What We Thought About How We Thought

In the winter of 1850, Phineas goes to Boston so the doctors there can see for themselves. What are doctors like in 1850? They look like gentlemen, or at least they do in the oil portraits that they have painted of themselves to boost their social status. If you lined up a gallery of these doctors' portraits, you'd see a long row of wise faces, satin waistcoats, gold watch chains, and side-whiskers. By 1850, there are photographs of doctors, showing wise faces, satin waistcoats, and whiskers. Photographs of doctors at work, 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.

Meantime, Dr. Harlow has another letter from Dr. Bigelow at Harvard, who thanks him for collecting the eyewitness statements about the accident. Would Mr. Gage consider coming to Boston at Dr. Bigelow's expense so his case could be presented at the medical school and before the Boston Society of Medical Improvement? Dr. Harlow and Dr. Bigelow make arrangements.

though, are rare. Photographing anyone or anything moving is difficult because the light-sensitive plates are very slow, and a single exposure can take a full minute. Yet the year before Phineas's accident, a Boston photographer named Josiah Hawes sets up his camera in a surgical operating theater and takes a "daguerreotype" (a photograph on a metal plate) that he entitles, "Third Operation Using Ether Anesthesia at the Massachusetts General Hospital." The operating room is called the Ether Dome and still exists today.

The picture that Hawes makes is probably the very first of doctors being doctors instead of doctors posing for portraits. In Hawes's photograph, the surgeons stand impatiently beside the operating table, ready to start work. This is truly a historic moment. Before the introduction of ether a few months before, surgeons had to employ powerful assistants to hold down patients or restrain them with leather-covered chains. Because of the discovery of ether anesthesia, the doctors in the Ether Dome can take their time operating.

Notice two things about Hawes's picture. First, it's all men. There are no female hospital nurses, let alone female doctors. The second thing you should notice is what the doctors are wearing—nothing special. They are in street clothes—black frockcoats, shiny satin vests, and linen shirts. No one is wearing surgical scrubs. No one is wearing surgical gloves, masks, or booties. These doctors may not wash their hands until *after* the operation. These men know nothing about bacteria—but they think they know all about the brain.

This is what an audience of doctors looks like when Phineas arrives in Boston in January 1850, tamping iron in hand. He is Dr. Bigelow's guest but also his prize specimen. Phineas is examined, measured, and discussed. He agrees to sit for a plaster "life" mask. Dr. Bigelow puts straws up Phineas's nose so he can

The patient is the one in the cotton gown and wool socks, lying unconscious on the table. Knocked out by inhaling ether fumes, the patient can feel no pain in this state of "twilight sleep." When word of the discovery of anesthesia reached England, a London newspaper rejoiced, announcing, "We Have Conquered Pain." *Massachusetts General Hospital, Archives and Special Collections; print courtesy of Harvard University Art Museums*

breathe while the doctor pours liquid plaster over his face. Then the plaster is lifted off to make a mold. From it, Dr. Bigelow casts a three-dimensional version of Phineas's face. His eyes are shut, but the enormous scar on his forehead is clear.

Phineas appears in person at Dr. Bigelow's lectures to convince the assembled doctors that his case is neither an exaggeration nor a fraud. Dr. Bigelow tackles that question head-on: "The leading feature of this case is its improbability," Dr. Bigelow admits. "A physician who holds in his hand a crowbar, three and a half feet long, and more than thirteen pounds in weight, will not readily believe that it has been driven with a crash through the brain of a man who is still able to walk off, talking with composure and equanimity of the hole in his head. Yet there is every reason for supposing it in this case literally true."

The evidence is standing before them, "crowbar" in hand. Even confronted with that, there are still doctors in the audience who don't believe that the tamping iron went through Phineas's brain. Perhaps, they say, it just hit him a glancing blow on the head. Dr. Bigelow reads out accounts from Dr. Williams and Dr. Harlow. He adds other eyewitness statements from Cavendish people including Mr. Adams, the hotel owner, and some of Phineas's workmen. Dr. Bigelow unveils his plaster life mask of Phineas. The casting clearly shows scars where the iron went in and came out. Yet there are doctors who think that Phineas is a humbug, a fake from the back woods of Vermont.

There are two other groups of doctors paying close attention to Dr. Bigelow's presentation. The two rival groups are eager to believe in Phineas's case. Their theories directly contradict each other, and yet both groups believe that Phineas's case supports their side. As it turns out, both groups are slightly right but mostly wrong. Yet their wrong theories—and Phineas himself—will steer our knowledge of the brain in the right direction.

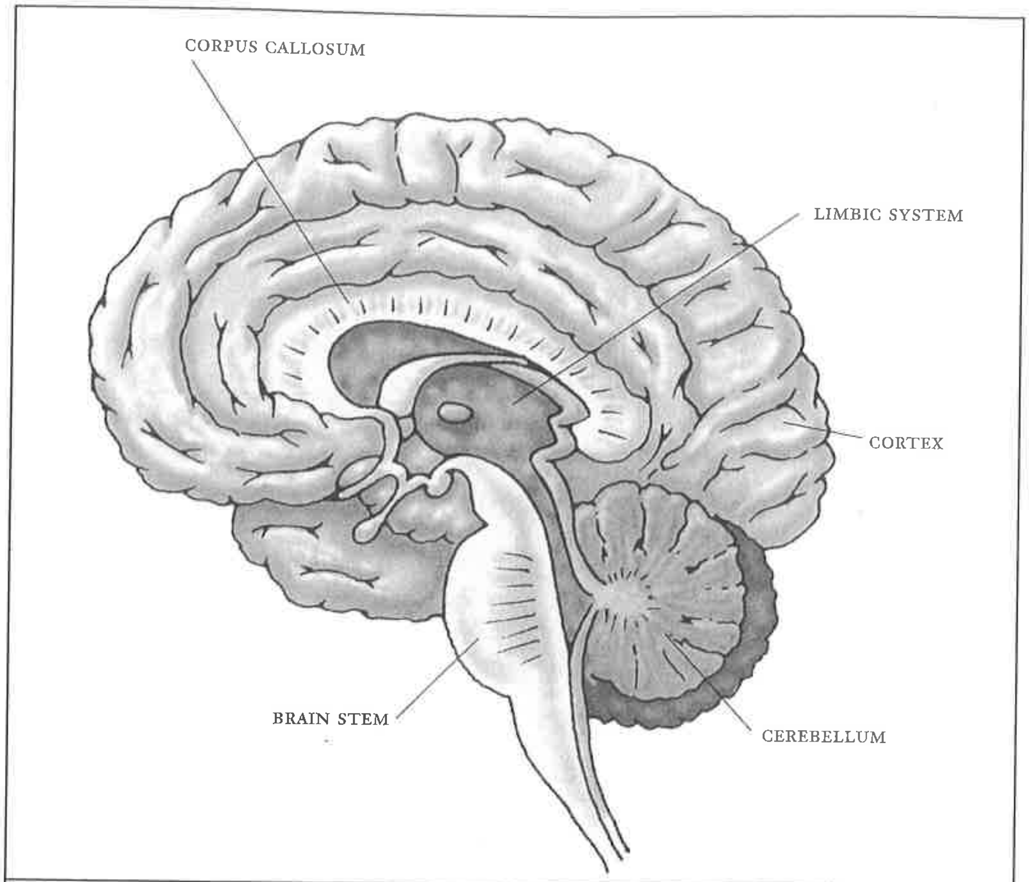
Everybody knows that people use their brains to think. Right? And, of course, emotions, especially love, come from the heart. Wrong? Obviously, our ideas about how the body works have changed. Three hundred years ago, everybody "knew" that anger was controlled by the spleen. Twenty-three hundred years ago, the ancient Greeks "knew" that the heart was the center of emotion and thought.

Aristotle, the greatest scientist of his time, "knew" that the primary function of the brain was to cool the blood. It isn't until 1800 that an Austrian doctor named Franz Josef Gall declares that the brain is the seat of the intelligence, the emotions, and the will. Still, it takes time for new ideas to sink in. Even today, we don't talk about a lover who's been dumped as feeling "broken-brained."

By Phineas's time, doctors know what a brain looks like, at least from the outside. They learn as students of gross (a term for "large-scale") anatomy by dissecting the cadavers of paupers, prisoners, and the unclaimed. By 1850, all doctors know the gross anatomy of the skeleton, internal organs, muscles, and, of course, the brain. They just don't know how the brain works.

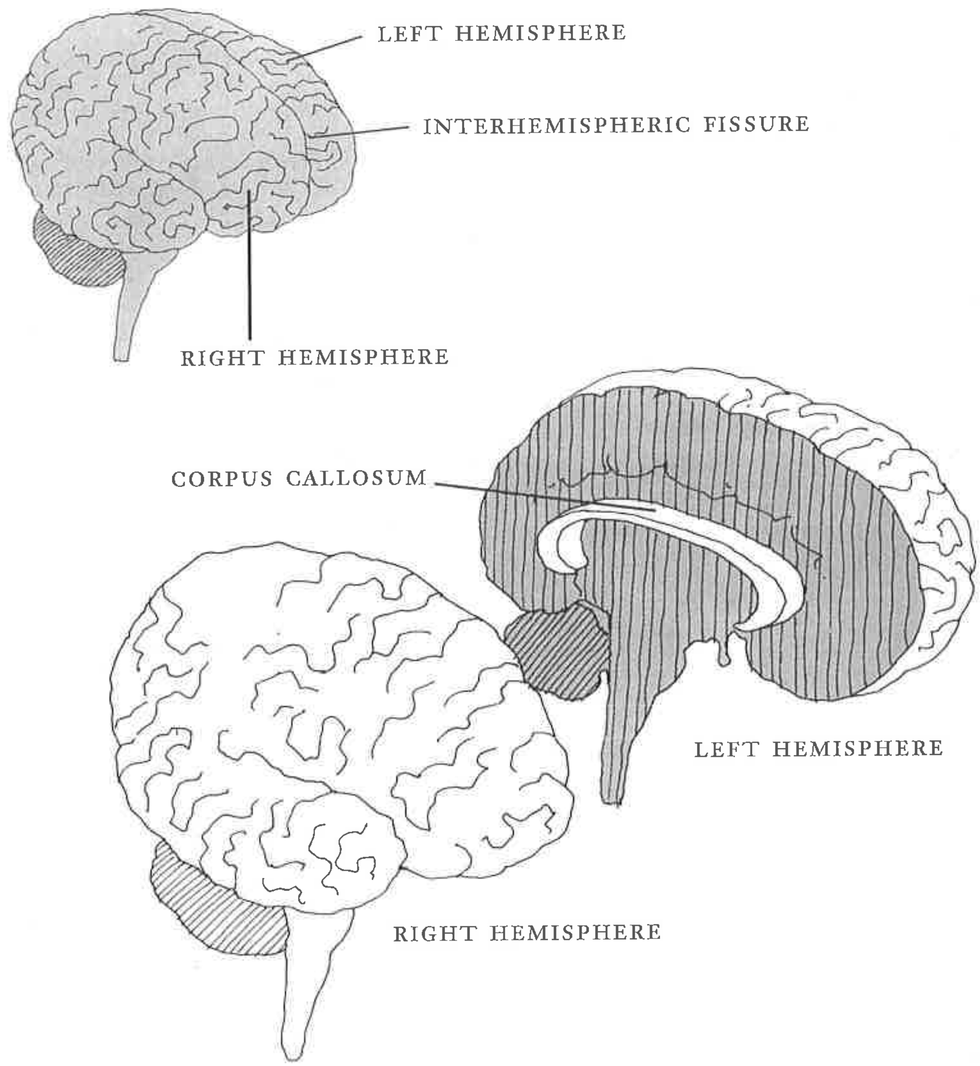
You can have a look for yourself. Imagine you could click open the top of your head and lift your brain out. It weighs about three pounds. Some compare it to half of an enormous walnut, but if you can't visualize a three-pound walnut half, think of a bicycle helmet (bicycle helmets look the way they do so they can surround the brain). Think of your brain as a big cap perched on a stalk and protected by the neck flap. The big cap is your cerebral cortex. The stalk is your brain stem, which plugs into your spinal cord. The brain stem keeps many of your automatic functions going, like your breathing and heartbeat. The neck flap covers your cerebellum, which coordinates movement. Without your cerebellum, you couldn't walk upright, touch your finger to your nose, or turn this page. Without your brain stem, you couldn't breathe. Without your cerebral cortex, you wouldn't be human.

The cortex is where you think, remember, learn, imagine, read, speak, listen, and dream. In the cortex, you feel your emotions and you make sense of what your senses are telling you. The cortex is where you actually see what



This is half a brain. On top and in front is the cortex. In the back and underneath are the cerebellum and the brain stem. On the bottom of the cortex is the limbic system, which coordinates memory, sensation, and emotion. In Phineas's case, the tamping iron passed through the frontal cortex, leaving the rest of his brain relatively unharmed. *Illustration by Jerry Malone*

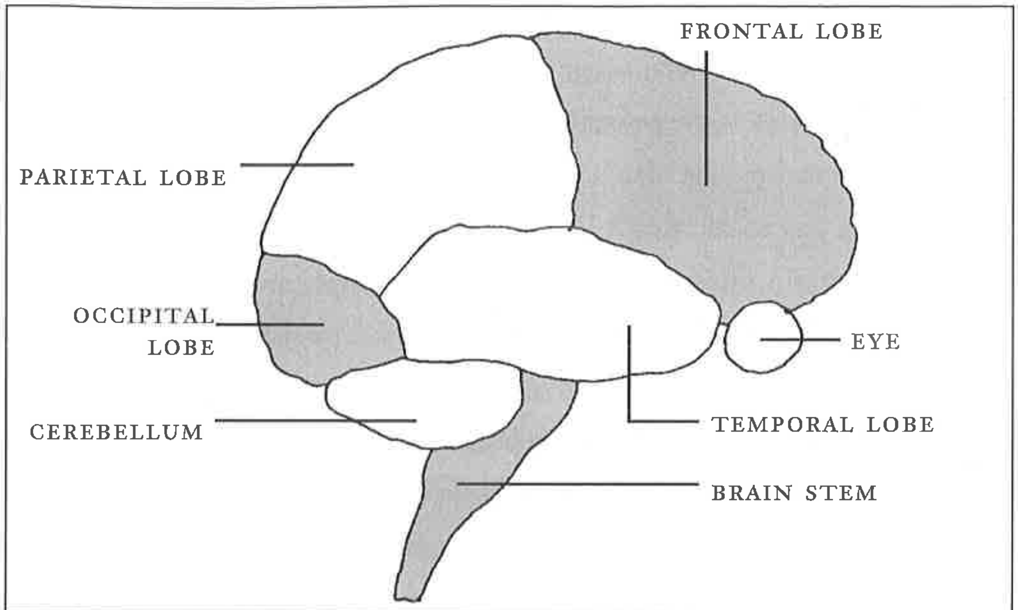
your eyes transmit, smell what your nose senses, taste what your tongue samples, touch what your nerves report, and hear what your ears pick up. None of this vital activity is visible in gross anatomy. By just holding a brain in your hands you (and the doctors of Phineas's day) can't see the thing that makes this



Here you can see the division between the two hemispheres of the cortex. The crack between them is called the "interhemispheric fissure." The two hemispheres specialize in different mental skills, but brain functions are not as neatly divided as they appear. Phineas's tamping iron struck the left hemisphere first but also grazed the right hemisphere on the way out. He lost something from both hemispheres. *Illustration by David Macaulay* organ work, the brain's fundamental unit, which is the brain cell, or neuron. You'll need a microscope and a lot of skill to see a single neuron, but all of these structures—the cortex, cerebellum, brain stem, and spinal cord—are made up of neurons specialized to relay and transmit tiny electrical impulses. By layering and connecting billions of neurons, you get a brain.

But by looking at your brain in your hand, you'll notice that the cortex splits in half right down the middle. The left hemisphere and the right hemisphere are separated on top by a deep crack—the interhemispheric fissure—but joined in the middle of the brain by a thick mat of nerves—the corpus callosum. The corpus is the switchboard for signals back and forth between the two halves. In recent times, scientists have learned that the two hemispheres specialize in certain skills. Sometimes you'll hear brain researchers talk about a "right brain" or a "left brain" skill. They really mean right or left hemisphere. But you can't see any skills by looking at the outside of a brain.

Indeed, if you're looking at your brain from the outside, you might wonder if you're holding the cortex backwards. The front of the cortex seems to be hanging in space until you realize that your face fits the space underneath. The part of the cortex above your face is the frontal lobe. The frontal lobe is the part that concerns us most regarding Phineas, but you should know the other lobes—the parietal lobe on top and the occipital lobe at the back of your head, right above your cerebellum. Wrapping around your temples on the side of your head are the temporal lobes. Each hemisphere has its own frontal, parietal, occipital, and temporal lobes. All together, the cortex is a soft mass of folded nerve tissue. It looks as if your cortex was folded up quickly and stuffed in any old way, but the truth is that every human brain is folded in exactly the



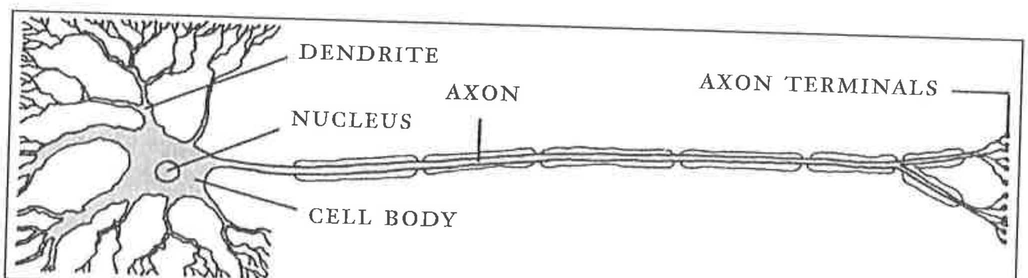
The brain cortex is like a city; every part has an address. Instead of a city's east or west side, the cortex has a left and right hemisphere. The folds and ridges in the hemispheres are like cross streets, and medical students must memorize every one. The cortex also has four lobes —the frontal (in front), the parietal (on top), the occipital (at the back), and the temporal (on the side). A brain "address" can specify left or right hemisphere, the lobe, the nearest ridge or fold, and whether the location is on top or bottom, inside or out, and front or back. Phineas was injured most seriously on the inside of the left frontal lobe, but scientists are still arguing about the exact address. *Illustration by David Macaulay*

same way. How the neurons inside those folds and ridges connect is what makes every human being singular.

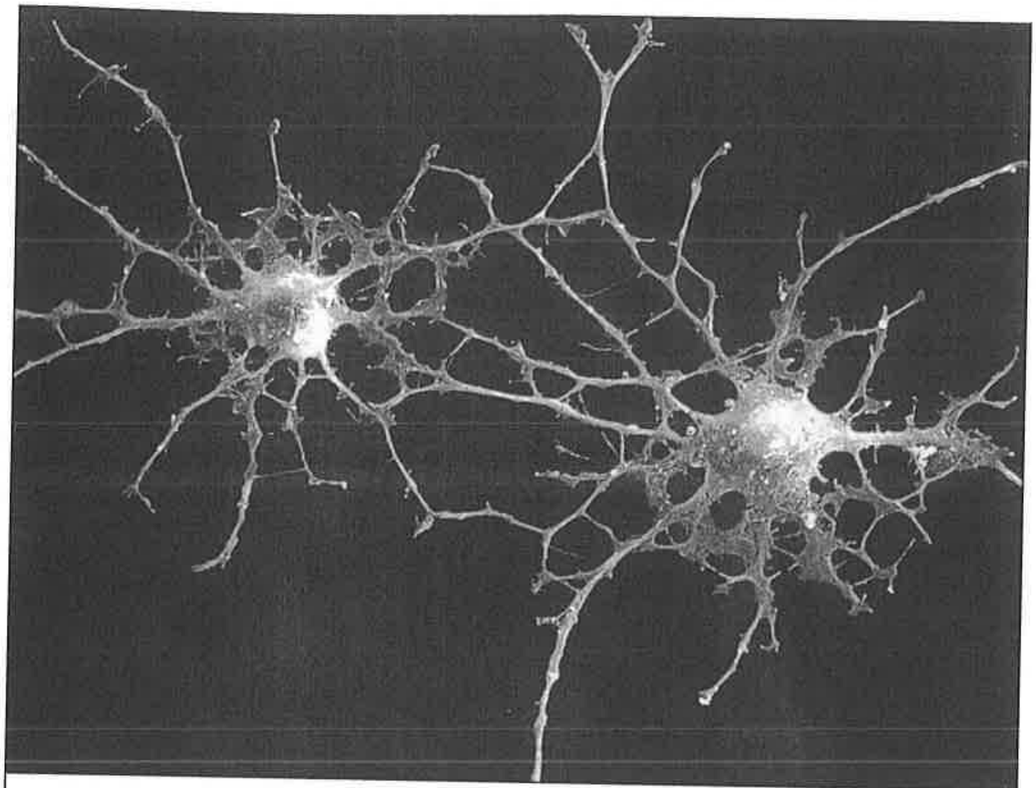
After this tour of the outside of the brain, what you and the Boston doctors in 1850 still lack is a map of the nerve cells. In 1850, the Boston doctors know very little about any kind of cell, even though the cell revolution is getting under way in Germany, thanks to Matthias Schleiden and Theodor Schwann. Working independently, they both revisit the work of Robert Hooke, the microscope observer who came up with the name *cell* in 1665. Hooke, they realize, was seeing empty cork cells because they were dead. Now, for the first time, Schleiden sees living cells in plants. Schwann sees them in animal tissue. Together, they realize that the cell is the fundamental unit of life. Everything alive, from slime molds to human beings, is composed of cells. It is the stuff inside the cell that controls every process of life, from digestion to reproduction.

As a living organism becomes more complex, its cells *differentiate*—that is, they specialize. A line of cells will differentiate and become muscle cells. Another will differentiate and become nerve cells. All complex animals have nerve cells, but no animal has as many nerve cells as humans do. Your brain and spinal cord have about 100 billion neurons.

A neuron is basically a wire with plugs at each end. Unlike most wires, most neurons have many, many plugs so they can both relay messages and switch



The nerve cell, or neuron, is a living, one-way wire with switches at both ends. Messages arrive chemically in the dendrites, where they are converted to electrical impulses, which travel down the axon, the long body of the cell. At the terminal on the far end, signals are converted back into chemical messengers, called neurotransmitters, for the short voyage across the synapse to the dendrites of the next neuron. Amazingly, neurons can work as fast as thought. *Illustration by David Macaulay*



Here two human nerve cells show off their intricate network of axon terminals and dendrites. These connections are so fine that they cannot be seen through a conventional light microscope. A scanning electron microscope (SEM) was used here to capture the details. *SEM photograph by Andrew Leonard, Photo Researchers Inc.*

them. A neuron is a long, skinny cell with a tangle of receivers at one end called dendrites, a long connector called an axon in between, and at the other end a smaller tangle of transmitters called axon terminals. Neurons never actually touch one another or splice together. There is always a tiny gap between the axon terminal of one neuron and the dendrite of the next. The gap is called a synapse. It is bridged by signaling chemicals called neurotransmitters. A message travels as an electrical impulse through the axon, down the body of the nerve cell, to the axon terminal. There the electrical impulse is converted into a chemical neurotransmitter to float across the synapse to the next neuron. Here's where the complications begin. In your brain, your neurons have lots of choices. Your brain has lots of synapses because the neurons are layered and clumped together so that the number of possible connections is huge. Each neuron can have anywhere from 1,000 to 6,000 synapses. That means the 10 billion neurons in your brain and spinal cord have a possible 10 *trillion* synaptic choices to make. Complexity is good. Making synaptic connections is how your brain actually thinks, learns, remembers, acts, and reacts.

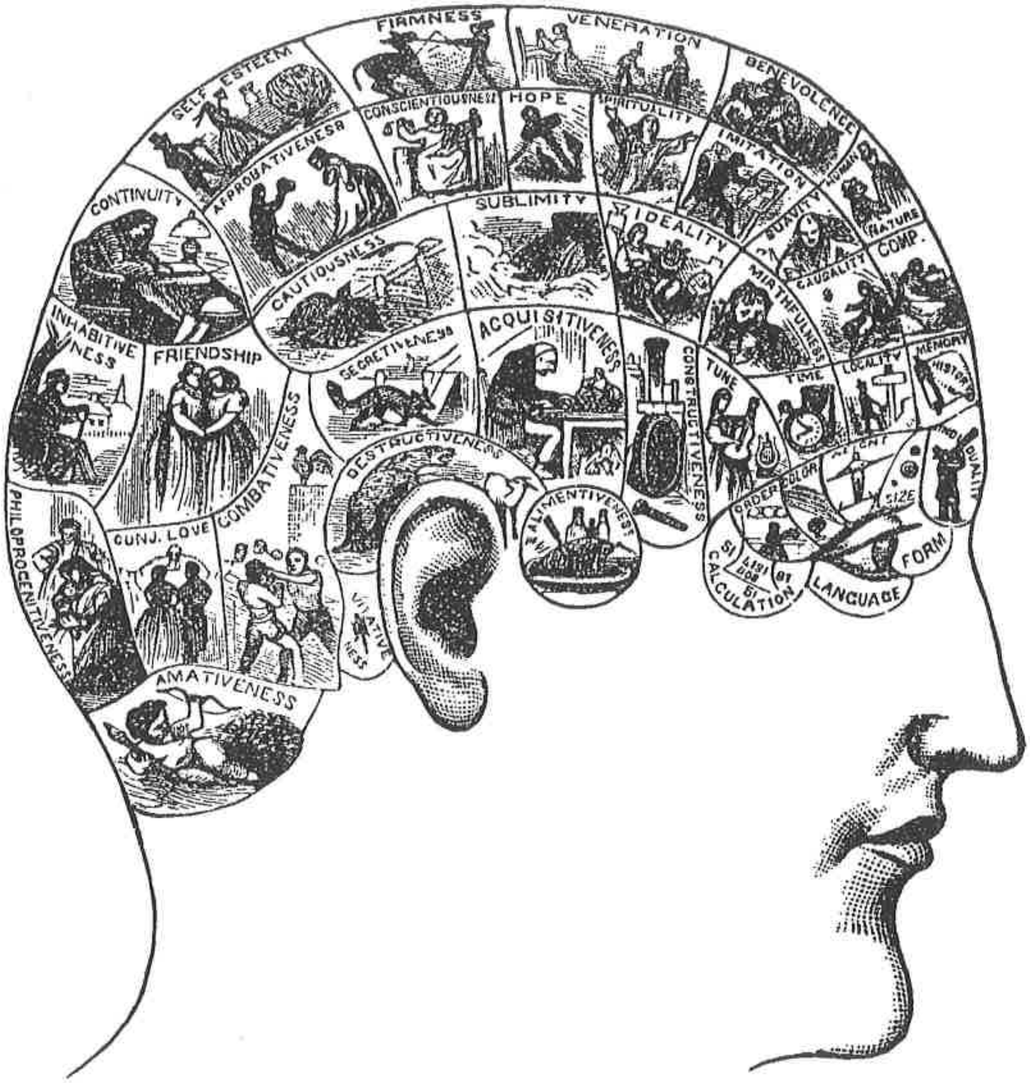
The Boston doctors watching Phineas in 1850 haven't a clue about neurons, which won't be discovered for another twenty years. Still, these doctors know that the brain sits atop the spinal cord, a thick, bundled cable of thousands of threads. Doctors do not know that each thread is a bundle of microscopic neurons. They do know that cutting the spinal cord results in paralysis. The higher the break in the spinal cord, the more complete the paralysis. They know that if the cord is cut at the base of the brain stem, the patient dies.

That's why Phineas interests the doctors. His injury is not at the back of his head in the cerebellum or at the bottom of the brain near the brain stem. He was struck through the forehead, and the iron must have pierced the frontal lobe of the cortex. If Phineas survived with a large piece of his cortex destroyed, then what does the cortex do? Across America and Europe, doctors are fiercely divided over this very question. These are the two rival schools. One group thinks the brain is a "whole intelligence," that is, that your brain is one interconnected "mind." Let's call them the "Whole Brainers." They think of the cortex as a chamber holding a formless cloud or jelly driven by a mysterious "vital force." Through this force, every part of the brain is connected to every other part. The Whole Brainers believe that thoughts and commands can originate anywhere in the brain jelly/cloud and flash into action. If one part of the brain is injured, then the functions or thoughts that came from there will flow to another part.

Unfortunately, the Whole Brainers have no hard evidence for their theory. Instead they must look for unusual cases that might back them up. Phineas seems to be such a case. Dr. Bigelow of Harvard thinks so. He is a Whole Brainer.

His opponents believe in "localized function"; that is, they believe that the brain is divided into specific areas that control specific things. Let's call them the "Localizers." They are followers of the Austrian Dr. Gall, who started the brain revolution by declaring that the brain was the seat of intelligence, emotions, and will. Dr. Gall called his brain science "phrenology" (a made-up Greek word). By any name, the Localizers, or Phrenologists, believe that "organs" inside the brain control specific functions. They draw up a model Phrenological Head to show the "organs" in their correct positions. The "Organ of Veneration [respect]" and the "Organ of Benevolence [kindness]," for example, are supposed to be just above the left eyebrow. (Remember where Phineas was hit by the iron? Stay tuned.) Unfortunately, the Phrenologists have no way of knowing which part of the brain controls what. "Benevolence" cannot be seen on the outside of the brain.

Later in the nineteenth century, scientists will discover that a weak electrical current applied to the exposed brain of a laboratory animal will make cer-



A Phrenological Head is definitely an eye-catcher—bald as a billiard ball and each "organ" carefully outlined and labeled. By the middle of the nineteenth century, a popular parlor game is "reading" one's character by feeling the skull for bumps and dips and then matching them to a head chart such as this one. *Hulton Collection, Getty Images* tain muscles twitch involuntarily and certain senses sharpen or go dead. In the early twentieth century, scientists will invent more sophisticated and less dangerous ways to "see" brain activity. Eventually they will chart the brain's electrical signals by attaching electrodes to the scalp for an "electroencephalograph," or EEG. The EEG plots amazing patterns of electrical activity that match specific areas of the brain with specific functions. Toward the end of the twentieth century, scientists will invent brain scanners that can "image" the electrical and chemical activity inside a living brain.

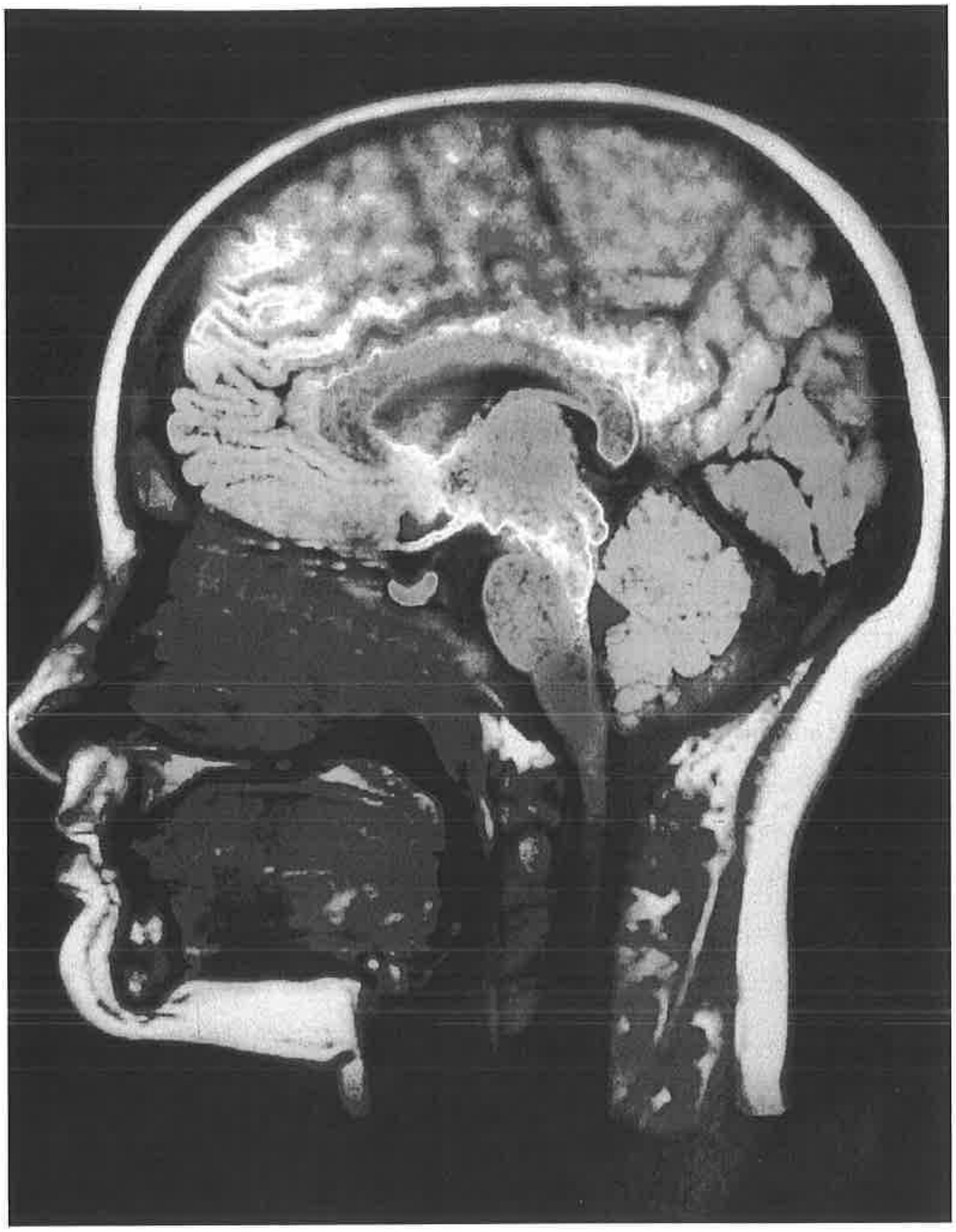
Back in 1850, the Localizers/Phrenologists haven't seen a single thought or brainwave. Still, that doesn't stop them from identifying thirty-seven "organs" of the brain. How do they do it? Bumps. That's right. Bumps on the head. The Phrenologists reason that if you have a strong organ, it will be big and project from your skull as a bump. If you have a weak organ, it will be small and you'll have a dip or depression in your skull. Run your hand over your own skull and you will find all sorts of knobs, bumps, dips, and so on. The Phrenologists decide that if you have a bump over your Organ of Amativeness, you are a person with a strong talent for physical love. If you have a dip or a depression over your Organ of Philoprogenitiveness (also known as parental love), you're not going to be fond of children.

Among Boston doctors, phrenology is considered serious stuff when Phineas walks into the middle of the debate of the Whole Brainers versus the Localizers. Both sides seize him as proof of their belief. Dr. Bigelow and his fellow Whole Brainers say that Phineas would surely have died if specific areas of the brain were vital to specific functions. After all, the tamping iron carried away pieces of Phineas's brain. If every part of the brain was vital, then he should be dead. Yet here is Phineas alive in Boston, walking, talking, and taking care of himself. Therefore, say the Whole Brainers, the whole brain must be able to perform any function of one part.

On the other side, Dr. Harlow is a Localizer, or at least he is a friend of some leading Localizers/Phrenologists. The Localizers say Phineas proves their theory. The tamping iron has not killed him because the damage is limited to specific organs that are not critical to life. Yet the Localizers/Phrenologists don't have all the facts. In 1850, when Phineas comes to Boston, Dr. Harlow feels he must keep the details of his patient's personality problems confidential, but he does tell some of the truth to Dr. Nelson Sizer. Dr. Sizer is a big man in phrenology and lectures on it all over New England. Dr. Harlow leaks the information to Dr. Sizer that the "completely recovered" Phineas is not the old Phineas. Dr. Sizer tries to disguise the source of his report to the *American Phrenological Journal* in 1851, writing, "We have been informed by the best authority that after the man recovered, and while recovering, he was grossly profane, coarse, and vulgar, to such a degree that his society was intolerable to decent people."

Dr. Sizer's report is wonderful news for the Localizers/Phrenologists. As Dr. Sizer explains, "If we remember correctly, the iron passed through the regions of the organs of BENEVOLENCE and VENERATION, which left these

An MRI scan allows us to look inside a living person's head and see a slice of everything from the throat to the spinal cord. Inside the brain, you can see the different lobes of the cortex; the corpus callosum, which joins the two hemispheres; the cerebellum at the back of the head; and the brain stem. Compare this to the phrenological chart on page 36.
MRI scan by Scott Canzine and Sue Trainor, Photo Researchers Inc.



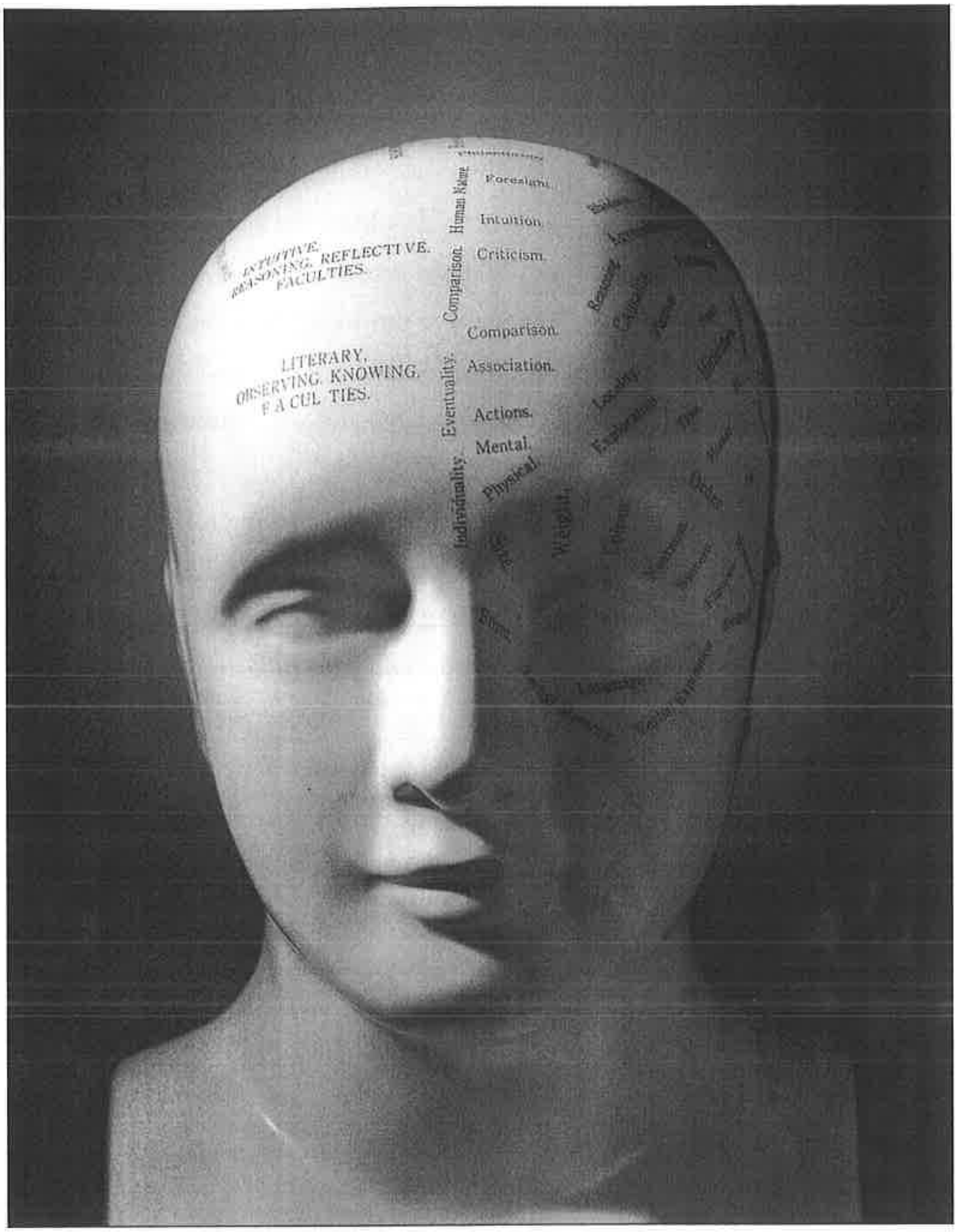
organs without influence in his character, hence his profanity, and want of respect and kindness."

In the long run, the Localizers will turn out to be somewhat right about localization but completely wrong about phrenological organs. The Whole Brainers will turn out to be right about the complex interconnections of the brain but wrong about the brain acting as a whole. The 10 billion neurons in your brain are not connected at random. They are organized into "local circuits" within the cortex; the local circuits form "subcortical nuclei," which together form "cortical regions," which form "systems," which form "systems of systems," which form you.

Specific areas of the brain do control specific functions and behaviors, but it's not always as "logical" as we would imagine. Skills that you think should be in the same brain patch are scattered about in different places in the cortex. Different areas of the cortex let you recognize letters in a book or faces in a crowd, or know whether you are standing upright. Yet many of these localized functions are also controlled by interactions with other parts of the brain. The human brain, it turns out, is both localized and interconnected. We know so much more about the brain today than the Phrenologists and the Whole Brainers did in 1850, yet we really understand only the rough outlines.

Back in 1850, Dr. Bigelow tells the Boston doctors, "Taking all the circum-

This ceramic bust by L. N. Fowler was to help serious phrenologists locate the thirty-seven "organs" of the brain while feeling around on the head for bumps and dips. Phrenology lost credibility as science found better ways to probe the brain. Compare this to the "coronal" MRI on page 68. *Photograph by D. Parker, Photo Researchers Inc.*


INTUITIVE. REASONING. REFLECTIVE. FACULTIES.
LITERARY, OBSERVING. KNOWING. F A CUL TIES.
Human Nature
Foresight.
Intuition.
Comparison.
Criticism.
Comparison.
Eventuality.
Association.
Actions.
Mental.
Physical.
Individuality.
Weight.

Around 1920, a group of Harvard Medical School students gather around the skull of Phineas Gage. The life-size plaster model of Phineas's head made by Dr. Bigelow stands on the left corner of the table. Time has made the skull fragile, but Phineas Gage's fame still draws visitors to Harvard's Countway Library to look without touching. *Photograph from the Warren Anatomical Museum, Countway Library of Medicine, Harvard Medical School*

stances into consideration, it may be doubted whether the present is not the most remarkable history of injury to the brain which has been recorded." He also announces that Mr. Gage has graciously agreed to donate his famous tamping iron to the Harvard Medical College. Dr. Bigelow donates the plaster head of Phineas to go with it. The plaster head remains in Boston, but Phineas and his tamping iron soon slip out of town.

Following Phineas Gage

The story of Phineas Gage is famous, and when people repeat famous stories they have a tendency to improve them. The famous story about Phineas says that after hanging around the Boston medical school for weeks, he grows bored and restless. Phineas takes back his tamping iron and hits the road, traveling from city to city through New England and ending up at P. T. Barnum's American Museum on Broadway in New York City. Barnum's museum has nothing to do with our modern idea of a museum. It is a freak show.