent memorial to Phineas. If you go to Vermont, you can read it yourself. It explains what happened in Cavendish, what happened to Phineas, and what happened to Dr. Harlow. It explains what happened to our knowledge of the brain as a result.

The plaque does not answer the question of Phineas's luck. I said at the



In 1998, one hundred and fifty years after his terrible accident, the town of Cavendish, Vermont, held a medical seminar and festival to honor Phineas Gage. The climax was the dedication of a memorial plaque explaining what had happened to Phineas and to brain science as a result. *Photograph by Amy Flynn*



This Concord stagecoach ended its days in Bulawayo, Zimbabwe, Africa, far from the New Hampshire factory where it was made. Phineas Gage ended his days in San Francisco, far from New Hampshire, where he was born; far from Vermont, where he was injured; and far from Chile, where he drove a Concord stagecoach like this one. *New Hampshire Historical Society*

beginning that you could decide for yourself what kind of luck he had at the end. This is what I think: Phineas Gage was lucky. His accident was terrible. It changed him into someone else, and yet Phineas figured out how to live as that new person for eleven years. He was limited in ways that are important to all human beings, but he found a way to live, working with horses. He took care of himself. He saw the world. He died with his family around him, the only people who knew both the old and new Phineas. And he drove a six-horse stagecoach. I bet Phineas Gage drove fast.