University of BRISTOL

Computational Neuroscience

COMS30127

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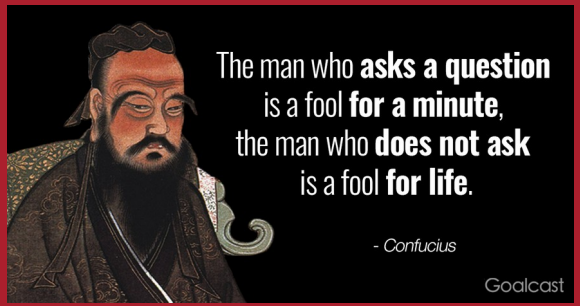
Github:

github.com/coms30127

Reddit

Ask Questions!



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Introduction to the brain

Part I: Brain Anatomy

A brief introduction to what we know about human brain anatomy and how we know it

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Learning Objectives

To gain an understanding of the basic anatomy of the human brain

To appreciate the affect of damage to example brain regions

Have fun and be inspired by the brain!

What's the point of a brain?

Why did brains evolve?

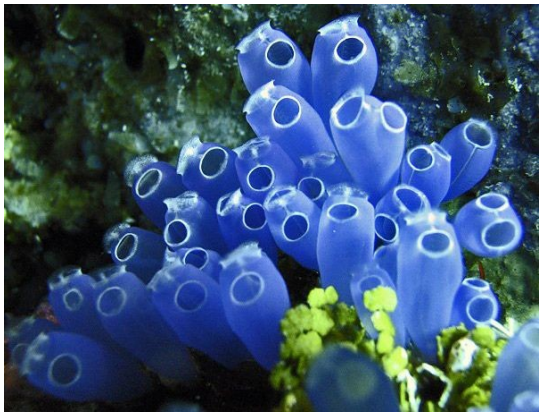
- To survive we must sense and respond to our environment
- To achieve this, cells within a multi-celled organism must be able to communicate with one another
- The first brain cells were probably connected in a diffuse network across the body
    - This structure can still be seen in jelly fish and sea anemones today
- Groups of neurons then began to appear and this allowed information to be processed rather than just relayed
    - Animals can then move and respond to the environment in ever more sophisticated ways…

…. movement!

What's the point of a brain?

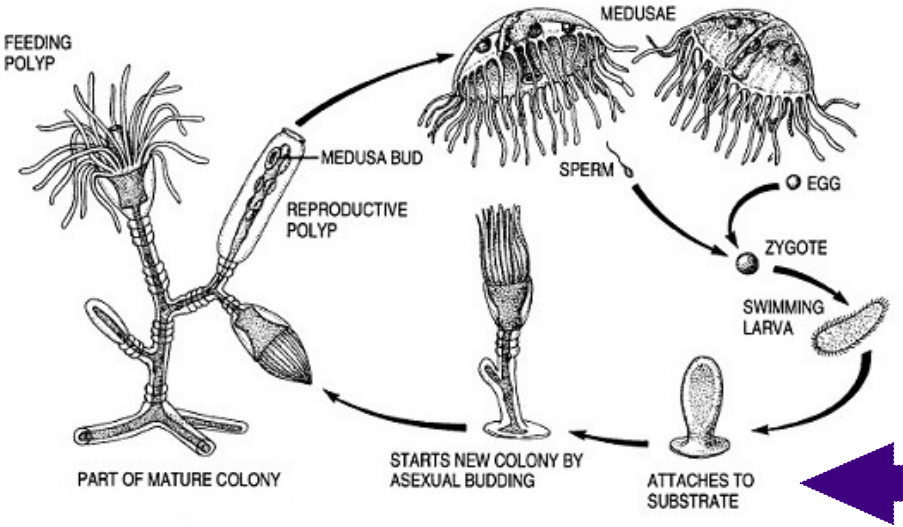
Why did brains evolve?

- One argument for the driver of the evolution of the brain is movement
    - Without movement our ability to sense and respond to our environment is severely impaired
    - The sea squirt



What's the point of a brain?

Why did brains evolve?



AND EATS ITS OWN BRAIN!!

The human brain

~ 1.5 Kg

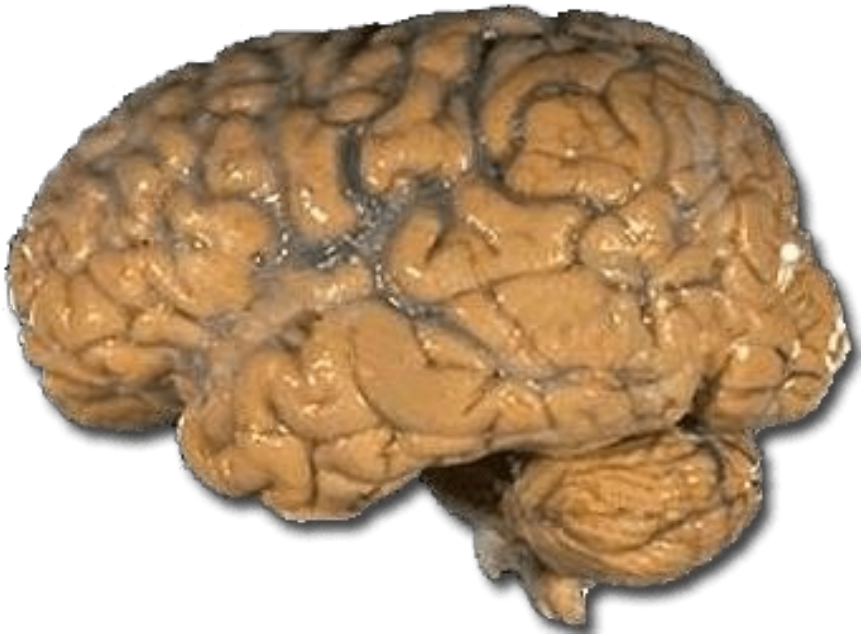
Uses ~20% of total oxygen in our blood

- blood vessels supplying the brain are ~ 100000 miles long

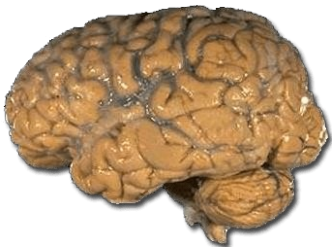
Surrounded by three membranes

- dura mater
- arachnoid
- pia mater

Cerebrospinal fluid bathes the whole brain



The human brain vs. computer



Chips

Neurons

“Clock speed” - the operating speed of a computer or its microprocessor, expressed in cycles per second:

~4 GHz

~1 kHz

Processing rate is limited by energy use for both

The case of Phineus Gage, 1836

Phineus Gage was a railway worker and excited discussion about the mind and brain.

In 1848 he had an accident at work - a large tamping iron was driven completely through his head – he somehow survived, but the rod obliterated most of his left frontal lobe

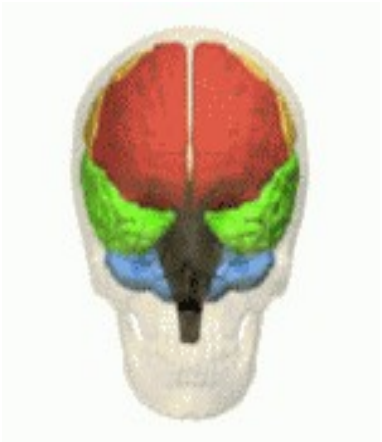
He was able to walk and talk, but his personality was said to have been completely changed: he became surly and aggressive and ‘no longer Gage’

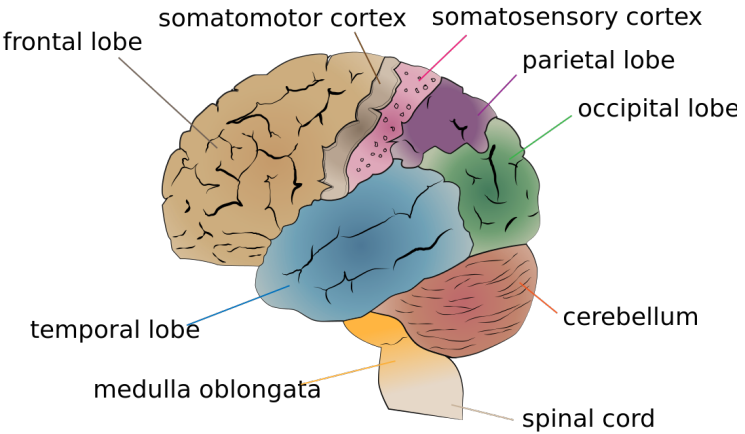
- possibly the first case to show that the brain determined personality

- illustrates that damage to specific parts of the brain caused specific mental changes

… This and world wars!!
… Before this, phrenology.

Brain anatomy – cortical lobes



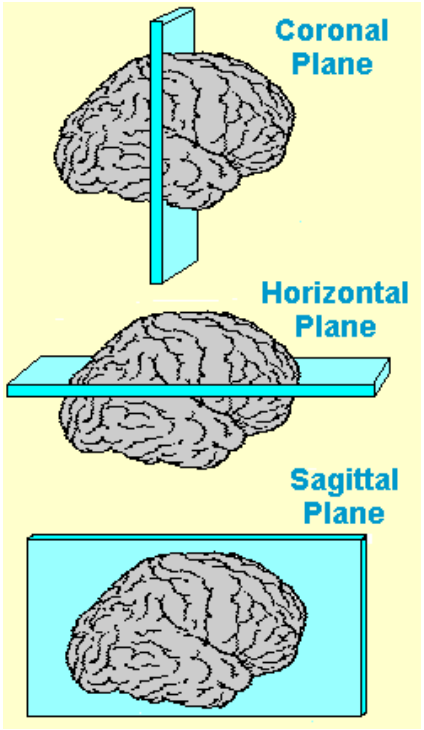


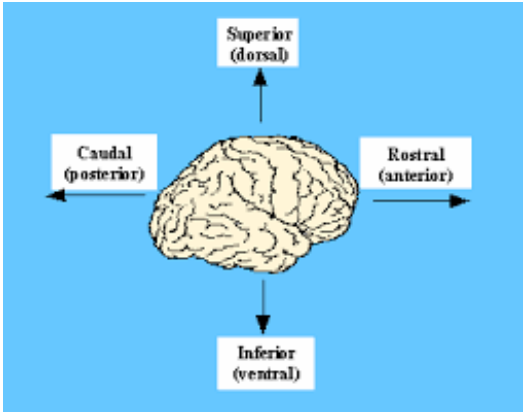
Orange – Frontal Lobe
Yellow – Parietal Lobe
Green – Temporal Lobe
Pink – Occipital Lobe
Blue – cerebellum

https://en.wikipedia.org/wiki/Functional_specialization_(brain)

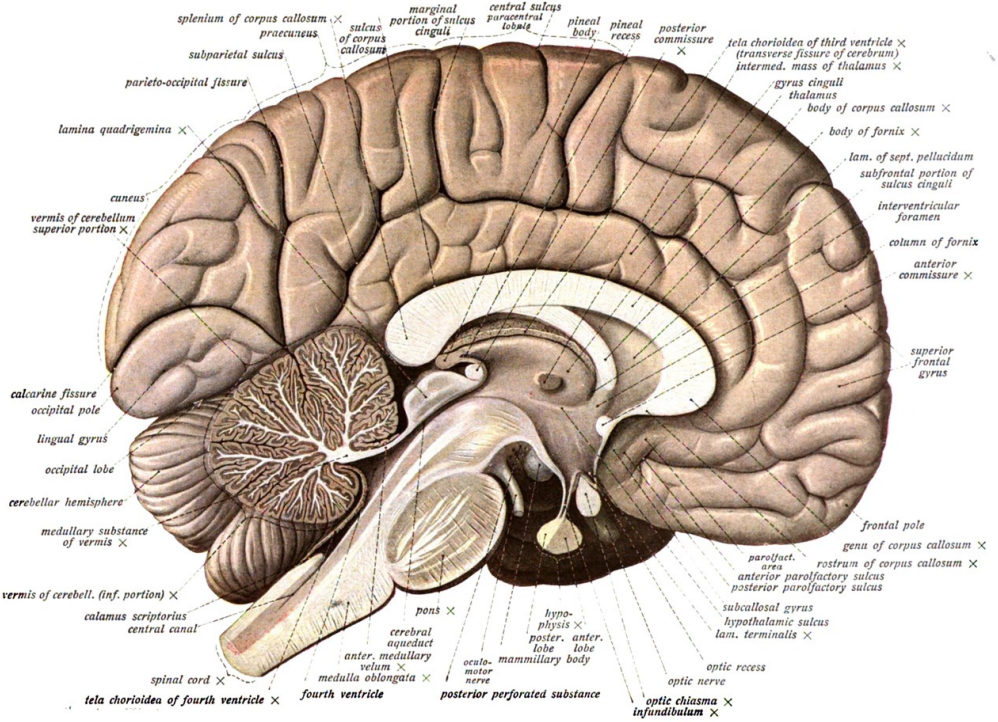
https://en.wikipedia.org/wiki/File:Four_lobes_animation_small2.gif

Brain anatomy – sections



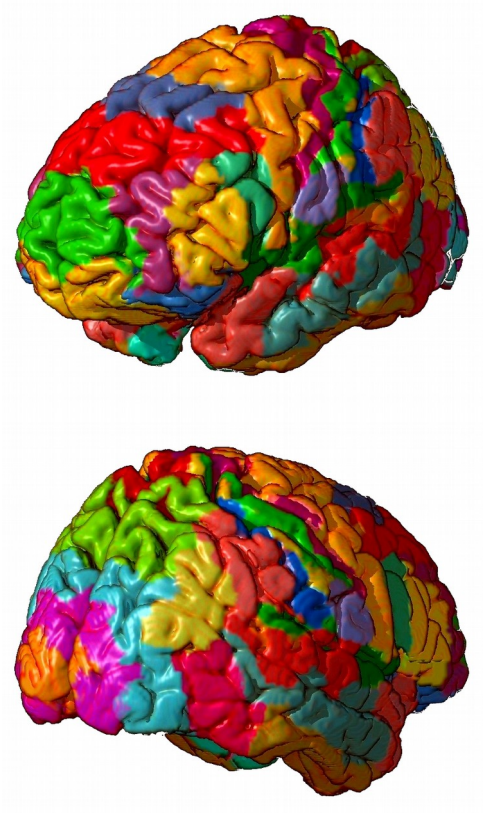


Functional brain anatomy



https://en.wikipedia.org/wiki/Neuroanatomy

Brain anatomy – Brodmann areas



The cerebral cortex can be separated into 52 distinct anatomical regions, called Brodmann areas, based on specific cytoarchitecture (histological structure and cellular organisation).

This distinct anatomical regions often correspond to distinct functional regions

Different areas of the brain specialise in processing different and specific things.

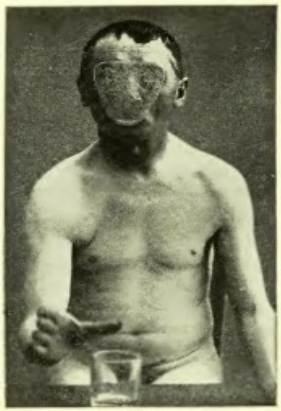
https://en.wikipedia.org/wiki/Brodmann_area

Cerebellar Ataxia

Inability to coordinate balance, gait, extremity and eye movements.

https://en.wikipedia.org/wiki/File:Thomas-fig68,69-p127.png

Cerebellar Dysmetria



62

63

FIGS. 62 and 63. Dysmetria in an individual probably affected with cerebellar atrophy. Exaggeraed opening of the hand to let go of a glass. The phenomenon is more marked on the left where the other symptoms predominate. (André-Thomas and Jumentié, *Revue Neurologique*, November, 1909.)

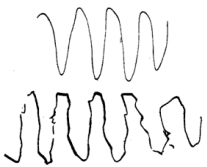
When the movement was executed spontaneously and naturally, it was done in several stages—it was not continuous. There was, so to speak, a certain degree of intention tremor. Also when the finger reached the nose, the hand was unstable and executed alternative movements of supination and pronation before reaching a state of repose; the tremor, therefore, was both kinetic and static. It will be studied further on. If the movement was made slowly and carefully, it was practically executed correctly, continuously, and did not extend further than it should have.

If the movement were rapid, the finger passed over the object and touched the cheek at the side of the nose; this time it was very clearly out of proportion, and there was dysmetria.

Dysmetria existed in all movements; if he tried to take hold of a glass the hand was opened too far (Figs. 62 and 63).

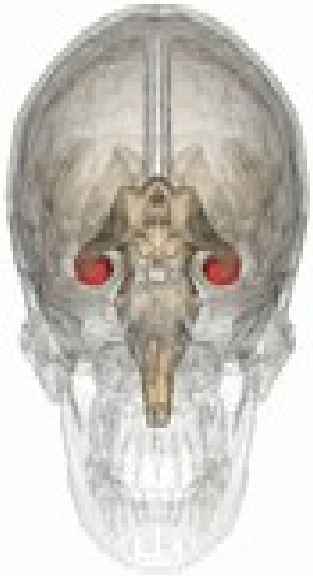
If the patient was lying down on the back, and he was asked to place the heel of one side upon the knee of the other side, the heel was lifted too high and passed by the knee, but was then replaced upon the knee. The patient, if he was standing and asked to raise his foot and then to put it down again, the foot was so replaced that the heel struck the ground, although the patient was held during this test in a manner to avoid any disturbance of equilibrium.

Dysmetria differs from peripheral ataxia by two fundamental characteristics: the complete or almost complete orientation towards the object, and the almost entire absence of the influence of sight upon the regulation of movement.

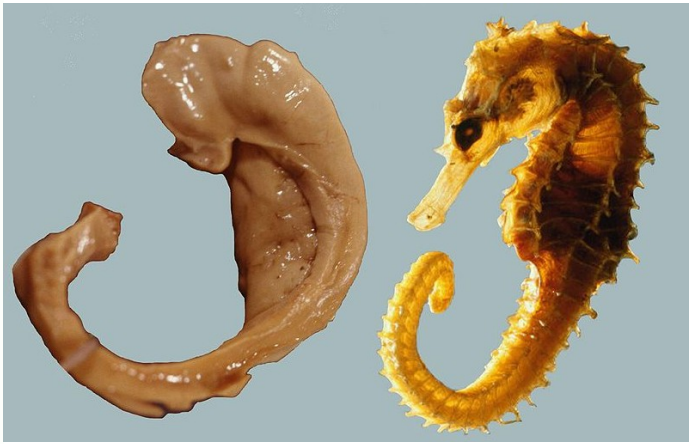


From Thomas: Cerebellar Functions (1912)

Hippocampus



Brain names often refer to structure and not function. Hippocampus = seahorse



https://commons.wikimedia.org/wiki/File:Hippocampus_small.gif
https://en.wikipedia.org/wiki/File:Hippocampus_and_seahorse_cropped.JPG

Hippocampus – Patient H.M.

H.M suffered from severe epilepsy and had a bilateral, temporal, medial lobotomy. It cured his epilepsy but left him with a permanent inability to form any new memories. He could remember some things from childhood but suffered complete anterograde amnesia.

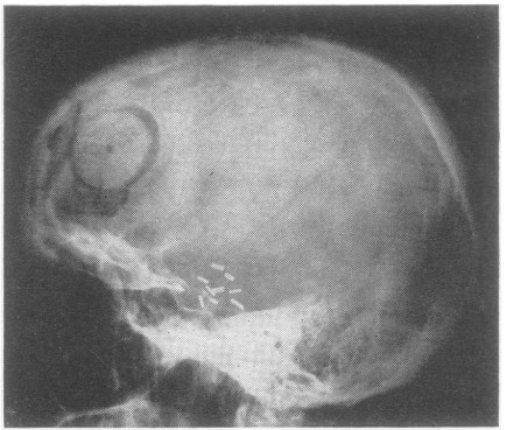


FIG. 3.—Post-operative skull radiograph with silver clip markers outlining extent of bilateral resections limited to the uncus and amygdala.

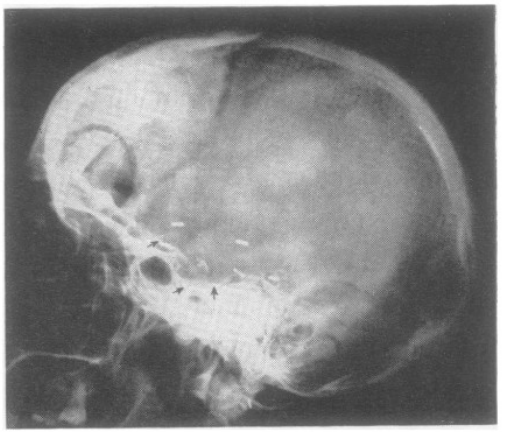


FIG. 4.—Post-operative skull radiograph with silver clip markers outlining the extent of the bilateral resections including the anterior hippocampal complex (approximately 6 cm. posterior to the tip of the anterior temporal fossa).

Scoville, W. B., & Milner, B. (1957).
Loss of recent memory after bilateral hippocampal lesions.
Journal of neurology, neurosurgery, and psychiatry, 20(1), 11.

Patient Clive Wearing

Clive contracted herpesviral encephalitis that damaged his hippocampus. This resulted in severe anterograde as well as retrograde amnesia. Referred to as ‘30 second Clive’ as he could not remember past memories, or form new memories.

> “In a diary provided by his caretakers, Wearing was encouraged to record his thoughts. Page after page is filled with entries similar to the following:
>
> ~~8:31 AM: Now I am really, completely awake.~~
>
> ~~9:06 AM: Now I am perfectly, overwhelmingly awake.~~
>
> 9:34 AM: Now I am superlatively, actually awake.
>
> Earlier entries are usually crossed out, since he forgets having made an entry within minutes and dismisses the writings: he does not know how the entries were made or by whom, although he does recognise his own writing. Wishing to record "waking up for the first time", he still wrote diary entries in 2007, more than two decades after he started them. “

https://en.wikipedia.org/wiki/Clive_Wearing

London cab drivers

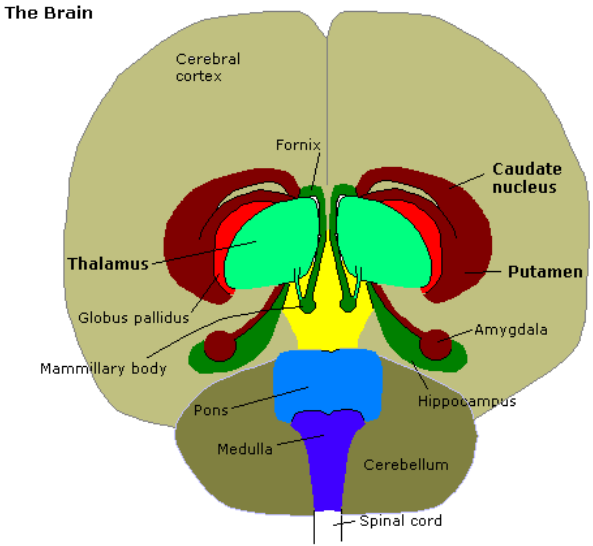
The hippocampus and spatial navigation

Cab drivers' given brain scans have a hippocampal grey matter volume that is significantly greater than in the average person. This helps them store a detailed mental map of the city.

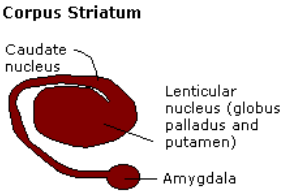
More time on the job = bigger hippocampus

Maguire et al., 2006

Amygdala



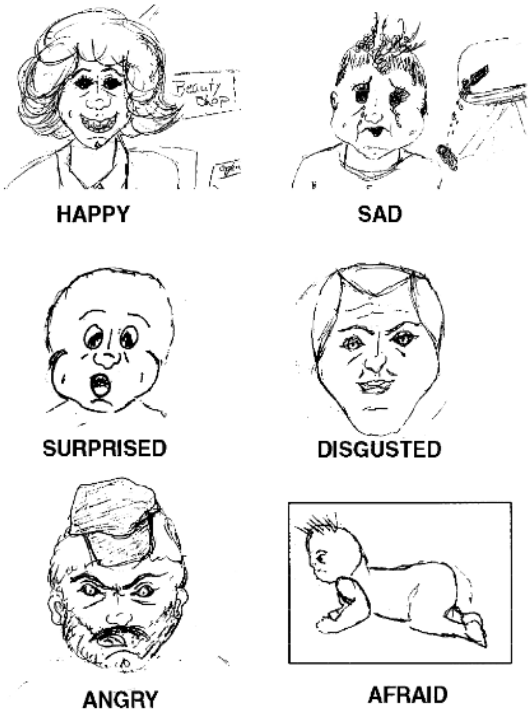
The brain as viewed from the underside and front. The thalamus and Corpus Striatum (Putamen, caudate and amygdala) have been splayed out to show detail.



Amygdala is a set of neurons deep in the medial temporal lobe.

It is involved in the processing of, amongst other things, emotional responses (like fear, anxiety and aggression) and decision-making.

Amygdala – Patient S.M.



Patient S.M suffered from Urbach-Wiethe disease in her early adulthood.

This caused severe bilateral damage to the amygdala.

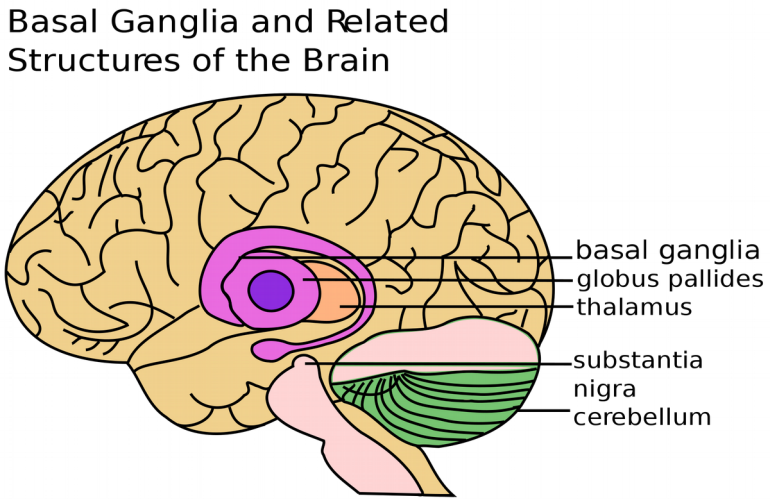
Since then she has lost the ability to experience fear.

This has caused her to have numerous near death encounters, but remain psychologically unscathed.

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. R. (1995).
Fear and the human amygdala.
The Journal of neuroscience, 15(9), 5879-5891.

Basal Ganglia

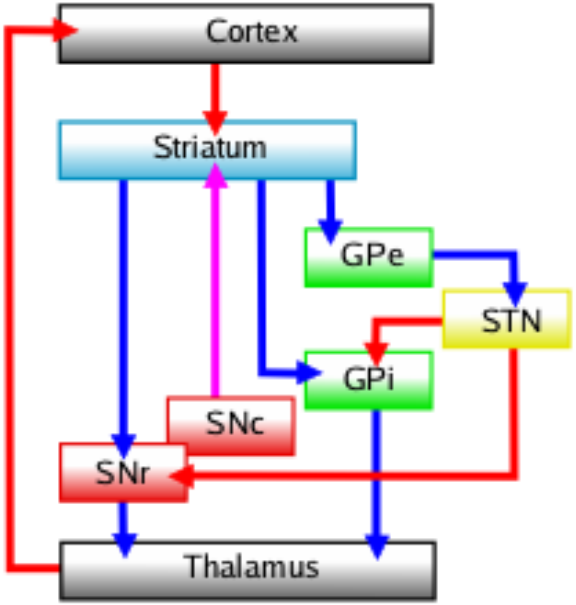
The basal ganglia is a group of highly connected nuclei and is associated with things such as the control of voluntary movements, emotional processing, decision-making and habit learning.



https://en.wikipedia.org/wiki/File:Basal_Ganglia_and_Related_Structures.svg

Basal Ganglia

The basal ganglia is used for action selection: when deciding between cortical areas that are competing for motor control: should I reach for tea or biscuits?



https://en.wikipedia.org/wiki/File:Basal-ganglia-classic.png

Basal Ganglia – Parkinson's

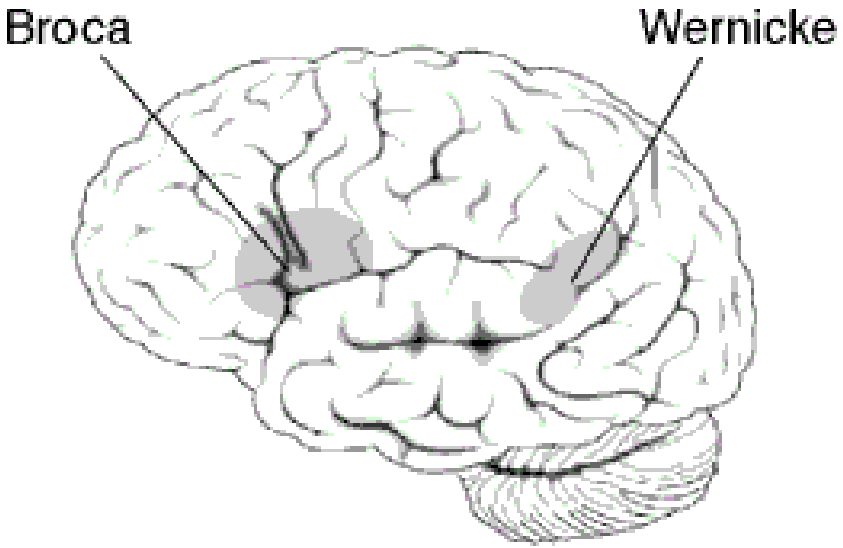
Parkinson's occurs after the destruction of cells within the substantia nigra. Patients struggle to initiate and stop movements, suffer tremor, sleep problems, slowed thinking, depression

https://www.youtube.com/watch?v=aaY3gz5tJSk

http://en.wikipedia.org/wiki/Parkinson's_disease

Speech and language – Broca's and Wernicke's area

Language is a uniquely human ability. How the brain processes language is still up for debate.



https://en.wikipedia.org/wiki/File:BrocasAreaSmall.png

Broca’s aphasia – Tan / Hodor

Patient ‘Tan’ was perfectly capable of understanding speech but was only able to utter a single syllable – ‘Tan’. This was often repeated twice - ‘Tan Tan’. He said this syllable with intonation, expression and accompanied by gestures and wished to communicate.

Broca’s aphasia – loss of articulated speech (speech production)

A biopsy of patient Tan’s brain revealed a large lesion in the frontal area—specifically, in the posterior inferior frontal gyrus, a section that corresponds roughly to Brodmann’s areas 44 and 45.

Wernicke's area

Brodmann area 22. Damage to this area results in the lack of meaningful speech and language comprehension.

Finally, although the phonemic and lexical aspects of the coherent speech of these patients are grossly disturbed, characteristically the *intonational and melodic aspect of their speech as a rule remains intact*, and by its aid the listener can understand the meaning of the patient's apparently incoherent speech. Who, listening to a flow of words such as 'well now. . . I mean . . . so . . .we . . . now . . . went. . .went . . . suddenly . . . now this . . . like this . . . bang! . . . and then – nothing . . . nothing . . . and since . . . little by little . . . better still . . . quite . . . and now . . . do you see?' – completely devoid of substantives, could guess that a person wounded in the temporal region was describing how they were going, how the exploding shell stunned him, how he lost consciousness, and how his consciousness gradually returned, although his speech still remained difficult?

A.R. Luria (1973) The working brain, an introduction to neuropsychology. p140

Thalamus

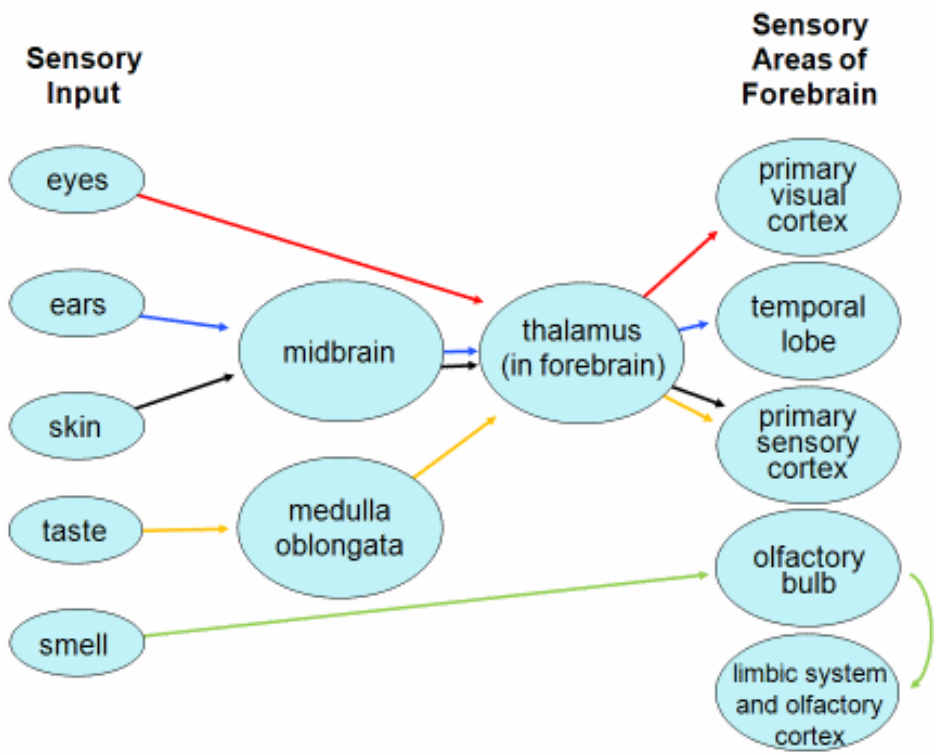
The thalamus is kind of like a central hub. It is a dense mass of cells that relay information to all areas of the cerebral cortex and cerebellum.

It helps regulate consciousness, sleep and alertness.

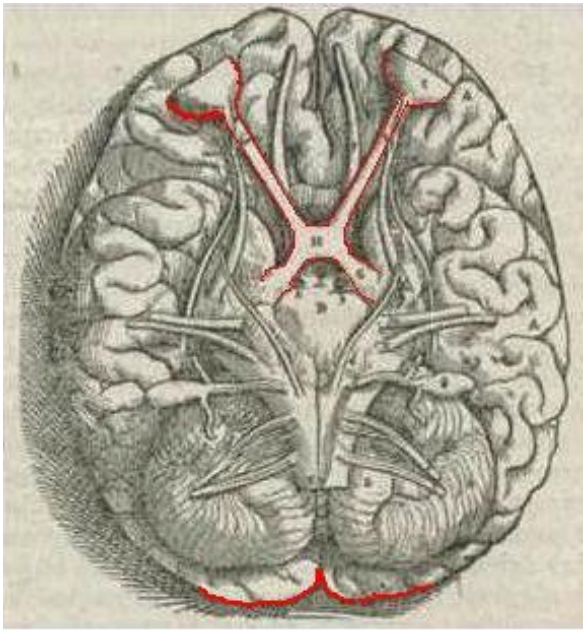
Routes sensory information.

https://en.wikipedia.org/wiki/File:Brain_chrischan_thalamus.jpg

Thalamus – Routes information



Andreas Vesalius' sketch of the visual pathway from 1543.

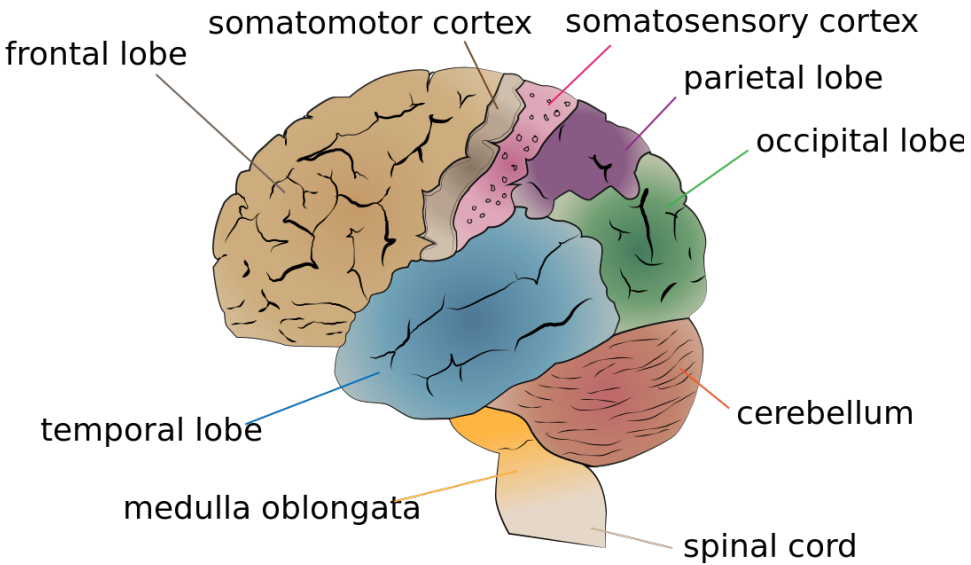


Visual cortex has six layers and processing visual information hierarchically.

V1 – edge-detection
V2 – visual attention
V3 – object motion (speed and direction)
V4 – shape recognition
V5 – complex integration of motion
V6 - object motion relative to background. Topographical map for vision. Connects to arm-moving cortices.

https://en.wikipedia.org/wiki/File:1543,Vesalius%27Fabrica,VisualSystem,V1.jpg

Somatomotor and somatosensory cortices



https://en.wikipedia.org/wiki/File:Cerebrum_lobes.svg

The motor homunculus

There is a map of brain areas dedicated to processing motor information for different parts of the body.

Movement, or thoughts about movement, of particular parts of the body are topographically represented in the brain.

http://commons.wikimedia.org/wiki/File:Homunculus.PNG

The sensory homunculus

http://commons.wikimedia.org/wiki/File:Homunculus.jpg

Conclusions

- The brain is not a homogenous structure
- Groups of specialised neurons are organised in a very precise manner
- Specific neurons work together to perform specific tasks
- There are short range connections within these groups and long range connections between groups