

COMS30017

Computational Neuroscience

Brain anatomy



Intended learning outcomes

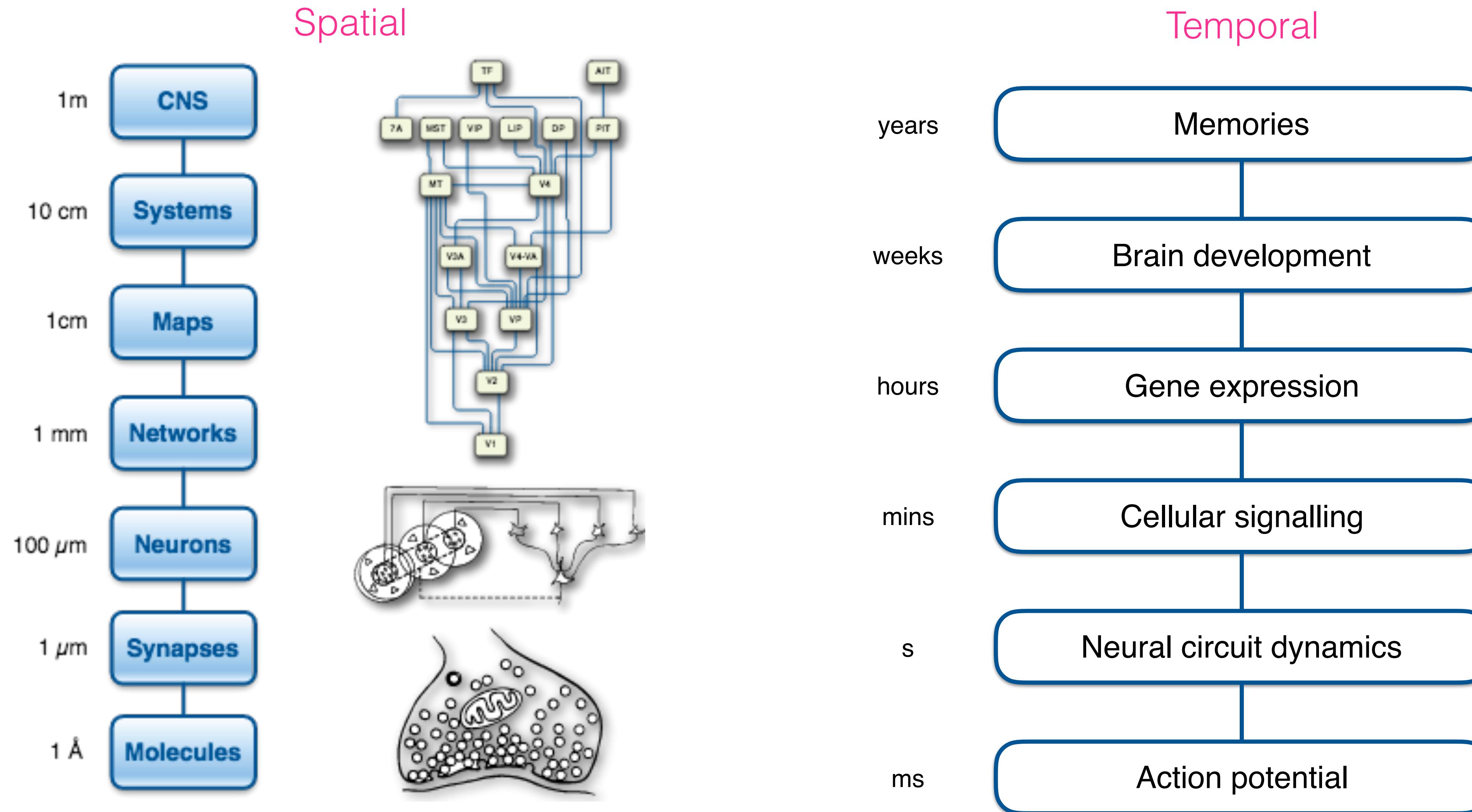
- To gain an understanding of the large-scale anatomy of the human brain.
- To relate some key brain parts to their primary function.
- To appreciate the effects of damage to example brain regions.

The human brain

- ~1.5 Kg (~2% of total body weight).
- Uses ~20% of total body's energy.
The bulk of that energy is used for neural communication.



Spatial and temporal scales in the brain



Some key brain regions and their functions

- Hippocampus: long-term memory, and spatial navigation.
- Cerebellum: skilled motor control.
- Basal ganglia: decision making, action selection, reward-based learning.
- Amygdala: emotional and fear memories.
- Neocortex: sensory processing, motor control, language, speech, working memory.
- *Note that these are just five of ~100 distinct brain regions in the human brain.*

Hippocampus

- Seahorse-shaped structure in the middle of the brain.
- Two key functions:
 - Long-term memory formation.
 - Spatial navigation.
- People with hippocampal damage unable to form new memories, and have limited retrograde amnesia (forget the recent past).



[https://commons.wikimedia.org/
wiki/File:Hippocampus_small.gif](https://commons.wikimedia.org/wiki/File:Hippocampus_small.gif)



Hippocampus: Patient H.M.

- Henry Molaison had both hippocampi and surrounding tissue removed in surgery in 1953 in a (successful) attempt to control his epilepsy.
- However after the surgery he had short-term retrograde amnesia (could not remember the past few months), and also could not form new long-term memories.
- He was studied by neuroscientists (most notably Brenda Milner) for 40 years before he died in 2008.

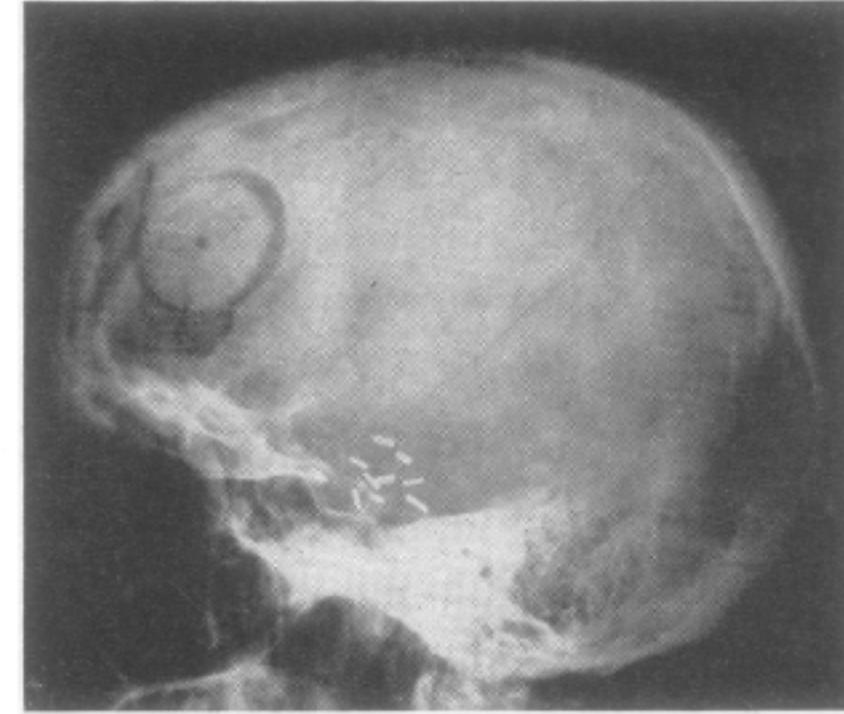


FIG. 3.—Post-operative skull radiograph with silver clip markers outlining extent of bilateral resections limited to the uncus and amygdala.

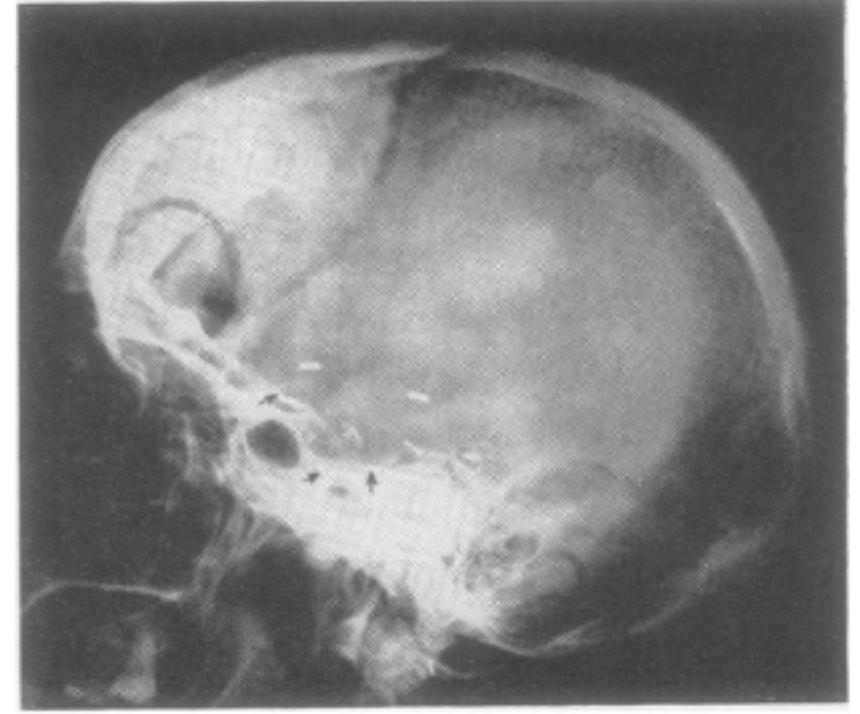


FIG. 4.—Post-operative skull radiograph with silver clip markers outlining the extent of the bilateral resections including the anterior hippocampal complex (approximately 6 cm. posterior to the tip of the anterior temporal fossa).

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

Other hippocampal patients



A screenshot of a YouTube video player. The video shows a man with short-term memory loss, Clive Wearing, from a BBC documentary. He is seated at a grand piano, looking intently at an open book of sheet music. The BBC Four logo is visible in the top left corner of the video frame. The YouTube interface includes a search bar at the top, a play button, a progress bar showing 0:17 / 3:04, and standard video controls at the bottom.

Clive Wearing - The man with no short-term memory

1,277,310 views • Oct 2, 2007

3.9K 65 SHARE SAVE ...

Clive Wearing

3 min clip from BBC documentary:
<https://www.youtube.com/watch?v=Vwigmktx2Y>



"Memento" (2000) directed by Christopher Nolan

Cerebellum

- Smallish and somewhat separate structure at the lower-back of brain.
Name literally means “little brain”.
- Contains most of the brain’s neurons (large number of tiny granule cells).
- Plays a key role in skilled motor control (but probably also cognitive functions).



[https://en.wikipedia.org/wiki/
Cerebellum#/media/
File:Cerebellum_animation_small.gif](https://en.wikipedia.org/wiki/Cerebellum#/media/File:Cerebellum_animation_small.gif)

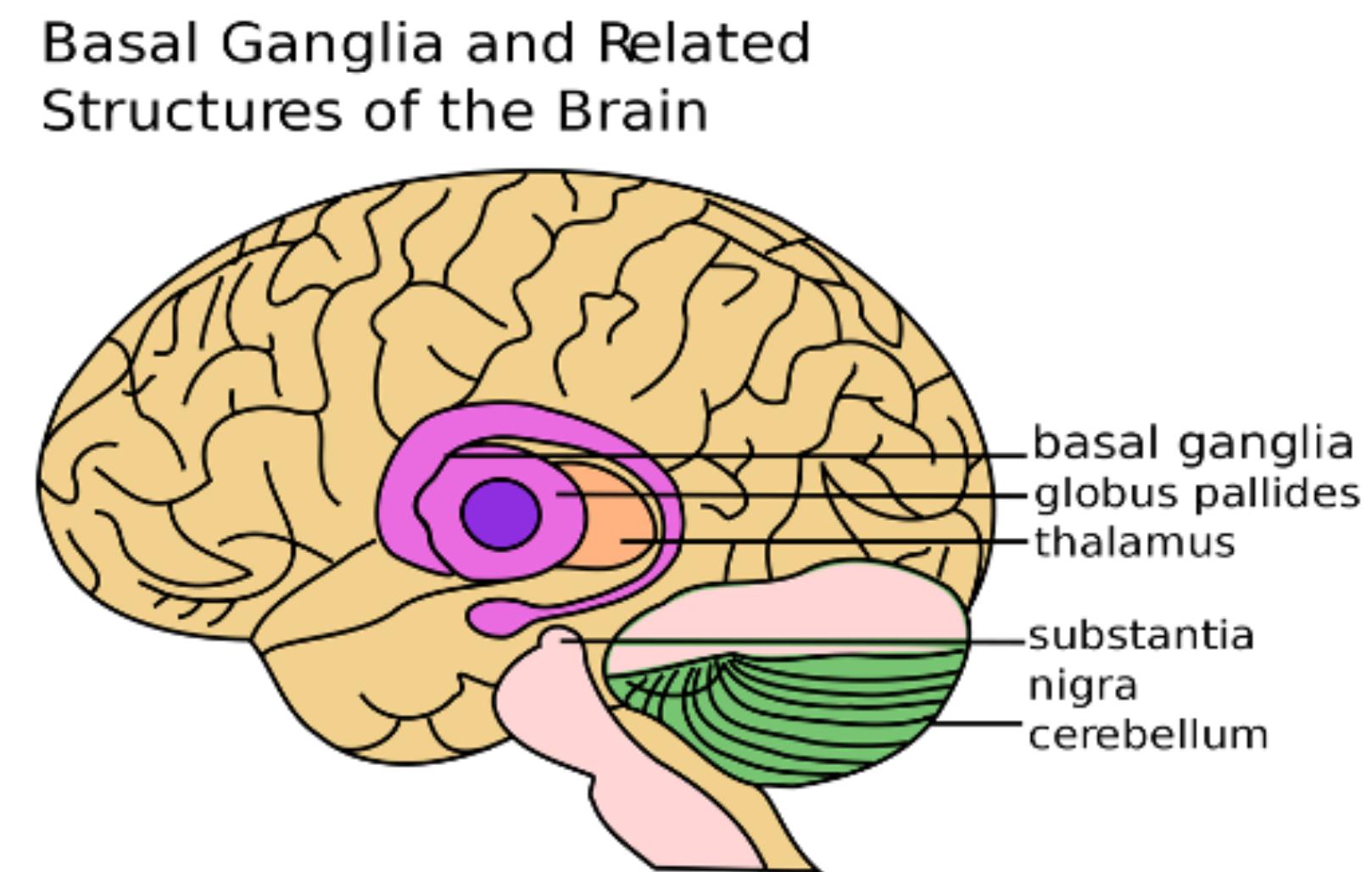
Cerebellar ataxia

- Damage to the cerebellum can cause deficits in motor control: clumsy or uncoordinated movements.

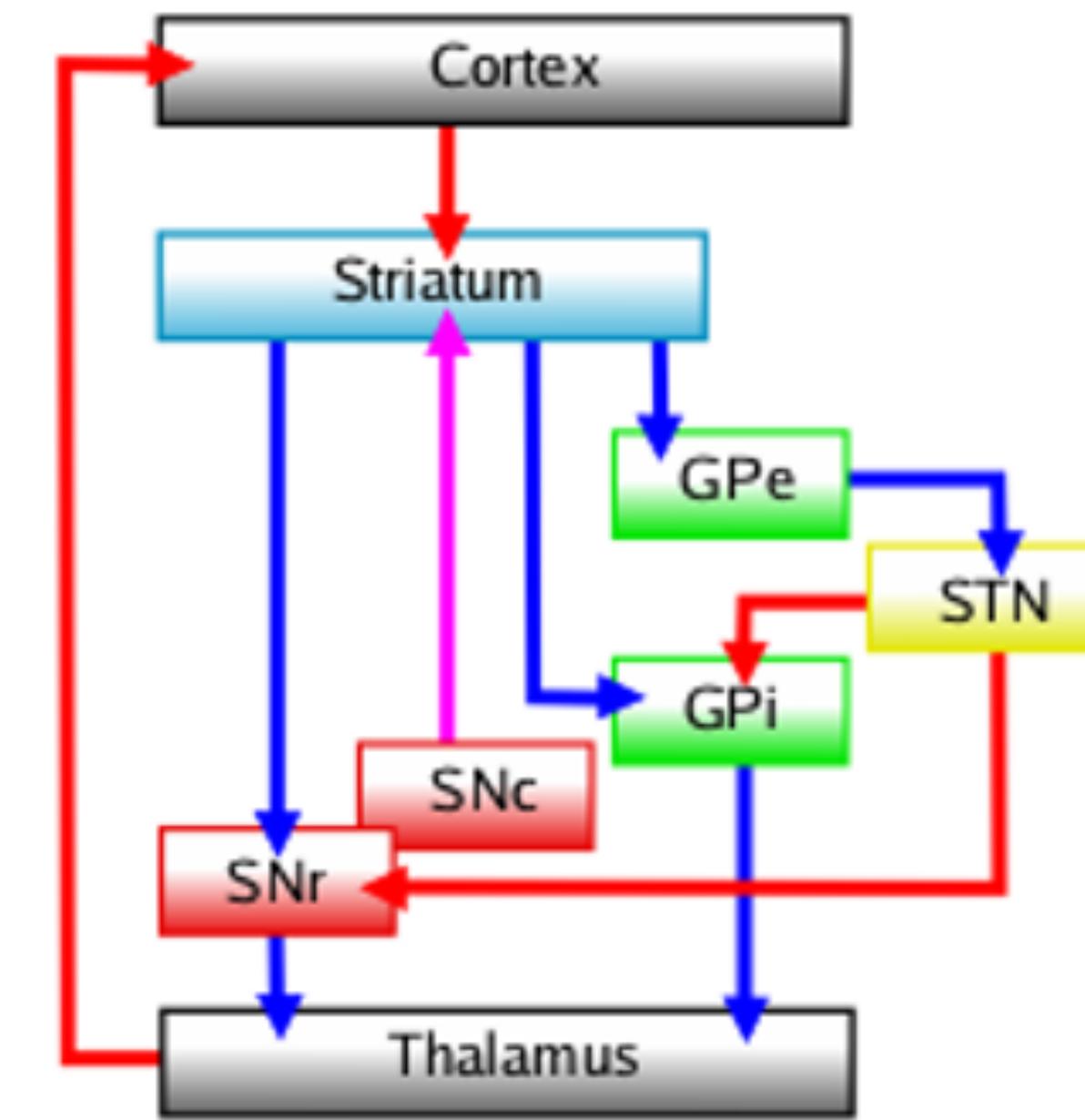


Basal ganglia

- The basal ganglia are a collection of nuclei deep in the brain.
- They play key roles in decision making and motor control.
- They also play a role in reward-based learning via their production of the neuromodulator dopamine.



[https://en.wikipedia.org/wiki/
File:Basal_Ganglia_and_Related_Structures.svg](https://en.wikipedia.org/wiki/File:Basal_Ganglia_and_Related_Structures.svg)



[https://en.wikipedia.org/wiki/File:Basal-
ganglia-classic.png](https://en.wikipedia.org/wiki/File:Basal-ganglia-classic.png)

Parkinson's

- Parkinson's disease is a neurodegenerative disorder caused by cell death in the basal ganglia.
- Main symptoms involve altered motor function: tremor, slowness, poor motor control.
Video here: <https://www.youtube.com/watch?v=pFLC9C-xH8E>
- Can also show more cognitive deficits in decision making and dementia, and sleep problems.

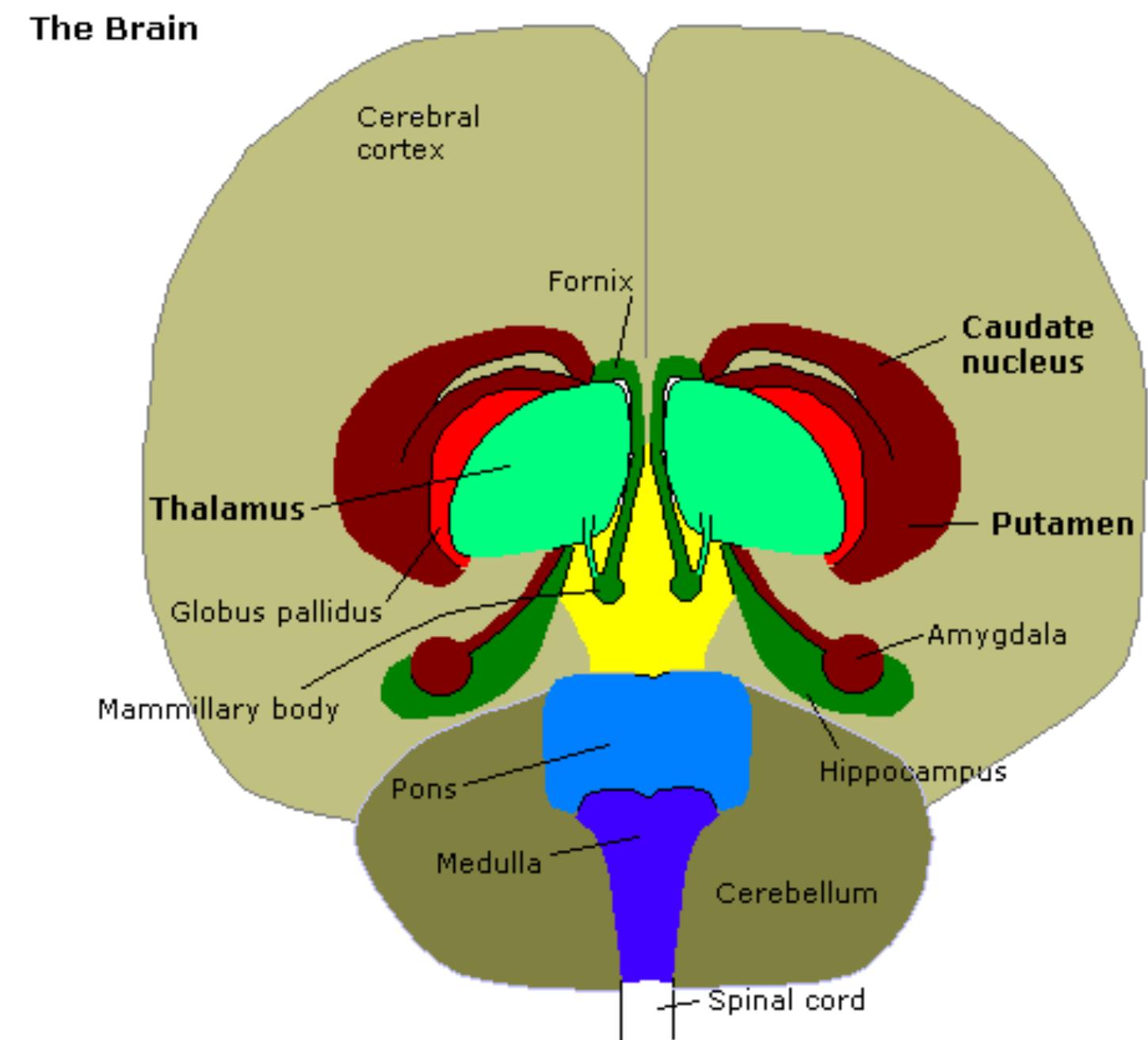


Parkinsonian gait

[https://en.wikipedia.org/wiki/Parkinson%27s_disease#/media/File:Paralysis_agitans_\(1907,_after_St._Leger\).png](https://en.wikipedia.org/wiki/Parkinson%27s_disease#/media/File:Paralysis_agitans_(1907,_after_St._Leger).png)

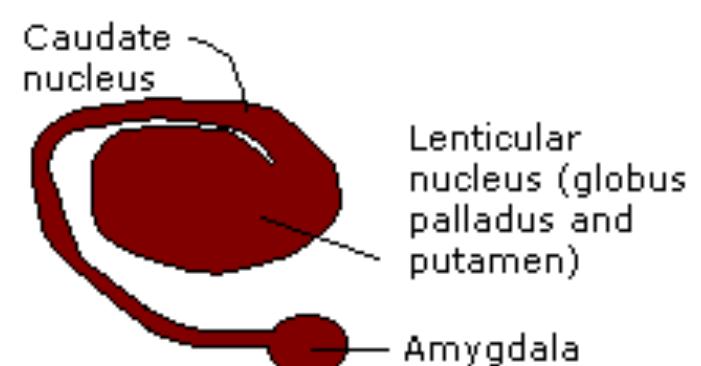
Amygdala

- Small almond-shaped cluster of nuclei deep in the brain.
- Plays a key role in emotional responses and memories.



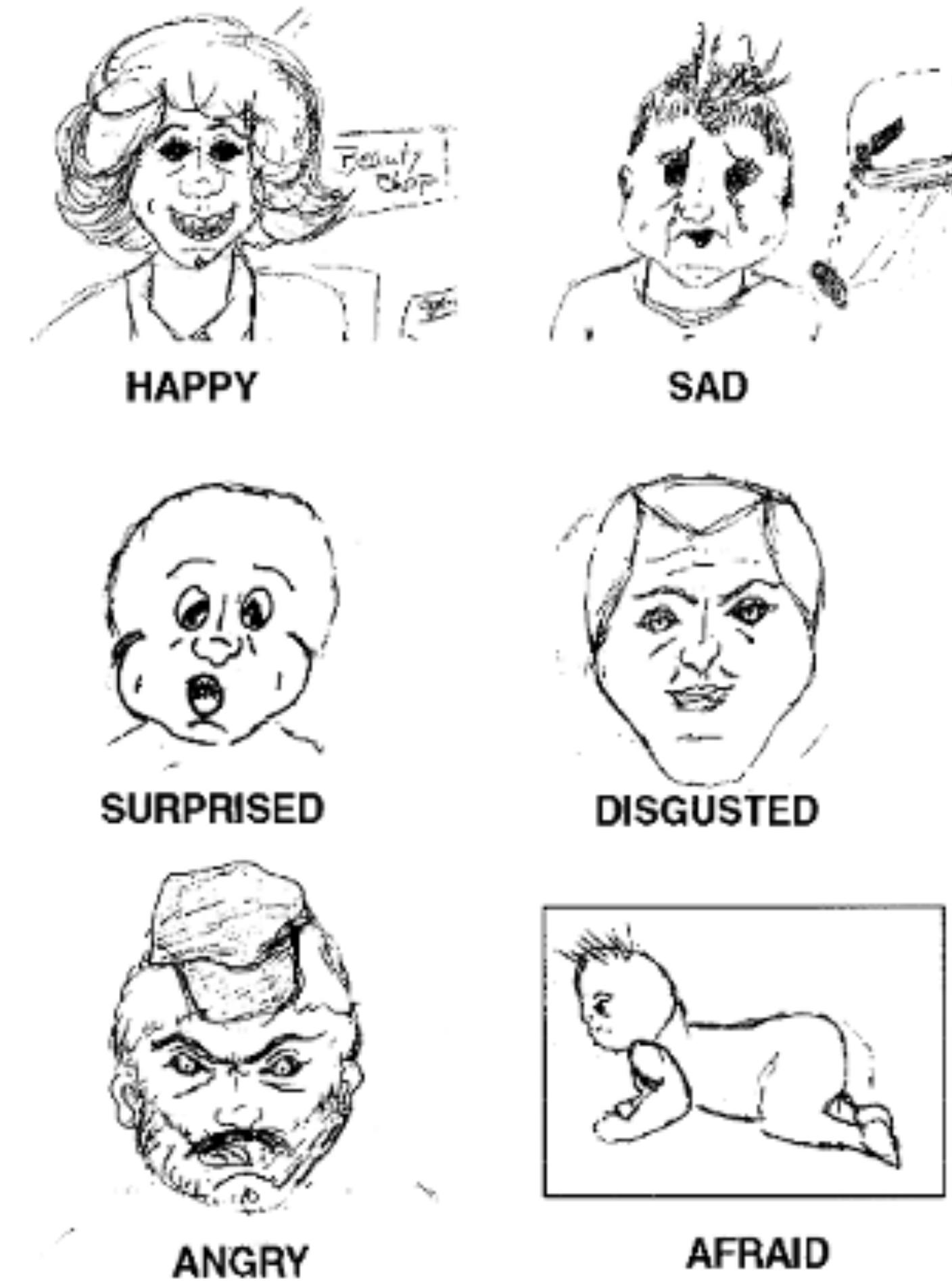
The brain as viewed from the underside and front. The thalamus and Corpus Striatum (Putamen, caudate and amygdala) have been splayed out to show detail.

Corpus Striatum



Amygdalae damage

- Patient S.M. is a woman with bilateral damage to her amygdala (due to a rare genetic condition).
- She is unable to experience fear.



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

Neocortex

- The neocortex (or just cortex) is the most familiar part of the brain - the folded sheet on top.
- It is only folded in large mammals. In smaller mammals like rodents it is smooth.
- Adult human neocortex is around $\sim 0.25\text{m}^2$ when folded flat.
- It has a six-layer structure and looks mostly similar across its extent.
- Plays key function in sensory processing, motor control, and higher-order cognitive functions like language, speech, planning.

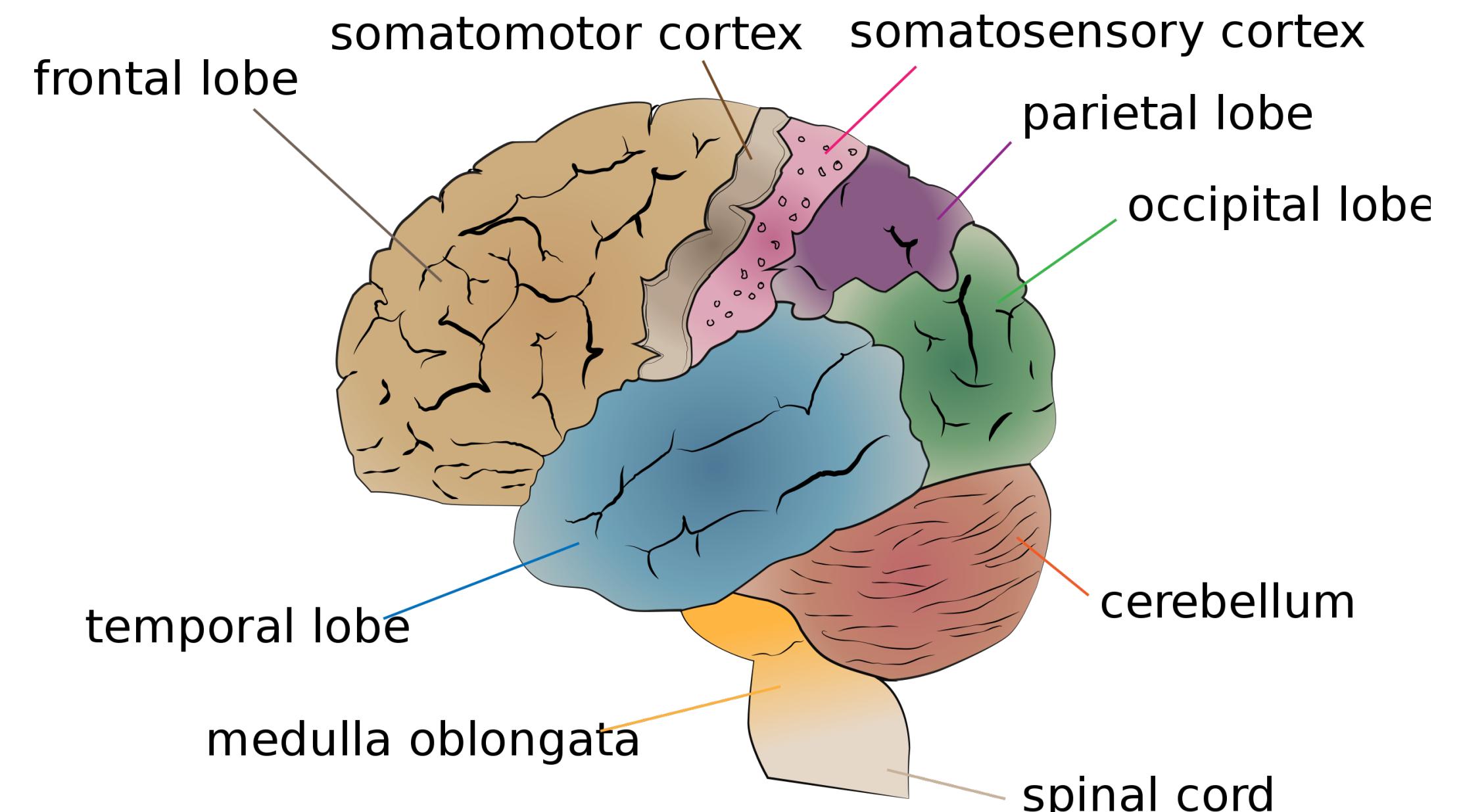


Cortical lobes



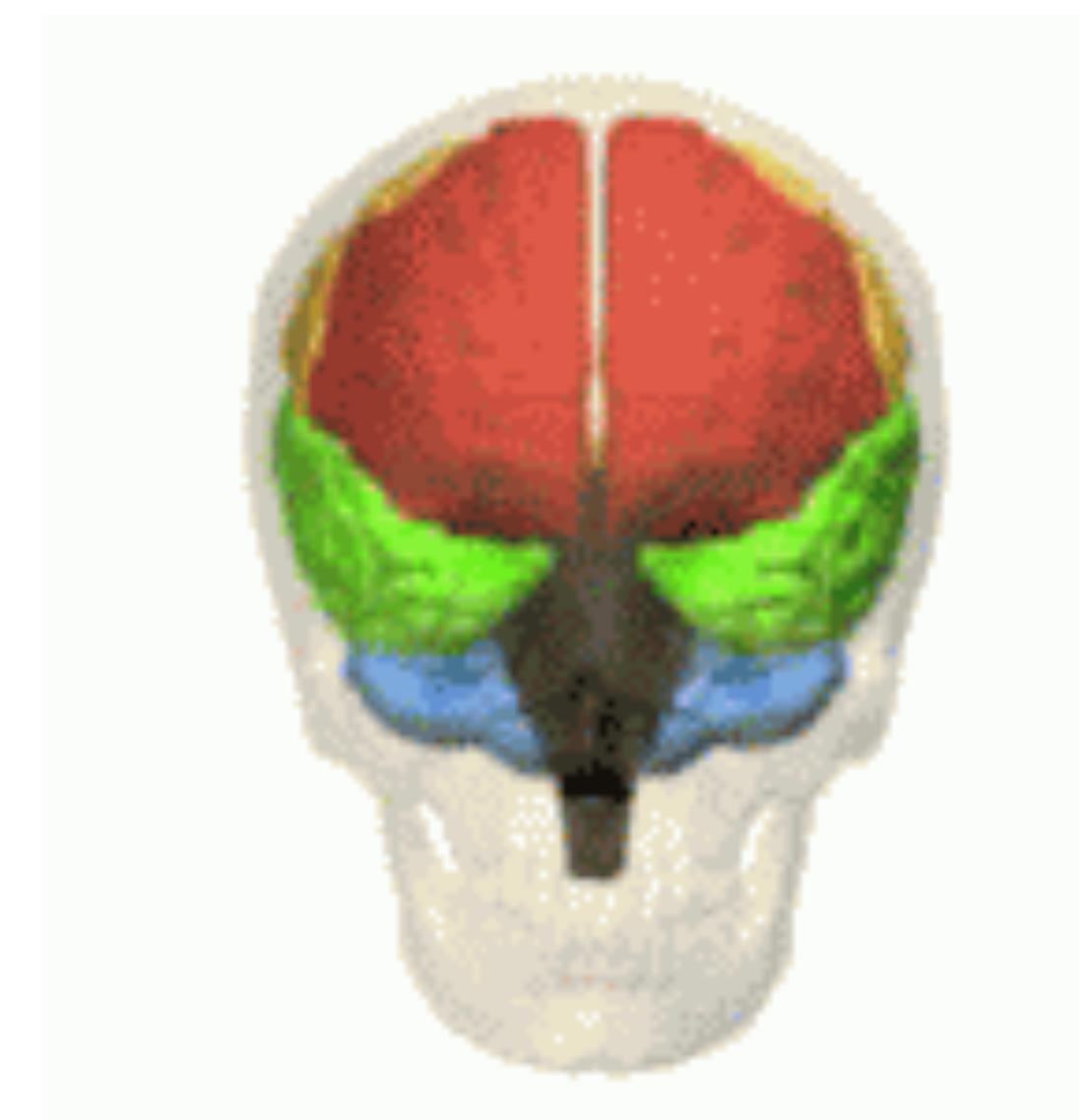
- Red: frontal lobe
- Orange: parietal lobe
- Green: temporal lobe
- Yellow: occipital lobe
- Blue: cerebellum

[https://en.wikipedia.org/wiki/
File:Four_lobes_animation_small2.gif](https://en.wikipedia.org/wiki/File:Four_lobes_animation_small2.gif)



[https://en.wikipedia.org/wiki/
Functional_specialization_\(brain\)#/
media/File:Cerebrum_lobes.svg](https://en.wikipedia.org/wiki/Functional_specialization_(brain)#/media/File:Cerebrum_lobes.svg)

Cortical lobes



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File:Four_lobes_animation_small2.gif](https://en.wikipedia.org/wiki/File:Four_lobes_animation_small2.gif)

Armaan Fallahi
@circuitfreud

Hi @elonmusk, just thought you should know that on the @neuralink website the somatosensory cortex and motor cortices are swapped. Small oopsie!

neuralink.com/applications/

#Neuralink #NeuroTwitterNetwork

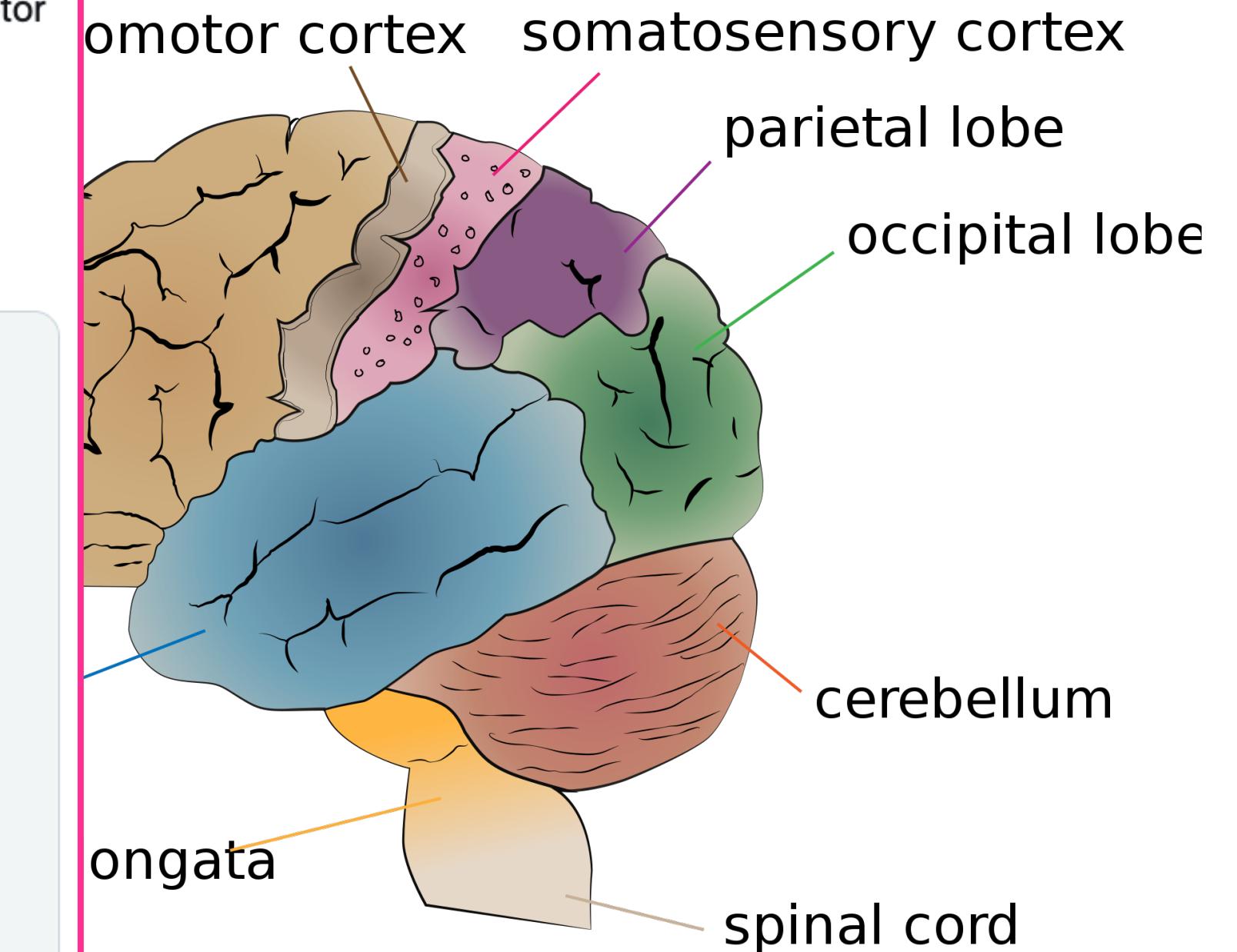
SOMATOSENSORY CORTEX
Helps process sense of touch.

MOTOR CORTEX
Responsible for planning and executing motor movements.

FIG. 2

8:03 PM · Sep 3, 2020 · Twitter Web App

6 Retweets 1 Quote Tweet 22 Likes



[https://en.wikipedia.org/wiki/
Cerebral_spatial_organization_\(brain\)#/
File:Cerebrum_lobes.svg](https://en.wikipedia.org/wiki/Cerebral_spatial_organization_(brain)#/File:Cerebrum_lobes.svg)

Motor homunculus

- Different parts of the body are represented by different parts of the motor cortex in a fairly topographic layout.
- The relative amount of cortical area for each body part is disproportionate to the sizes of the corresponding body parts.



Sensory homunculus

- There is also a topographic layout of somatosensory cortex (dealing with touch).



Test yourself questions

- What brain region did patient H.M. have removed that caused him to be unable to create new memories?
- Neurons from which brain region die in Parkinson's disease?

Summary

- The brain is not a homogenous structure.
- Specific, semi-specialised neural circuits perform specific tasks.
(we will revisit most of these brain regions during the unit)
- However there are lots long-range connections between regions. The brain is really just one big recurrent circuit with some weak modularity.