

PHINEAS GAGE

The Man With a Hole in His Head

Phineas Gage was the 25-year-old foreman of a construction crew preparing the path for a railroad track in the late summer of 1848. By all accounts he was reliable and friendly, both a good worker and a pleasant companion. But in an instant his life was changed through a terrible accident that would haunt him until his premature death at age 36.

Gage's accident also had ramifications for scientists who were trying to understand the relationship between the brain and behavior. Although the implications of his accident were not immediately appreciated, his case became a common fixture in basic textbooks in psychology, neurology, and related fields. His case has also been used to demonstrate the role of the brain in determining personality. But the account of the accident has also been filled with errors and exaggeration, sometimes making it difficult to separate the facts from fiction.

THE ACCIDENT

Late in the afternoon of September 13, 1848, Phineas Gage was working with his crew near Cavendish, Vermont, preparing the way for a new track bed for the Rutland and Burlington Railroad. The crew was using explosives to blast away rock. It was a slow process that required precision in determining where to bore the holes and estimating how much explosive powder to use. Gage would place a fuse in the hole, followed by gunpowder, and then fill the rest of the hole with sand. Gage had a long iron rod, a tamping iron, which he used to pack down the sand. This last operation was necessary to ensure a powerful explosion; the smaller the area containing the explosive powder, the greater the force of the explosion.

The tamping iron was Gage's own creation, 3 feet 7 inches long, with a diameter one and a quarter inches at the blunt end and tapering to a rough point at the other. A blacksmith had prepared it especially for Gage. It was an imposing object and more than half the height of Gage himself, who stood about 5 feet 6 inches. Usually, after Gage tamped down the sand to his satisfaction, he would light the fuse, and everyone would run for cover. The ensuing explosion, if successful, would break down the rock

into pieces small enough for the work force to handle and remove. That was the way it was supposed to happen. But this time, something went terribly wrong.

Eyewitnesses varied slightly in their descriptions about what happened next. It appears that Gage poured gunpowder into the hole in the rock but had not yet covered it with sand when something distracted him. As he turned his head slightly away from the rock, the tamping iron dipped into the hole and created a spark setting off an explosion. The tamping iron then became a projectile, with the sharp end entering Gage's left cheek, moving through his head, and exiting through the top of his skull. The rod itself was later found more than 30 feet away, encrusted with brain matter. Gage was thrown on his back by the force of the explosion but, to everyone's astonishment, he remained conscious. He was completely aware of what had happened to him and even engaged his fellow workers in conversation.

Gage's coworkers helped him walk to an oxcart that took him into town about three-quarters of a mile away. His destination was the tavern where he had been boarding on the town's main street. Within a half hour, he was examined by a physician, Dr. Edward Williams, who found it difficult to believe the story that Gage and his coworkers told him. How could Gage still be alive if an iron rod had passed through his head?

About an hour later, another physician arrived, Dr. John Martyn Harlow. Williams and Harlow brought Gage to his room and began tending to his wounds. In addition to the obvious head injuries, he had also suffered some burns on his hands and arms. After a further evaluation of their patient, the physicians didn't have much doubt about what had happened. The hole in Gage's cheek was readily apparent as was the hole in his skull. In fact, Harlow could view Gage's brain through the hole.

The physicians cleansed the wounds, carefully removing the tiniest of the skull fragments and maneuvering the larger pieces back into place as best they could. Neither had ever witnessed such an injury before and they did not have much hope for Gage's recovery. Gage was now vomiting blood and becoming weaker. Harlow, who lived a short distance away from the tavern, returned again and again to tend to Gage. His goal was only to make him more comfortable. He didn't expect him to survive.

Gage's mother, who lived about 30 miles away in Lebanon, New Hampshire, where Gage was born, was notified of the accident. She and Gage's uncle arrived early the next morning, surprised that Phineas was still alive. Everyone around Gage seemed to understand how serious his injuries were—except for Gage. He spoke of going back to work the next day or perhaps the day after.

He would soon find out the unrealistic nature of his plan. After resting for only a short time and seemingly on the road to recovery, Gage developed a fever and his pulse quickened. Despite all the efforts of Dr. Harlow to cleanse his wounds, Gage had developed an infection. This was a common occurrence in the days before antibiotics and the results were often fatal. The fever persisted, then worsened, with Gage sometimes drifting in and out of consciousness.

Harlow tried all the tactics he could think of to help Gage, including the use of purgatives, bloodletting, and restricting Gage's diet. Other symptoms developed along with the fever. At one point, Gage's pulse went up to 120, higher than it had ever been. It appeared that Gage would never recover. One of the locals suggested that Harlow should terminate treatment so that his patient wouldn't have to suffer any further. The local undertaker even measured Gage for a coffin.

But Harlow was now on a mission and would not give up. He continued to treat Gage with all that was available to him. Finally, after more than two months, all of Gage's symptoms appeared to have abated. His strong constitution had won out. Soon after, toward the end of November, Harlow deemed Gage well enough to travel and he was able to return to the family home in New Hampshire.

Harlow visited Gage in New Hampshire shortly after the New Year and found Gage walking about, seemingly symptom-free. He was not quite as strong as he had been before, but his physical condition had improved considerably. Although he had lost sight in his right eye, his cheek had healed over, and the top of his skull had begun to heal too, although a part of the brain was still visible through a small opening. Gage was eager to return to his job on the railroad, but now he had a new set of problems.

The railroad declined to hire Gage back at his old position. Something had happened to him that went beyond his physical injuries. He had previously been a good worker—industrious, social and friendly, and well organized. Now he had become argumentative and short tempered, and his language had become vulgar. He was not the leader that he once was. He had difficulty planning, and his friends no longer cared to be with him. His personality had changed so much that Dr. Harlow would later write, "He was no longer Gage." This was a surprising development and one that would cause great difficulty for Gage himself. Moreover, there were far-reaching implications of Gage's injuries for the scientific community.

GAGE'S ACCIDENT BECOMES MORE WIDELY KNOWN

Gage's case immediately generated interest, mostly because of the horrific nature of his accident, and several stories about him appeared in local publications. One of the people who became attracted to the case was Dr. Henry Bigelow, a physician, soon to be a professor of surgery at Harvard Medical School. At first, Bigelow was skeptical about the stories he had heard. It just didn't seem possible that Gage could have survived an object as large and destructive as the tamping iron passing through his head.

To satisfy his curiosity, Bigelow wrote to Harlow, asking for further details. He also asked Harlow to collect descriptions from others about what had happened. The details Bigelow received began to convince him. Eventually, Bigelow arranged

for Gage to visit Boston so that he could examine him. Bigelow paid all the expenses. By the time Bigelow had completed his examination of Gage, he was no longer skeptical. In fact, he had become a strong believer. He even wrote several short articles about Gage and the accident.

Several months after examining him, when Gage's wounds had healed even further, Bigelow presented his case at a meeting of the Boston Society for Medical Improvement. Using a skull that he had prepared to resemble Gage's injury, Bigelow was able to demonstrate to other physicians how Gage's survival was possible, assuaging many of their doubts. Bigelow's support went a long way to establishing the legitimacy of the case. Some began to speculate that the Gage case might offer some insight into a current debate about the brain and its function.

FRANZ GALL AND PHRENOLOGY

The understanding of how the brain works was primitive in the mid-1800s. The existence of neurons was unknown, for instance, as was the electrochemical nature of brain function. Instead, one of the central disagreements of the time involved the degree to which the brain acted as a whole or, conversely, had areas devoted to specific functions. We now know that, to a degree, both of these are true: the brain has some general, overall functions as well as some functions assumed by specific regions.

Franz Gall (1758–1828), a German physician, had developed a belief system about the brain's functions that became known as *phrenology*. Gall was a well-regarded anatomist and was probably more important than anyone in convincing fellow scientists that the brain was the source of psychological functions. Phrenology was Gall's attempt at describing this relationship.

Gall asserted that many psychological functions could be traced to very specific areas of the brain. He believed that the development of these areas reflected dominant personality characteristics whereas less developed regions reflected less dominant characteristics. Therefore, personality could be determined by “reading” the bumps and indentations on the skull. Although phrenology did not have strong support from scientists of the time, it remained very popular with the general public. Gage's case had the potential to shed light on this ongoing debate.

When Gage was brought to Boston in late 1849, members of the medical profession were allowed to examine his head and even to view the tamping iron, which he usually carried with him. It was clear to most of them that the story of Phineas Gage was not a myth. Those who remained skeptical about the details accepted the general nature of the accident. Bigelow had arranged for a life mask to be made of Gage's face and skull so that his visage, including the external signs of his injuries, could be preserved for future generations. Many years later, two portraits of Gage would be discovered—one



► **Image 3.1** Phineas Gage with his tamping iron

a daguerreotype (Wilgus & Wilgus, 2009), the other a photo. Each depict Gage, dressed in a formal outfit, looking proud and holding the tamping iron.

For those who believed that the brain acted as a single unit, the Gage case represented a setback. If the brain was a single unit, how was it possible that Gage's brain could have suffered so much damage and still retain its earlier function? Later, when the phrenologists learned of Gage's change in personality, they used that information to support their own position.

THE CHANGE IN PERSONALITY

While early interest in the case focused mostly on the physical trauma that Gage had suffered, later interest concentrated more on his personality change. This part of his story was more difficult to document than the physical aspects of the case. There were no objective measures of Gage's personality before the accident, which made a clear comparison difficult. Much of the reported change relied on anecdotal reports and hearsay. Some of it may have been exaggerated.

Descriptions of Gage before the accident depict him as energetic, shrewd, and a smart businessman. Others described him as the best foreman the railroad had contracted. Harlow noted some periods of disorientation and even intellectual lapses a few weeks after the accident but wrote nothing specific about Gage's personality. He wrote that Gage's memory remained excellent. However, following the earliest period, Harlow's written descriptions began to change. He noted that Gage had become obstinate and sometimes childish. His friends had difficulty subduing him. Harlow wrote an even more damning retrospective appraisal of Gage in 1868 in which he outlined the reasons that Gage was not hired back at his old job. Harlow described him as impatient, unwilling to heed advice, grossly profane, and, again, obstinate and childish. In short, he had changed radically (Macmillan, 2002).

GAGE'S LATER YEARS

Most of what can be verified about Gage following his time in Boston is based on reports from his mother and from Harlow. Little information about Gage can be found in the public record. For instance, it was rumored that he was seen begging in Boston on several occasions, but there is no independent verification of that behavior. What appears to be true is that Gage became restless after his visit with Bigelow in Boston. He had always been engaged in hard work, much of it physical, and he was eager to continue it.

For several years Gage drifted in the New England area, exhibiting himself and his tamping iron up and down the East Coast. He even appeared at a museum that had been organized by the famous P. T. Barnum in New York City. For more than a year he worked at a livery stable and as a stagecoach driver in Hanover, New Hampshire. But then a very different opportunity presented itself.

A stagecoach line was being developed between Valparaiso and Santiago in Chile, a distance of 75 miles. Gage was offered a position as a driver. He left Boston in August 1852 and spent the next seven years in Chile. While there is no record of his service there, it is likely that the demands of the job were considerable.

Stagecoaches in Chile in that period typically employed six horses, a challenge requiring many skills. The driver not only had to interact with the passengers, but he also had to take care of the horses. According to Gage's mother, her son had developed a particular affinity for working with animals, and he was a successful driver. The fact that Gage could work at such a demanding job for as long as he did has been offered as evidence that his dramatic personality changes were not permanent (Macmillan & Lena, 2010).

While her son was in Chile, Phineas Gage's mother had moved to San Francisco to be closer to her daughter, and it was in San Francisco that Gage made his next appearance. According to Gage's mother, he experienced several bouts of illness while in Chile. By mid-1859, his health issues had become more serious and he returned to the United States by ship to San Francisco, ill and in need of help. He attributed his illness to seasickness; he pointed out that he had also been very ill on his initial trip to Chile. And, indeed, sea sickness might have been part of his health issues.

Gage seemed to regain some of his health for a brief period, and he was even able to secure work on a farm. But while dining at his sister's home one evening, he suffered a seizure. Gage's ability to work became more unsettled after this incident. Several more seizures followed. The assumption has always been that his seizures were related to his accident. The physical damage to his brain was finally expressing itself in less subtle ways, perhaps because of scarring or other brain changes associated with age.

Gage continued to work occasionally, usually in farming or with animals, but he could not sustain a single place of employment, and his health continued to deteriorate. The time between his seizures grew shorter and shorter. He moved into his mother's house and after only a brief period there, he suffered a series of quick seizures. Finally, Gage's increasingly frail body could take no more. He died on May 20, 1860, at the age of 36 and was buried in San Francisco's Lone Mountain Cemetery (later renamed Laurel Hill Cemetery). Most accounts indicate that his tamping iron was buried with him, although this has been disputed. The cause of death was listed as epilepsy.

AFTER HIS DEATH

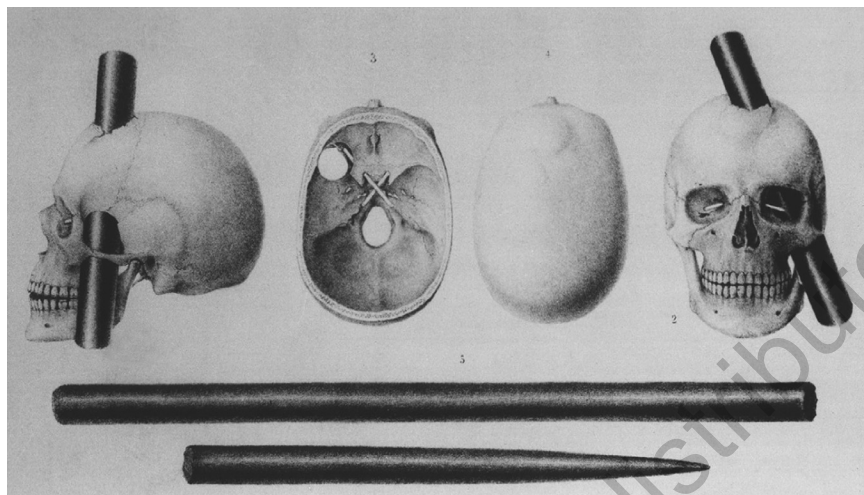
Gage's story might have ended there except for Dr. Harlow, the physician who tended to him after the accident. Harlow had been in contact with Gage during his early years in Chile but had lost contact with him. When he finally wrote to Gage's mother, she informed him that her son had died several years before. It was then that Harlow made an unusual request.

His interest in Gage's case had remained strong. Now, with the death of Gage, he had the opportunity to add more information to the case study. Would Gage's mother permit her son's body to be exhumed and his skull removed so that it could be more carefully examined? Such an examination might help to clarify exactly the kind of brain injury that Gage had suffered. She agreed, attesting to her confidence in Harlow's intentions and, perhaps, also understanding the importance of her son's injuries to science.

Gage's skull and his tamping iron soon found their way to Harlow's home in Woburn, Massachusetts. It was immediately apparent from the skull that some additional healing had taken place after the accident. The hole in Gage's head had begun to mend although it was still not completely closed by the time of his death.

After examining the skull for several months, Harlow held a gathering at the annual meeting of the Massachusetts Medical Society in 1868 to display the skull and present a follow-up on the unusual case. It was here for the first time that he outlined some of the psychological difficulties that Gage had suffered as a result of his injuries. This aspect of the case had been minimally examined in most of the earlier reports, and indeed, not much attention was paid to it immediately after this report.

When Harlow was finally finished working with the skull, both it and the tamping iron were deposited in the Warren Museum of the Harvard University Medical School. There they remain, along with the model of Gage's head, both a real and a symbolic reminder of Gage's struggle to conduct a life after suffering such a cruel misfortune. But Gage's story was still not complete. The fact that his skull and even his tamping iron were saved for posterity has led to further study.



Everett Collection Inc/Alamy Stock Photo

► **Image 3.2** The skull and tamping iron of Phineas Gage, U.S. National Library of Medicine/Science Photo Library

THE LEGACY OF PHINEAS GAGE

When Gage's mother agreed to have her son's body exhumed and his skull removed, she could not have anticipated the important role her decision would play in the history of brain-related sciences. The cemetery where her son's remains were interred—and where her remains were ultimately interred as well—was later demolished by the city of San Francisco to make way for a new highway. The remains of both mother and son were moved to a common burial ground and their identity was eventually lost. If a later scientist had been interested in exhuming Gage's body, it would not have been possible. But thanks to his mother's decision, his skull and tamping iron remain available for study today.

The implications of Gage's case became apparent to physicians and surgeons soon after his case was publicized. If Gage could live so long after such a horrendous accident, then surely it was possible to operate on the brain successfully, for instance, to remove a tumor. The possibility became even stronger once medicine adopted aseptic procedures. In addition, using Gage's case as a starting point, physicians began to use personality changes as guides in a rudimentary approach to diagnosis. Diagnosing brain disorders on the basis of personality changes has serious flaws, and brain surgery experienced many failures before it became the success it has become today. Yet both diagnosis and brain surgery ultimately benefitted enormously from the case of Phineas Gage.

PSYCHOSURGERY

One of the more negative developments attributed to the Gage case is that of psychosurgery, that is, using surgery to directly address psychological characteristics rather than physical ones. Although there were a number of such surgeries before the 1930s, the work of Egas Moniz (1874–1955) had the greatest impact. Moniz, a Portuguese neurologist, introduced a form of surgery in 1936 known as a prefrontal leucotomy (later referred to as a lobotomy) in which the frontal lobes of the patient were either disrupted or severed from the rest of the brain, usually in an effort to reduce the symptoms of severe mental illness. Walter Freeman (1895–1972), a physician, along with neurosurgeon James W. Watts (1904–1994), was responsible for introducing a form of this surgery to the United States. Freeman is believed to have operated on several thousand patients, some of them as young as seven years old, over the course of his career. Moniz eventually won a Nobel Prize for his work before his procedure and those of Freeman were discredited. Did the Gage case play a role in encouraging such procedures as some critics have charged?

It seems likely that Moniz or Freeman or any physicians practicing such surgery would be familiar with the case of Phineas Gage. It is simply too rudimentary to the history of brain science for it to have been unknown to them. And it is true that the Gage case centered on damage to the frontal lobes. But the evidence from Gage would appear to contradict the goal of Moniz and Freeman. Gage exhibited behaviors that society found unsatisfactory after damage to his frontal lobes. That would hardly be a reason for surgeons to operate on the frontal lobes. Moreover, there is no direct evidence that Moniz or Freeman or anyone else used the Gage case as grounds to support their approach to psychosurgery, except to point out that patients could survive damage to their frontal lobes.

PHINEAS GAGE TODAY

Modern medical technology has grown significantly since Bigelow was able to take Gage's tamping iron and demonstrate the likely path that the iron took through Gage's skull. Computers can not only simulate the skull and the internal parts of the brain, but they can also provide probabilities for the most likely path or paths that the iron took. These modern studies reveal that Gage was very lucky. That seems like an odd thing to say for someone who experienced severe physical trauma, but the point is that it could have been far worse. For one thing, the iron must have missed the major speech areas of the brain since it was known that Gage exhibited no apparent problems with either understanding or producing speech after the accident.

Even with modern technology, however, the precise path that the tamping iron took was not easily determined. When the rod exited his skull, it took related bone with it. Even the precise point of entry has been debated. A husband and wife team of neuroscientists, Hanna and Antonio Damasio, have tried to clarify many of the remaining questions about Phineas Gage. Their research focused on using CT scan technology and computers to plot out likely paths that the rod could have followed. Based on known information about Gage's condition, they were able to identify several possibilities. They concluded that the assumed damage to the left frontal cortex would be consistent with symptoms noted in other victims with frontal lobe injury. However, in the end, we will probably never know the precise path the tamping rod took. The inconclusive evidence from the skull, combined with known individual differences in the brain, will continue to raise doubts about any suggested model (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994).

The interest of the Damasio's, and other researchers, is not simply historical curiosity. Patients who suffer frontal lobe damage through tumors or injury may also experience personality change, though perhaps not as dramatic as that of Phineas Gage. The Damasio's have been particularly interested in studying the emotional changes that accompany brain injury. At the same time, they're trying to understand the role that emotion and the brain play in our intellectual activity. In their view, what we call intellectual activity and emotional activity are connected, and that connection is in the brain. In a real way, their studies began with the case of Phineas Gage and they have continued to use that knowledge to investigate brain behavior at the University of Southern California (Damasio, 1994).

THE MEMORIAL

Over the weekend of September 12–13, 1998, a memorial event was held in Cavendish, Vermont, to celebrate the 150th anniversary of the famous accident to Phineas Gage. His skull and tamping iron were on display, as were a number of documents related to the case. Tours were arranged to relevant locations in the town, such as the site of the tavern where he had stayed. (The tavern itself no longer exists.) A series of symposia were presented related to the accident and to the frontal lobes in particular, once again pointing to the Gage case as the first to clearly establish the relationship between the brain and personality. Finally, a plaque was placed in the Cavendish Town Green to commemorate the event and testify to the fact that after so many years, the case of Phineas Gage still matters.

REVIEW/DISCUSSION QUESTIONS

1. The injury to Gage was horrific. How did he manage to survive?
2. In what way did Gage's personality change after the accident?
3. Phrenology was popular around the time of the accident. How would a phrenologist interpret Gage's postaccident behavior?
4. What impact did Gage's case have on the development of brain surgery? On prefrontal lobotomies?
5. Why does the Gage case continue to hold so much interest?

NOTE

The book by Malcolm Macmillan (2002) cited earlier (see References) was the major source for this chapter. It not only contains a thorough and detailed review of the case, with copies of original documents, but also analyzes the myths that have developed regarding Phineas Gage. Macmillan and others have created a Phineas Gage Information Page on the University of Akron website with updated material and additional information.