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Grey Matters:
How controversial and drastic neurosurgeries have contributed to our knowledge of the brain

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Transcripts of the ancient philosophers tell us that early man often wondered if the human mind was not more complex than the physical brain. It was thought that there existed a soul component to the human body that separated man from animal. Thousands of years later, mankind is still grappling with the same questions. Moreover, what we have learned about the physiology and development of the brain since ancient times has only increased the depth and breadth of the questions we ask. Surprisingly. the destruction of the brain, has played quite a role in our understanding of human life. It wasn't until we started destroying brains to save people that our rigorous attempts to answer questions started bearing tangible fruit.

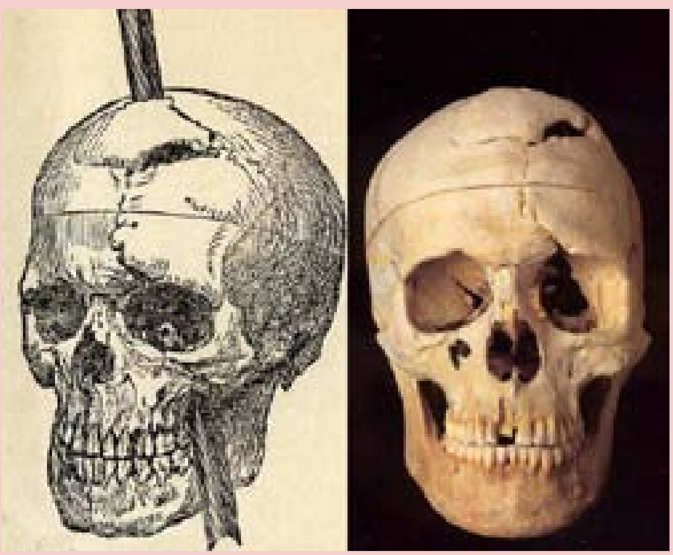


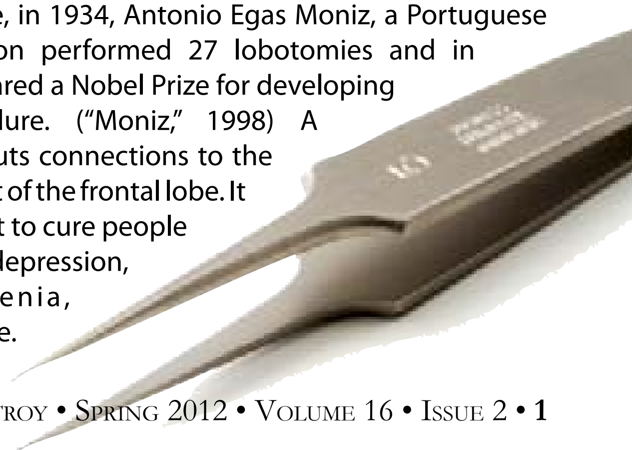
Figure 1. An illustration and model of Phineas Gage's skull

Trepanned skulls, or skulls with holes drilled through to the outermost later of the brain, the dura mater, have been found at a number of ancient sites spanning multiple continents including modern day Europe, and South America. These findings date back to as early as 2000 B.C. The trepanations themselves span from centimeters in diameter to the size of half of the skull. Scientists and anthropologists alike hypothesize that ancient peoples performed such surgeries as medical cures for headaches, seizures and the like. Some also propose that trepanation might have been seen as a method for removing evil spirits from the body. ("An illustrated," 2008). Both theories have valid supporting arguments, and we will never know for sure what the reasons for trepanation were.

> "destruction of brain structures can result in newer and stronger brain"

Fast forwarding to more recent history however, in 1848, Phineas Gage, a railroad worker, had a work-related accident that resulted in metal rod going through the frontal lobe of his brain. Doctors removed the rod to the best of their ability, and Gage, surprisingly, survived. But the damage done to the frontal lobe of his brain caused him to have significant behavioral changes. Friends who previously described him as being organized and dependent did not recognize the man that came out of the accident. The post-accident Gage was described as lacking the ability to formulate and carry out complex plans, and as being unreasonably belligerent and profane. Some accounts even claim that Gage began molesting children post-accident (Costandi, 2010). Scientists of the era were able to hypothesize the functions of the frontal lobe, based on the type of changes that Gage underwent. These behavioral changes caused scientists of the era to realize that the mind and brain may be one and together, and that behavior may be encoded in the physical brain. This realization took society one significant step further to solving the mind-brain problem, and was the basis for the neurosurgical experimentation of the 1900s.

For example, in 1934, Antonio Egas Moniz, a Portuguese neurosurgeon performed 27 lobotomies and in 1949, he shared a Nobel Prize for developing the procedure. ("Moniz," 1998) A lobotomy cuts connections to the anterior part of the frontal lobe. It was thought to cure people of tension, depression, schizophrenia, and the like.



His associate, an American named Walter Freeman, was performing up to 25 lobotomies a day by the year 1952. Freeman performed surgeries on patients as young as 12 years old, with varying success. One of his many patients, Patricia Moen says of her surgery, "I was a more free person after I'd had it. Just not to be so concerned about things... I just, I went home and started living..." (Kochhar, 2005b). However, others like Anita McGee have spent the rest of their lives in mental institutions due to the damages incurred by Freeman's procedure (Kochhar, 2005a).

"After half of the brain is removed, it would seem as though all is lost..."

Thus, human history has seen the human brain sliced in an impressive variety of ways under the pretense of saving lives. Procedures that may, in retrospect, seem haphazard laid the groundwork for the life-saving, highly effective techniques used today. Additionally, modern neurosurgeries have continued to constantly contribute to our understanding of the nature of the elucidating the mind. Neurosurgical procedures to cure epilepsy have become quite common-place and have been instrumental in this process.

Epilepsy is a relatively common neurological disorder. 50 million people worldwide, and 200,000 people in the US have epilepsy. Some people live with the symptoms for up to 20 years before being clinically diagnosed and treated (Bardi, 2011). Genetic predisposition and head trauma are just a couple of the numerous causes underlying the condition, and some patients may have distinct environmental triggers such as flashing lights, and loud noises. The symptoms of epilepsy are numerous, but the symptom that is typically considered to be the most hindering is the seizures. Many people take anti-convulsant drugs to prevent seizures, but when this is ineffective, surgery may be required to remove the critical portions of the brain where the abnormal neuronal firings that cause the seizures and other symptoms are occurring. (Weiner, 2004)

An often referred studied epileptic is Henry Molaison, more commonly known as H.M. At age 9, Molaison suffereed from a falsly inoccuous brain injury caused by running into a car while riding his bicycle. However, as a result of this injury, Molaison began to experience severe seizures, and his quality of life was serverly hindered. When he was 27 years old, in order to give him a normal life, doctors attemped to remove slices of the offending tissue in the hippocampus. Their aim was to eliminate the convulsions and blackouts that prevented him from working as a mechanic, and living a normal life (Carey, 2008). Instead, Molaison's memory was severely affected. He lost all memory previous to shortly before the surgery. In addition, he lost the ability to form new memories. In essense, he was living from moment to moment. The interesting aspect of Molaison's resulting state was that while he could not formulate new memories and only had limited access to memories about his young adult life, he was able to learn how to perform motor actions, such as making coffee- even though he could not remember learning those actions. In other words, his procedural memory mechanisms were intact (Anderson, 2010). From Molaison's case, scientists and doctors were able to hypothesize that different types of memory were encoded in different parts of the brain and that the hippocampus isn't the center of all types of memory.

Studies on H.M and a number of such epilepsy patients have elucidated the roles of certain parts of the brain. Although their stories can be quite heartbraking, epileptic patients and others that have had portions of their brain removed have contributed incomparably to our knowledge of the functions of different parts of the brain. Another type of neurosurgery that has illuminated the way the brain works are hemispherectomies. Hemispherectomies, where one hemisphere of the brain is entirely removed, were being performed unsuccessfully in the 1920's in order to remove tumors and cure seizures. It wasn't until the 1980's however, that they started being performed successfully. Children with Rasmussen's syndrome (an autoimmune disease which is linked to epilepsy and which results in the destruction of half of the brain), congenital vascular disease, cortical dysplasia,

"...but as researchers have found, the brain has an incredibly amount of neural plasticity"

and Sturge-Weber syndrome to name a few, require this procedure (Kossoff, Vining, Pillas, Pyzik, Avellino, Carson, 2003). The symptoms of the afore-mentioned diseases do not outweigh the loss of half of the brain. For example, Cameron Mott, like many of the children who are diagronosed with Rasmussen's disease, had about 10 or more seizures a day previous to surgery. Her only real option was a hemispherectomy (Celizic, 2010).

After half of the brain is removed, it would seem as though all is lost, but as researchers have found, the brain has an incredibly amount of neural plasticity, and all of the special skills that the removed hemisphere is responsible for are taken on by the remaining hemisphere. After a hemispherectomy, the remaining hemisphere forms synapses between neurons where needed in order to compensate, in a process called synaptogenesis. Although adult brains have some amount of neural plasticity, synaptogenesis is most vivid in childhood, which is why hemispherectomies are not performed in adults unless as a last resort (Kossoff, Vining, Pillas, Pyzik, Avellino, Carson, 2003).

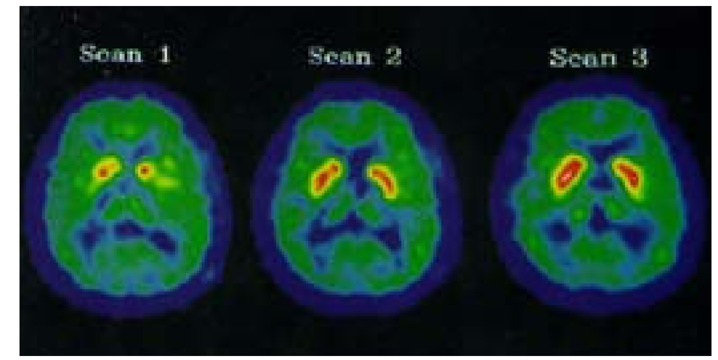


Figure 2. PET scan of a patient with Parkinson's disease. The basal nuclei are shown in red, marking hyperactivity of the nuclei.

Patients who have undergone hemispherectomies have allowed researches to learn an incredible amount about the development of the brain, from neurogenesis, the formation of neurons, during gestation to synaptic pruning, the refinement of connections between neurons, post-birth. Additionally, much of what we know today about neural plasticity comes from patients like Mott.

As technological advances occur, we will be able to unlock even more specific knowledge about the brain. For example, deep brain stimulation uses electrical pulses to selectively destroy neurons in the basal nuclei as a treatment for Parkinson's disease. The exact mechanism between destruction of those neurons and the alleviation of Parkinson's symptoms is unknown, but will allow scientists a greater understanding of the pathology of the disease once it is determined (Widmaier, Raff, Strang, 2011). In this way, the advent of technologies such as deep-brain stimulation will not only increase the probability of saving lives, but will also allow us to figure out what it is we do and don't truly understand about the mind and brain.

As we've seen, partial destruction of brain tissue, although it sounds terrible, can be life-saving. And in the wake of destruction, there has been an incredible amount of learning and growth. For one, destruction of brain structures can result in newer and stronger brain structures, as in the case of neural plasticity. But even when it doesn't result in new growth, destruction has also been incredibly important in providing information about how the brain works. Scientists have been able to take this information and use it to create better procedures for treating people with neuropsychological and neuronal diseases- at the most basic level. Brain studies are also important for anthropologists studying the way in which different cultures behave, for computer scientists interested in artificial intelligence, and for the general public that is trying to reconcile the physical brain with the intangible mind.

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