Neuroanatomy primer

Take home goals

- Familiarity with terms
  - Parts of brain
  - Cortical structures
  - Anatomical terms

- Familiarity with functional areas

- You do not need to remember all these details.

If you want to know this properly, go to:

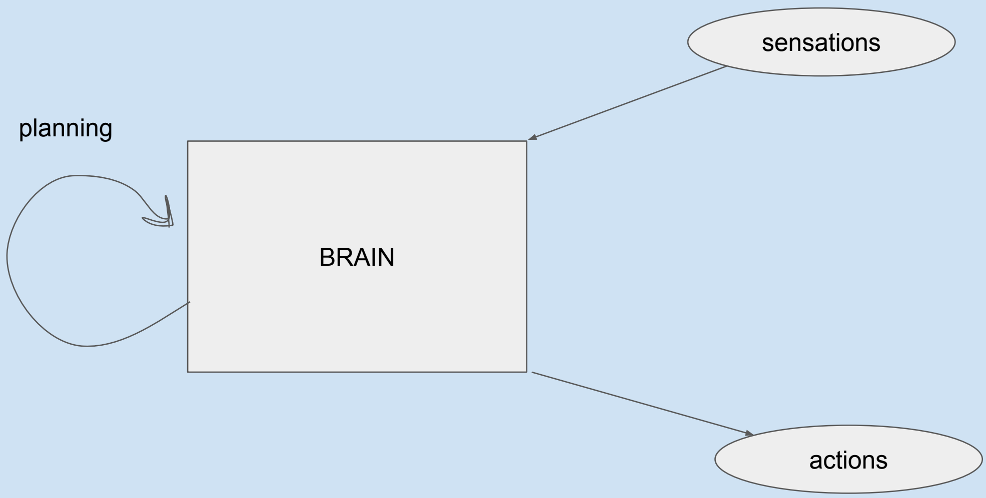
https://www.neurocourses.com/

3-day human brain anatomy
13th - 15th November 2017

2-day limbic systems
20th - 21st November 2017

Some of you probably know more neuroanatomy than me. Please join in the discussion, correct me, add anecdotes, etc.
The goal is not to remember all these details, just to make it neuroscience lectures slightly less “foreign language” for you. If you want more, go to the Johns course at Kings.

What does a brain need to do?



- Inputs, direct outputs, a la Braitenberg machines
- Inputs, basic processing, outputs, a la arduino/light following
- Inputs, processing, planning, a la arduino/light following + exploration
- Centralised, higher order processing, a la arduino/network computer vision

How to build a brain

- The following is a story. Don't quote me on the specifics.

- Where does animal evolution begin?

First animal is a sponge, for this story. (comb jelly maybe wins in reality).

Animals are multicellular, cells have nuclei, generally move, eat organic matter, reproduce sexually, and embyronic development includes a blastula stage

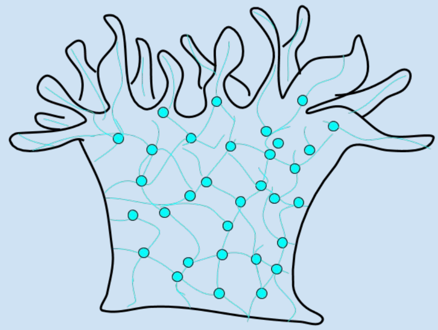
Sponge

Doesn’t need to take any actions. Water does the acting for it, providing oxygen for respiration, food, waste disposal, sperm distribution.

Sponges need to:
- Eat
- Breathe
- Reproduce sexually

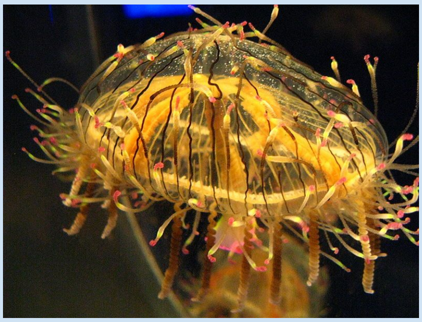
They do this by:
- Sitting back and letting water do it all

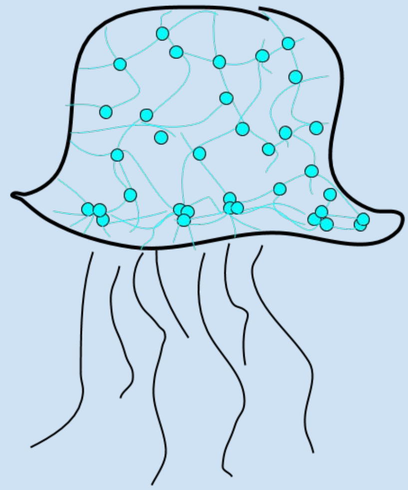
Sea anemone



Same ecological niche as a sponge, but a bit smarter.
This is a braitenberg vehicle, can react to stimuli and open/close etc

Jellyfish





Nerve nets, no central processing. There are maybe ganglia which are local processing stations. Like arduinos following light (or jellyfish moving to better areas based on vision). Interestingly, jellyfish have recently been shown to sleep…

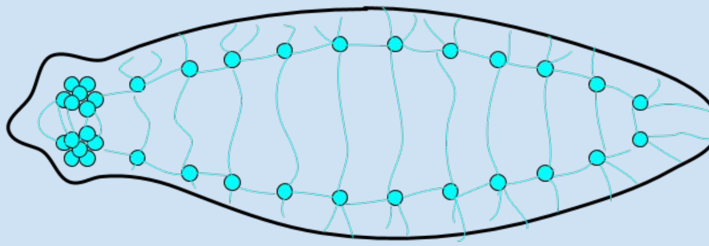
Jellyfish need to:

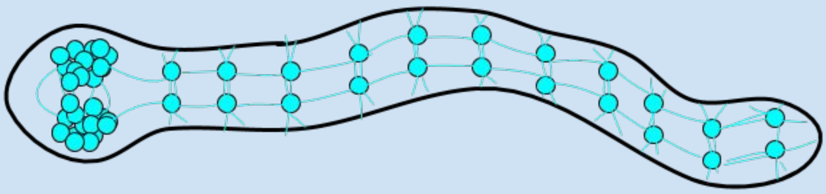
- Eat
- Breathe
- Reproduce sexually
- Move to better areas
- Capture prey

They do this by:

- Diffuse nerve net
- Some have small ganglia as local processing stations
- Some vision

Worms

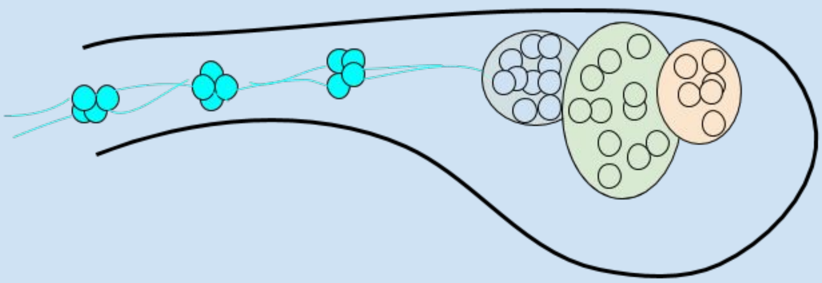




INVERTEBRATES:
Brain is basically the “master” ganglion, or “central nervous system”. No cortex!
Worms can do lots of things without their brain.
Invertebrates higher up the evolutionary ladder have more of their nervous system concentrated in their brain.

Worms can learn, remember, and regrow after decapitation.

Vertebrates..



HIND BRAIN
- Staying alive
- Housekeeping

MID BRAIN
- Arousal
- Somesensory processing

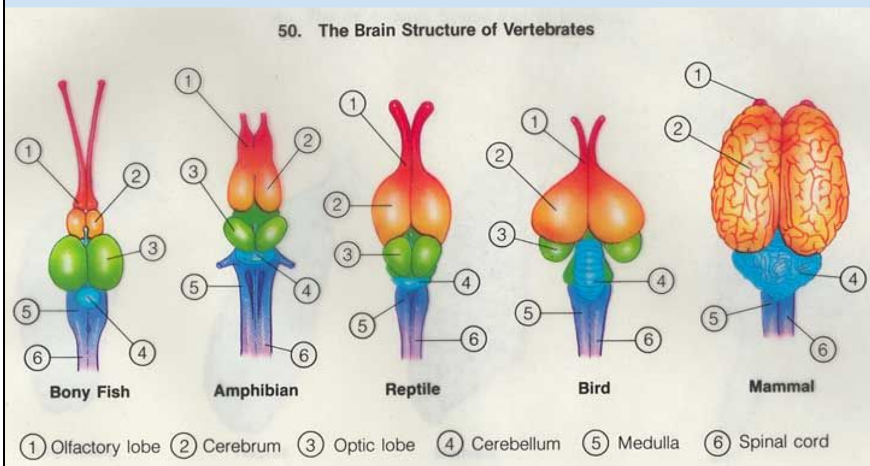
FORE BRAIN
- Emotion
- Intelligence

Now we start to see 3 distinct brain-parts, developing from different embryonic cell types and fulfilling different functionality. Forebrain will turn into cortex in higher vertebrates.

These begin to form structures:
- What did we call clusters of neurons? Ganglia.
- In the brain, we use the word “nuclei” instead EXCEPT the “basal ganglia” (wrapped on top of thalamus)

Special layered structure gives us CORTEX

Vertebrates



HIND BRAIN
- Staying alive
- Housekeeping

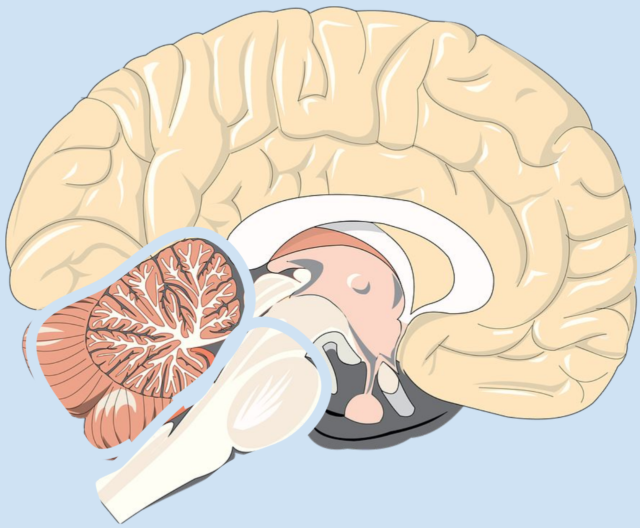
MID BRAIN
- Arousal
- Some sensory processing

FORE BRAIN
- Emotion
- Intelligence

Olfactory bulb grows then shrinks.
Hind brain stays about the same relative size - staying alive is already pretty much figured out
Forebrain explodes in size.
Mid-brain shrinks and functionality moved to cortex, e.g. visual processing.
Cerebellum is ~10% by weight, but >50% by neurons. The human cerebellum does not initiate movement, but contributes to coordination, precision, and accurate timing, motor learning. Stuff that is affected by alcohol. Cerebellum is 3-layer cortex

Large optic lobe in earlier things gets replaced by small optic tectum == superior colliculus, most visual processing moves to cortex.

Humans



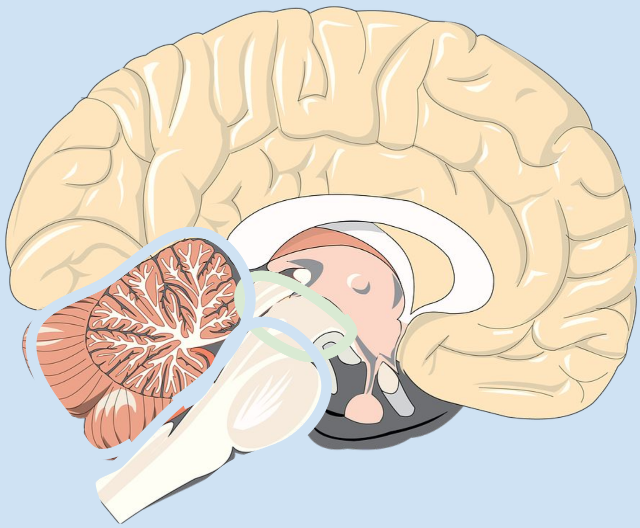
HIND BRAIN
- Brainstem: staying alive
- Cerebellum: balance, fine motor control

MID BRAIN
- Arousal,
- Dopamine (substantia nigra)
- Superior/inferior colliculi - map vision/sound to outside world

FORE BRAIN
- Limbic system: emotion
- Cortex: intelligent behaviour

Approach from the spinal cord, you hit hind brain first, what are the two key components of hind brain? What do they do?
Pons is round thing, medulla slab below.
Brainstem is life support system: breathing, heart rate, blood pressure, reflexes (cough/sneeze/gag), consciousness, sleep/wake cycles
Cerebellum does everything that alcohol messes up: balance, coordination, speech articulation, motor learning

Humans



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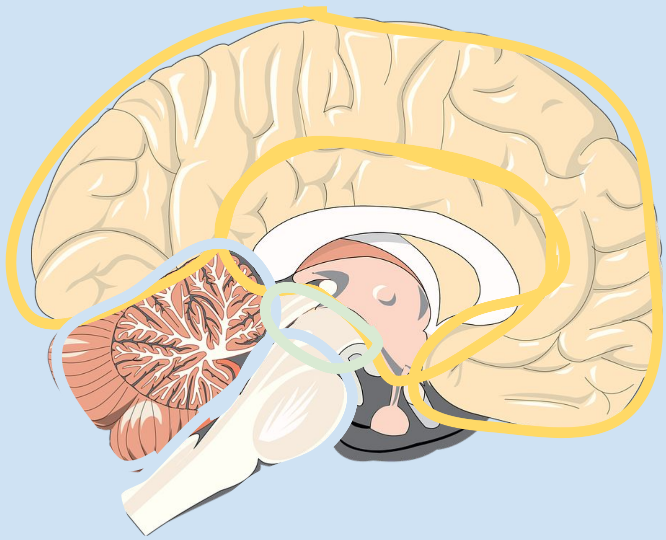
- Cortex: intelligent behaviour

Midbrain is pretty small in humans

Humans



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FORE BRAIN
- Limbic system: emotion
- Cortex: intelligent behaviour

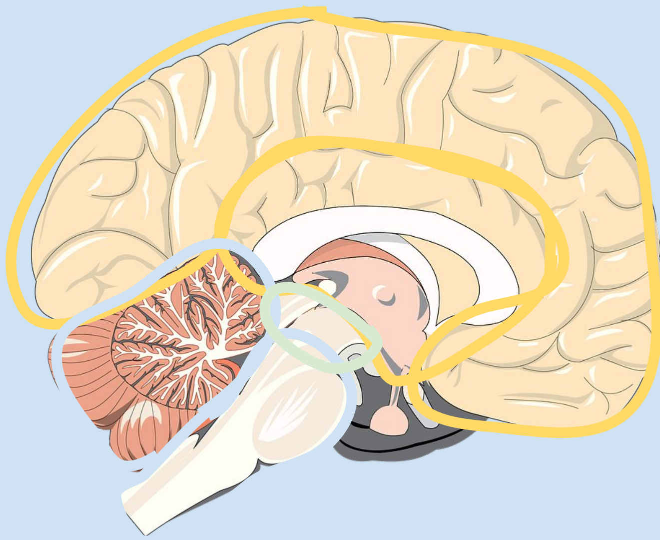
Limbic means “wrapped around”. Point out corpus callosum. Cortex means bark, rind, shell or husk.

Limbic lobe includes cingulate gyrus and innermost bits of other cortical lobes.

We’ll come back to the fiddly limbic system later. First we’re looking in from the outside.

After a quick diversion into coordinate systems and cortex

Humans



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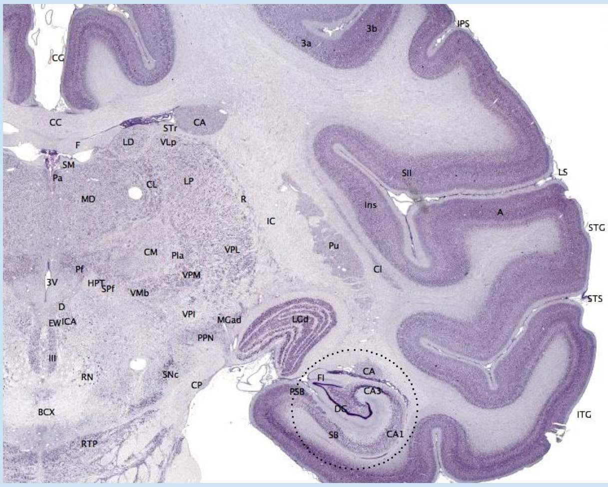
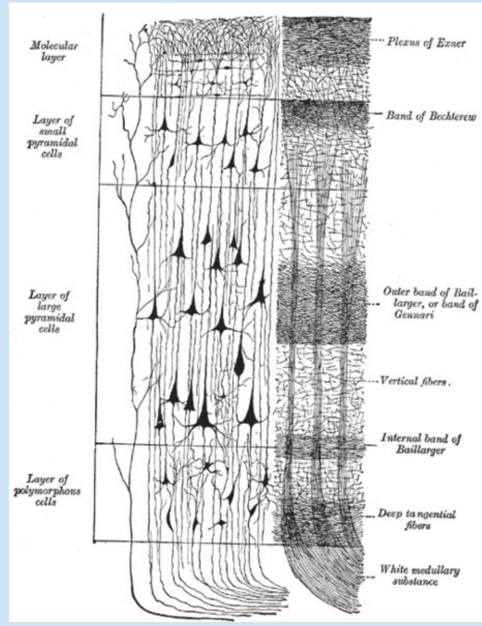
Cortex

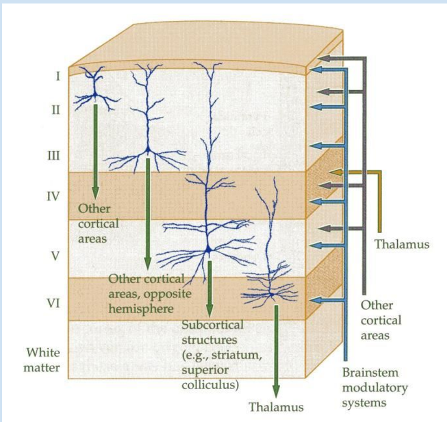


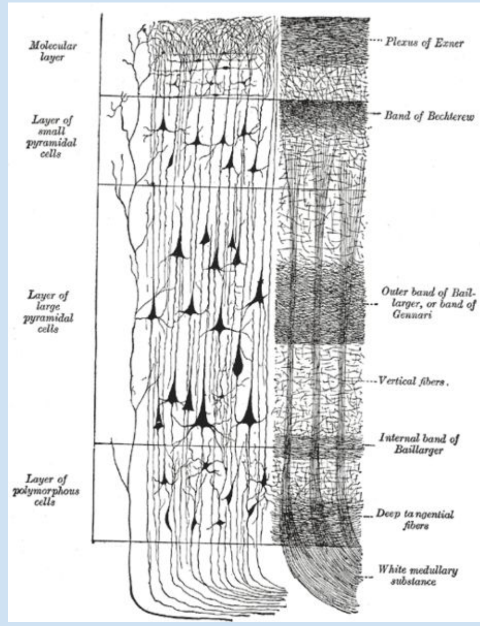


Wrinkly shape - maximise grey matter surface area. Lower animals much less wrinkly. (macaque), cortex in dark purple, (grey matter), hippocampus is circled. Sulci (valleys) and gyri (peaks)

Hippocampus is only 3-4 layers, not neocortex.

Cortex



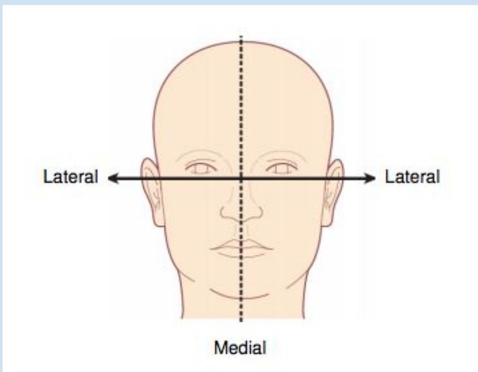


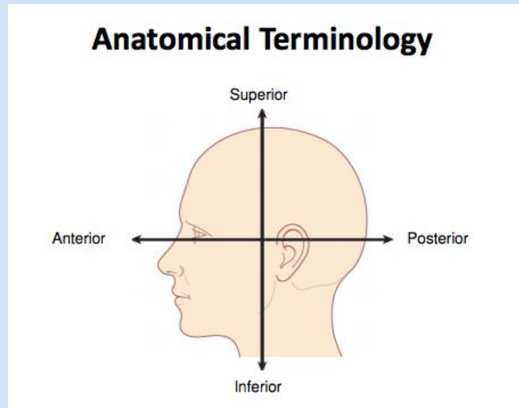
Most neurons are very localised, excitatory pyramidal neurons have long axons for longer range connections.

- There are layers.
- They are pretty much self containing processing units
- They sometimes get referred to as L1, L2 etc.

Older cortex has fewer layers “allocortex” vs “neocortex”

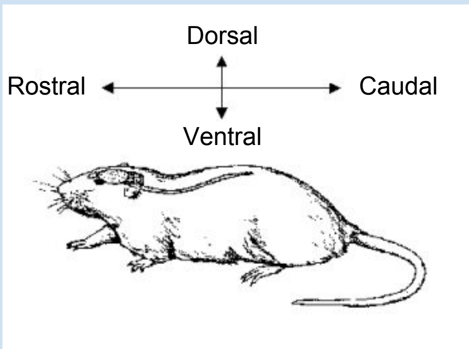
Coordinate systems

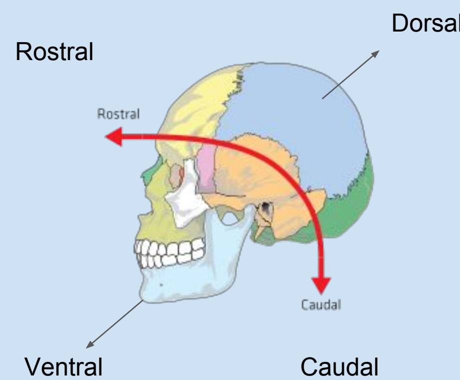




Bilateral, ipsilateral, contralateral, medial

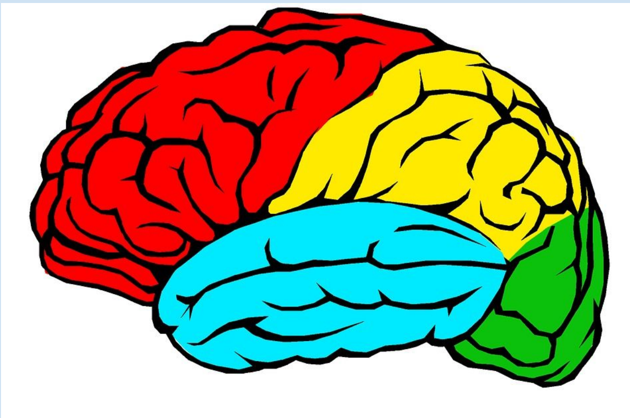
Coordinate systems





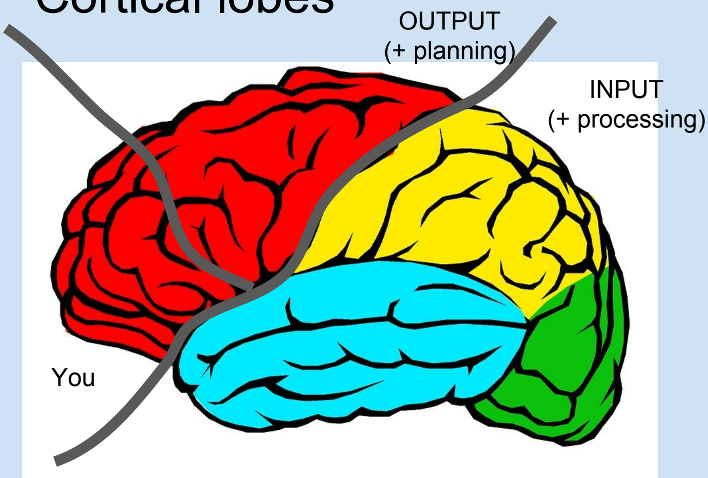
Dorsal fin

Cortical lobes

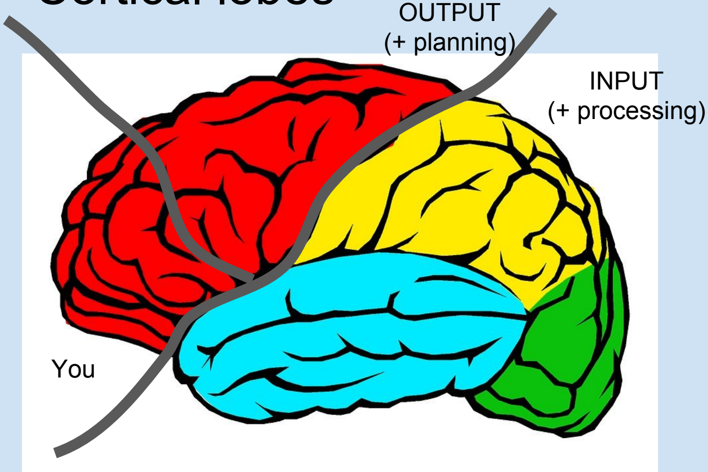


Note boxing glove. Central sulcus

Cortical lobes



Cortical lobes



FRONTAL LOBE
- Motor
- Prefrontal cortex

PARIETAL LOBE
- Sensory perception

OCCIPITAL LOBE
- Visual processing

TEMPORAL LOBE
- Audition
- Memory
- Speech

- Frontal Lobe- associated with reasoning, planning, parts of speech, movement, emotions, and problem solving
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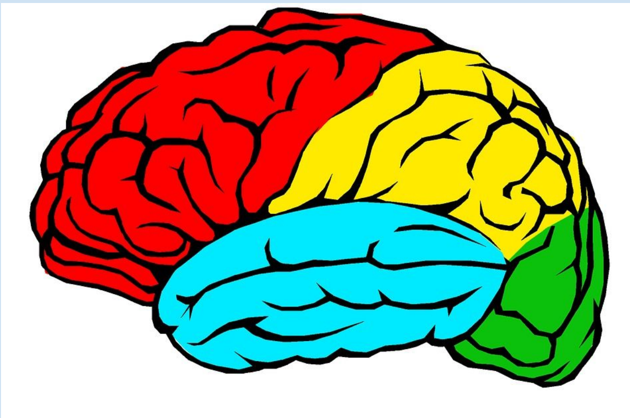
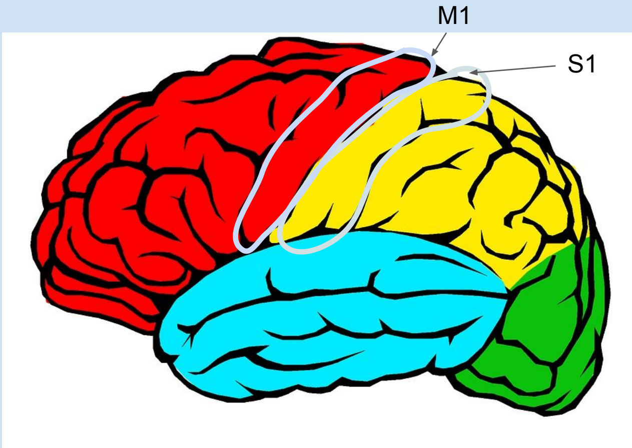
Pre-central gyrus



Pre = anterior to = in front of
Let’s identify the pre-central sulcus. How about post-central sulcus?

What function does each play? Motor versus sensory, M1, S1. What do they do?

Pre-central gyrus



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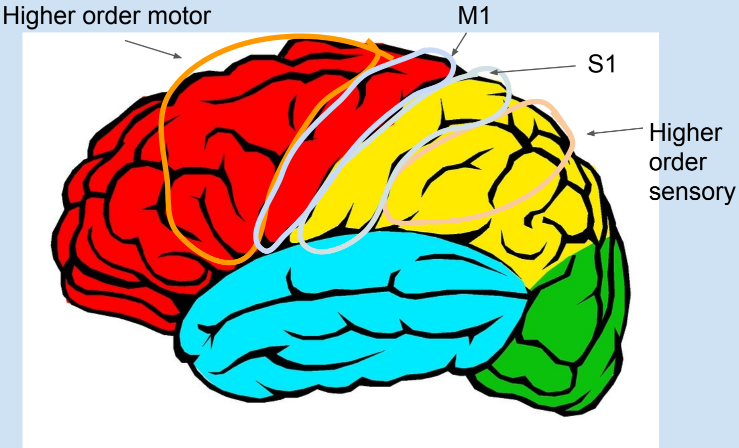
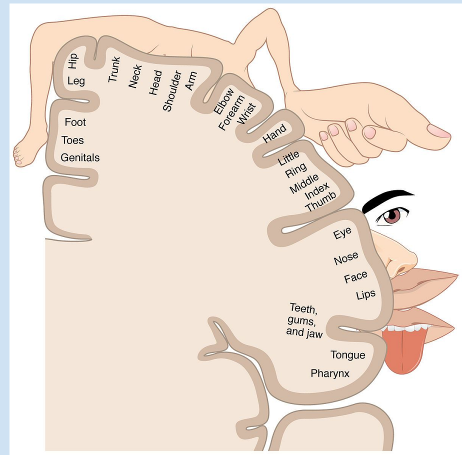
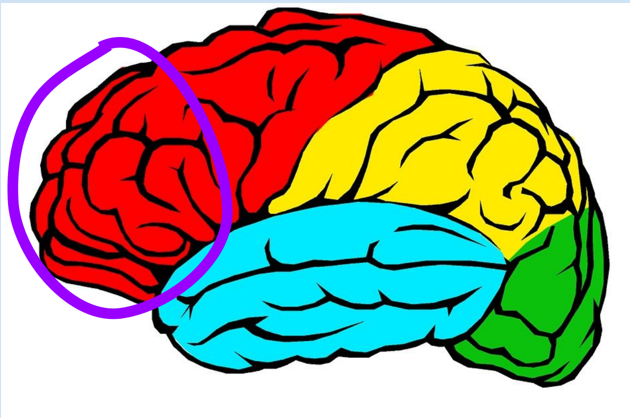
Sensory/motor homunculi





Sensory/motor homunculus, compare with models.

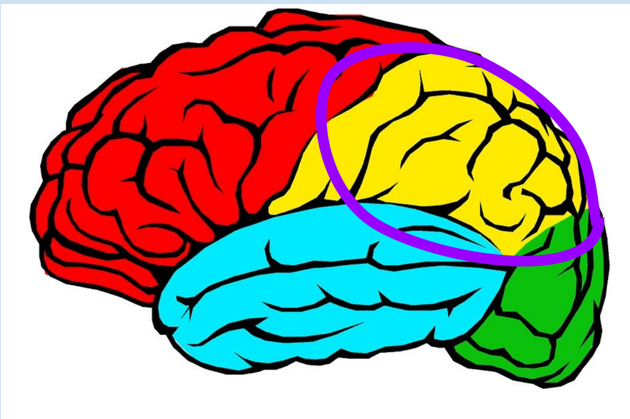
Prefrontal cortex



- Executive function
- Personality
- Moderating social behaviour
- Internal goal-driven decisions

Let's examine the brain models. What can we see.
Executive function:
planning complex cognitive behavior, personality expression, decision making, and moderating social behavior.[
orchestration of thoughts and actions in accordance with internal goals.
Damage:
Phineas Gage, left frontal lobe was destroyed when a large iron rod was driven through his head. retained normal memory, speech and motor skills, but became irritable, quick-tempered, and impatient.
Other patients can verbal appropriate social responses, but when actually performing, they pursue immediate gratification, despite knowing the longer-term results would be self-defeating.

Parietal lobe



Processing of sensory input:

- Somatosensory input
    - Touch
    - Pain
    - Temperature
- Proprioception (space)
- Visual “where/how” stream

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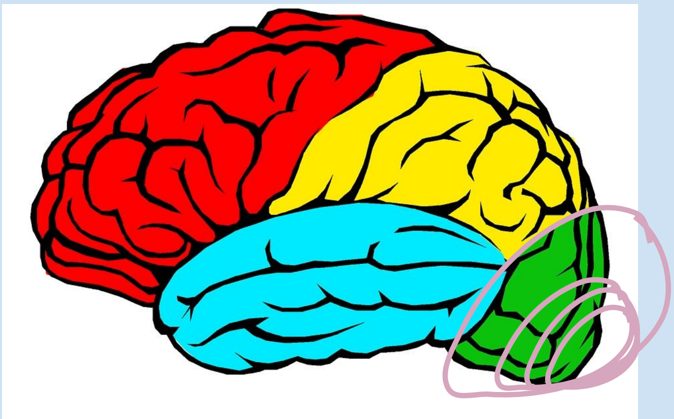
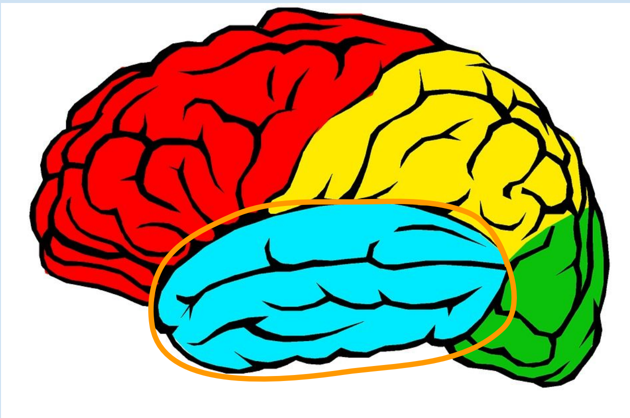
Occipital lobe



Occipital lobe is all vision.
What did we call the lowest-order motor and sensory areas? ”Primary”, “S1” “M1”.
Vision has “V1” then “V2” “V3” and the rest gets split up into higher order areas

Temporal lobe

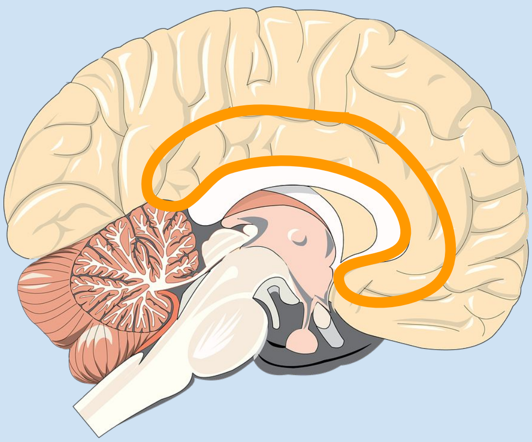


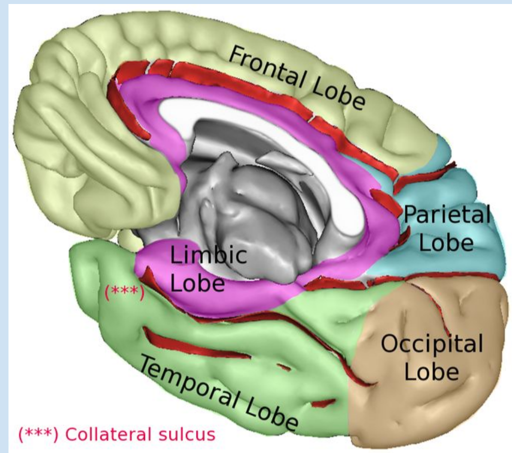
Abstract/high order processing of sensory input:

- Hearing (low+high order)
  - Speech comprehension, semantics
- Visual memory
- Visual object recognition
  - Faces
  - Scenes

processing sensory input into derived meanings for the appropriate retention of visual memory, language comprehension, and emotion association
What lives on the inside of the temporal lobe and lookes like a seahorse? Hippocampus.
Hippocampus does memory. Adjacent temporal lobe handles associated visual memories.
faces = fusiform gyrus
Scenes = hippocampal gyrus

Limbic lobe

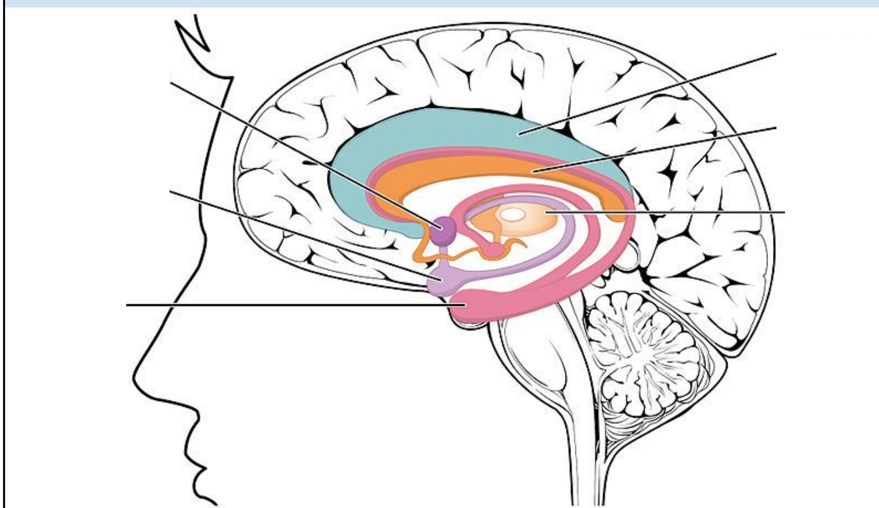




This is the cingulate gyrus, part of the limbic lobe, what does it do? emotion, motivation, learning, and memory.

Limbic lobe also includes hippocampus (parietal)

Limbic system



CINGULATE GYRUS
- Learning links between behaviour and emotion

THALAMUS
- Gateway to the cortex

AMYGDALA
- Emotion, fear

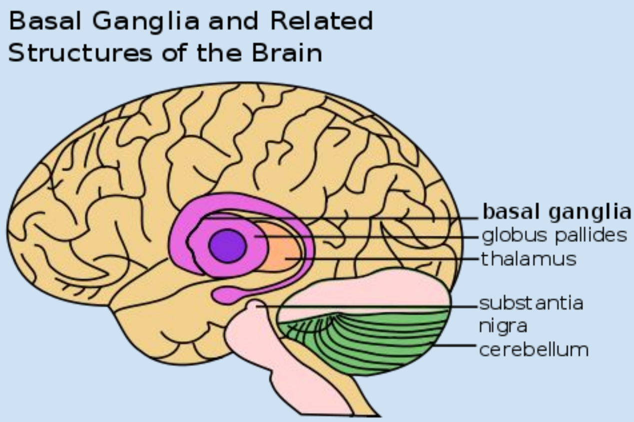
HIPPOCAMPUS
- Space
- Memory

Limbic system = **paleomammalian cortex**.
Includes limbic lobe (cortical) plus many sub-cortical structures
supports a variety of functions including emotion, behavior, motivation, long-term memory, and olfaction
Amygdala - almond shaped
Hippocampus - sea horse

In Alzheimer's disease (and other forms of dementia), the hippocampus is one of the first regions of the brain to suffer damage; short-term memory loss and disorientation are included among the early symptoms

Cingulate gyrus involved in linking behavioral outcomes to motivation (e.g. a certain action induced a positive emotional response, which results in learning).[5] This role makes the cingulate cortex highly important in disorders such as depression[6] and schizophrenia.[7]

Limbic system



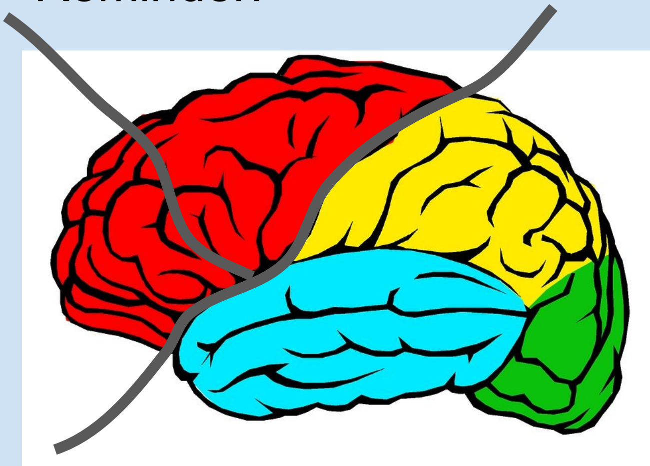
BASAL GANGLIA
- Action selection

Basal ganglia is cluster of nuclei involevd in voluntary motor control.

If your basal ganglia is broken, you can catch a ball but not throw it.

Parkinsons: cell death in basal ganglia, substantia nigra doesn't produce dopamine, you can't initiate movement, freezing.

Reminder:



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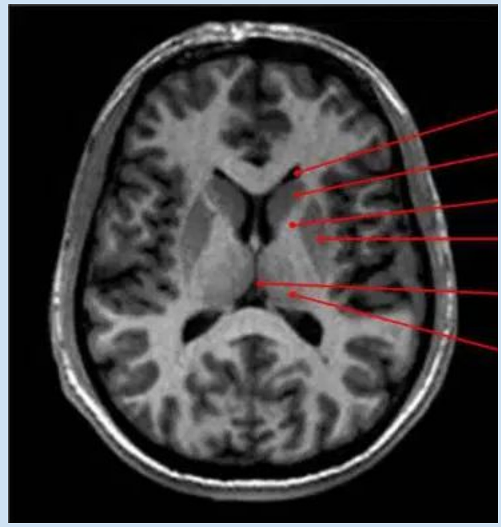

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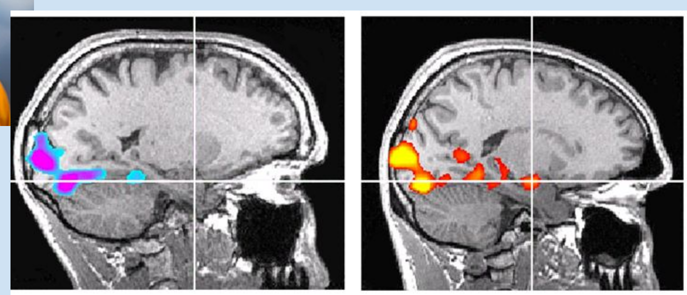
Case study

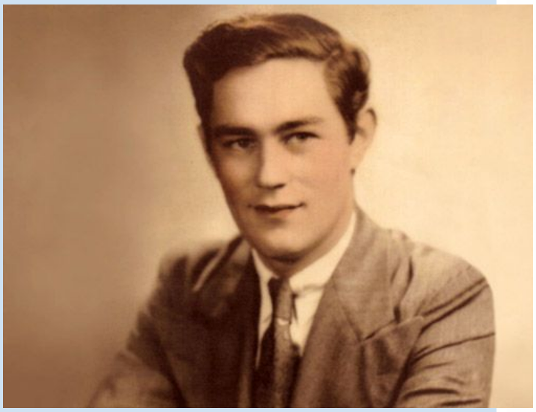
Former Mayor of san diego, over the course of 10 years, developed new gambling habit, lost $13 million and stole $2 million from her husband's non-profit.
After reporting hallucinations, doctors found a golf-ball sized tumour in her "medial orbitofrontal cortex" (part of PFC)
logic, reasoning and judgment
there are a number of reports in the neurological literature of patients who do incur large gambling debts during the time a slow-growing, non-fatal tumor impinges upon the frontal lobes.

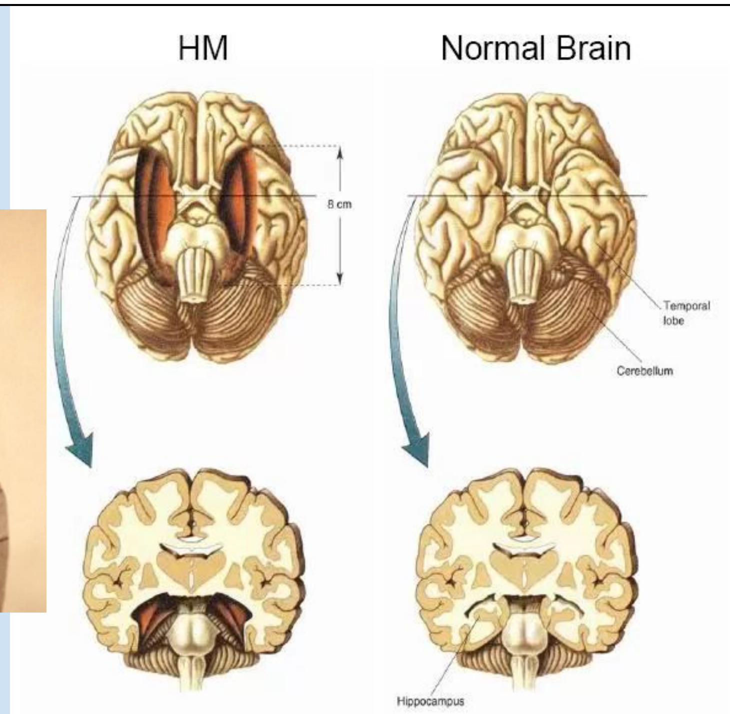
Case study



Alex Honnold, free-climbed El Capitan in Yosemite a couple of months ago. fMRI while viewing emotive images,
Control subject—a high-sensation-seeking male rock climber of similar age to Honnold—for comparison. Like Honnold, the control subject had described the scanner tasks as utterly unstimulating. Yet in the fMRI images of the two men's responses to the high-arousal photographs, with brain activity indicated in electric purple, the control subject's amygdala might as well be a neon sign. Honnold's is gray. He shows zero activation.

Case study



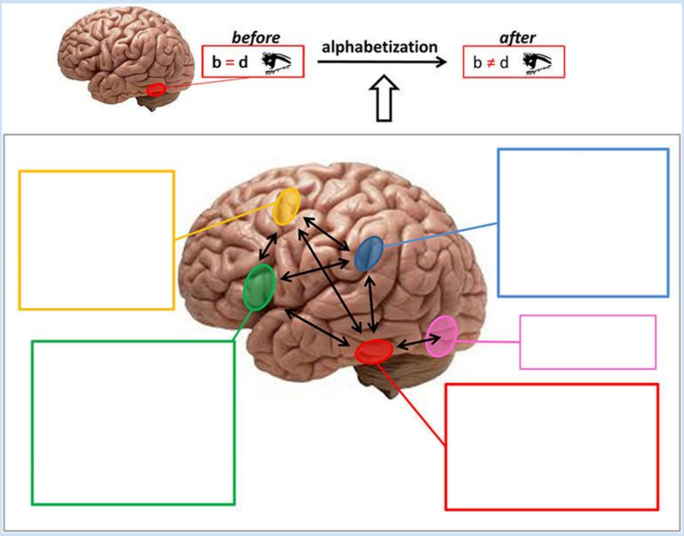


Henry Molaison, H.M.

After the surgery, which was successful in its primary goal of controlling his epilepsy, Molaison developed severe anterograde amnesia: although his working memory and procedural memory were intact, he could not commit new events to his explicit memory. According to some scientists, he was impaired in his ability to form new semantic knowledge,[10] but researchers argue over the extent of this impairment. He also had moderate retrograde amnesia, and could not remember most events in the one- to two-year period before surgery, nor some events up to 11 years before, meaning that his amnesia was temporally graded. However, his ability to form long-term procedural memories was intact; thus he could, for example, learn new motor skills, despite not being able to remember learning them.

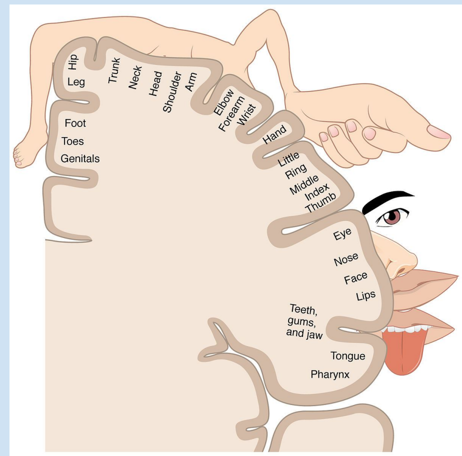
In an attempt to remove the part of the brain that was causing Henry's fits, two holes were drilled in the front of his skull and a portion of his brain, the front half of the hippocampus on both sides, and most of the almond-shaped amygdala, was sucked out

Case study



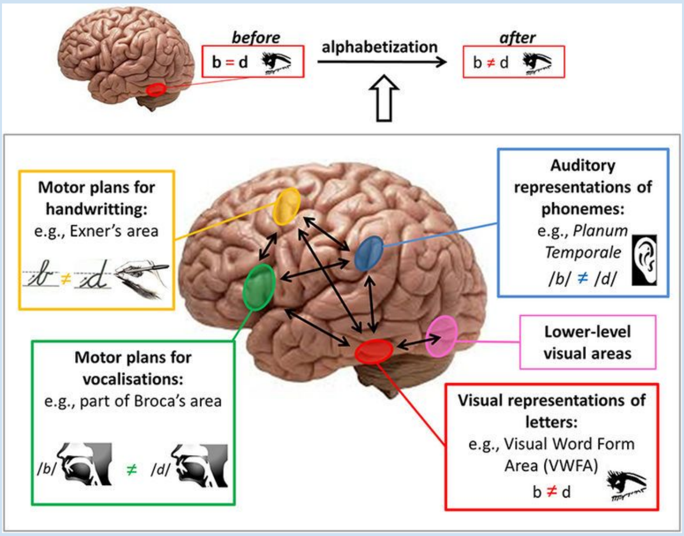
Components required:

- Motor control for writing “b” or “d”
- Motor control for speaking “b” or “d”
- Visual input
- Visual recognition of “b” or “d”
- Auditory recognition of “b” or “d”



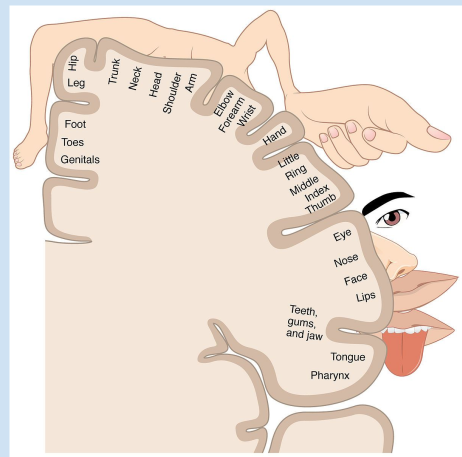
Which parts of the cerebral cortex are used to learn to distinguish between mirror-symmetric letters?

Case study



Components required:

- Motor control for writing "b" or "d"
- Motor control for speaking "b" or "d"
- Visual input
- Visual recognition of "b" or "d"
- Auditory recognition of "b" or "d"



Which parts of the cerebral cortex are used to learn to distinguish between mirror-symmetric letters?

Lateralisation

https://www.youtube.com/watch?v=aCv4K5aStdU

Lateralisation
- Generally symmetric, crossed to other side.
  - Terms ipsilateral, contralateral
- Functional Lateralisation
  - Broca/Wernicke language areas
    - Both in left hemisphere for 95% of right handed, 70% left handed
  - Language production
    - In left for 90% R-handed, 50% l-handed
  - Intonation/meter/accentuation In right (mainly)
  - Spatial manipulation, facial perception are bilateral but may show right-hemisphere dominance.
- Split brain patients, corpus callosum