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Gage, Phineas

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Phineas P. Gage is one of the most famous named cases in the history of psychology and neurology, owing to brain damage suffered in a construction accident which reportedly resulted in a marked alteration in his personality. Gage was the foreman of a gang of workers excavating rock while preparing the bed of a railroad in 1848 near what became Cavendish, Vermont. His survival of a massive injury to the left side of his brain immediately turned him into a medical curiosity. Later reports of changes in his behavior contributed to physiological, psychological, and philosophical debates that continue today over the localization of functions in the brain.

Phineas Gage was born on approximately July 9, 1823, in or around Lebanon, New Hampshire, and died on May 21, 1860 in San Francisco (both the date and place of his birth are uncertain; for an authoritative account of Gage's life and medical history, see Macmillan 2000a, 2012). What detailed knowledge we have of Phineas Gage is limited, and likely to remain so. Up to 2018, we had only five contemporaneous sources to provide descriptions of him: two by the physician who treated him and followed him up; a detailed account from an important physician who saw him over a period of some weeks almost a year after the accident; a very short account by an interested physician who visited his family; and one by a seemingly anonymous contributor to a phrenological journal. From these sources, we can say that Phineas was a well-liked young man, of strong build, temperate, hardworking, and judged by his employers and peers as reliable and trustworthy. As foreman, and probably a sub-contractor, he was unusual in treating his men fairly.

Tamping and the Accident

As foreman, Gage decided where the rock was to be blasted. The blasting itself required a charge of blasting powder having no detonator but using a recently invented safety fuse, to be *tamped* or packed tightly in a blasting hole with the larger end of his specially made smooth javelin-like crowbar. Sand was added and again packed down before the fuse was lit to cause an explosion at the deepest point of the hole. Unfortunately, on September 13, 1848, at about 4.30 PM, Phineas tamped the charge down for the final time but before the sand had been added. His tamping iron struck the rock, generating a spark which lit and exploded the charge, driving the iron obliquely upwards and backwards to enter his skull under the left zygomatic arch (left cheek

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bone) before passing behind the left eye, and travelling completely through his skull to exit it in the median line at the junction of the coronal and sagittal sutures before landing on the ground some 25 m behind him.

The force of the explosion knocked Gage over; his legs gave a few convulsive movements, and he may have briefly lost consciousness. Soon recovering, he then walked with help to an oxcart where he sat against the headboard while being driven ¾ mile to the inn of Mr. Joseph Adams, where he was living. There he sat on the veranda telling the bystanders what had happened. About an hour later, he greeted the first physician to arrive, Dr. Edward Higginson Williams of nearby Proctorsville, with one of the great medical understatements: "Doctor, here is business enough for you." Dr. John Martyn Harlow of Cavendish proper, who may have been under contract to the railroad construction company, arrived close to 6 PM when he and Williams helped Phineas upstairs where the wounds were examined. Gage was hemorrhaging profusely and continuously; he swallowed blood occasionally only to vomit it about every 15 or 20 min together with pieces of brain; and his lower extremities were continuously agitated like the shafts of a nineteenth-century fulling mill.

Treatment and Recovery

The two physicians managed to staunch the bleeding and Harlow searched for bone fragments by joining his index fingers through the upper and lower openings in the skull. Harlow also removed some pieces of brain and smaller pieces of skull with his fingers and made an attempt to replace the larger pieces. Phineas's scalp was shaved, adhesive straps were used to approximate the lacerations of his scalp, and a dressing of a compress, night-cap and roller applied. His facial wounds were left open but simply dressed and bandaged; the burns on his face and forearms were dressed; and, to assist with drainage from the wound, he was left with his head elevated with his attendants instructed to keep him in that position. Harlow had learned this technique as a student at Jefferson Medical College, from witnessing Pancoast's famous demonstration of the importance of drainage in the treatment of open wounds.

Five hours later, although the dressings were saturated with blood, the hemorrhaging was abating and he had vomited only twice more. His sensory powers were unimpaired and he mentioned his friends by name, adding that he did not want to see them because he expected to be back at work in a day or two. By the next morning, Phineas was still hemorrhaging slightly, and his lower extremities were still continuously agitated, but he was rational enough to ask, "Who was now the foreman."

Between September 14 and November 8 Harlow himself changed Phineas' dressings three times a day, covered his main wound with an oiled silk cloth underneath wet compresses, cleaned off the discharges externally, kept ice water on his head and face, occasionally bled him (still a common medical treatment at the time) or administered purgatives (another common treatment), and had the attendants clean Phineas' mouth and oral cavity with water and disinfecting solutions. In all of this treatment Harlow, as Barker (1993, 1995) has shown, was applying what he had learned at Jefferson.

With one exception, Phineas required little other special attention. The exception was when fungal growths, that had been present as early as 6 days after the accident increased, and on September 28 suddenly began pushing up from the main wound on the top of his skull and protruding from the left inner canthus. At the same time Gage became dazed and unresponsive; his pulse increased, and he showed other physical signs of infection. Harlow used a pair of curved scissors to cut the fungi from the top of his skull and apply a caustic cleaner freely to them. He also used a scalpel to access and drain eight fluid ounces of excessively fetid ill-conditioned pus and blood from the nasal area. Over the next 8 days, the discharges remained very profuse and fetid after which they and other signs of

infection gradually started to cease. Phineas appeared demented, or in a state of lethargy ["hebetude"]. Five days later, on October 6th, the swelling was abating and the discharges were now of thick and creamy pus suggesting that the infection was clearing.

Published Reports of Psychological Change

The very first report of Gage in the medical press, by Harlow in the *Boston Medical and Surgical Journal* (December 13, 1848), was a matter-of-fact chronicle of his accident and acute treatment, and the case was notable for the fact that Gage survived his injuries at all. From that point on, however, as early as 1868, medical interest in Gage gradually began to focus on personality changes that may have been caused by his brain damage. However, many of these interpretations went beyond what is known for certain about Gage's postmorbid life (for details, including facsimiles of all known primary sources on Gage, see Macmillan 2000a, Appendix A).

From early October, 30 days after the accident, Harlow's notes tended to be more about Gage's mental state than his physical recovery, stressing the normalcy of his recollections of the accident coupled with the childish and capricious nature of his behavior. Harlow said his will was as indomitable as ever and he was obstinate, not tolerating restraint, especially when it conflicted with his desires. This was exemplified when Harlow was away and his friends were unable to control him: he suffered a 3-day period of high temperature and pain following a chill he got from going outside in cold and damp weather. Harlow resorted to further bleeding and purgatives to end the episode. Phineas then made steady progress and was allowed to go home to Lebanon, riding 30 miles in a closed carriage on November 25. When Harlow saw Gage the following week, he was continuing to make progress: he was walking about the house, felt no pain, and, said Harlow, was in a way of recovering if he could be controlled. According to Harlow, Gage continued to improve in flesh and strength over the next 2–3 months before he came back to Cavendish, with his tamping iron, to visit Harlow. At that point, Harlow was inclined to say Gage had "recovered."

During early 1849, and possibly at about the same time, Dr. John Barnard Swett Jackson, a very curious and active member of the Boston Society for Medical Improvement, visited Cavendish in order to examine Phineas for himself, but he was absent and he had to console himself with a report from the family. They told him that on returning home, Phineas had been weak and childish but, by February, was able to do a little work around the horses and the barn, feeding the animals, and 3–4 months later he could bear ploughing for half a day. He was then, they said, well in mind except that his memory was somewhat impaired but strangers would notice nothing peculiar. An anonymous medical report of early 1850 claimed the family described his mental processes rather more negatively: greatly impaired and continuing to degenerate but his bodily powers less so. A second anonymous report, for which Harlow may have been the source, denied there was no change in his mental processes: Phineas had become so gross, profane, coarse, and vulgar that his society was intolerable to decent people. This was the first report of such a change and was not repeated until some 20 years later.

Harlow gave his main report of changes in a follow-up paper (Harlow 1868). In that paper, Harlow noted that:

> The equilibrium or balance, so to speak, between his intellectual faculties and his animal propensities, seems to have been destroyed. 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, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operation, which are no sooner arranged than they are abandoned in turn for others appearing more feasible. A child in his intellectual capacity and manifestations, he has the animal passions of a strong man. Previous to his injury, although untrained in the schools, he possessed a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing all his plans of operation. In this regard his mind was radically changed, so decidedly that his friends and acquaintances

> said he was "no longer Gage". (Harlow 1868, pp. 339–340)

These 163 words, culminating in the often-quoted assertion that the postinjury Gage was "no longer Gage" are all that most people know of the psychological changes in Phineas. They are commonly interpreted as having turned him from an upstanding, kind, responsible, reliable worker, and family man into a permanently unstable, impatient, foul-mouthed, work-shy drunken wastrel, who drifted around circuses and fairgrounds, totally unable to look after himself, and who died penniless in an institution. None of this psychopathic-like description is true. There were changes, to be sure, but not these, and they were neither so extensive nor were they permanent.

Gage's Last Years

Except for two important errors, the general compass of what Harlow tells us about Phineas after the accident is correct, though lacking in detail. The errors are the dates of where he lived and worked and the date of his death. The account which follows here is documented or is reasonably inferred from that documentation (Macmillan 2000a; Macmillan and Lena 2010). Although Harlow had described him as recovered in 1849, Phineas was unsuccessful in regaining his position on the railroad. In 1850, he exhibited himself throughout New England with his tamping iron and a model skull, as well as at Barnum's Museum in New York City. In 1851 and 1852, he worked in the livery stable of Johnathan Currier in Dartmouth, New Hampshire. In 1852, he was engaged by the founder of a stagecoach line and left the United States for Chile, where he drove heavily laden 6-horse teams. A visiting physician who had the opportunity to observe Gage during this period saw no impairment whatever in his mental faculties.

In 1859, Gage became ill, and in 1860 he returned to his family, which now lived in San Francisco (Daniel D. Shattuck, his brother-in-law, was later elected to the San Francisco Board of Supervisors). In 1860, having recovered from his illness, Gage worked on farms in the Santa Clara area. That year he suffered his first epileptic seizure. Gage continued working, but, according to his family, became "unsettled." Gage died on May 21, 1860. Unfortunately, no autopsy was performed, nor was his brain preserved.

Originally interred in Laurel Hill Cemetery, Gage's remains were later removed to the Laurel Hill Mound of Cypress Lawn Memorial Park in Colma, California, where his name is inscribed on the Pioneer Monument. In the absence of autopsy or preservation of his brain, David Shattuck donated Gage's skull and tamping iron to Harlow. They eventually found their way to the Warren Museum of Harvard Medical School, where they can be viewed today. In an interesting coincidence, another member of the Shattuck family, George C. Shattuck, onetime dean of Harvard Medical School underwrote the medical journal which published Harlow's 1868 report of the case.

The Brain and Changes in Phineas's Behavior

Until about the end of the eighteenth century, the brain was not held to carry out any special functions of its own. For most authorities, the heart was the organ of intelligence, a remnant of a theory that survives when we say that we learn something by heart. In this view, the brain merely cooled the blood. Injuries to the brain tended to be evaluated simply by their severity, usually by their fatality. All this changed in the early part of the eighteenth century when experimental and clinical observations were brought together. Two opposed theses then emerged: either the brain acted as a single organ, with no specific functions, or different parts of the brain acted as separate organs, each responsible for a separate activity. The argument over these theses had not been resolved at the time of Phineas Gage's accident.

That no effects of Phineas Gage's accident, other than his survival, were reported is not surprising therefore. Neither, with one exception, were there reports that the accident had changed his behavior in any way. The exception was an anonymous note in a phrenological journal of 1851 stating that Gage had become gross,

profane, coarse, and vulgar, to such an extent that his society was intolerable to decent people.

Phrenology and the Changes

The changes Harlow described were readily explained by phrenologists whose theory related specific areas of the brain to particular mental functions. The sizes of the areas, and therefore their importance as causes of behavior, were assessed by protuberances on the skull ("bumps"). Many phrenological areas were relevant to personality and social behavior (Gall 1822–1825/1835; see also Kihlstrom 2010). Nelson Sizer, a prominent American phrenological practitioner, traced Gage's ostensible changes in personality and social interaction to damage to the frontal lobes "in the neighborhood of Benevolence and the front part of Veneration" (Macmillan 2000a, p. 350). In fact, there are reasons to think that Harlow himself believed in phrenology, and was even acquainted with Sizer, and that his knowledge of Gall's faculty psychology may have affected his assessment of the lack of damage to Gage's right hemisphere. It should be understood that Harlow's treatment of Gage's wounds and infections met or exceeded the standard of care in that preantiseptic, preantibiotic era of medicine (Macmillan 2001).

Although by the latter part of the nineteenth century, the specific propositions of phrenology had been largely discredited; three clinical papers by Paul Broca had, by 1865, located or localized a function ("faculty") for producing language in the front left convolution of the brain. Nine years later, in 1874, Karl Wernicke localized another area, in the left posterior superior temporal gyrus, for understanding spoken language. In 1878, David Ferrier, the English experimental physiologist, localized a major function in the frontal lobes, one that inhibited or controlled behavior driven by impulses. At the time, Ferrier caused a worldwide stir by explaining the changes in Phineas because of the loss of this inhibitory faculty.

In tandem with these localization proposals, and also beginning in the nineteenth century, several attempts were made to reconstruct the passage of the tamping iron through Gage's brain. Knowledge of that passage, it was expected, would give knowledge of the damage to the brain itself. This did not happen, and debate about the passage of the iron continued into the twentieth century. Ken and Rick Tyler X-rayed Gage's skull to help resolve the issue (Tyler and Tyler 1982), and in 1994, Hannah and Antonio Damasio used a CT model of Gage's skull in their attempt to locate the passage. Neither solution resolved the issue: the passage lay either left or right of the midline and the exit either forwards or behind the coronal and sagittal sutures.

Subsequently, Peter Ratiu and his colleagues, using Gage's actual skull and considering the fractures in it in greater detail than before, showed the passage to be left-sided with the exit through the junction of the sutures (Ratiu et al. 2004). Their reconstruction was based on a CT scan of Gage's real skull, not a model of it made by deforming a model of another skull. From this model, they believed the skull hinged open as the tamping iron passed through it and that once it was completely through, the muscles and other soft tissues of the face contracted and caused the skull to close. The damage to the brain was to the left frontal lobe. This passage was confirmed by John Van Horn and his colleagues who were mainly concerned to estimate the degree of damage to the white matter or connective tissue in Gage's brain (Van Horn et al. 2012). Although Ratiu et al. had to make some assumptions about Phineas' brain that might not have been completely true, theirs is the most accurate to date of the attempted reconstructions. Two of Gage's descendants have published a studio portrait of him posing with his tamping-iron (Wilgus and Wilgus 2009; see also Della Sala 2011). The original image was a daguerreotype, which is a mirror image of the real object. The published image was therefore rotated vertically, to correctly show that Gage's injury was on his left side.

Were the Changes Permanent?

The question also gradually arose about the permanence of the behavioral changes in Gage. Usually Gage and other victims of frontal damage have not been considered to have changed much after initial recovery – that is, they remain seriously and permanently impaired for the rest of their lives. A challenge to this rather pessimistic conclusion seems to have been first issued by Aleksandr Romanovich Luria, the founding Soviet neuropsychologist who was responsible for the assessment and rehabilitation of function in soldiers who had suffered brain damage during World War II (Luria 1962/1966). Largely on the basis of his developmental studies of the function of language, Luria argued that the frontal lobes were particularly important for executive functions – for the use of internal language in self-regulation, in the planning of action, and in checking actual against anticipated consequences. His method of rehabilitation attempted to reinstate the patient's use of his/her internal language. In an environmentally sparse situation where distractions from other stimuli were minimal, the patient was first required to speak and follow with action the therapist's precise descriptions of the behavior to be controlled, and to do this many times. Eventually, after many repetitions, some patients could control their actions by speaking "internally" for themselves. Luria did not report his results fully and it seems the method may have been successful in only a small proportion of his cases (Macmillan and Lena 2010).

Informal treatments resembling Luria's have sometimes been reported as reestablishing control over behavior. Thus, Thomsen et al. (1990) described a female patient who made a good psychosocial adaptation many years after suffering severe bilateral fronto-orbital damage when she was 17. She showed typical uninhibited behavior until, 10 years postaccident, she began living with a man who was not sexually involved with her but who drew up a simple written program of personal and household tasks that she had to perform in exactly the same order every day. Two years of this routine enabled her – at 19 years postaccident – to care for herself and do housework and shopping. She was by no means "cured," being still childish, exhibiting mild irritability and mild temper with her memory still impaired but it was clear that she had made a remarkable psychosocial adaptation.

A similar remission may have occurred with Gage. Macmillan and Lena (2010) have pointed out that, far from being completely unemployed or unemployable, Gage worked on his family farm in Vermont within 4 months of the accident and sought his old position as foreman on the railroad construction crew within another four. Within 2 or 3 years Gage was exhibiting himself around New England, possibly managing his own appearances, his advertising, and his travel independently, and probably relearning any lost social skills. In working for Currier during 1851–1852, he acquired the complex skills to drive stagecoaches, and presumably continued his social relearning. His behavior was settled and reliable enough for an employer to take him to Chile as a stagecoach driver. There he worked in a highly structured occupation, possibly for the one employer, for 7 years. He adapted to the language and customs of a new country, employed the complex psychological and cognitive-motor skills required by his job, with his mental faculties eventually being seen as unimpaired by a professional observer. Following an unspecified illness, he returned to his mother in California where after recovering he was "anxious to work" and found farm employment in the San Francisco area. He continued to work even after his first seizure. Only at the very end of his life did he become unsettled and dissatisfied with his employers (Macmillan and Lena 2010).

Relevance to Psychology and Neuroscience

Gage might have remained merely a medical curiosity – a man who lived to tell about an extraordinary brain injury – had he not been taken up by various trends in nineteenth and twentieth-century psychology (Griggs 2015; Macmillan 1996). First, of course, were the phrenologists, who were the first to argue that specific areas of the brain were associated with particular mental functions – many of which were relevant

to personality and social behavior (Gall 1822–1825/1835). Later in the nineteenth century, David Ferrier cited Gage in his argument that thinking entailed the inhibition of action, in which the frontal lobes played a major role (Ferrier 1886; Macmillan 1992, 2000b, 2004).

By the latter part of the nineteenth century, the specific ideas of phrenology had been largely discredited, but interest in the frontal lobes was revived in the twentieth by the apparently minimal effects on them of radical brain surgery. Luria's work on the assessment and rehabilitation of function in soldiers who had suffered brain damage during World War II, which was mentioned in the previous section, also played a very important part. Although Luria did not reference Gage, the characteristics he described were precisely the functions that seemed to be impaired in his case, and in this way Gage began to enter the textbooks – mostly, unfortunately, in exaggerated form (Macmillan 2000a).

In the 1960s, interest in functional specialization was revived by studies of H.M. and other brain-damaged patients, and Gage took his place as an illustration of the role of the frontal lobes in behavioral inhibition, self-control, and decision-making (de Schotten et al. 2015). For example, in his theory of multiple intelligences, Gardner (1983) explicitly cited Gage as evidence for an interpersonal form of intelligence, defined as "the ability to notice and make distinctions among other individuals", and isolable by brain damage from other intellectual abilities. Just as H.M. revealed the role of the hippocampus in long-term memory, so Gage served to illustrate the importance of the ventromedial prefrontal cortex, and especially the anterior cingulate gyrus, for social decision-making in emotional contexts – as it were (Damasio 1994).

Of course, any such conclusions depend on more than the case of Phineas Gage: too little is known for certain about the actual location of his injury and the actual extent of his postmorbid behavioral changes. Still, more than a decade before Broca and Wernicke reported their eponymous cases of aphasia, Phineas Gage was inspiring discussion of the neural substrates of personality and complex social behavior (Kihlstrom 2010; Macmillan 2000c). If Harlow had had access to his brain for anatomical study, and not just his skull, and more reliable and detailed observations of his behavior, Gage might be known to history as the first convincing proof of the neuroscientific doctrine of modularity and functional specialization in the brain (Fodor 1983). As it is, however, rightly or wrongly, Gage should be considered to be the index case for social and affective neuroscience.

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Phineas Gage, Neuroscienceâ€™s Most Famous Patient. Each generation revises his myth. Hereâ€™s the true story.Â On Sept. 13, 1848, at around 4:30 p.m., the time of day when the mind might start wandering, a railroad foreman named Phineas Gage filled a drill hole with gunpowder and turned his head to check on his men. It was the last normal moment of his life. Other victims in the annals of medicine are almost always referred to by initials or pseudonyms. Not Gage: His is the most famous name in neuroscience. Railroad foreman Phineas Gage survived a horrific brain injury that left him with an altered personality. His story revealed the complex functions of the frontal lobe decades before scientists began studying it in animals. Brain Bytes showcase essential facts about neuroscience. Phineas Gage was an American railroad worker who suffered a severe injury that turned him into one of the most famous cases in neuroscience. Check out this biography to know about his childhood, family, personal life, career, and achievements.Â Phineas Gage was an American railroad worker who suffered a severe injury that turned him into one of the most famous cases in neuroscience. After an iron rod went through his head, it was highly improbable for him to survive.