LING 1010

Language and Mind

Prof. Jon Sprouse

04.05.21: Introduction to the Brain

Phineas Gage (1823-1860)

Phineas Gage was a 24 year old foreman of railroad construction crew in Vermont in 1848.

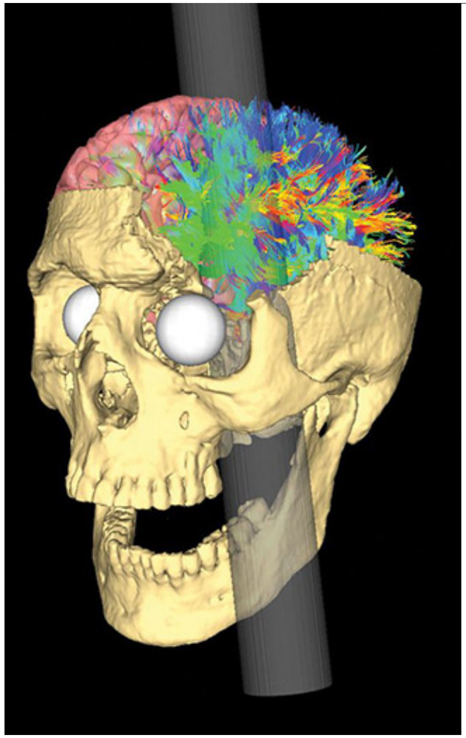
He was overseeing the detonation of some rock formations that were in the way of track construction, when an accidental explosion sent his tamping iron straight through his head (literally 25 feet in the air).

What made this incident famous is that he survived for another 12 years, and lived a relatively normal life.

He even moved to Chile in 1852 to become a coach driver on a mountain pass, and to San Francisco in 1859 to work on a farm.

The damage and the consequences

Our information about Gage is limited. Neuroscientists have tried to determine the extent of his injuries based on scans of his skull, and reports from witnesses and doctors.



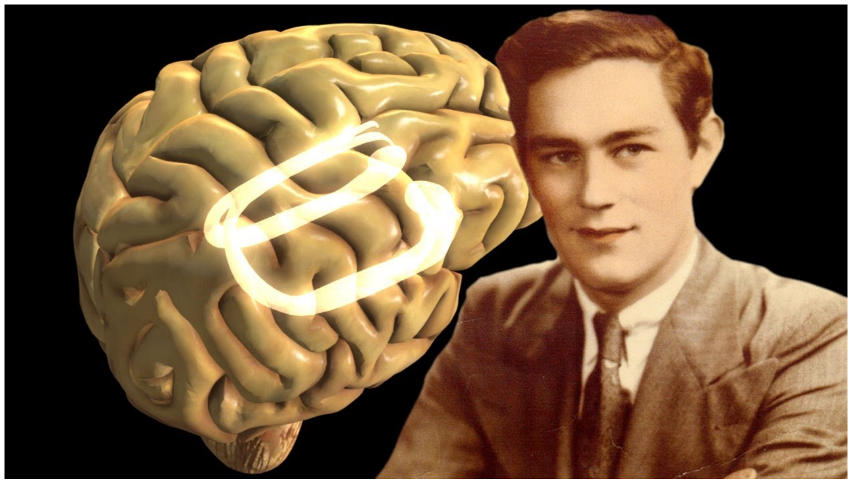
It looks as though the iron would have damaged the left frontal portion of his brain.

Our information about the consequences is also limited. The few written reports that remain suggest two things:

1. Gage suffered a fairly substantial personality shift, turning from a mature, responsible foreman into an impulsive, possibly rude and aggressive man.

2. Gage was still able to perform relatively complex tasks (speaking, living, driving a coach on a mountain pass!).

Henry Molaison (HM; 1926-2008)



Born (and lived) right here in Hartford (and Windsor Locks).

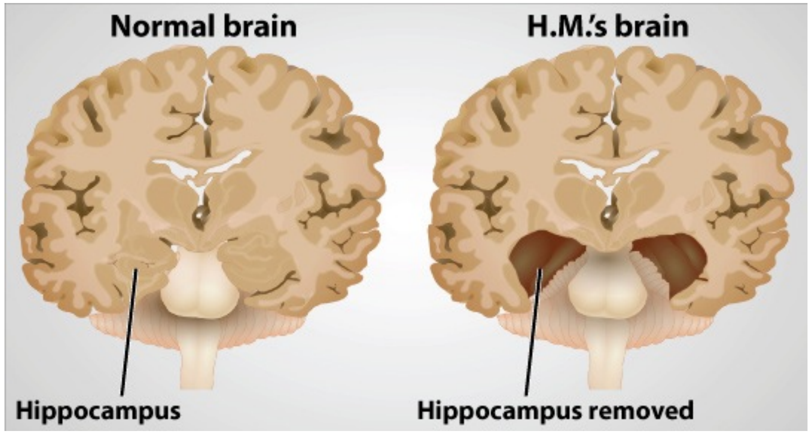
Suffered small seizures from age 7 through 16, thought to be due to a bicycle accident.

At age 16, started experiencing large (full-brain) seizures.

Seizures of this kind are both debilitating and life threatening, so he visited a neurosurgeon at Hartford Hospital in 1953 (age 27) to attempt to have them corrected.

The neurosurgeon removed parts of the medial temporal lobe on both sides of his brain, crucially removing the hippocampus (pictured above)…

The surgery and the consequences



Unlike Phineas Gage, the consequences of HM's surgery were well studied from 1953 until 2008.

HM primarily suffered from anterograde amnesia. He could not form new long-term episodic memories.

Basically, HM is the inspiration for any movie you've seen with that plot (e.g. 50 first dates).

HM taught us quite a bit about the biological bases of memory. Because he could still form short-term memories, we believe that short-term and long-term memories have different biological foundations. And because he could still learn new skills, we believe that procedural memory (skills) and declarative memory (episodes) have different biological foundations.

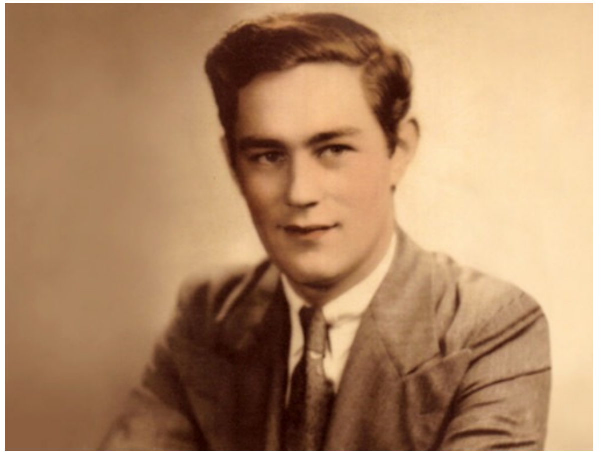
We don't have much video of HM for privacy reasons, but we do have video of a patient with similar amnesia, who we call EP:

https://kaltura.uconn.edu/media/SAF+-+Memory+Loss+-+A+Case+Study+%28Patient+EP%29.mp4/1_uz2mtsvh

The take-home message of PG, HM, and EP

Phineas Gage and Henry Molaison are in many ways responsible for setting the agenda of the field of cognitive neuroscience.

From their tragedies, neuroscientists have learned:



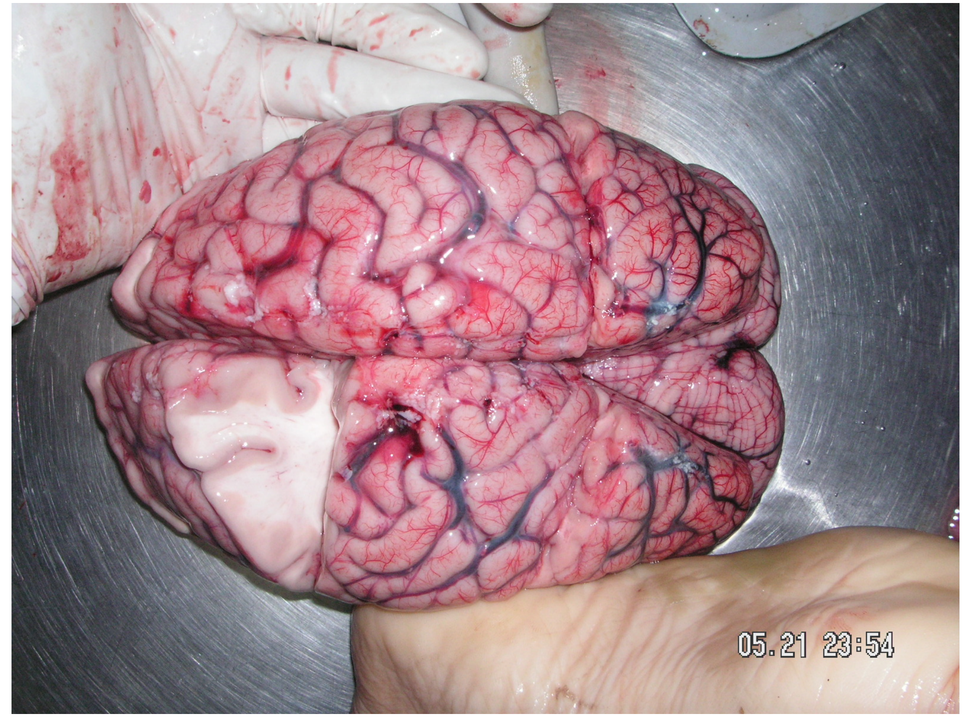
1. Brain injuries are a potential source of information about the biological bases of cognition.
2. Injuries to different areas of the brain appear to result in distinct impairments, suggesting that different areas of the brain perform different functions.
3. Humans possess some (limited) ability to recover from brain injury, suggesting that some parts of the brain can (partially) compensate for injuries to other parts of the brain (often called “brain plasticity”).

The form of the brain: neuroanatomy

It looks like an undifferentiated lump…

First impressions of the brain are that it is just one undifferentiated lump, not unlike other organs.

Cutting into a brain doesn't help much either. We can see a difference between the grey outer layer (grey matter) and the white inner layer (white matter), but it still seems like a relatively unstructured mass.



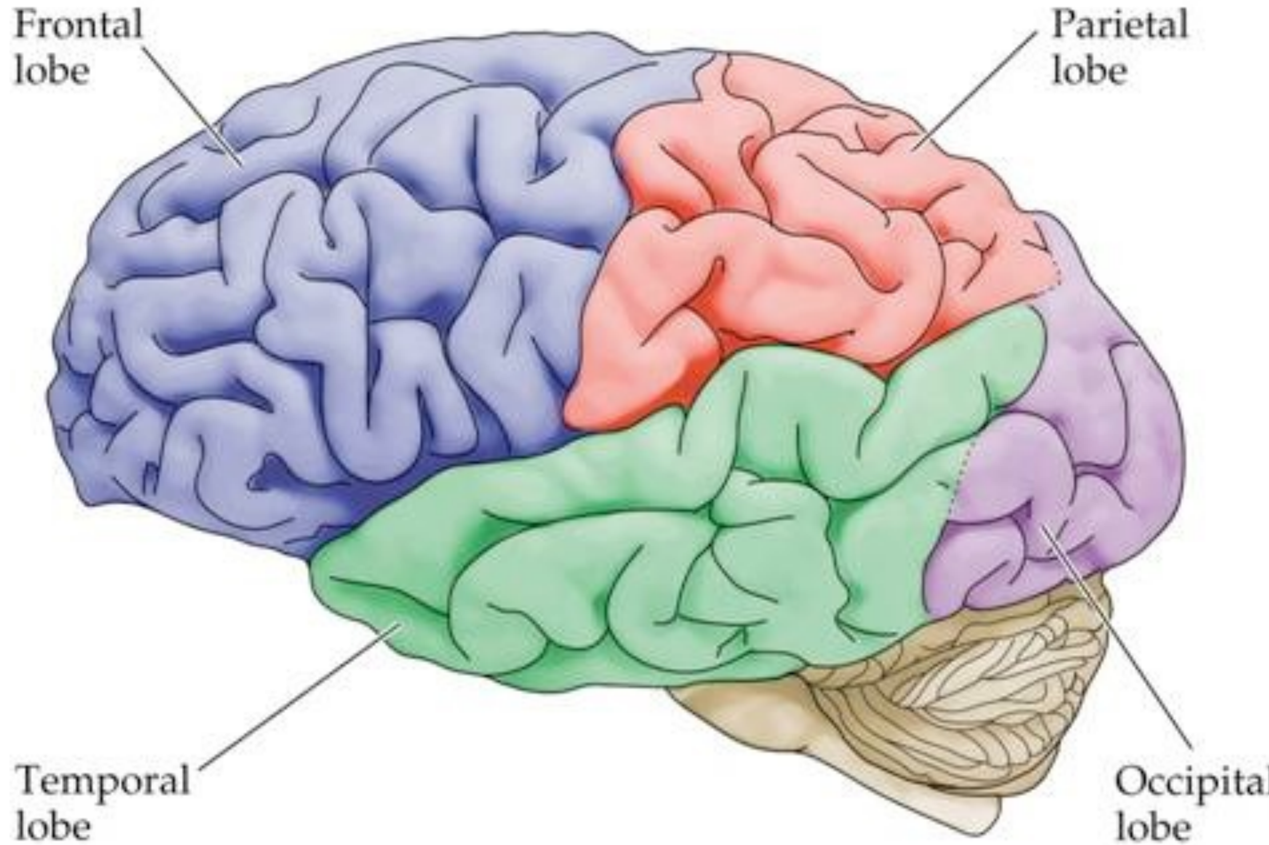
One leading idea of neuroanatomy is that different areas of the brain perform different functions. This is one of the conclusions we reach from cases of neurological injury. In other words, the brain is not an undifferentiated mass.

So one thing we want to do is delineate some finer parts of the brain, so that we can try to link those parts to the different cognitive processes that humans seem to be able to deploy (such as all of the linguistic knowledge we learned about in the first segment of the course).

Gross Anatomy: Lobes

superior

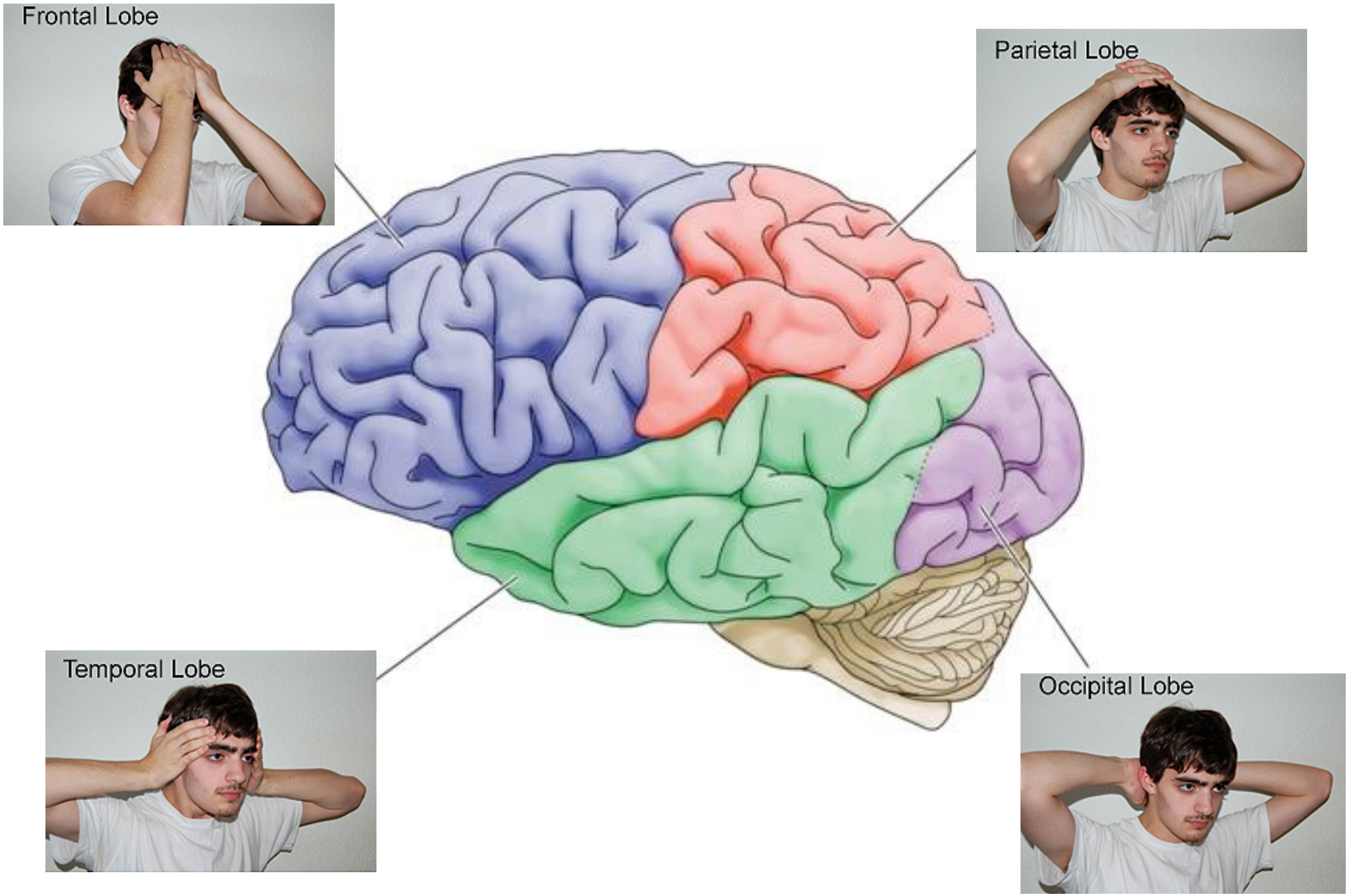
inferior



anterior

posterior

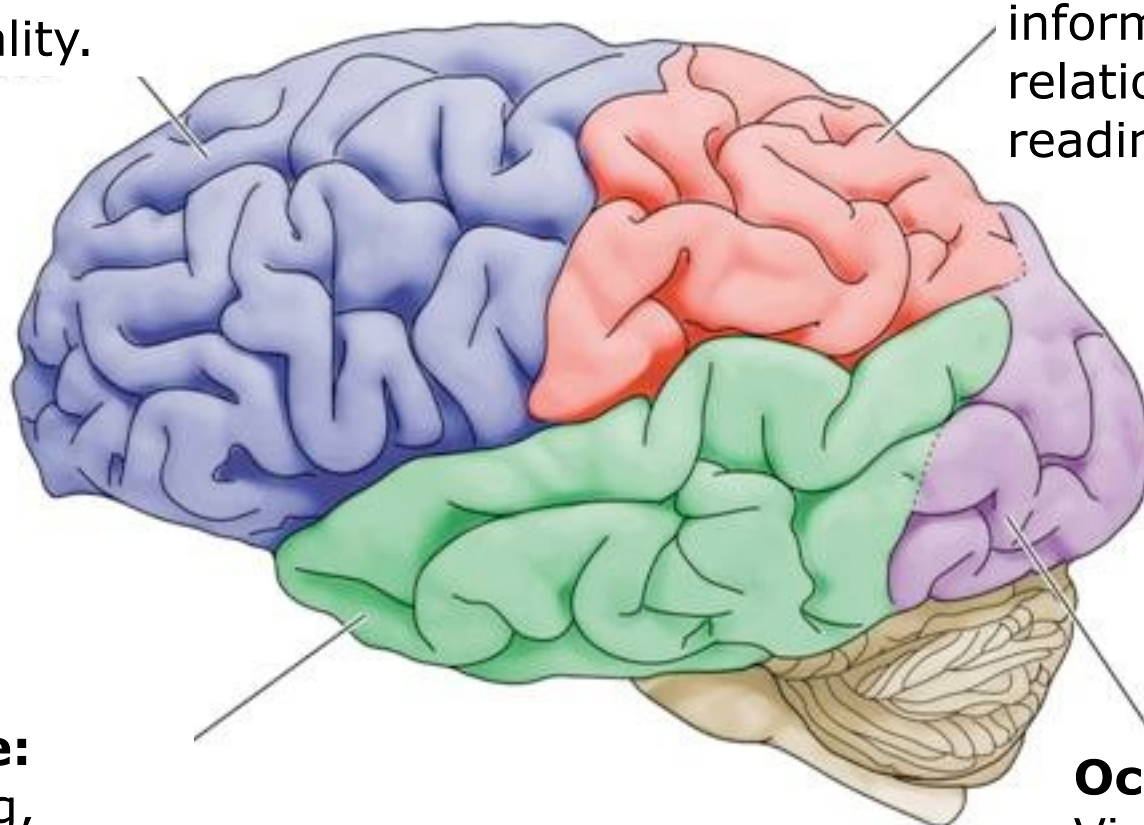
Gross Anatomy: Lobes



Gross Anatomy: Lobes

Frontal Lobe: decision making, planning, emotions/personality.

Parietal Lobe: integration of sensory information, spatial relationships, touch, reading.



Temporal Lobe: Memory, hearing, emotion

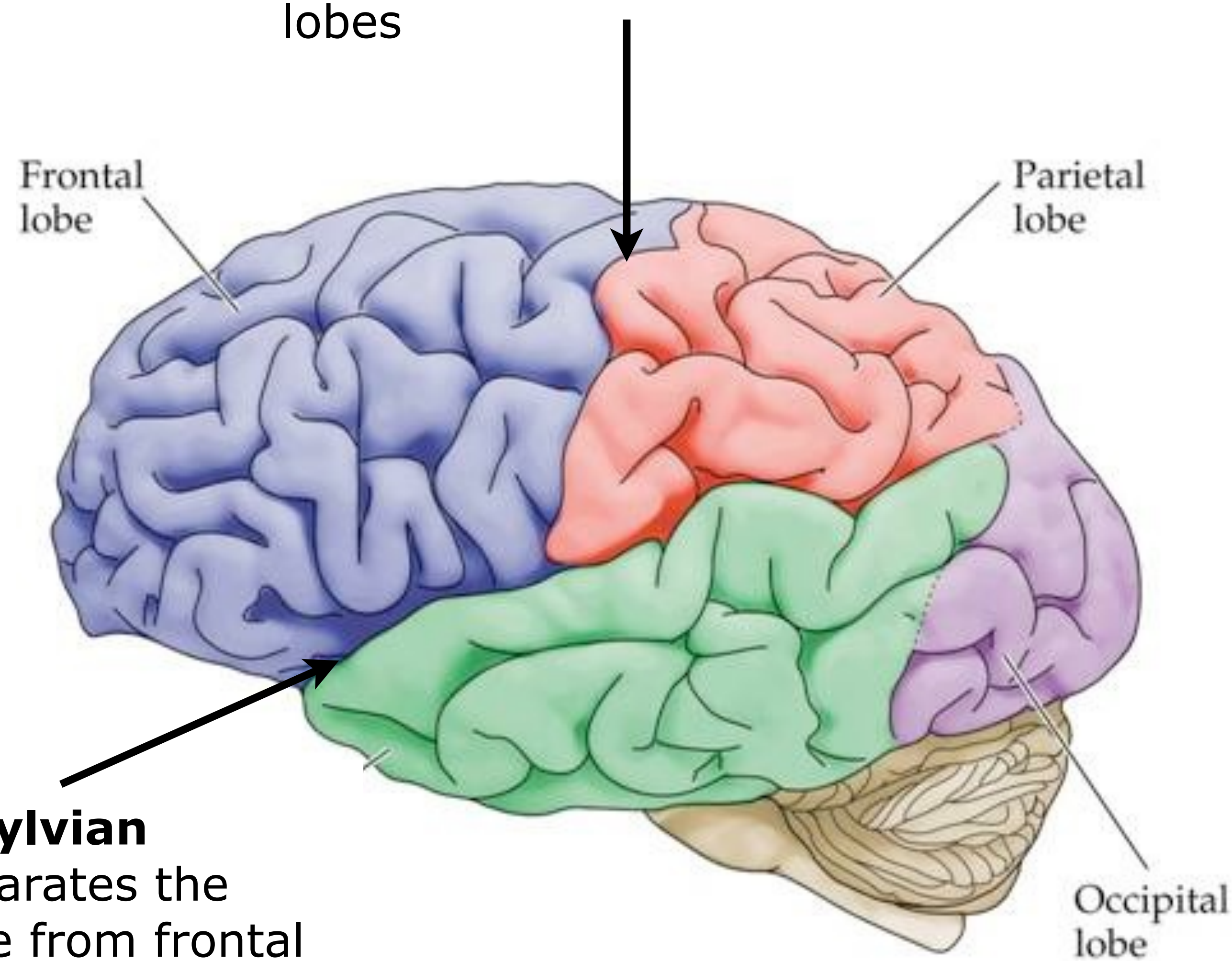
Occiptal Lobe: Vision

Gross Anatomy: Gyri and Sulci

Gyrus: a ridge of the cerebral cortex. Plural: gyri. Also called a convolution.

Sulcus: a furrow (valley) of the cerebral cortex. Plural: sulci. Also called a fissure, especially for the major sulci.

Central Sulcus: separates the frontal and parietal lobes

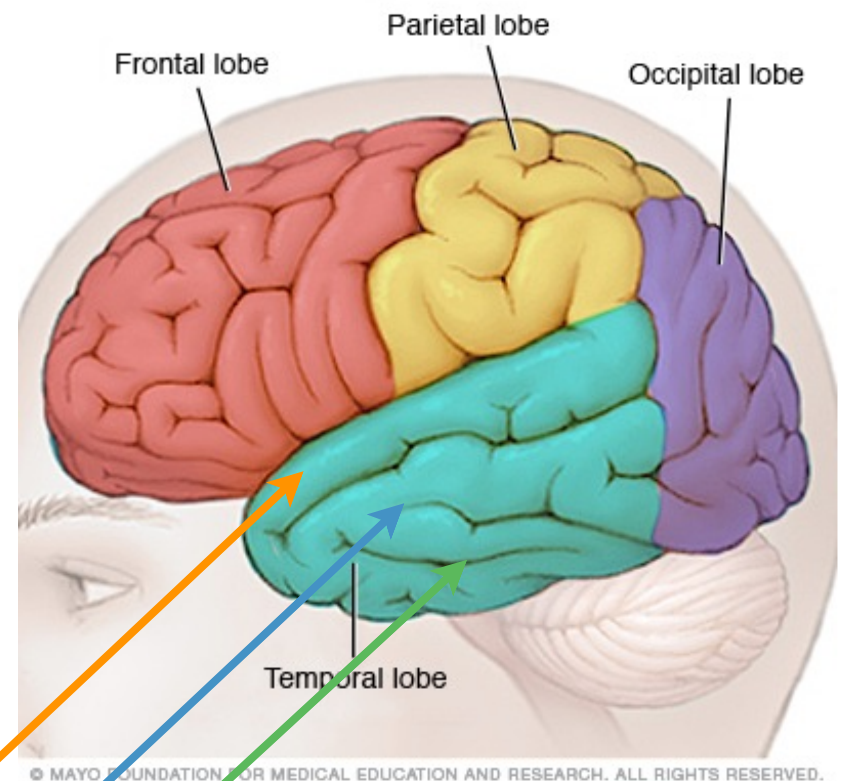


Lateral or Sylvian Fissure: separates the temporal lobe from frontal and parietal lobes

Naming Gyri and Sulci

We can use relative directions and lobe names to name gyri and sulci:

Directions	**Lobes**
superior	frontal
medial	temporal
inferior	parietal
	occipital
anterior	
posterior	



Superior Temporal Gyrus

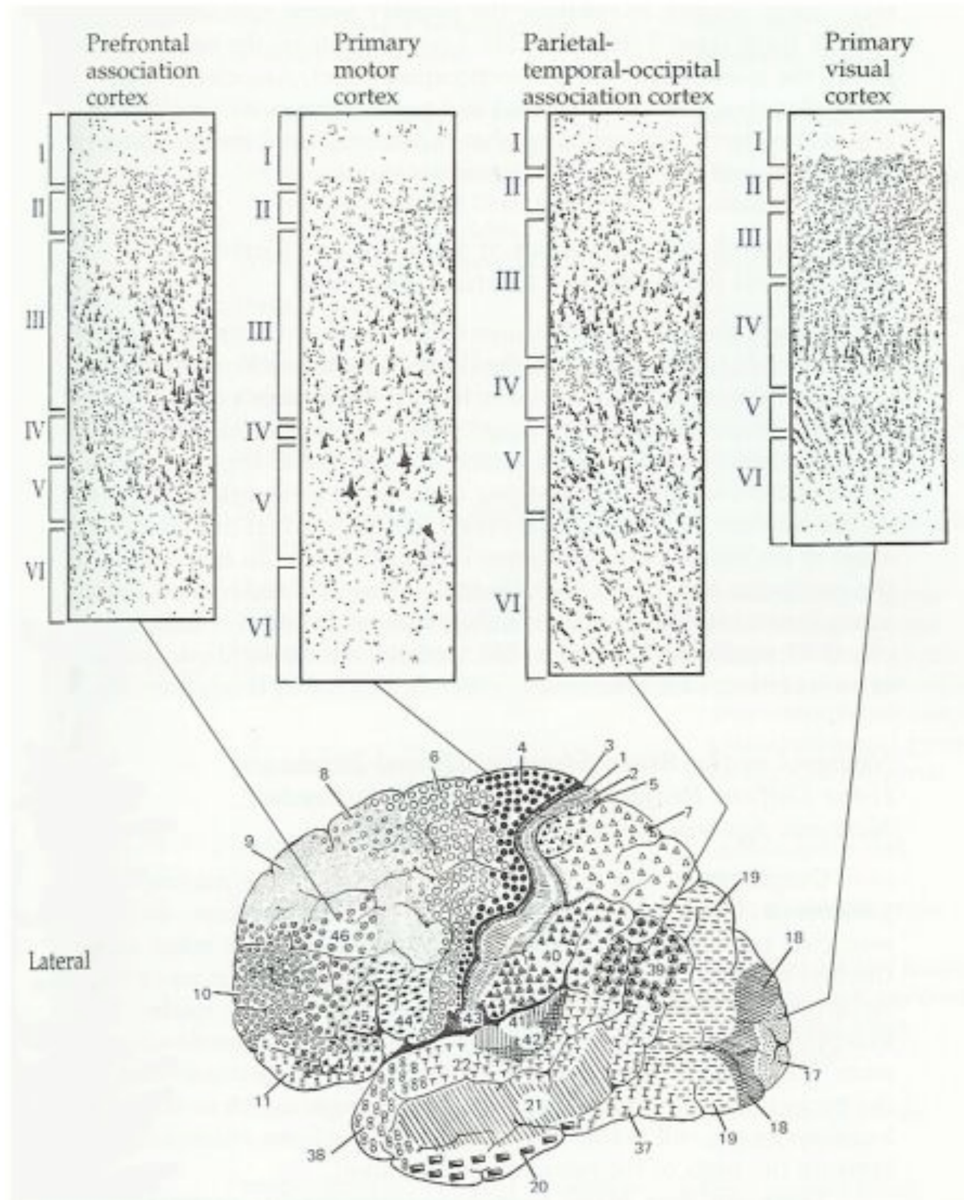
Medial Temporal Gyrus

Inferior Temporal Gyrus

Cytoarchitectonics and Brodmann areas

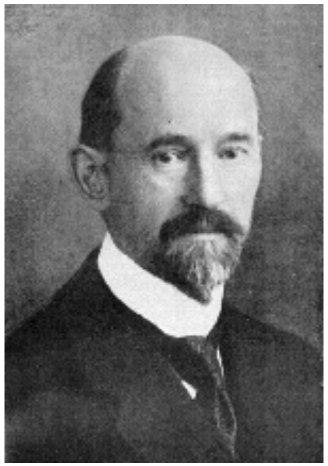
Cytoarchitectonics refers to the arrangement of neurons in layers.

It turns out that different areas of the brain display different cytoarchitectonics (different arrangements of neurons in layers).



I. Molecular
II. External granular
III. External pyramidal
IV. Internal granular
V. Internal pyramidal
VI. Polymorphous

Cytoarchitectonics and Brodmann areas

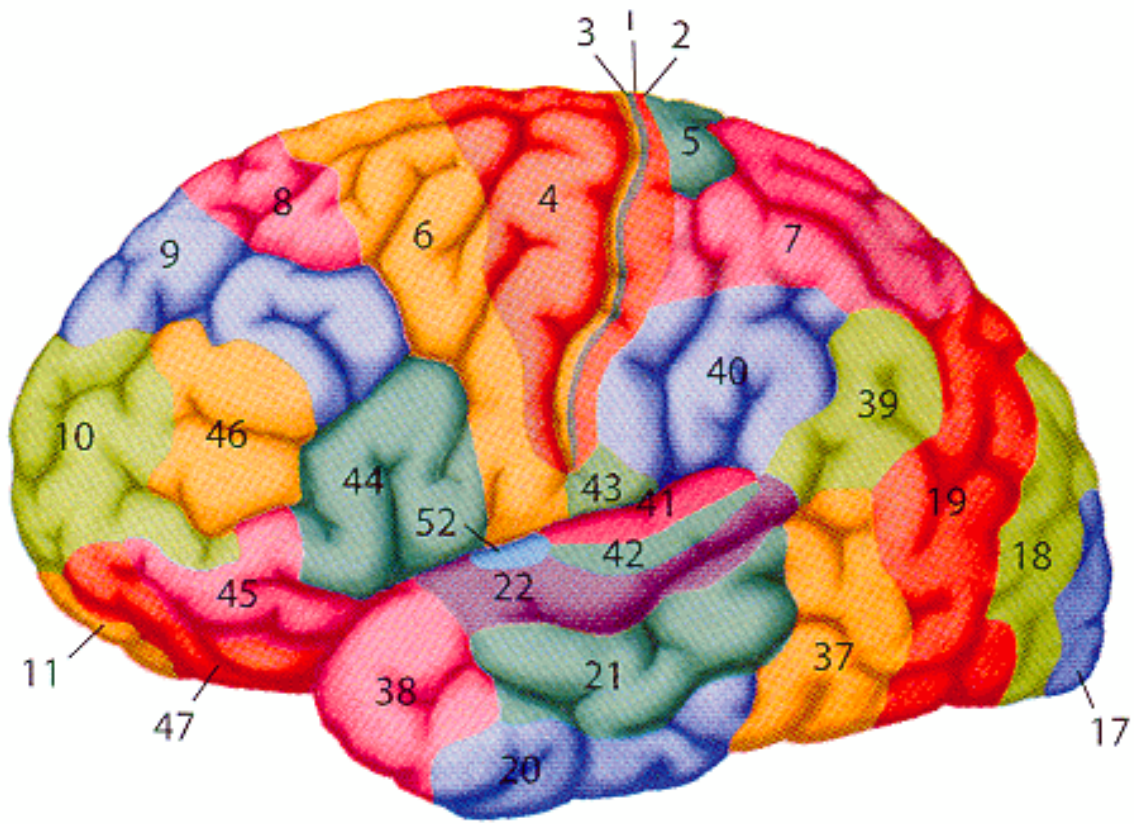


German neurologist **Korbinian Brodmann** spent years slicing and staining different areas of human (and monkey) brains.

In 1909 he published a map of his results, dividing the brain into areas that share the same cytoarchitectonics.

Although his results have been refined by more recent studies, we still use the term **Brodmann areas** to refer to areas of the brain identified based on cytoarchitectonics.

The hypothesis is that areas with **different forms** perform **different functions**.

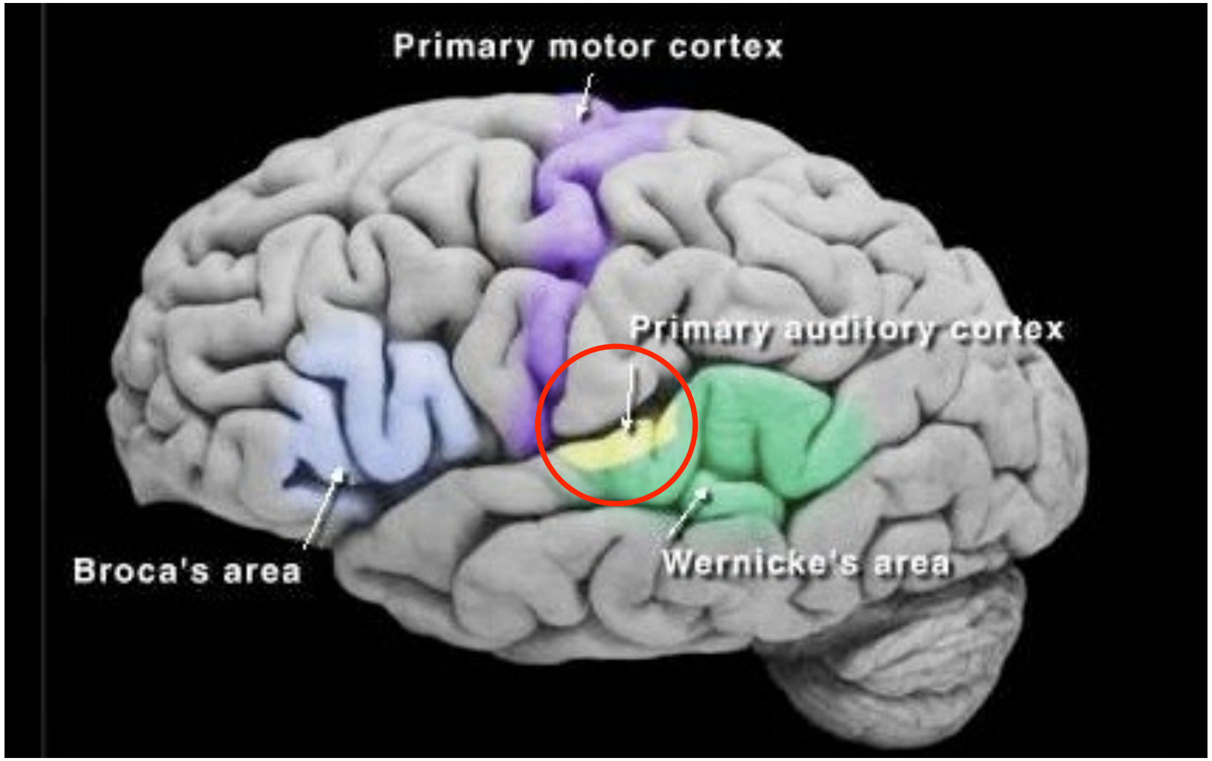


The function of the brain: mapping form to function

Hearing and the Auditory Cortex

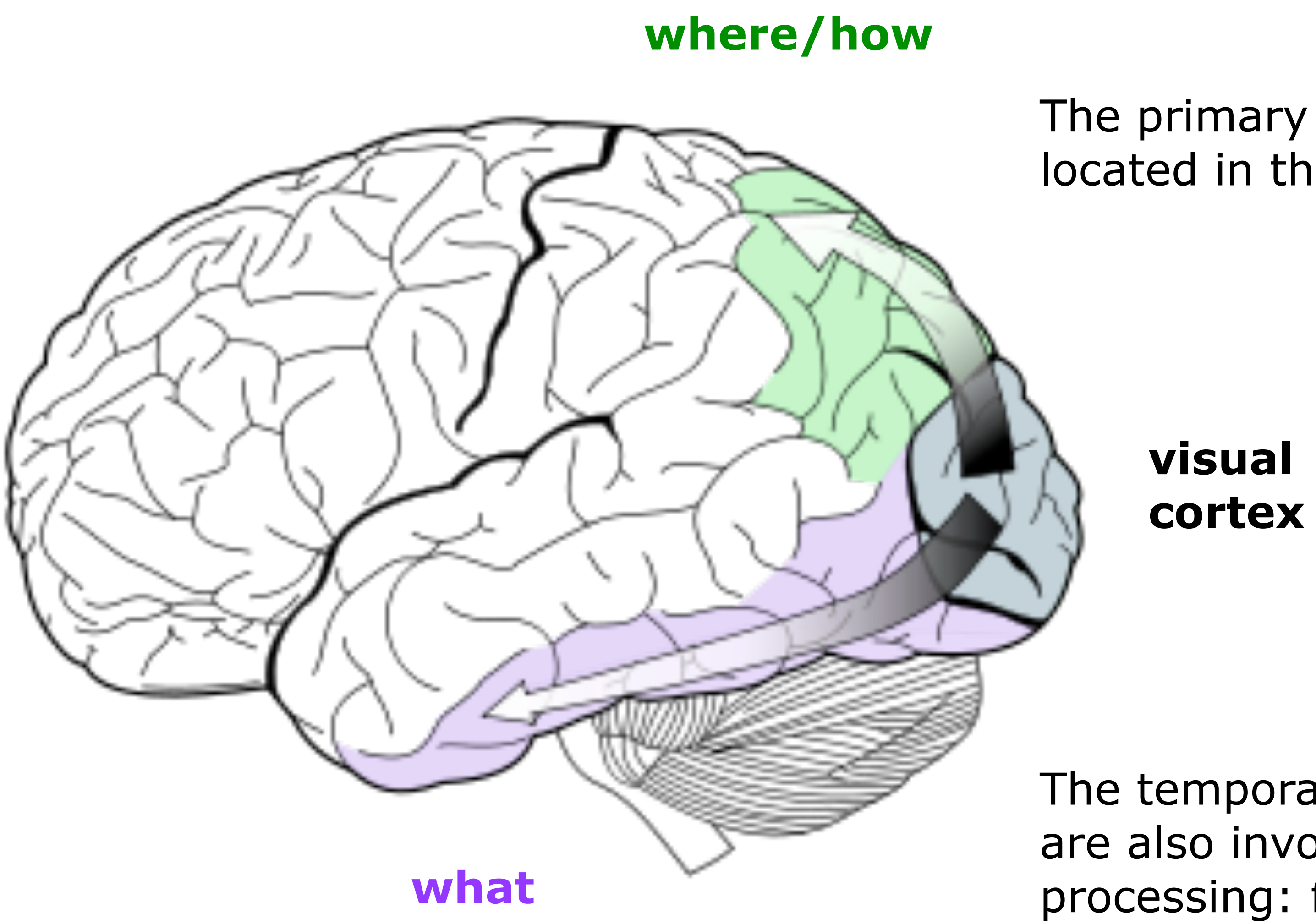
The primary auditory cortex is the first section of cortex that receives auditory information.

The auditory cortex is located in the **superior temporal lobe**, and is comprised of the **transverse temporal gyri** (also known as Heschl's gyri).



What this means in plain English is that the gyri of the auditory cortex are buried inside of the lateral fissure (also known as the Sylvian Fissure). They are called transverse because they run toward the inside of the brain instead of front-to-back like the visible gyri of the temporal lobe.

Vision and the Visual Cortex

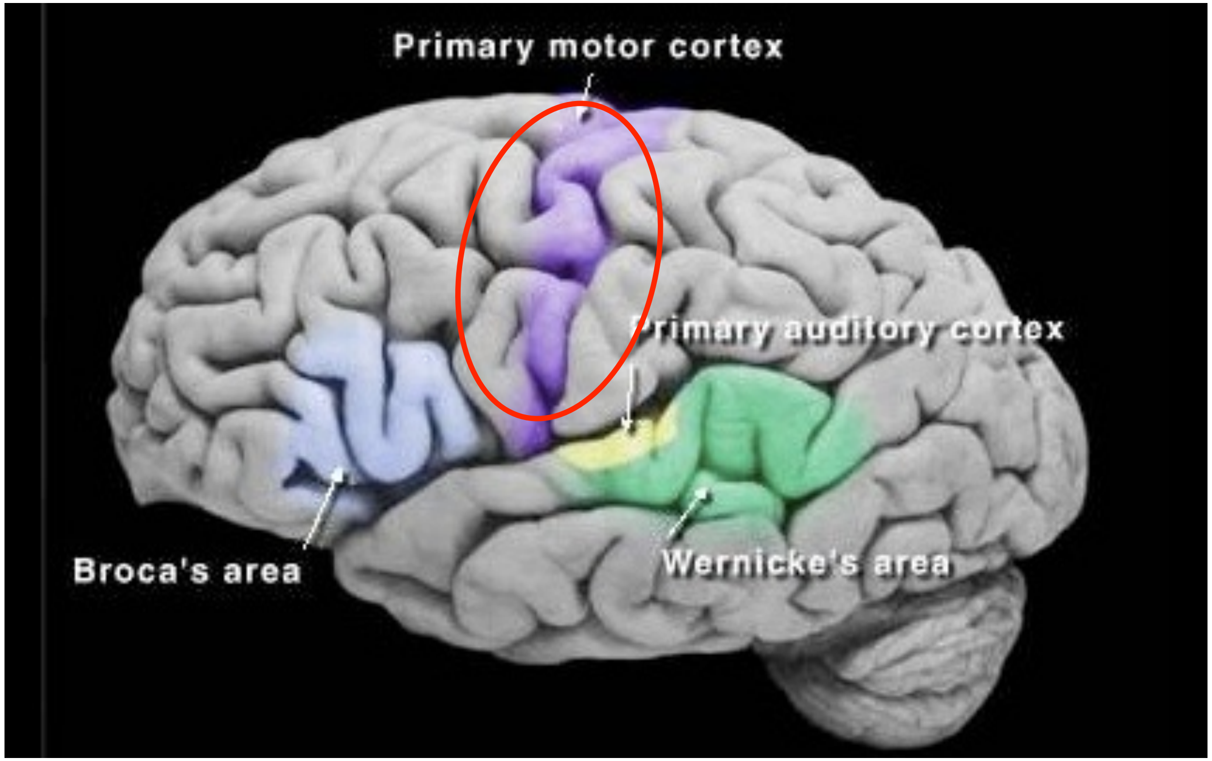


The primary visual cortex is located in the occipital lobe.

The temporal and parietal lobes are also involved in visual processing: for identification of objects (what), and location of objects (where).

The Motor Cortex

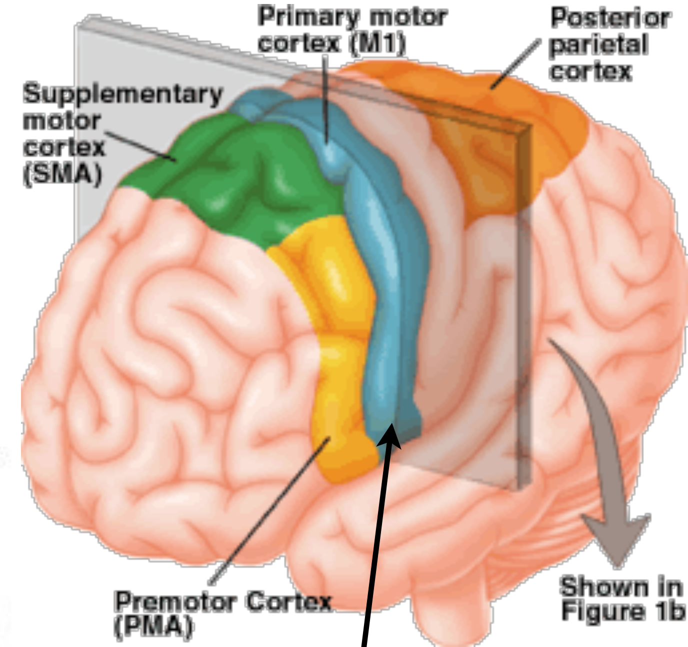
As the name suggests, the (primary) motor cortex is an area that is directly responsible for body movement.

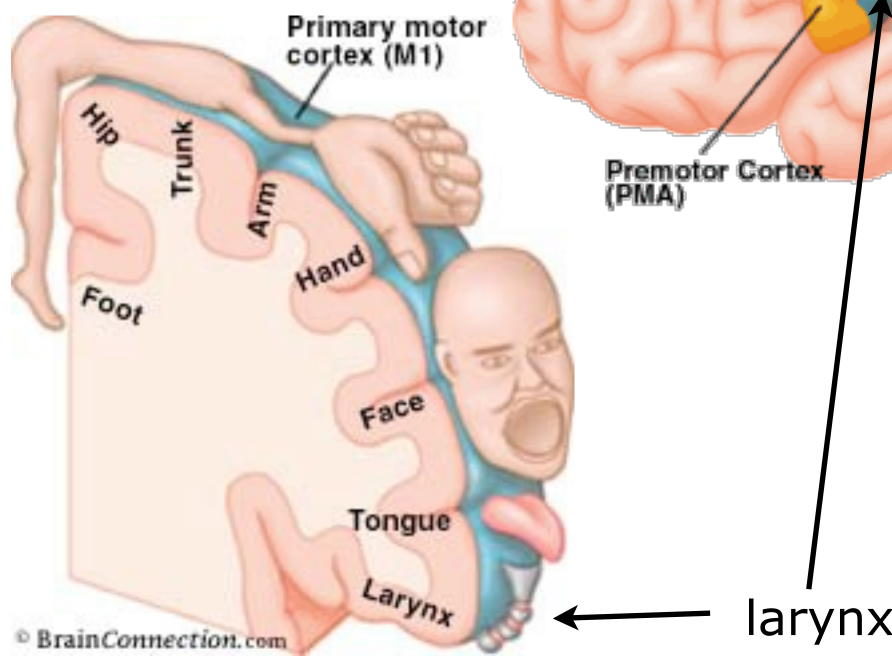


The motor cortex is the most **posterior** portion of the **frontal lobe**, and lies along the central sulcus.

The (primary) motor cortex

The (primary) **motor cortex** does not control specific muscles, but rather organizes complex movements that involve body parts, and therefore consist of large groups of muscles.





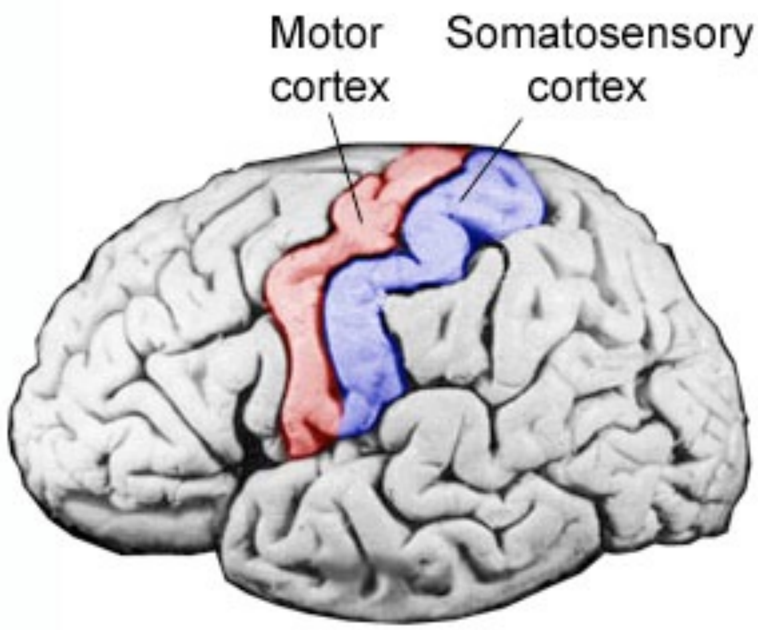
The (primary) **motor cortex** is organized around a map of the human body (somatotopically):

The size of the cortical area devoted to a body area is proportional to the specificity of the movement:

Finer movements are allocated larger areas of cortex, coarser movements are allocated smaller areas of cortex.

The somatosensory cortex

Just across the central sulcus from the motor cortex lies the **somatosensory cortex**, which occupies the anterior portion of the parietal lobe.



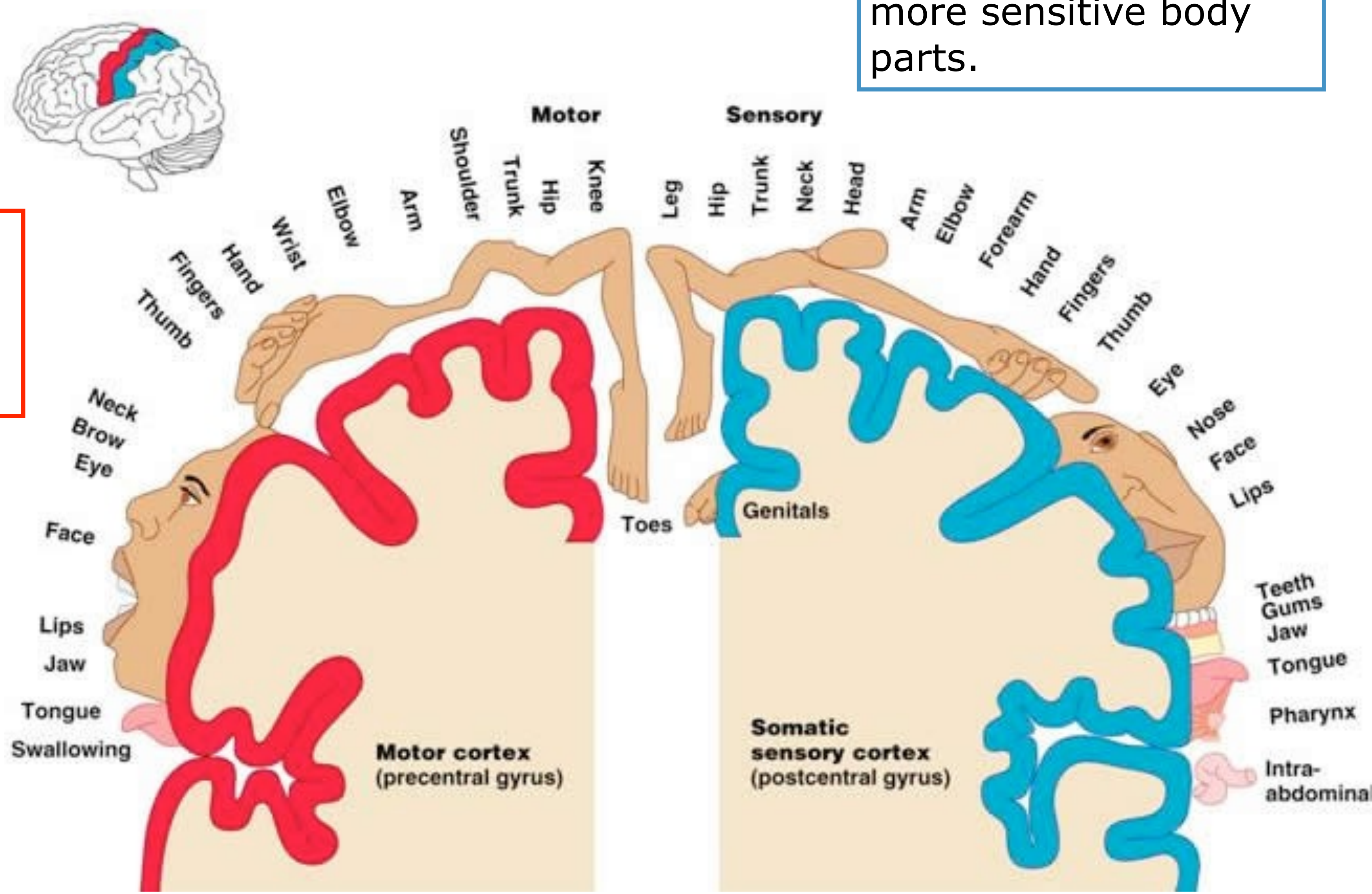
The somatosensory cortex is the primary receptive area for tactile sensation in the body.

The somatosensory cortex is not very relevant for language, but I bring it up because just like the motor cortex, the somatosensory cortex is arranged somatotopically...

The somatotopic maps of the motor and somatosensory cortices

Larger areas represent more sensitive body parts.

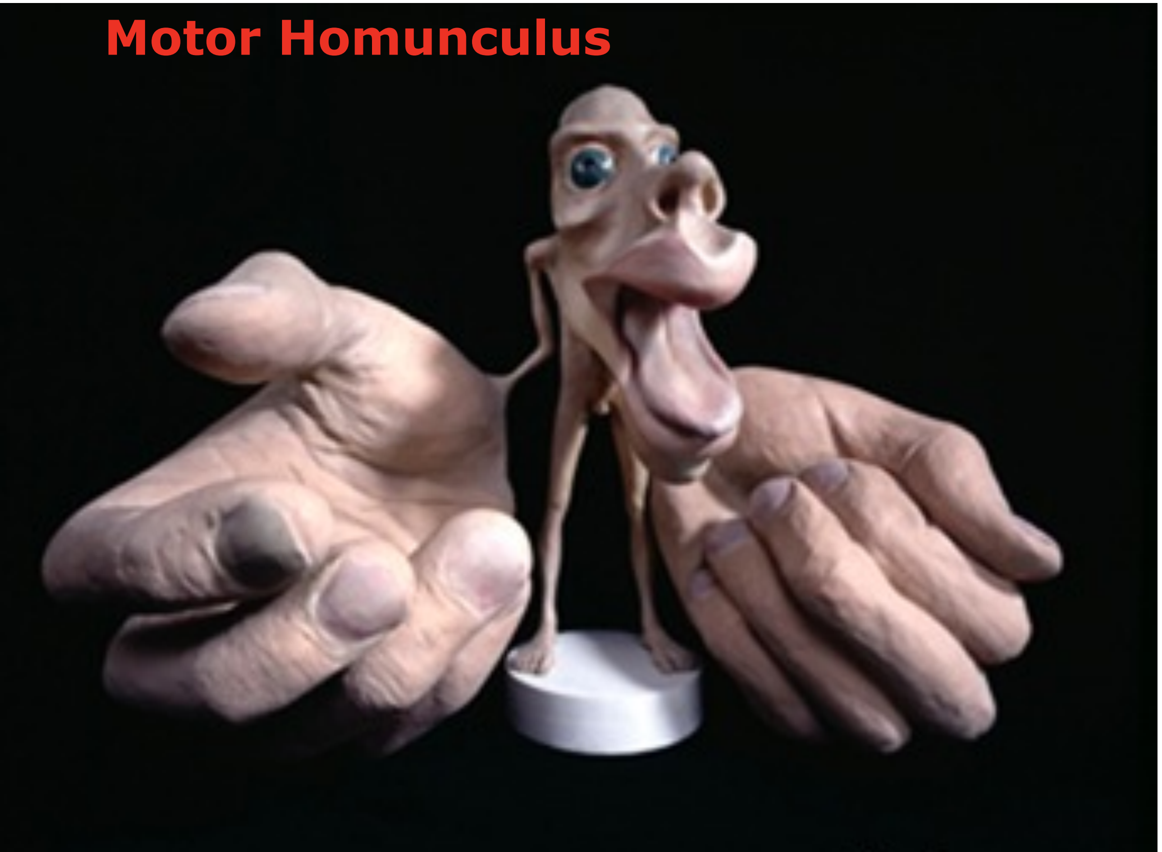
Larger areas represent finer-grained motions.



Homunculus, Homunculi, Homunculuses?

Homunculus is Latin for “little man”, and it is a way of representing the proportion of cortex devoted to body parts according to the somatotopic maps.

These are approximately scaled correctly, so size differences are meaningful.



Some (non-language) disorders

Prosopagnosia

Prosopagnosia is the inability to recognize faces. It can either be the result of injury to the brain or a congenital.

Symptoms

1. Failure to recognize a close friend or family member.
2. Focusing on hairstyles or clothes instead of faces.
3. Confusing characters in movies and on TV shows.
4. Failure to recognize yourself in older or other people's photographs.
5. Difficulty recognizing people out of the typical context (e.g., a coworker on the street) or after a haircut or wardrobe change.

The fusiform face area appears to be dedicated to face recognition. It suggests there is domain specificity in the visual system.

Dyslexia

Dyslexia actually comes in (at least) three flavors: auditory, reading/visual, and attentional. But we will focus on the reading version here. In reading/visual dyslexia, the person has trouble decoding written text, often complaining that letters are reversed, out of sequence, or even “jump around”.

Here are two links to simulations of (reading/visual) dyslexia:

http://webaim.org/simulations/dyslexia-sim.html

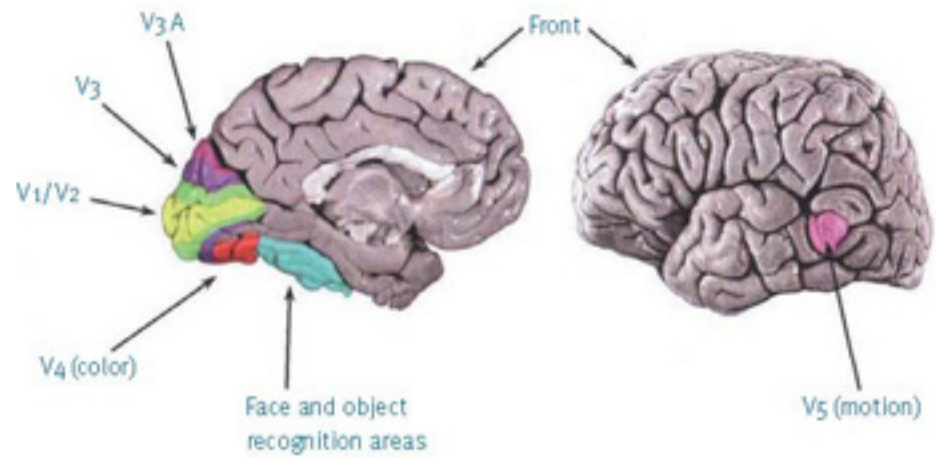
http://geon.github.io/programming/2016/03/03/dsxyliea

Dyslexia is dissociated from intelligence (just like SLI) — sufferers are neither lazy nor stupid. It is a congenital disorder, and most likely genetic/hereditary.

There is no “cure” for dyslexia, but there are a number of treatments that sometimes help, such as training on reading skills, extra time on written tasks, and specialized fonts.

Akinetopsia

Akinetopsia is the inability to see motion. It arises from damage to a part of the visual cortex called V5. Remember, the input to the visual system are individual images… it is up to V5 to integrate them into motion.



The most common form of akinetopsia is called inconspicuous akinetopsia. Sufferers report vision that is like a movie reel, or movement under a strobe light.

But there have a been a couple of cases of gross akinetopsia, with patients reporting the inability to see motion in general. In these cases, the patients only see people and objects when they are still. It is as if people/objects pop into existence when they stop moving!

Aphantasia

Aphantasia is the inability to imagine sensory experiences, such as visualizing a scene, hearing music in the mind, or imagining a specific smell.

Aphantasia has not been extensively studied. It was first named in 2015 (though it may have been noticed earlier), and didn’t gain widespread attention in the media until one of the co-creators of Firefox (Blake Ross) wrote an essay about how he suffers from aphantasia and never realized that he was different from the rest of the world.

A quick aphantasia test:

1. Imagine an image of a friend that you see frequently. How clearly can you see their face, head, and body?

2. Imagine an image of a rising sun. How clearly do you see the colors of the sun? The colors of the clouds in the sky?

3. Imagine a lightning storm erupting in the sky. How well can you see the clouds and lightning?

4. Imagine a rainbow appearing after the storm? How vivid is the picture of the rainbow in the sky?

Aphantasia

Aphantasia is the inability to imagine sensory experiences, such as visualizing a scene, hearing music in the mind, or imagining a specific smell.

Aphantasia has not been extensively studied. It was first named in 2015 (though it may have been noticed earlier), and didn't gain widespread attention in the media until one of the co-creators of Firefox (Blake Ross) wrote an es … lized that he was dif …

If you said "there is no image" or the image was "very vague", please send me an email. Aphantasia is so new, nobody has looked at its effect on language processing. We might be able to contribute to the understanding of this new disorder together!

A quick a …

1. Imagine … can you see their face, head, and body?

2. Imagine an image of a rising sun. How clearly do you see the colors of the sun? The colors of the clouds in the sky?

3. Imagine a lightning storm erupting in the sky. How well can you see the clouds and lightning?

4. Imagine a rainbow appearing after the storm? How vivid is the picture of the rainbow in the sky?

Some conclusions

One leading idea of neuroanatomy is that different areas of the brain perform different functions. In other words, the brain is not an undifferentiated mass.

The major lobes of the brain are: frontal, temporal, parietal, and occipital.

The **central sulcus** divides the frontal lobe from the parietal lobe. The **lateral (or Sylvian) fissure** divides the temporal lobe from the frontal lobe.

Brodmann areas are areas of the brain identified based on cytoarchitectonic differences.

Major functional areas of the brain include the auditory cortex, the motor cortex, the somatosensory cortex, and the visual cortex.

Damage (from genes, disease, or injury) to specific areas of the brain can lead to various cognitive disorders, such prosopagnosia, dyslexia, akinetopsia, and (presumably) aphantasia.