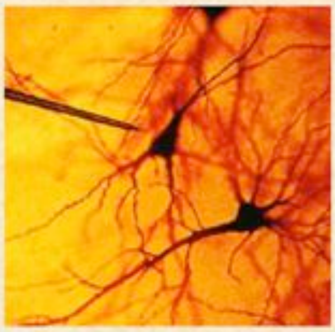
Mind, Brain & Behaviour 1

Behavioural Neuroscience



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Course details

- Jason Forte
  - Lab - Room 929, Redmond Barry Building
  - jdf@unimelb.edu.au
- *Learning Management System (LMS)*
  - contains lecture slides & notes
  - *http://www.lms.unimelb.edu.au/*
- *Student Manual*
  - Available on LMS

2

Course assessment

- Multiple choice exam
  - Base solely on the lecture slides and notes
- Essential rules…
  - If it is in the notes, it could be in the exam
    - So if I don't mention it, it could still be there…
  - If it isn't in the notes, it can't be in the exam
    - So if I do mention it, it might not be there…
- Feel free to enhance your experience by reading any textbook of your choosing…

3

Structure of lectures

- Learning objectives
- Content
- Summary
- Supplementary reading
  - Not necessary for my part of the course

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Mind, Brain & Behaviour 1
Behavioural Neuroscience

Introduction to behavioural neuroscience

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Learning objectives

- What is *behavioural neuroscience*?
- What are the *important historical milestones* in the development of our understanding of the link between brain and mind?
- What *methods* have been used to determine this link?

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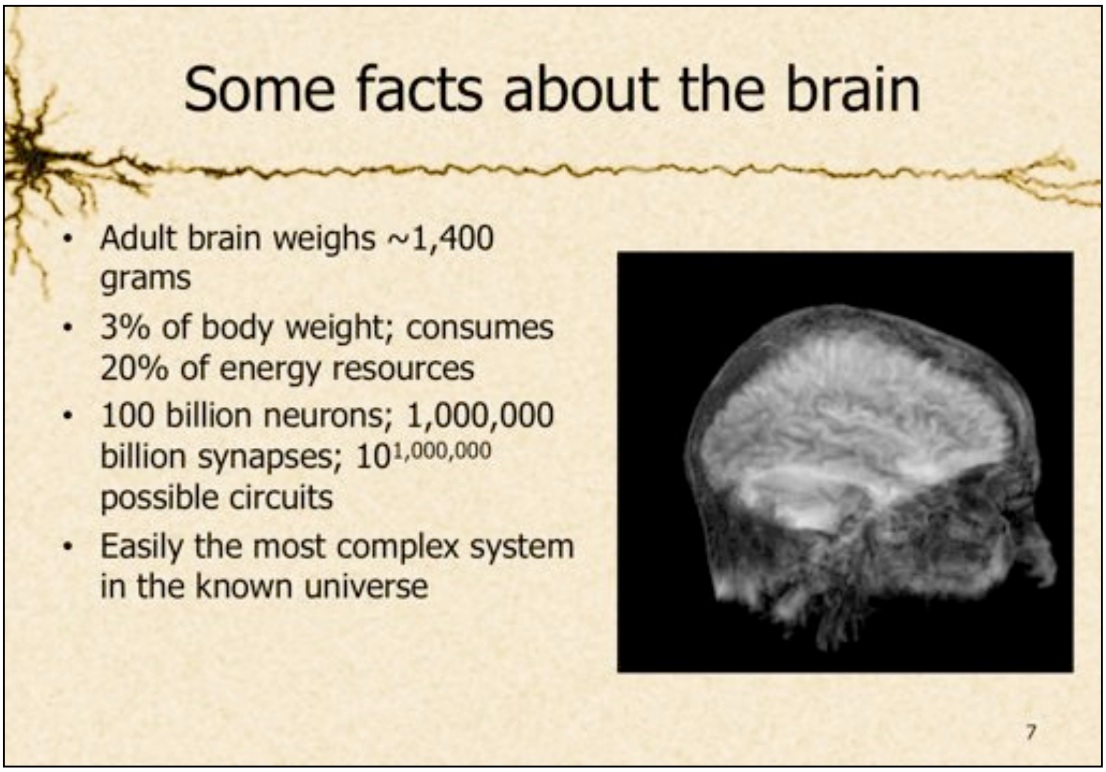
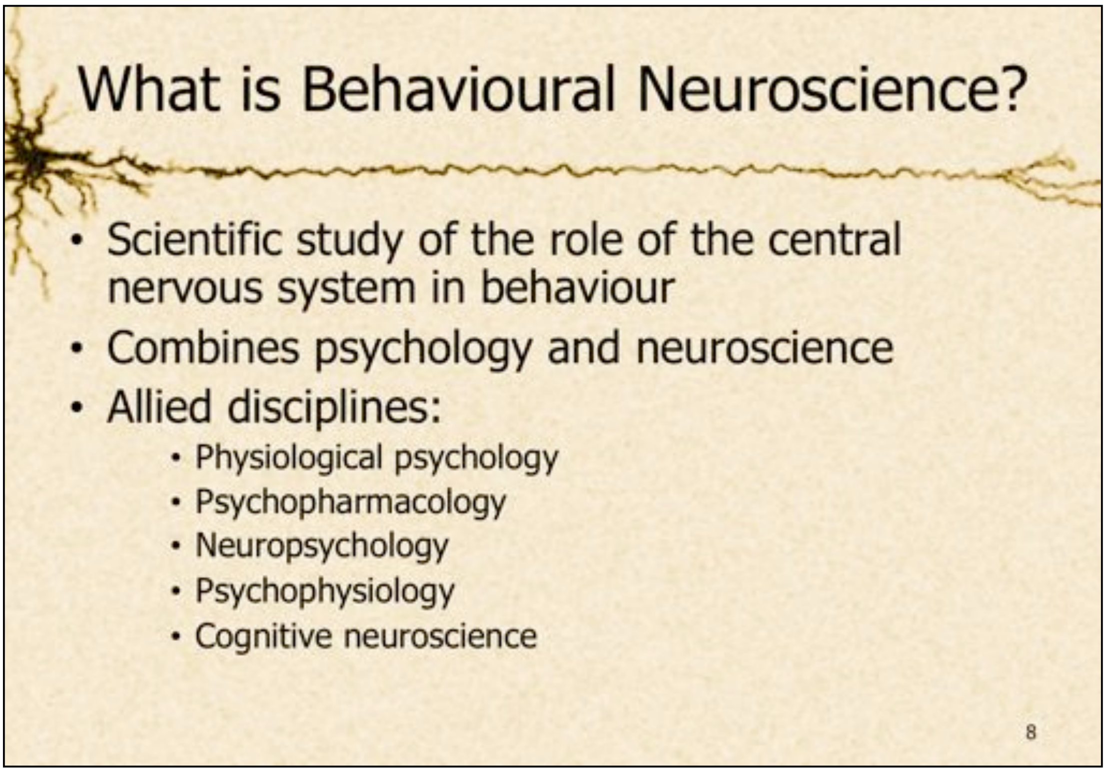


The human brain constitutes only 3% of our body weight, but uses 20% of our energy resources.

It is made up of around 100 billion **neurons** (nerve cells that receive and transmit electrochemical signals), and approximately a million billion **synapses** (small gaps between neurons, across which **neurotransmitter** substances pass). The number of different pathways or circuits that can be formed by chains of neurons is practically infinite (or at least inconceivably huge)!

The human brain is the most complex system known to science; how the brain gives rise to behaviour, thinking and feeling is probably the last great mystery of science.

In Behavioural Neuroscience, we assume that the mind (thinking, feeling, behaving) is produced by the workings of the brain. But how is this achieved? How can that jelly-like mass in our heads give rise to something so intangible as a feeling of sadness, or the smell of coffee, or, ultimately, **consciousness** (our awareness of thoughts, perceptions, memories and feelings)?



Behavioural Neuroscience – the division of psychology that attempts to describe how the structure and function of the central nervous system (CNS), and the brain in particular, gives rise to psychological phenomena such as perception, attention, language, learning, memory, emotion, and so on.

Behavioural Neuroscience is a **bridge** between psychology (the study of behaviour) and neuroscience (the study of the CNS)

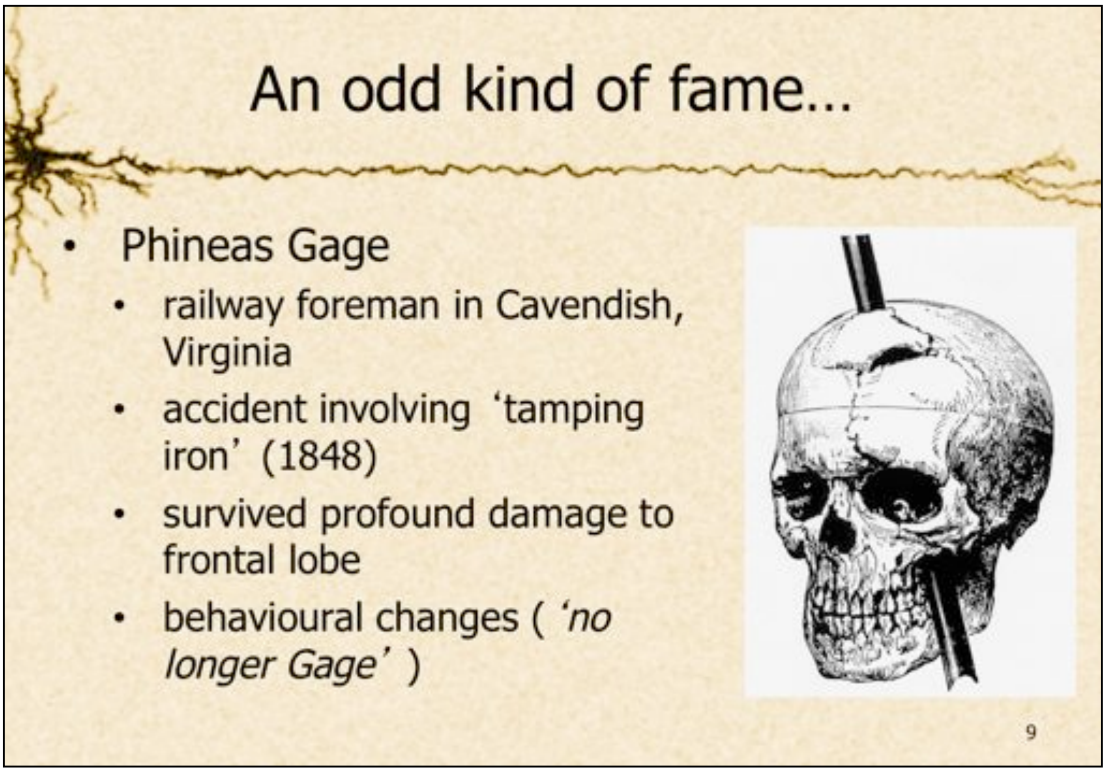
Allied disciplines:

•**Physiological Psychology** – study of the effects of manipulations of the CNS on behaviour (e.g., effects of surgical lesions, electrical stimulation of the brain)

•**Psychopharmacology** - study of the effects of pharmacological substances (drugs) on behaviour (e.g., the effects of caffeine or nicotine on attention)

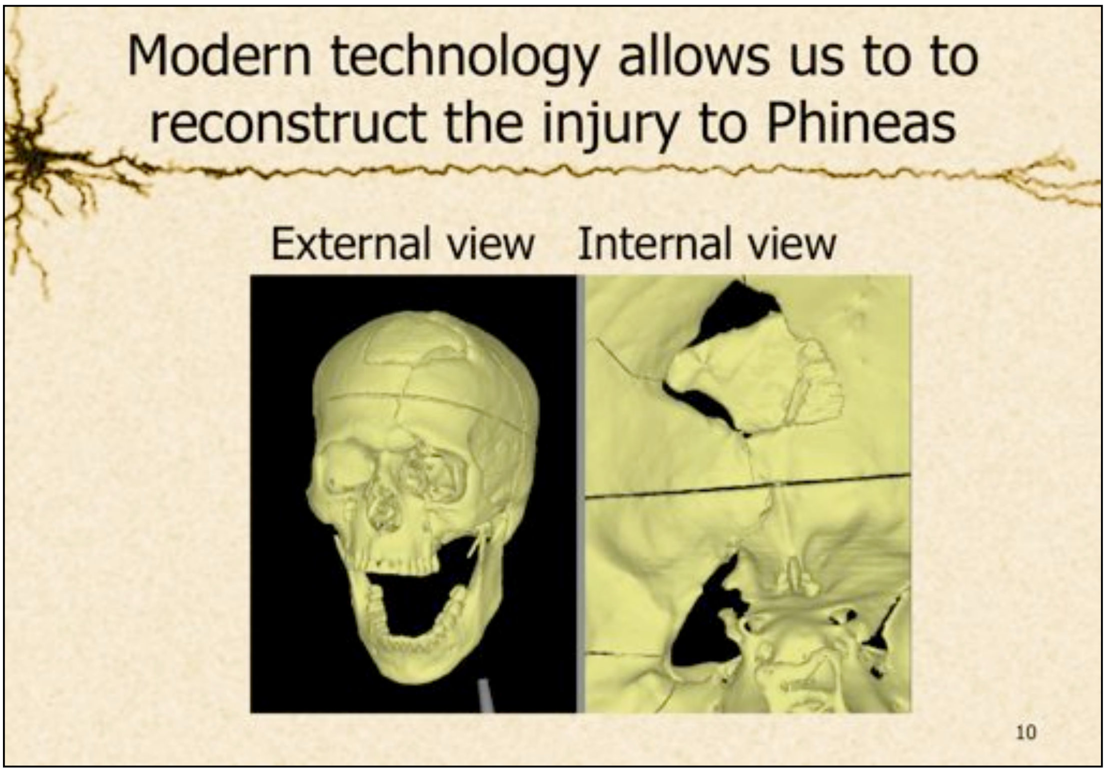
•**Neuropsychology** – study of the effects of brain damage (lesions) on behaviour (e.g., the effects of stroke or head injury on learning and memory)

•**Psychophysiology** - study of the relationship between neurophysiological activity and behaviour (e.g., the pattern of electroencephalographic (EEG) activity associated with sleep and dreaming)

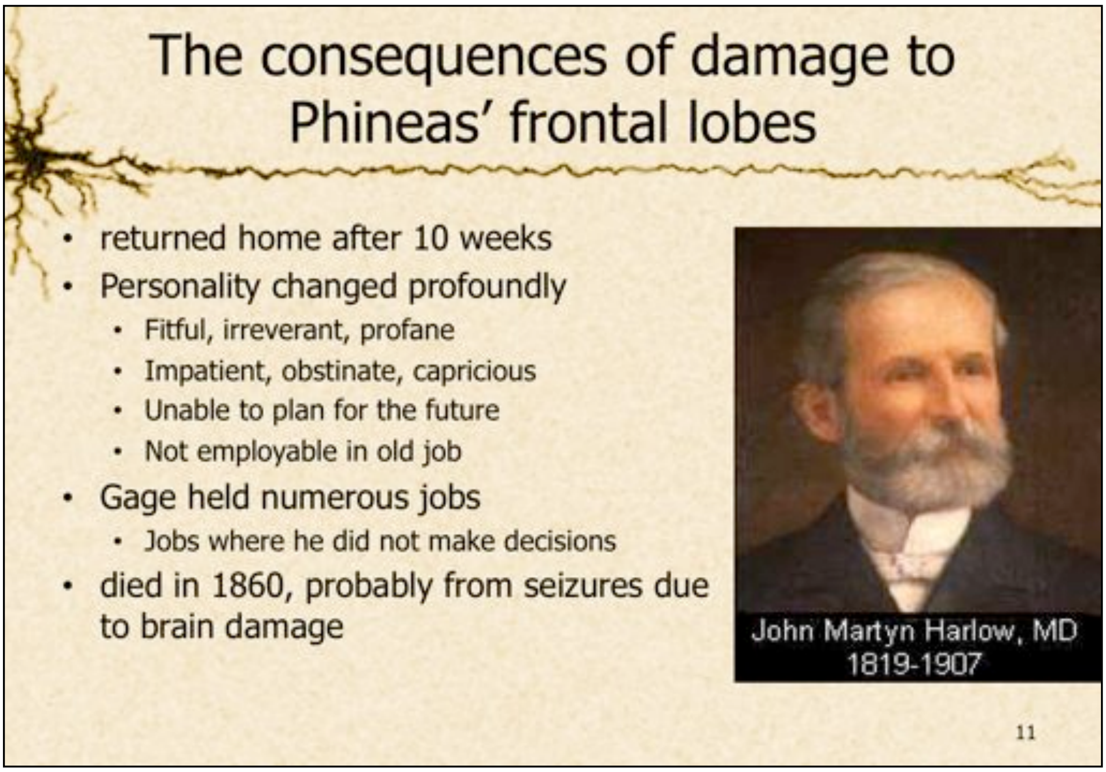


In considering the history of ideas about the brain and behaviour, we can begin with the unusual case of Phineas Gage, a railway foreman in Virginia in the mid-19th century. He survived an horrific brain injury that left him a changed man.

Phineas Gage was using a tamping iron to lay charges in rock, which was being blasted to create a cutting for a railroad track. While tamping a charge into the rock the tamping iron created a spark that ignited the gunpowder and sent the tamping iron shooting back up from the hole and into Phineas’ head.



Scientists recently have been able to reconstruct the path taken by the tamping iron as it made it's "wonderful journey through skull and brains" (Macmillan, 1986). Phineas Gage's skull was placed into a computerised tomographic ('CT') scanner and a three-dimensional reconstruction was made of the most likely path taken by the tamping iron as it passed underneath the left eye and out the top of the skull (Ratiu, P. & Talos, I-F. (2004). The tale of Phineas Gage, digitally remastered. *New England Journal of Medicine*, 351, 21). The animation reveals that the left cheekbone was fractured beneath the eye, allowing the left side of the skull to swing out laterally as the tamping iron passed through. The brain injury suffered by Phineas is likely to have been restricted to the left frontal lobe.

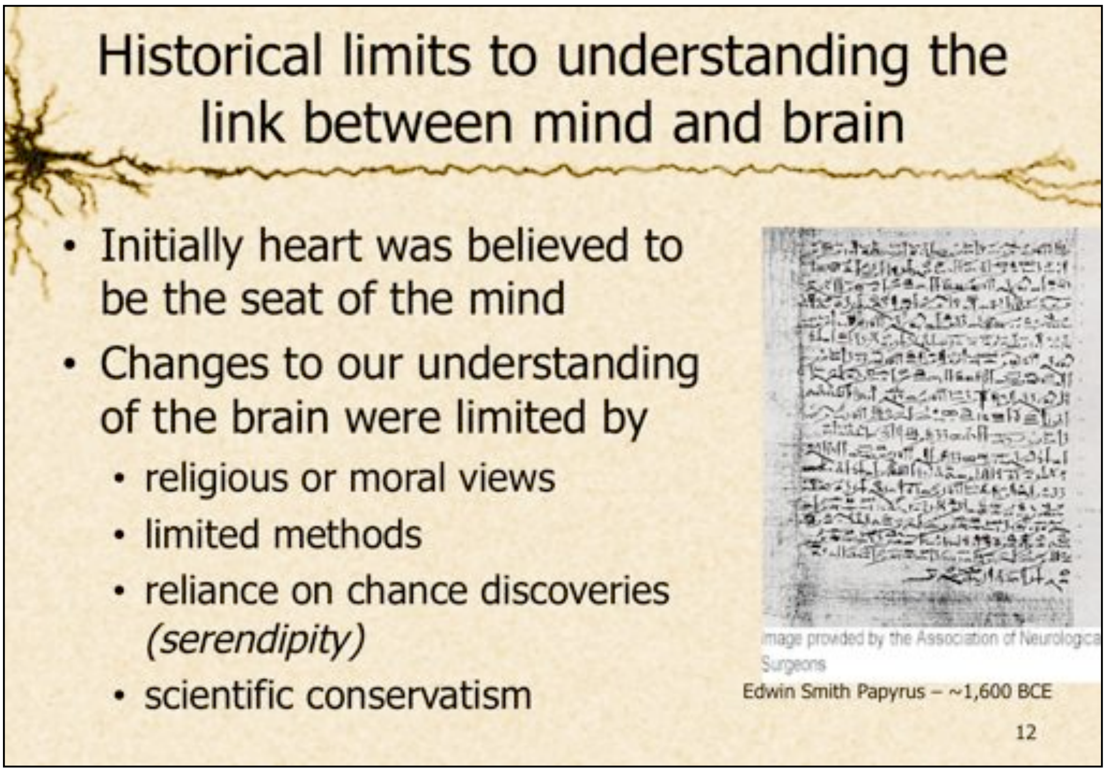


Dr. John Martyn Harlow, the young physician of Cavendish, treated Phineas with such success that he returned home to Lebanon, New Hampshire, 10 weeks later.

Some months after the accident, probably in about the middle of 1849, Phineas felt strong enough to resume work. But because his personality had changed so much, the contractors who had employed him would not give him his place again. Before the accident he had been their most capable and efficient foreman, one with a well-balanced mind, and who was looked on as a shrewd smart business man. He was now fitful, irreverent, and grossly profane, showing little deference for his fellows. He was also impatient and obstinate, yet capricious and vacillating, unable to settle on any of the plans he devised for future action. His friends said he was "No longer Gage."

As far as we know Phineas never worked at the level of a foreman again. According to Dr. Harlow, Phineas appeared at Barnum's in New York, worked in the livery stable of the Dartmouth Inn (Hanover, NH), and drove coaches and cared for horses in Chile. In about 1859, after his health began to fail he went to San Francisco to live with his mother. After he regained his health he worked on a farm south of San Francisco. In February 1860, he began to have epileptic seizures and, as we know from the Funeral Director's and cemetery interment records, he died on 21st. May 1860 (not in 1861 as Harlow reported).

[These accounts are taken from Macmillan, M. (2000). *An odd kind of fame*: *Stories of Phineas Gage*. Cambridge, MA: MIT Press].



The brain was not always considered the seat of the mind and soul. Because it is constantly active and beats faster with emotion and physical activity, many ancient cultures (Egyptian, Indian, Chinese) believed the **heart** was the seat of thought and emotion.

Even though the Egyptians thought the heart was the seat of the mind, there is evidence that they understood that brain damage could affect behaviour. In the Edwin Smith Papyrus (named after the archaeologist who came across it in Luxor in 1862), the symptoms and diagnosis of two individuals with brain injuries are described.

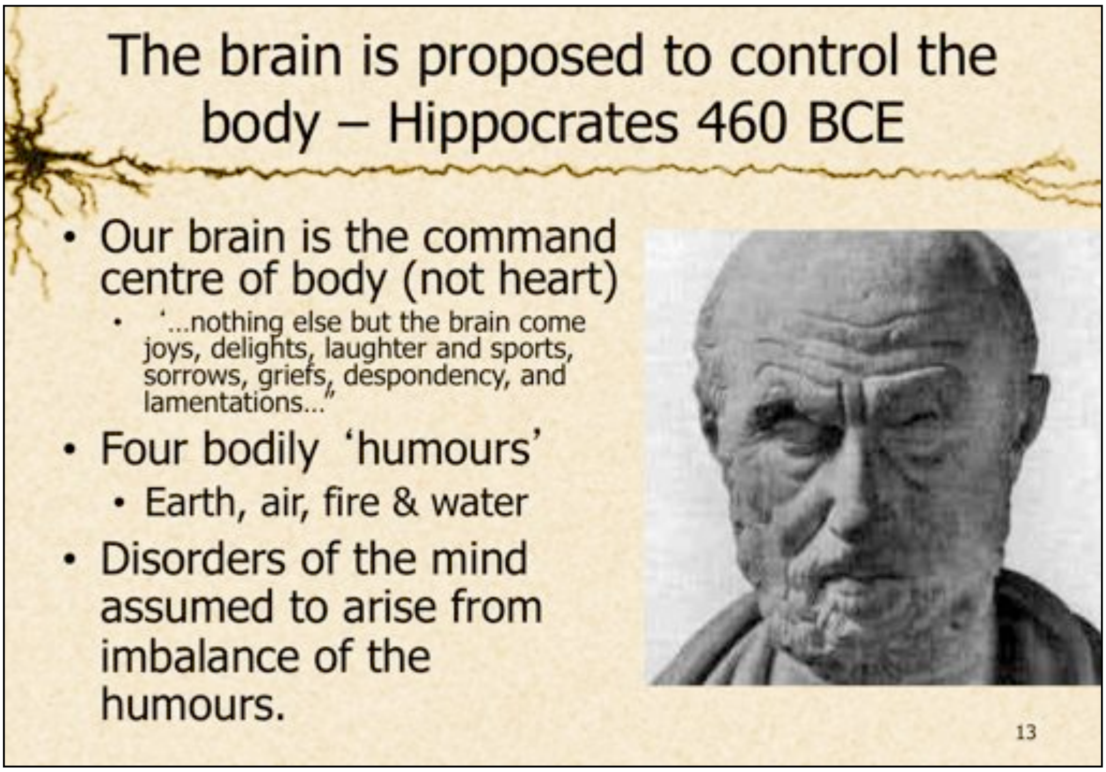
There are **four key themes in understanding historical views of the brain**:

1) the views often depended on **religious beliefs**

2) the extent to which the brain was understood depended on the **methods available** to study it

3) many of the dramatic changes in how people viewed the brain occurred due to chance discoveries (**serendipity**)

4) new ideas about the brain were typically met with scepticism by the general and scientific communities, and invariably resulted in controversy

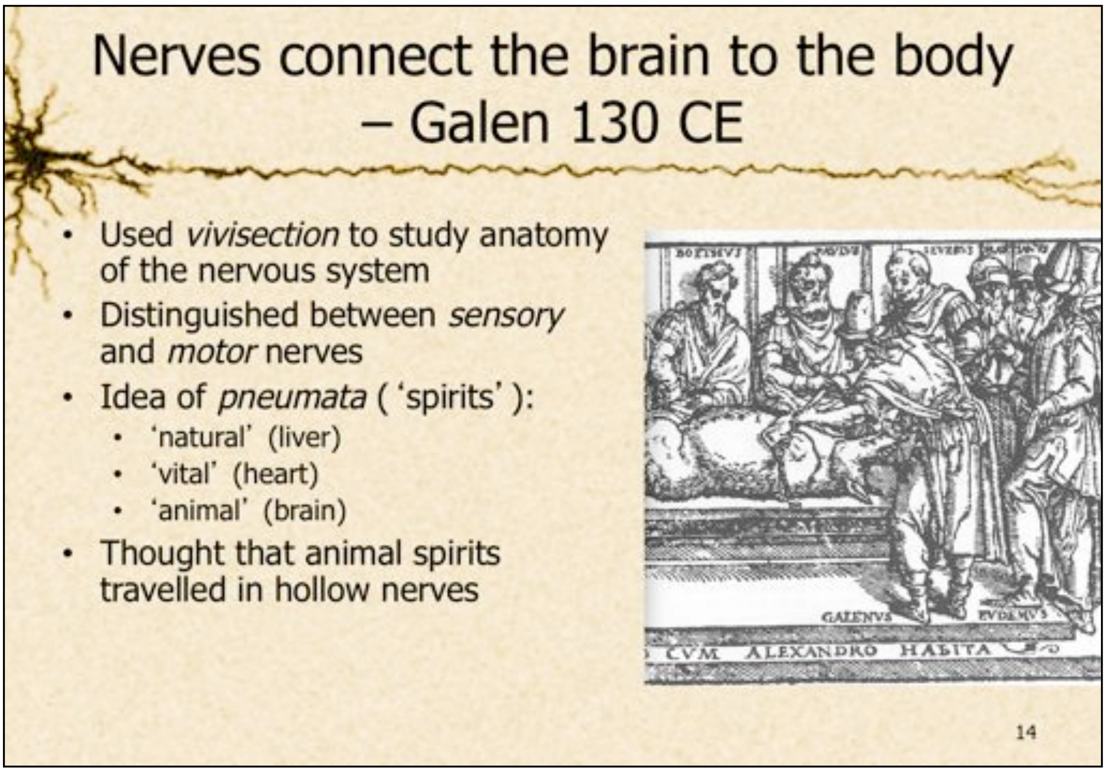


Hippocrates (Ancient Greece, 460 BCE)

Considered the father of modern medicine

First to suggest that the **brain is the centre of control for the body**. This conclusion was reached partly from observations of the effects of brain damage on behaviour (such as wounds to one side of the head causing convulsions that affected the opposite side of the body).

Human dissections were not permitted in the Hippocratic Era of Ancient Greece; people believed the human soul would not find peace until the body was laid to rest. Human anatomy therefore had to be guessed at from observation of open wounds in soldiers and gladiators.



Galen (Ancient Rome, 130 CE):

Galen idolised Hippocrates, and sought to extend his teachings; although religious sentiment was still strongly opposed to performing human **autopsies** (a term coined by Galen), society now accepted that physicians should be permitted to dissect live animals to understand their functioning (**vivisection**).

Galen's ideas about human anatomy therefore came from observations of open wounds, and from chance discoveries of human bodies (e.g., he once came across the remains of a robber who had been murdered in the woods, whose flesh had been picked bare by birds).

As a result of his animal dissections, Galen recognised two different types of nerves: **sensory** (carrying information from the body to the brain) and **motor** (carrying messages from the brain to the muscles).

In one example of vivisection on a pig, Galen found that the animal stopped squealing but continued breathing after he cut a pair of nerves in the throat. This demonstration he repeated many times in other animals, to the amazement of onlookers. He had found the 'nerves of voice' (now known as the recurrent laryngeal nerves).

Structure of the brain mapped in detail- Andreas Vesalius 1514 CE

- Revived dissection and vivisection after the Dark Ages
- Made the first careful and detailed drawings of the human brain
- Substantially advanced knowledge of brain structure; but failed to advance a new account of function to replace that of the pneumata (spirits)

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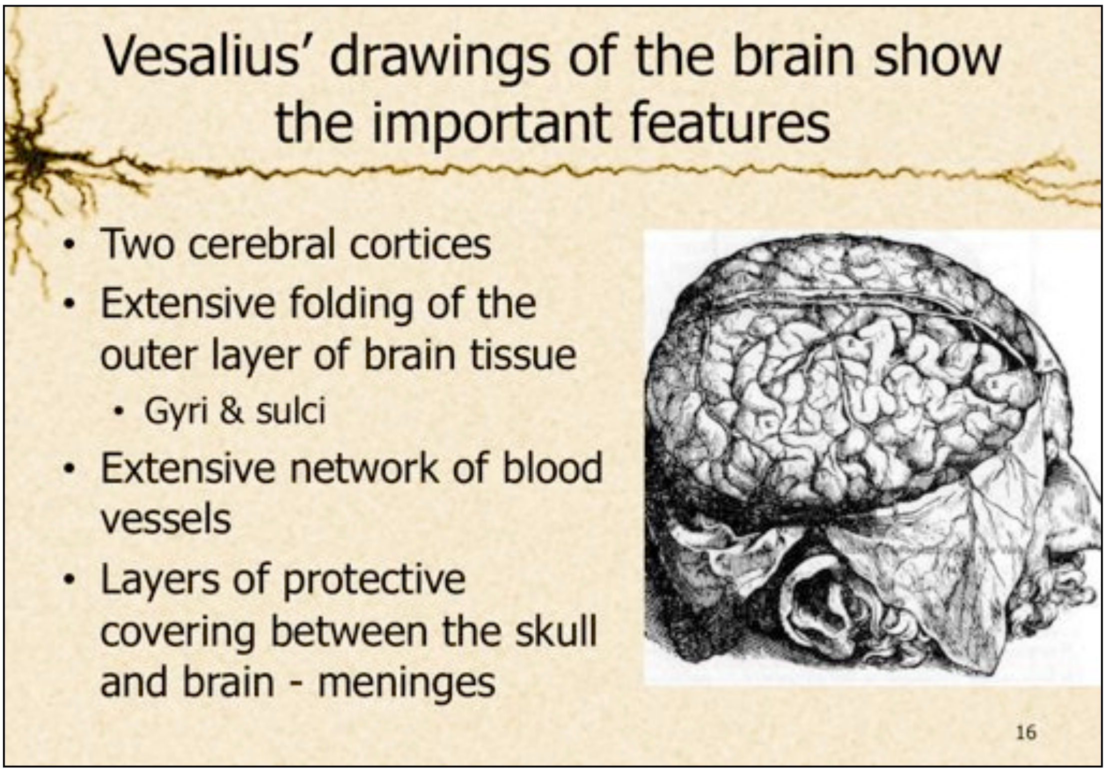
Andreas Vesalius (Brussels, 1514 CE):

Revived dissection and vivisection after the years of 'spiritualism' during the Dark Ages

Was a fine anatomist, and produced the first detailed drawings of the human body, including the brain

Despite advancing knowledge about the structure of the brain, Vesalius added little that was new to people's understanding of how the brain actually functions

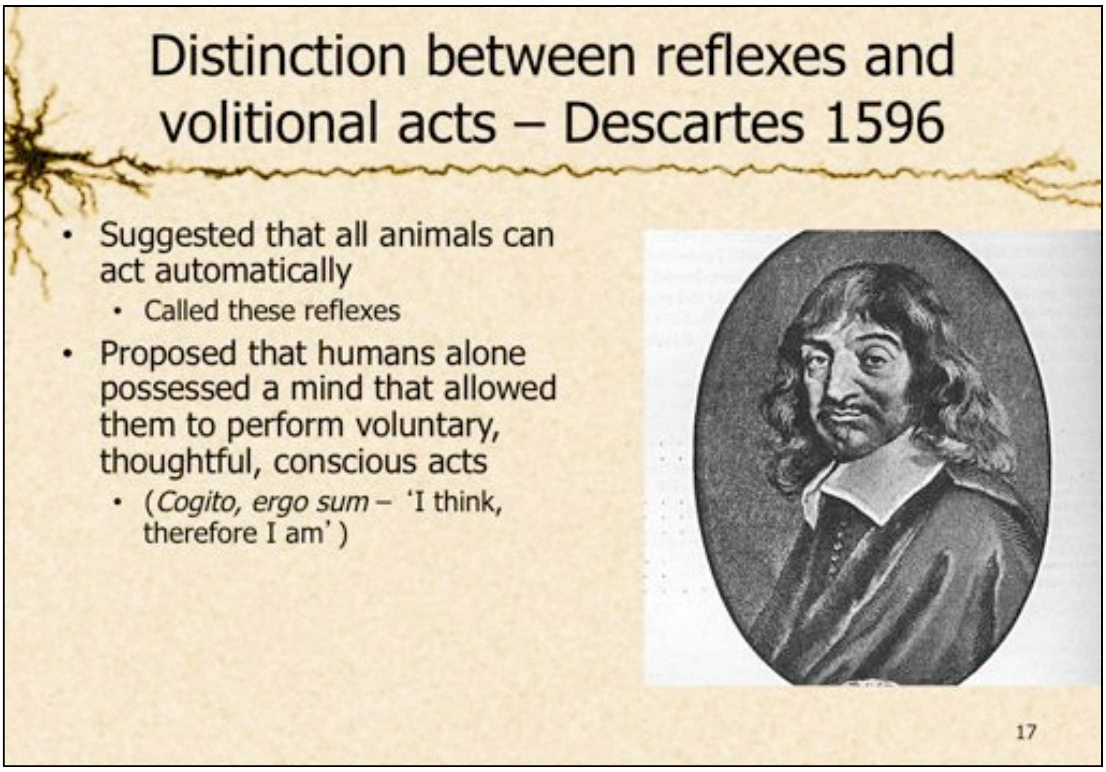


Vesalius' dissections revealed many important anatomical features of the human brain:

The folded outer layer of brain tissue (**cortex**), composed of **gyri** (convolutions) and **sulci** (grooves)

The network of blood vessels over the surface of the brain

The outer coverings of the brain (the **meninges**), immediately beneath the inner wall of the skull



René Descartes (France, 1596 CE):

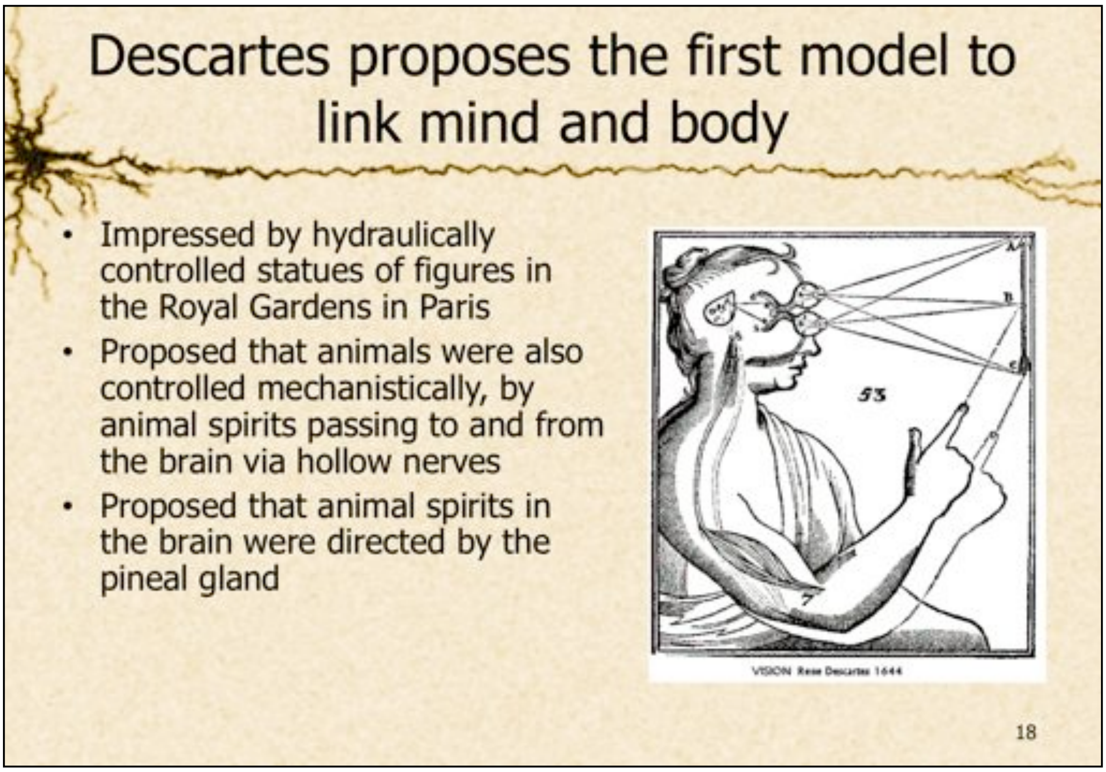
Descartes was a French philosopher and mathematician; some consider him the 'father of modern philosophy'

He observed that some actions are automatic and involuntary (such as a hand being drawn quickly away from a hot object) – he called these **reflexes**. He assumed animals only react to the world reflexively, whereas humans also have a mind that permits them to act voluntarily.

Later in life, Descartes theorised that animals, including humans, were like machines. But he also believed that humans are unique in possessing a mind, which allows them to perform voluntary and conscious acts.

Descartes, like many other philosophers of the time, viewed the mind and body as distinct entities (i.e., he was a **dualist**).

Although he believed that the mind is not subject to the physical laws of the universe, he was the first to suggest that there was a link between the physical brain and the non-physical mind.

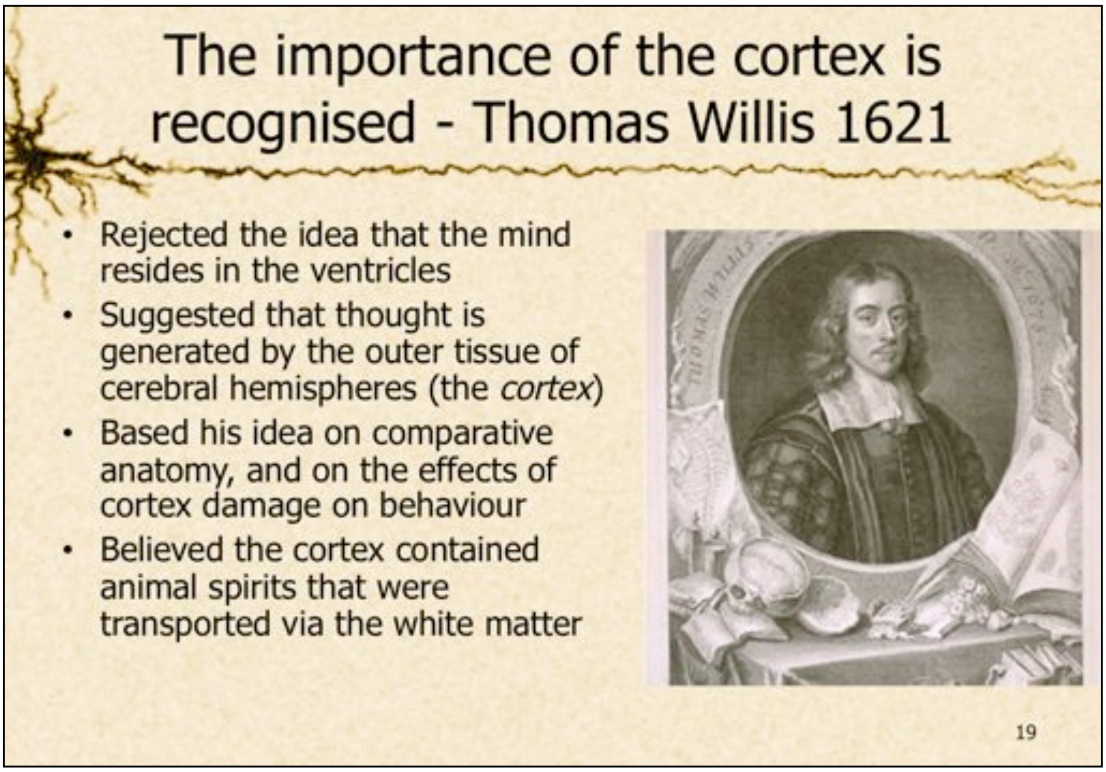


Descartes proposed a link between the physical brain and the non-physical mind.

As a young man he was impressed by the animated figures of Neptune, Diana and other creatures from mythology in the fountains of the Royal Gardens in Saint Germain, Paris. These figures moved hydraulically, i.e., by a system of pipes and valves through which water was pumped. Descartes wondered if humans might work in a similar way.

Descartes thought the pineal gland was able to direct animal spirits contained within the **ventricles** (fluid filled cavities inside the brain). The idea was that when the mind prepares to implement an action (such as the hand pointing), it tilts the pineal gland in a particular direction, like a tiny 'joystick in the head'. This opens valves within the ventricles which allows the animal spirits to flow out through specific nerves, which in turn caused the muscles to inflate and move the limb.

However absurd Descartes' idea may seem to us now, it represented a major step forward in how people thought about the interactions between the mind and brain. It is one of the first times a mechanical device was used as a **model** to understand a physiological function. Models are important in science – they are simplified systems that are well understood, and whose functions mimic those of the more complex system being studied.



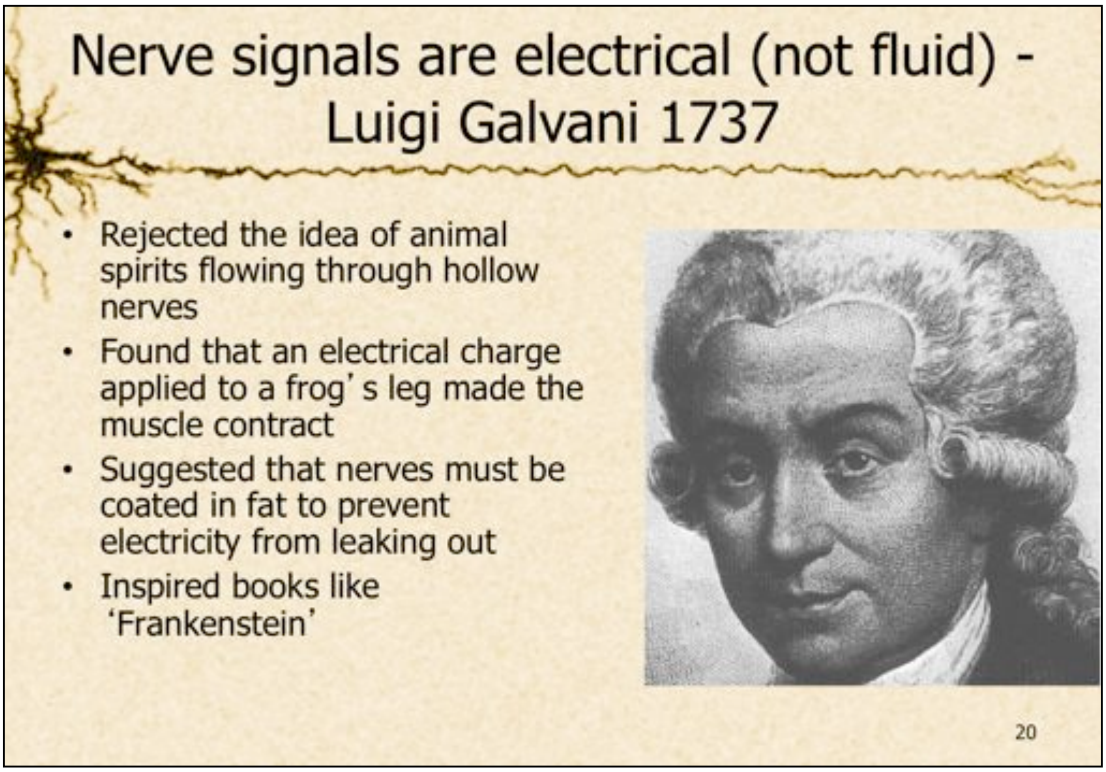
Thomas Willis (England, 1621 CE):

Willis rejected the idea that the ventricles were the seat of the mind, and suggested instead that it was the ‘outmost banks’ of the cerebral hemispheres that controlled thought.

His ideas were based on the observation that humans, whose power of thought and flexibility of behaviour outstrip those of all other animals, also possess a much more folded cortex than that of other animals.

As a physician, Willis had also observed that damage affecting the cortex resulted in profound impairments of thought and behaviour.

Willis was the first to distinguish between the grey and white matter of the hemispheres; but he still stuck to the old idea of ‘animal spirits’ being the driving force behind thought and action. He merely shifted the emphasis to the cortex as a place of storage for such spirits, and the white matter as the means of channelling the spirits to other parts of the body.



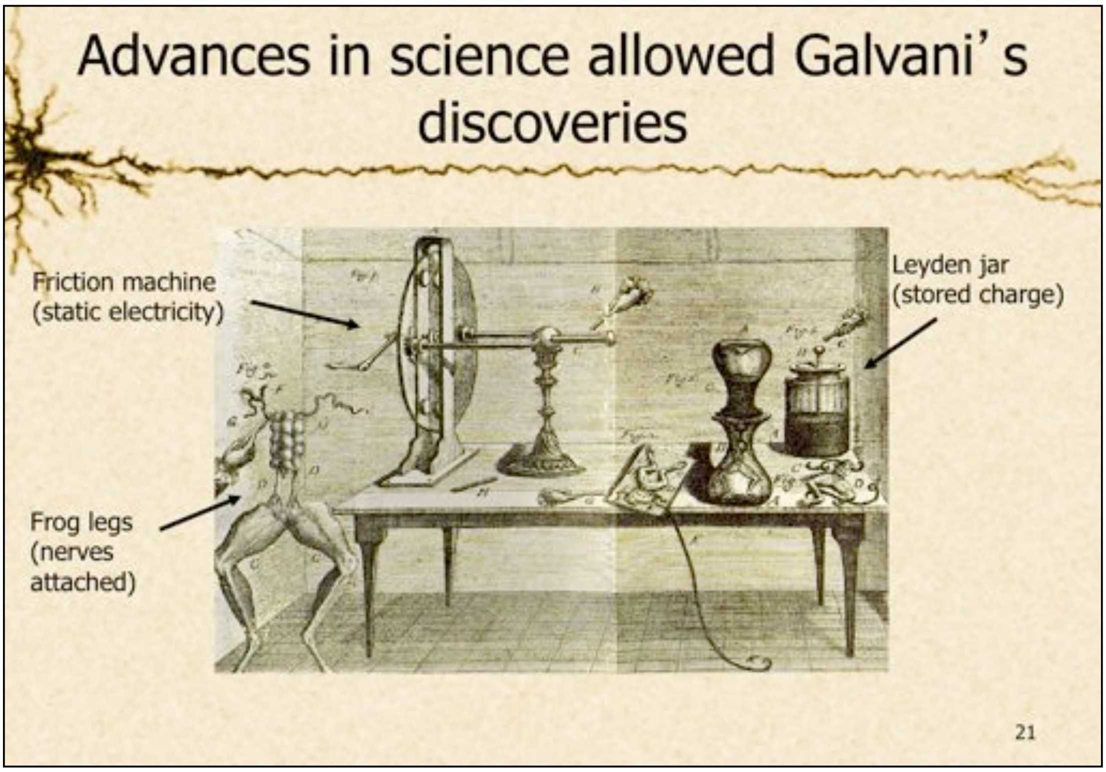
Luigi Galvani (Italy, 1737 CE):

Galvani was very interested in electricity, a topic that was extremely popular at the time

He knew that the ancient Greeks had used shocks from the electric stingray to help cure headaches and other ailments. This lead him to wonder whether electricity might in fact be the 'animal spirit' suggested by Galen to underlie nervous transmission

Galvani initially made a chance discovery: while dissecting a frog, his laboratory assistants were playing around with one of his 'friction machines', the purpose of which was to generate a static electrical discharge. The apparatus threw a spark at exactly the moment Galvani happened to touch one of the nerves leading to the frog's leg. This caused a sudden contraction of the frog's leg, much to everyone's surprise.

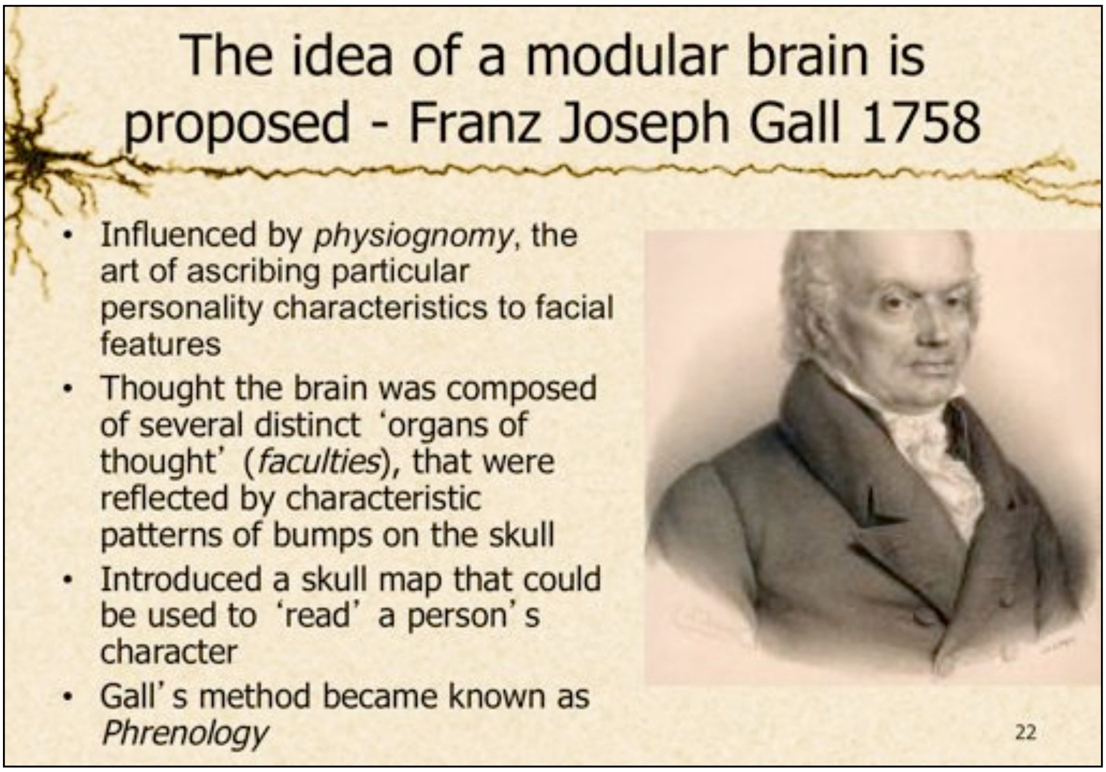
Galvani then performed several more tests: he found that simply touching the nerve with the scalpel in the absence of a spark did not cause the leg to twitch. This suggested that electricity must be able to travel through the human body (not a new idea), so that it could be transferred from the scalpel to the frog's nerve.



Galvani used a **friction machine** (essentially a large disk, cranked by hand, that rubbed against a surface) to generate a static electrical charge

The charge was stored in a **Leyden jar** (a glass jar with a metal coating on the outside and liquid on the inside, closed by a rubber stopper in the top, named after the Dutch city in which it was invented)

The charge could then be administered to the animal preparation at will



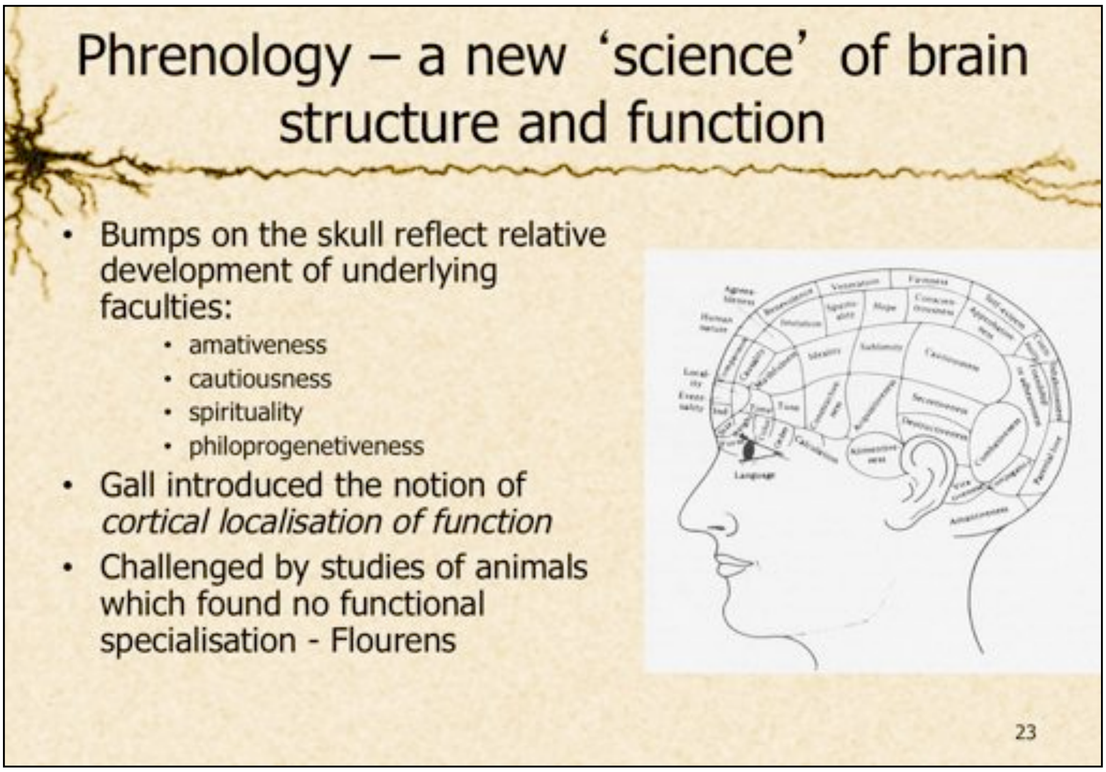
Franz Joseph Gall (Germany, 1758 CE):

Gall was an anatomist who was interested in the popular pursuit of **physiognomy**, the art of ascribing particular personality characteristics to facial features. The basic rationale behind physiognomy was that variations in structure must reflect variations in function.

Gall applied the basic premise behind physiognomy to the brain. He remembered a childhood friend who had an exceptional verbal memory, and who also had bulging eyes. He guessed that the bulging eyes reflected overdevelopment of a region of the brain that controls memory for words.

Gall created a map that divided the entire skull into separate 'organs of thought', or **faculties**. He believed these faculties were reflected by characteristic patterns of bumps on the skull.

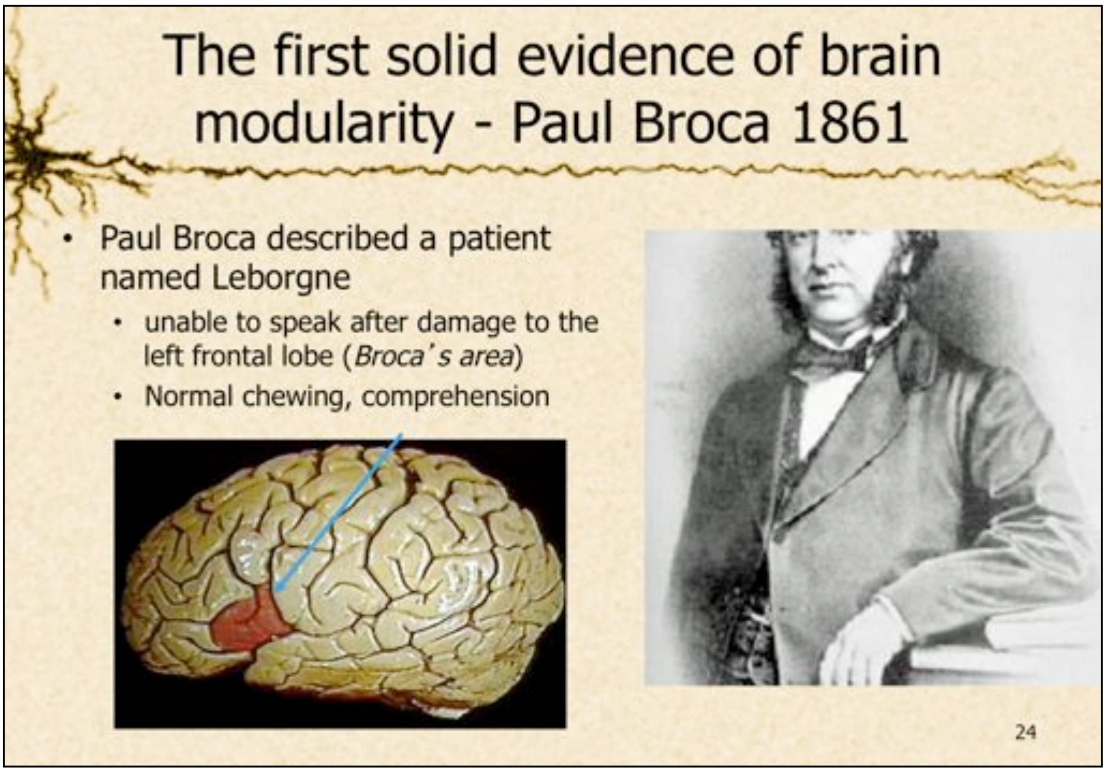
In developing these maps, Gall compared animal and human skulls. He also focused in particular on analysing the cranial features of people from the extremes of society, such as criminals, famous artists, politicians, and so on; his assumption was that these individuals were likely to have particularly overdeveloped faculties of a kind that was consistent with their behaviour and skills.



Most of the localised regions in Gall's map were assumed to be responsible for controlling complex personality characteristics, such as spirituality and cautiousness.

Gall's phrenology was challenged by many during his lifetime and for decades afterwards. His most notable critic was Pierre Flourens (France, 1794-1867), whose studies involved **surgical ablation** (destruction or removal) of different parts of the brains of animals (mostly birds and frogs). He found that all parts of the cortex are equally responsible for perception, action, and intelligence, and concluded that Gall's notion of localised brain functions was incorrect.

Gall and his supporters responded by pointing out that the animals Flourens examined, such as birds and frogs, have poorly developed cerebral hemispheres that could not possibly reflect the complexity of human brain anatomy.

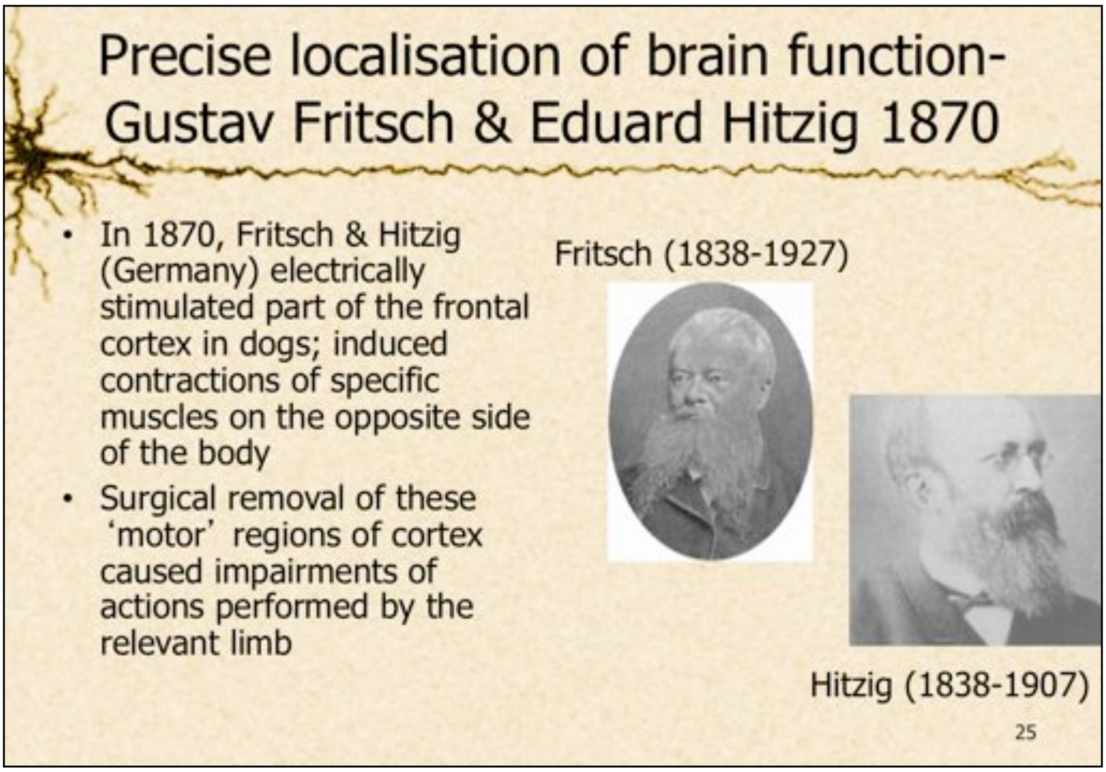


Paul Broca (France, 1824-1880):

In 1861, Paul Broca, a Paris physician, published findings that were to provide strong support for the **localisationists** (those who believed the brain was divided into distinct, specialised areas)

He described a patient, a 31 year old man named **Leborgne**, who had lost the power of expressive speech, even though he was still able to chew, swallow and make other complex mouth movements; and was able to understand what was said to him.

At autopsy, Leborgne was found to have a lesion in the **frontal area of his left cerebral hemisphere** (specifically the posterior part of the third frontal convolution). Based on several further cases of speech loss after similarly located damage, Broca concluded that this region of the left frontal cortex is the site of expressive language in humans.

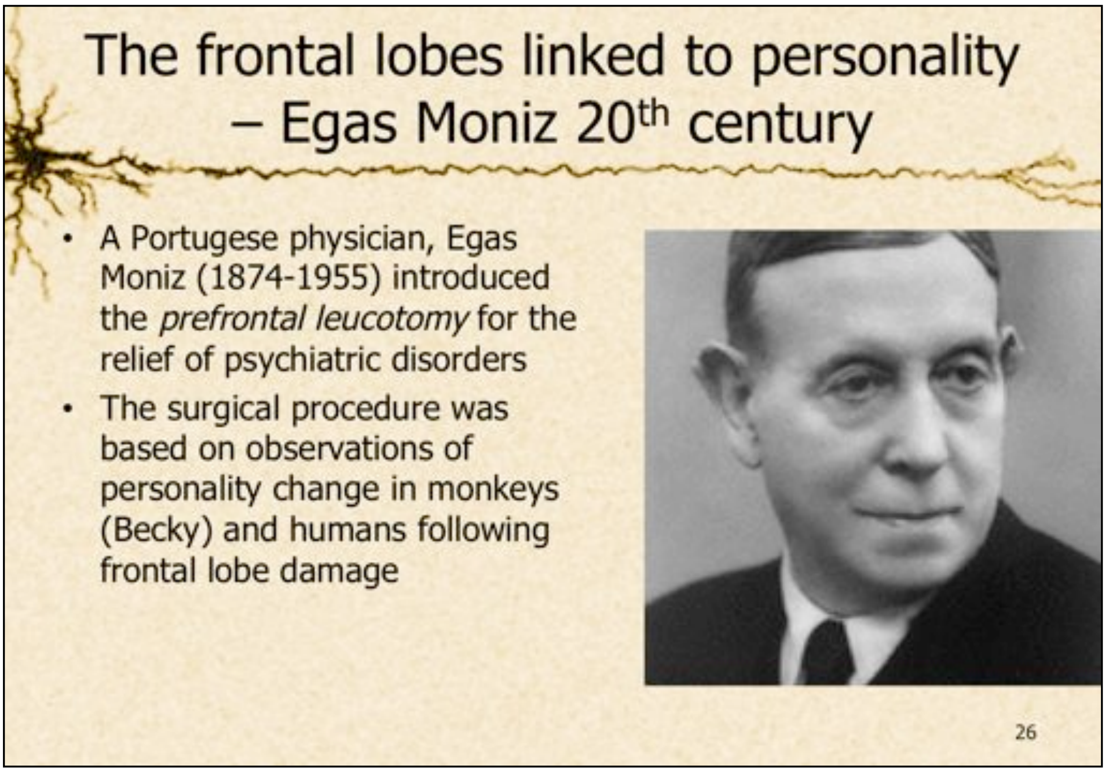


Gustav Fritsch (1838-1927) & Eduard Hitzig (1838-1907):

After Broca's descriptions of expressive language impairment following left frontal damage, the localisationist view of brain function gained wider acceptance.

Fritsch and Hitzig, two German physiologists, contributed further weight to the localisationist view. They electrically stimulated regions of the frontal cortex in dogs, and induced contractions of specific muscles on the opposite side of the body. They found that small patches of cortex in the frontal region seemed to be devoted to particular limbs and muscle groups. This region, in the dog as in humans and other animals, is now known as the **motor cortex**, and it is organised **somatotopically** (i.e., according to body parts).

Fritsch and Hitzig followed up their electrical stimulation experiments with surgical ablations of the same cortical areas. They found that removal of small parts of the cortex from sites at which electrical stimulation had produced limb movements would lead to clumsiness of that limb.



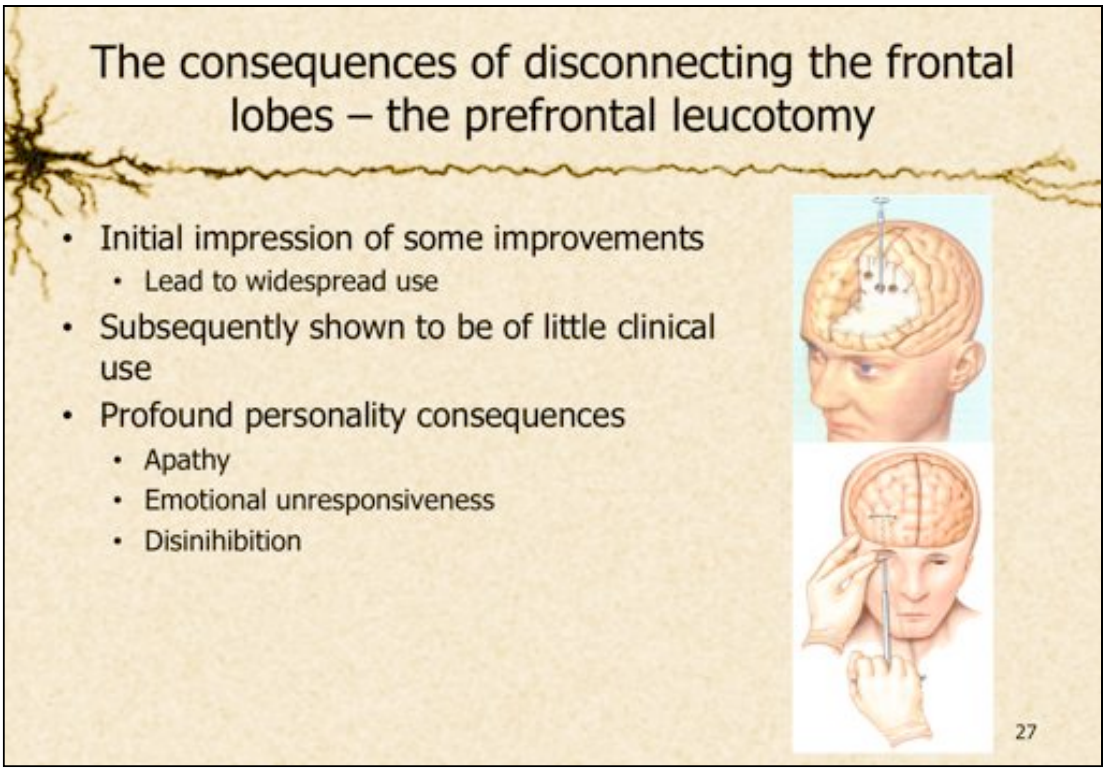
Egas Moniz (1874 – 1955):

Moniz was a neurologist who had read an account of a chimpanzee named 'Becky', who would become agitated when she made errors on a food reward task, but whose anxiety disappeared when the frontal lobes of both hemispheres were surgically ablated. He may also have been aware of the profound changes in personality that followed Phineas Gage's encounter with a tamping iron.

Based on this knowledge, Moniz wondered what would happen if psychiatric patients with extreme anxiety and other mood disorders had their frontal lobes removed.

He persuaded a neurosurgeon, Almeida Lima, to perform such an operation on a series of psychiatric patients. The patients' debilitating psychiatric symptoms seemed to improve, and the operation proliferated.

Moniz was awarded a Nobel Prize for his discovery in 1949.



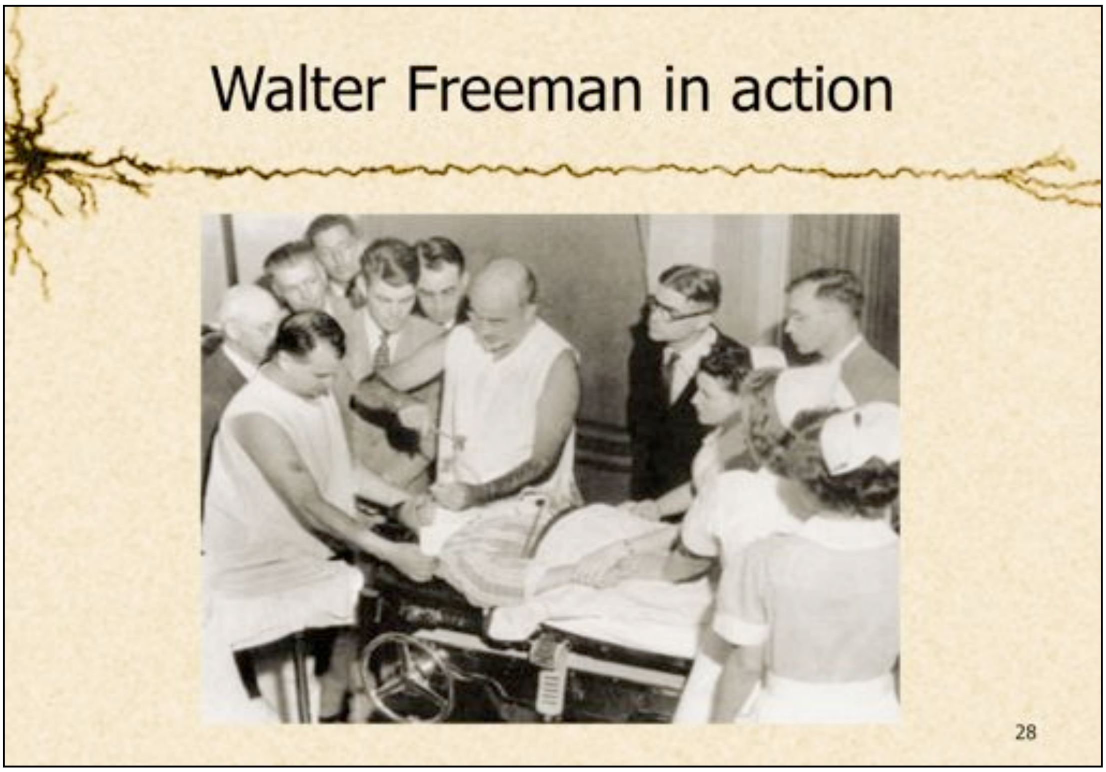
There were two popular forms of **frontal leucotomy**:

In one, a **leucotome** was initially inserted into one of several holes drilled in the skull, with its cutting wire retracted. The wire was then extruded from the tip and the leucotome rotated to remove a core of tissue.

In the other, a cutting implement was inserted above the eyelid, pushed through the base of the skull (which is very thin and brittle just above the eyes), and rocked from side to side to slice through the frontal lobes, thus separating them from the rest of the brain.

Moniz and his colleagues never properly evaluated the consequences of this drastic operation; they merely formed a 'clinical impression' of improvements in mood and behaviour (which they of course had a vested interest in observing). Eventually it became clear that prefrontal leucotomy was of little therapeutic value, and that it had many serious cognitive side-effects such as **apathy** (lack of motivation), **emotional unresponsiveness**, **disinhibition** (lack of self-control), lack of foresight and inability to plan, and so on.

The operation was eventually abandoned in most parts of the world, but not before more than 40,000 operations had been performed in the United States alone (and many hundreds in Australia).



In the 1940s and 1950s an American neurologist named Walter Freeman became a celebrity for his prefrontal leucotomies, which he performed, at the least excuse, without anaesthesia, almost anywhere, often to large audiences.

Eventually the medical profession and the general public became so sickened and outraged at the operation that Freeman and other ‘psychosurgeons’ like him were forced to desist.

Summary

- Behavioural neuroscience
  - scientific study of the role of the CNS in behaviour
  - Link between structure and function
- Methods of study driven our knowledge
  - surgical and accidental lesions
  - animal studies
    - brain stimulation and recording
- Modularity
  - The mind/personality is a product of the brain

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