

# Biological Foundations of the Brain

## Brain facts

- ✚ Composition of the brain: 78% water, 12% lipids, 8% protein, 1% carbs, 2% soluble organics, and 1% salt
- ✚ 10 seconds is the amount of time until unconsciousness after the loss of blood supply to the brain.
  - ↪ Most people can hold their breathe 1-2 minutes without training; the brain can typically stay alive for 4-6 minutes without oxygen; after that, cells begin to die.
    - *The record for a free dive is over 10 minutes!*
- ✚ The slowest speed at which information travels between neurons is 260 mph
- ✚ More electrical impulses are generated in one day by a single human brain than by all the telephones in the world.
- ✚ 89.06% is the percentage of people who report normally writing with their right hand, 10.6% with their left, and 0.34% with either hand.

# Phineas Gage

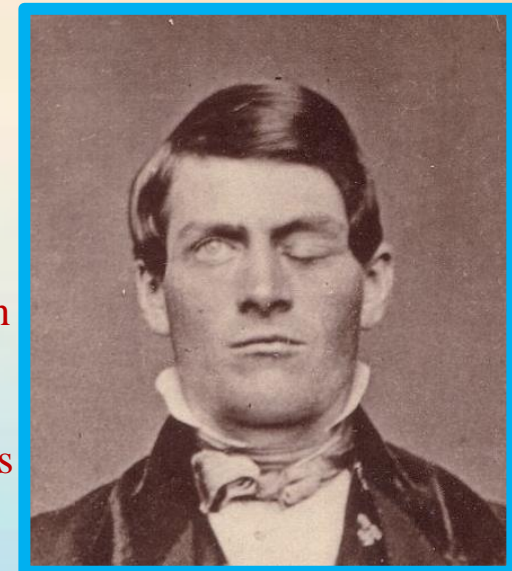
Born 1823 in New Hampshire. 1<sup>st</sup> of 5 children. He was literate  
Hard working, easy going energetic, motivated and shrewd

The accident on 13 September 1848

- Age 25, he worked as the foreman of a railroad crew in Vermont.
- He was using an iron tamping rod to pack explosive powder into a hole. Powder detonated, sending a 43" long, 1-1/4" diameter rod into his head, through the brain and landing 80 feet away!
- ↳ Gage was able to speak and walk to a nearby cart, so he could be taken into town to see a doctor.
- ↳ Still conscious later that evening, and able to recount names of his co-workers
  - + The rod destroyed 11% of the white matter in the frontal lobe, and 4% of the cerebral cortex

## Recovery

- Develops an infection. Two weeks in a semi-comatose state. Time improves function
- He knew how much time had passed, and remembered clearly how the accident happened, but he had difficulty estimating the size and amount of money
- Becomes socially combative, indecisive and did not express emotions. Some changes are temporary.
- Could not continue with his job
- To make money, he traveled the East Coast and Europe with the rod, making paid appearances
- Spent seven years as a stagecoach driver
- Moved in with his mom in San Francisco as his health deteriorated
- Epileptic seizures in final months, and died 1860 (12 years after the accident)



## Neuroplasticity / Neural Plasticity (Brain Plasticity)

Neuroplasticity is the ability of the brain to modify its connections or re-wire itself.

↳ Without this ability, any brain, not just the human brain, would be unable to develop from infancy through to adulthood or recover from brain injury.

This slows starting near age 25, when the brain plasticity starts to solidify, making it harder for brain recovery.

What helps develop neuroplasticity?

↳ Foods high in omega-3 fatty acids (fish, avocado)

↳ Exercise (30 minute brisk walk daily)

↳ 30 minutes leads to increased blood flow to the brain, leading to more energy, oxygen and increased neural performance.

## Brain Pruning

Little-used areas of the brains white matter dissolve during three distinct periods, leaving the brain more efficient and, with each pruning, opening up more abilities.

This occurs repeatedly in infancy, between puberty and mid-adolescence (roughly aged 14 and 17, +/- a year), and again in the early twenties (about age 22, +/- a year).

↳ For instance, the first pruning enables abstract philosophical thought.

↳ Schizophrenia emerges following the third pruning.

## Dark Matter v White Matter

The neuron highways! Using the concept of a computer as an analogy: gray matter can be thought of as the actual computers themselves, whereas the white matter represents the network cables connecting the computers together.

The brain can adapt to white matter damage. Unlike gray matter, which peaks in development in a person's twenties, the white matter continues to develop and peaks about middle age.

↳ In terms of oxygen consumed, 6% will be used by the brains white matter and 94% by the gray matter.

The development of Multiple Sclerosis and protein buildup associated with Alzheimer's both affect white matter

## Right and Left Hemispheres of the Brain

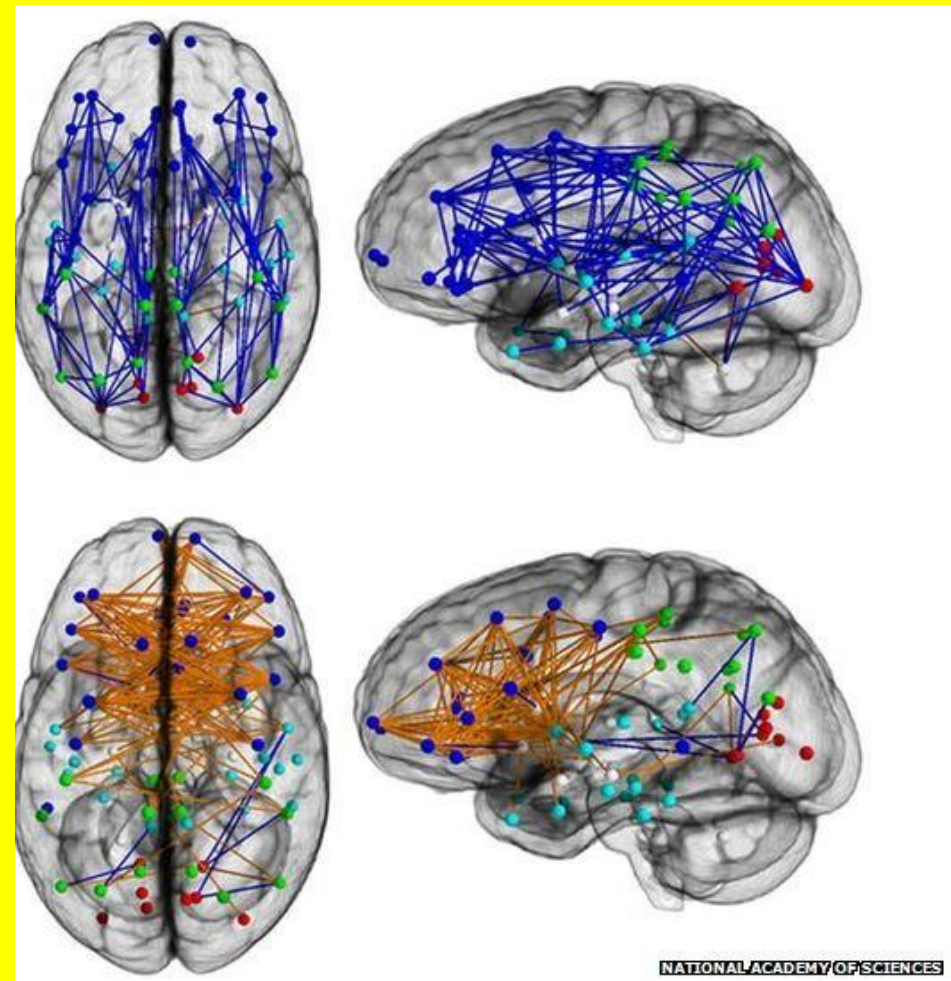
The brain is divided in half, with the Corpus Callosum bridging the two hemispheres. The right side of the brain controls the left side of the body, and the left side of the brain controls the right side of the body. The right side of the brain is generally more concerned with the artistic, spatial and musical inclinations while the left is more orientated toward the colder, linear, rational and verbal aspects.

- The left brain contains many areas which are vital for the processing and formation of speech. It helps children acquire language, make the connection between sounds heard and things seen or otherwise experienced, and seems to control speech in 96% of children. The left brain is good at exact and precise thought processes, and the pre-motor areas of this region deals with grammar. The left side of the brain controls actual speech movements that generate sounds. The Left Hemisphere of the brain has 186 million more neurons than the Right Hemisphere.
- The right side is involved in interpreting and generating speech with meanings. The right brain is apt at making broad and sweeping understandings and it can also decipher meaning by ‘the way you said it’, the point of emphasis, and comprehends humor.

People with Dyslexia have a slightly larger Right Hemisphere.

## What are the differences between the male and female brain?

- The neuron activity is dramatically different in the two genders. Male brains see most of their neuron activity firing front-to-back within each hemisphere of the brain, with little overlap. Girls' brains have less hemisphere-isolation and instead have much more cross-hemisphere neuron activity. (This may explain why girls can multitask better!)
- Men's brains are, on average, 10% larger than women's, and consequentially weigh slightly more, 3 lbs to 2¾ lbs. These size differences have been found repeatedly, but they emerge only when comparing large numbers of people, so some women's brains are larger than the average whereas some men's are smaller. These differences partly reflect the fact that men are generally bigger and taller than women, but they are not in any way related to differences in intelligence.



- Men and women's brains also differ in overall composition. Male brains contain about 6½ times more grey matter than women, while female brains have more than 9½ times as much white matter. The frontal and the temporal areas of the brain cortex are larger in volume in women.
  
- (as a percentage of total brain volume) the Amygdala is larger in girls
  - ↳ **Amygdala** – Helps in storing and classifying emotionally-charged memories. It plays a significant role in producing emotions, especially fear and jealousy.
  - ↳ Individuals with an enlarged-beyond-normal Amygdala have been diagnosed with manic-depressive disorder.
  - ↳ In teenagers (both genders), the Amygdala is more active than the Frontal Lobe
    - ↳ **Frontal Lobe** – The front part of the brain, involved in planning, judgment, reasoning, impulse control, organizing, problem solving, selective attention, personality, personality and a variety of “higher cognitive functions”, including behavior and emotions.

- The Hippocampus is activated on its right side in males yet on its left side in females.
  - ↳ **Hippocampus** – Its primary role is memory formation, classifying information and long-term memory. Leading thought hypothesizes that this area also intuitively informs a person of their place within an environment.
  - ↳ People with extensive damage to this part of the brain may suffer amnesia. Furthermore, in Alzheimer's Disease, this area is among the first to suffer damage.
  
- Stress has been found to induce an increase in serotonin and dopamine levels within the amygdala in males, but not in females. In females, both short-term and long-term stress have been found to actually enhance spatial memory while under duress

**IMPORTANT: the differences in male and female brains do not have an impact on intelligence.**



## *How do substances affect brain function?*

Meth –

- ↳ Meth is highly addictive.
- ↳ A single hit of the drug damages dopamine transporters in the brain.
- ↳ Some of the damage to the brain is irreversible. Studies of meth users have revealed severe structural and functional changes in the areas of the brain associated with emotion and memory.
- ↳ Chronic meth users can display a number of psychotic features, including paranoia, visual and auditory hallucinations, and delusions (for example, the sensation of insects crawling under the skin.)
- ↳ Meth use has been associated with changes in the size of certain structures within the brain. This is due to brain inflammation caused by the drug.

## Alcohol

- ↪ Alcohol is addictive
- ↪ The effect of alcohol on the brain is clear...difficulty walking, blurred vision, slurred speech, slow reaction times, impaired memory, and so on. Alcohol impairs the brain's functions.
- ↪ Using imaging with computerized tomography, several large studies compared brain shrinkage, a common indicator of brain damage, in alcoholic men and women and reported that male and female alcoholics both showed significantly greater brain shrinkage than the non-drinking control subjects. Studies also showed that both men and women have similar learning and memory problems as a result of heavy drinking. The difference is that alcoholic women reported that they had been drinking excessively for only about half as long as the alcoholic men in these studies. This indicates that women's brains, like their other organs, are more vulnerable to alcohol-induced damage than men's .
- ↪ Up to 80% of alcoholics have a deficiency in thiamine, and some of these people continue to develop serious brain disorders, such as Wernicke-Korsakoff Syndrome (which includes mental confusion, paralysis of the nerves which move the eyes, difficulty with muscle coordination, and so on.)
- ↪ Alcohol use in adolescence has impaired the pruning of the brain.
- ↪ Alcohol use by adolescents is directly responsible to a reduction in the size of the hippocampus (by as much as 10%!) The pre-frontal area of the brain is also affected.

## Marijuana –

- ↳ Marijuana is addictive. Research suggests that 9% of users become addicted. This number increases among those who start the drug young (at about 17% addiction rate) and among daily users (to 20%-25% addictive rate)
- ↳ The main active ingredient in marijuana interferes with the normal communication between neurons and between brain circuits. In other words, marijuana (1) impairs a person's ability to form new memories and (2) it disrupts coordination and balance by binding receptors in the cerebellum and basal ganglia...parts of the brain which regulate balance, posture, coordination and reaction time.
- ↳ Scientific evidence suggests repeated marijuana use during adolescence (four joints a week) can increase the risk for psychosis, decreased adult IQ, and lead to changes in the brain that increase vulnerability to more dangerous illicit drugs. (Studies show that those who start Marijuana in adulthood – after age 22 – did not show significant IQ declines.)
- ↳ Researchers have found that compared to nonusers, people over age 22 who smoked marijuana starting as early as age 14 have less brain volume (gray matter) in the orbitofrontal cortex. This is where decisions are made.
- ↳ Several studies draw a clear connection between marijuana use and mental illness. High doses of marijuana can produce a temporary psychotic reaction (involving hallucinations and paranoia) in some users, and using marijuana can worsen the course of illness in patients with schizophrenia. Adolescent

marijuana users have (later in life) been found to have a brain structure characteristic of those with schizophrenia.

- ↪ Marijuana use started in adolescence leads to a reduction of neuron connections
- ↪ Marijuana has an adverse impact on memory which persists even after the effects of the drug ends
- ↪ Marijuana raises the heart rate by 20%-100% shortly after smoking; this effect can last up to three hours. Consequentially, marijuana users have a 5% increased risk of heart attack in the first hour after smoking a joint
- ↪ Smoking Marijuana during pregnancy leads to a 2.3% increase risk of having stillborn birth (the child is dead upon birth) and a 1.5% increase risk in Autistic Spectrum

How does pollution affect the brain?

- ↪ Research suggests that fine particulate matter from cars, trucks and factories could have a long-term effect on the brain.
- ↪ Over time, exposure to levels of air pollution typically found in urban and suburban areas could actually shrink the brain by 0.32% (the equivalent of about one year of aging).
- ↪ It is theorized that pollution causes inflammation in brain tissue.
- ↪ Living in smog-dense areas was also linked to a 46% increase in the risk for “silent strokes”, which are associated with cognitive decline and dementia.

## Smoking

- ↳ Smoking is addictive.
- ↳ Chemicals (nicotine) inhaled while smoking enters the blood stream, which makes it way to the brain ten seconds after smoke is inhaled and remains active 20-40 minutes later. After reaching the brain, nicotine affects, changes and controls the specialized receptor cells (responsible for regulating the well-being, mood and memory) This, in turn, changes the chemistry of the brain, which finally affects the smoker's mood.
- ↳ Smoking leads to thickening and clotting of the blood, which leads to high blood pressure.
- ↳ Smoking causes a cognitive decline in men nearly 38% faster among persistent smokers relative to others.

## Vaping (E-cigarettes)

- ↪ Vaping is addictive (both in its nicotine products and in its non-nicotine products)
- ↪ Linked to higher risk of stroke, heart attack, diseased arteries and cancer.
- ↪ E-juice contains irritants that affect the lung, causing inflammation.
- ↪ “It is difficult to know exactly what chemicals are in e-cigarette because most products do not list all of the harmful or potentially harmful substances contained in them. Some products are also labeled incorrectly.”
- ↪ Nicotine in e-cigarettes raise blood pressure.
- ↪ Compared to nonusers, users of e-cigarettes have a 71% higher risk of stroke, 59% higher risk of heart attack and 40% higher risk of heart disease.
- ↪ Vaping (E-cigarettes) is a gateway substance

## LSD (Hallucinogen)

- ↳ LSD is not considered a highly addictive drug, but leaving it can be difficult.
- ↳ LSD increases blood flow in the brain, allowing parts of the brain which do not usually 'talk' to one another to do so. In particular, the visual cortex increases its communication with other areas of the brain (this may explain the vivid and complex hallucinations experienced under LSD)
- ↳ Neurons which normally fire together in a synchronized fashion lose that harmony of activity. The affect is correlated to a disintegration of a sense of self ("ego dissolution" as the term is known in psychological terms, the sense that a person is less of a singular entity and more melded with people and things).
- ↳ Some areas of the brain do have reduced blood flow.
- ↳ There is reduced communication between (1) the areas which store memory and (2) that which process information input from the eyes. Listening to music during this time, the music is processed partially in the visual cortex (not common in a non-drug induced state). This may account of the 'eyes closed' imagery

## OTHER FUNCTIONS OF THE BRAIN

**Hindbrain** or **Raptillian Brain** – This controls human’s primitive instincts and most basic functions. Consider: instincts for survival, dominance, mating and basic functions of respiration and heartbeat. This contains the Spinal Cord, Medulla Oblongata, the Pons and Cerebellum.

**The Limbic System** – Sometimes called the “emotional brain.” This is where human emotions reside, where memory begins and where these two functions combine together to make behaviors with positive or negative feelings. It’s where most unconscious value judgments are made. Information going through the Limbic system are filed under ‘agreeable’ or disagreeable’, and it also plays a role in attention, spontaneity and creativity. Located in the Limbic system are: the Amygdala, the Hippocampus, the Hypothalamus and the Thalamus.

**Neocortex** – This term is used to describe two-thirds of the brain (overlapping numerous smaller regions). It comprises the Frontal Lobe, the Parietal Lobe, the Temporal Lobe, the Occipital Lobe, Broca’s Area and the Corpus Callosum.

**Broca’s Area** – This part of the Neocortex controls speech, language recognition and facial nerves.

**Brain Plasticity** – A process which refers to how nerve cells and neurons physically change inside the brain, in response to a change in environmental circumstances over time and/or in response to brain injury. Current research in the field of stroke recovery and addiction has proved revealing.

**Cerebellum** – The portion of the brain (located in the back of the brain) which helps coordinate movement, such as balance, posture, movement and muscle coordination.

The Cerebellum contains half of all the neurons in the brain but comprises only 10% of the brain

**Cerebral Cortex** – This is the main area involving thinking, decision-making, emotions and the five senses.



**Corpus Callosum** – This structure connects the right and left hemispheres of the brain, and facilitates communication between the two. It is important for intelligence, consciousness and self-awareness. It is the largest White Matter structure in the brain, and reaches full maturity in the twenties.

**Frontal Lobe** – The front part of the brain, involved in planning, judgment, reasoning, impulse control, organizing, problem solving, selective attention, personality, and a variety of “higher cognitive functions”, including behavior and emotions.

➤ The Prefrontal cortex (front of the Frontal Lobe) is important to personality.

➤ The posterior (back) of the Frontal Lobe serves to modify movements

Both lobes grow measurably between ages 10 and 12 (with girls’ growth spurt generally coming a little earlier than boys), and then shrink in the twenties as extraneous branches are pruned back into efficient, well-organized circuitry.

**Hippocampus** – Its primary role is memory formation, classifying information and long-term memory. Leading thought hypothesizes that this area also intuitively informs a person of their place within an environment.

People with extensive damage to this part of the brain may suffer amnesia. Furthermore, in Alzheimer’s Disease, this area is among the first to suffer damage.

**Hypothalamus** – It controls many body processes, such as heart rate and feelings of hunger and thirst, as well as circadian (24-hour cycle) rhythms. It is located above the brain stem.

Failure to get 8-9 hours of sleep each night can disrupt teens circadian rhythm ‘clock’.

**Medulla Oblongata** – This governs involuntary processes, such as breathing, swallowing, defecation (ie, need to use toilet), digestion and heart rate. It is located on the lower half of the brain stem, next to the Pituitary Gland.

**Occipital Lobe** – A region in the back of the brain which processes visual sensations and information (images, shapes, colors). The Visual Cortex resides here, and it where reading is made possible.

- How our brains process eyesight: “Each hemisphere of the brain interacts primarily with one half of the body, but for reasons that are unclear, the connections are crossed: the left side of the brain interacts with the right side of the body, and vice versa. Motor connections from the brain to the spinal cord, and sensory connections from the spinal cord to the brain, both cross the midline at brainstem levels. Visual input follows a more complex rule: the optic nerves from the two eyes come together at a point called the optic chiasm, and half of the fibers from each nerve split off to join the other. The result is that connections from the left half of the retina, in both eyes, go to the left side of the brain, whereas connections from the right half of the retina go to the right side of the brain. Because each half of the retina receives light coming from the opposite half of the visual field, the functional consequence is that visual input from the left side of the world goes to the right side of the brain, and vice versa. Thus, the right side of the brain receives somatosensory input from the left side of the body, and visual input from the left side of the visual field -- an arrangement that presumably is helpful for visuomotor coordination.”

**Parietal Lobe** – This is involved in processing pain and touch sensation, as well as being involved in emotion, memory and speech. It integrates auditory, visual and tactile signals. It maintains two slightly different functions, depending on the right or left side of the area. They contain the primary sensory cortex which controls sensation (tough, pleasure). Behind this is a large association area that controls fine sensation (judgment of texture, weight, size, shape)

- Parietal Lobe, right: damage to this can cause visual-spatial difficulties (the patient may have difficulty finding their way around new or even familiar places)
- Parietal Lobe, left: damage to this area may disrupt a patient’s ability to understand spoken and/or written language.

These particular areas reach their Gray Matter peak at ages 10 (girls) and 12 (boys) before being pruned. These areas are immature until about the age 16.

**Pituitary Gland** – Secretes hormones which regulate the body. It controls temperature regulation, growth, blood pressure, water regulation in the body, breast milk production and sex organ functions of both genders. It is the size of a pea.

**The Pons** – This maintains a role in sleep, particularly in terms of being conscious (awake) or not, regulate consciousness and is associated with the sense of higher purpose.

↳ “Locked-in Syndrome”, a condition in which a patient is aware and awake but cannot move or communicate due to complete paralysis except for the eyes, occurs when a lesion damages the Pons.

**Temporal Lobe** – It may be considered that there are two temporal lobes, as one is located about ear-level in each hemisphere of the brain. They allow a person to distinguish between different smells and sounds. They also help with new information and are believed responsible for short-term memory.

➤ Right-hemisphere lobe: mainly involved in visual memory (memory for pictures, faces)

➤ Left-hemisphere lobe: mainly involved in verbal memory (memory for words, names)

↳ These areas reach their gray matter peak about age 16, followed by a decade of pruning.

**Thalamus** – Think of this as the relay station of the brain. All sensory input and output routes through this point. It also is suspected to play a function in muscle control. It is understood is in some manner governs sleep and wakefulness (see Pons above), as well as regulating important bodily functions including hunger, body temperature and breast feeding.

**Wernicke’s Area** – Responsible for language recognition, it is located in the Left Hemisphere of 90% of people. Damage to the Wernicke’s Area affect a persons ability to string together a coherent sentence or even the loss of the ability to understand language.

↳ Studies suggest the brains ability to link letter combinations with sound may not be fully developed until age 11.