PSY 511 (https://psu-psychology.github.io/psy-511-scan-fdns-2021)

CODE

Neuroanatomy

Rick Gilmore

2021-09-24 08:53:02

- Fun
- Resources
  - Harvard Brain Atlas
  - Brain anatomy through dance
- Directional terms
  - Bipeds vs. quadripeds
  - Image axes
- Supporting structures
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  - Ventricular system
  - Blood Supply
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- Organization of the Nervous System
- Organization of the CNS
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    - Cerebellum
    - Pons
  - Midbrain
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    - Tegmentum
  - Forebrain
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      - Hypothalamus
    - Telencephalon
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        - Temporal lobe
        - Parietal lobe

        - Occipital lobe
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        - Brainstem projections
        - Projection fiber tracts
        - Cortical white matter tracts
        - Commissural fibers
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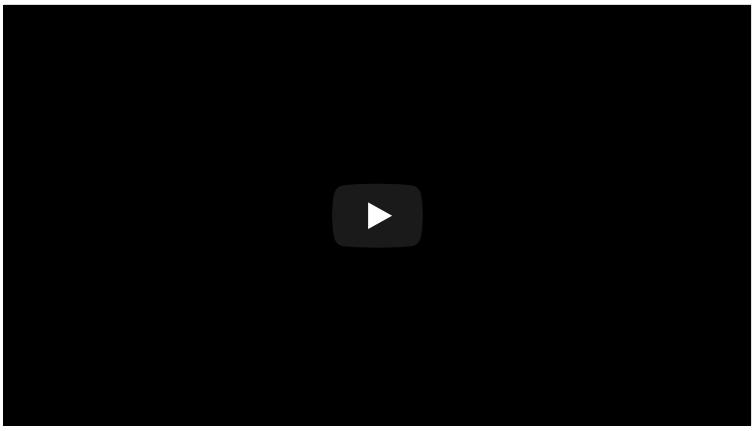
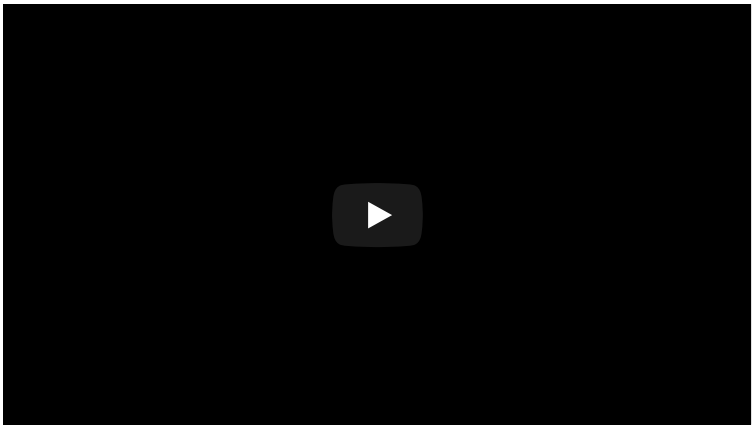
- Organization of the PNS
    - Somatic division
        - Cranial nerves
        - Spinal nerves
    - Autonomic nervous system
        - Sympathetic division
        - Parasympathetic division
        - Measures of ANS function
    - References

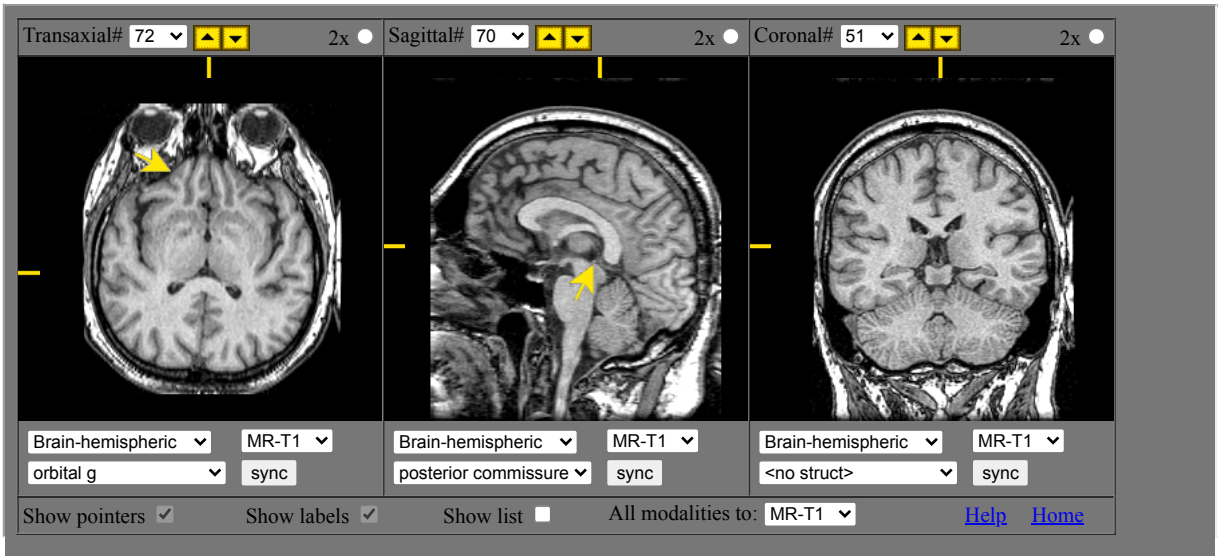
Fun





Resources

Harvard Brain Atlas



http://www.med.harvard.edu/aanlib/cases/caseNA/pb9.htm
(http://www.med.harvard.edu/aanlib/cases/caseNA/pb9.htm)

Brain anatomy through dance

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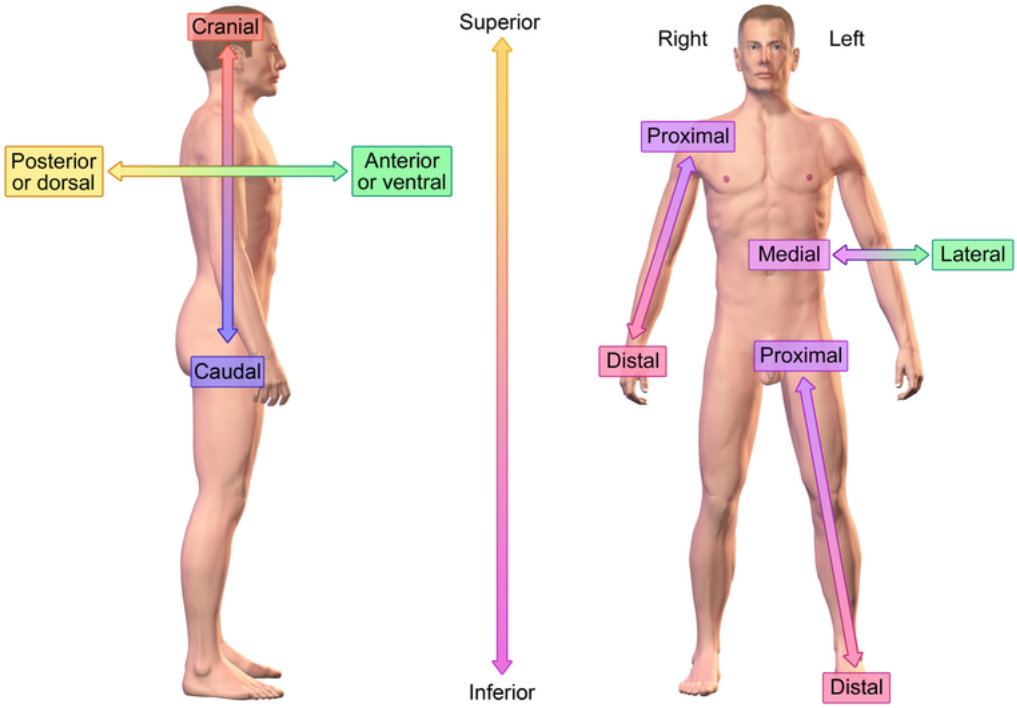
Directional terms

- Anterior/Posterior
- Medial/Lateral
- Superior/Inferior
- Dorsal/Ventral
- Rostral/Caudal



Lateral view

Anterior view

Directional References

Bipeds vs. quadripeds

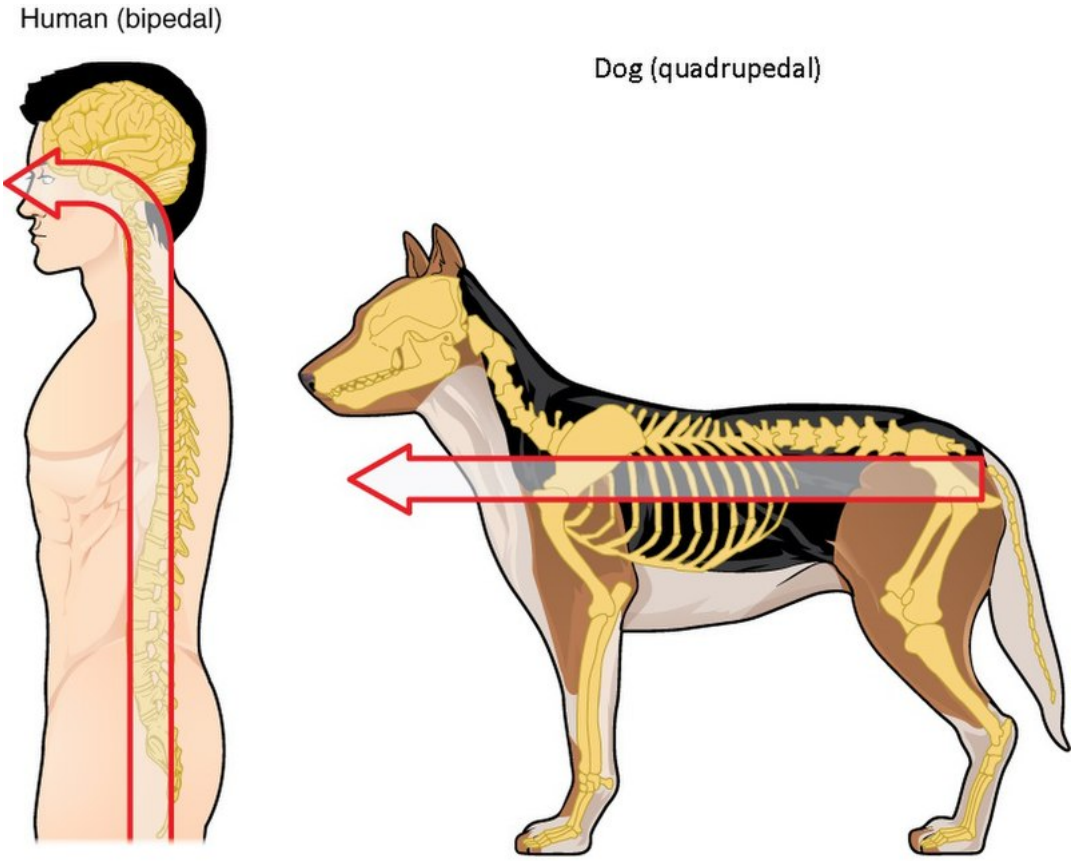


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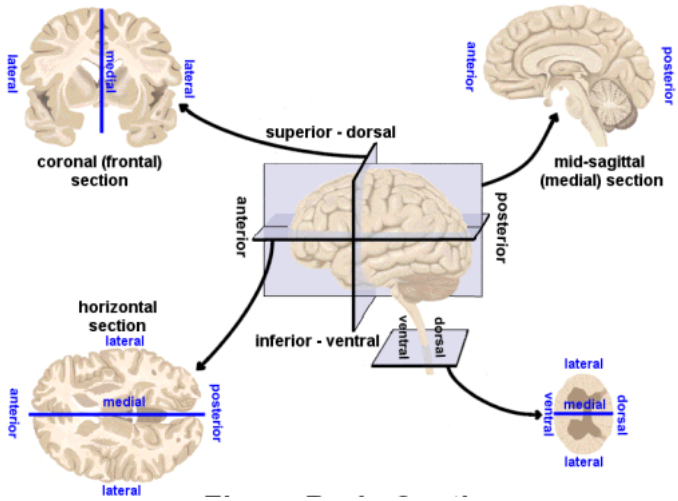
Image axes

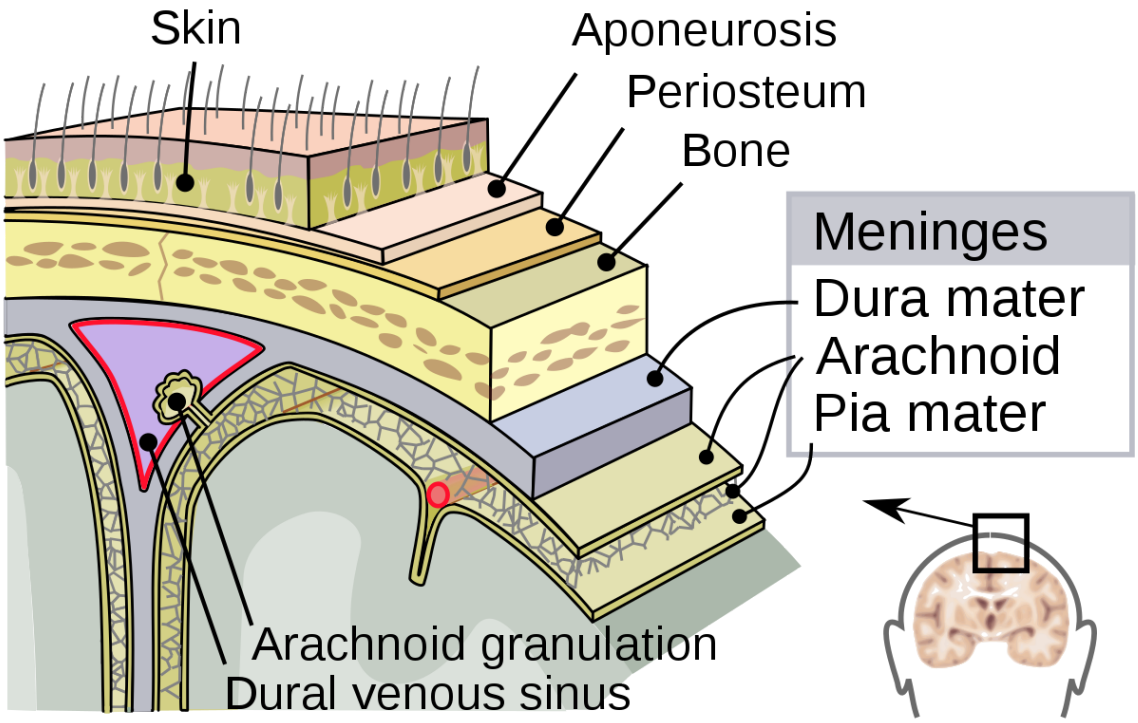
- Horizontal/Axial
- Coronal/Transverse/Frontal
- Sagittal (from the side)



Supporting structures

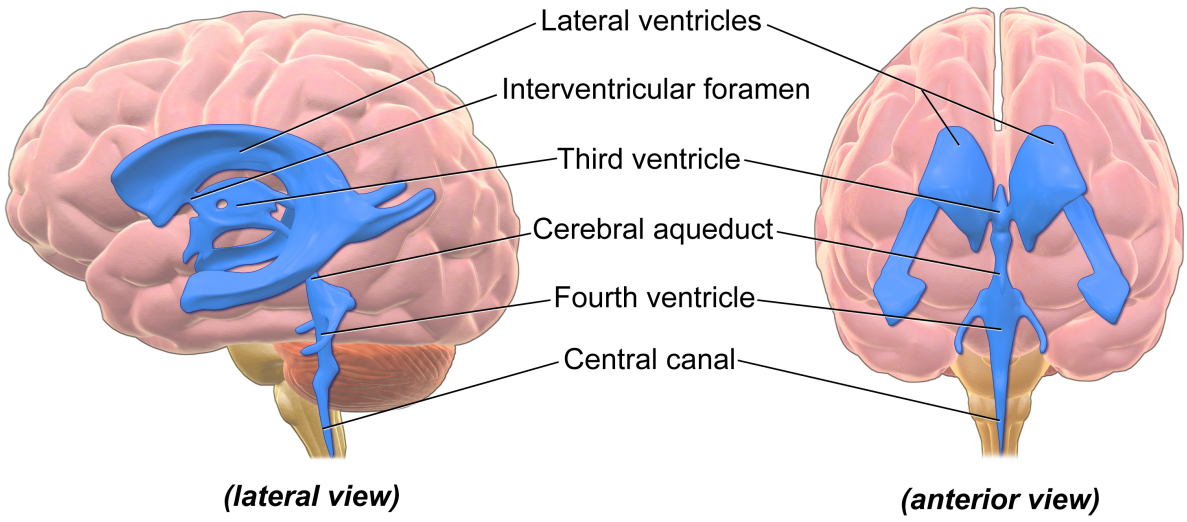
Meninges (outside -> in)

- Dura mater (‘tough mother’)
- Arachnoid membrane
- Subarachnoid space
- Pia mater (‘gentle mother’)
- Cerebrospinal fluid (CSF) between Arachnoid membrane and Pia Mater



Ventricular system

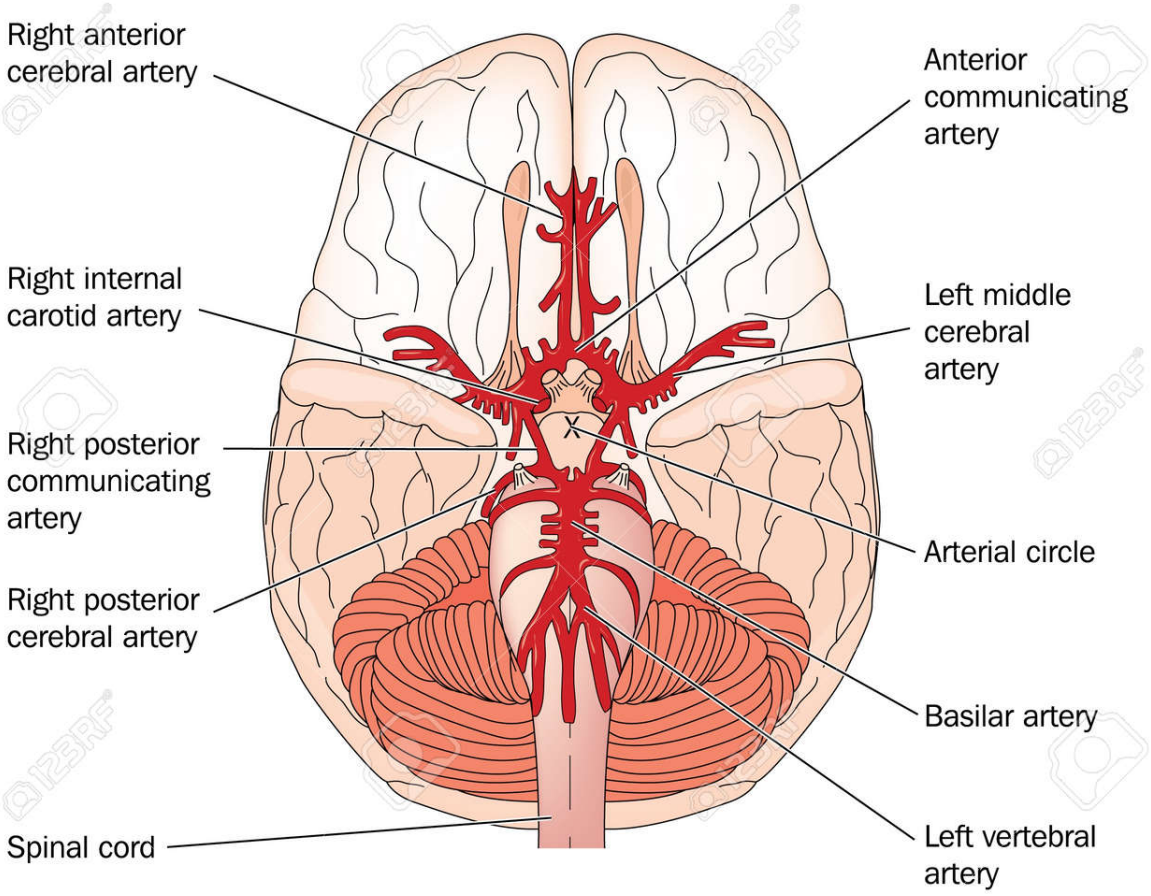
- Also known as cerebral ventricles
- Lateral (1st & 2nd)
  - Forebrain/telencephalon
- 3rd
  - Diencephalon
- Cerebral aqueduct
  - Midbrain
- 4th
  - Hindbrain



- Ventricles filled with cerebrospinal fluid (CSF)
  - CSF clears metabolites during sleep (Xie et al., 2013)?
  - Blockage of CSF flow -> hydrocephalus

Blood Supply

- Carotid & basilar arteries converge on Circle of Willis
- Anterior, Middle, and Posterior Cerebral arteries main output



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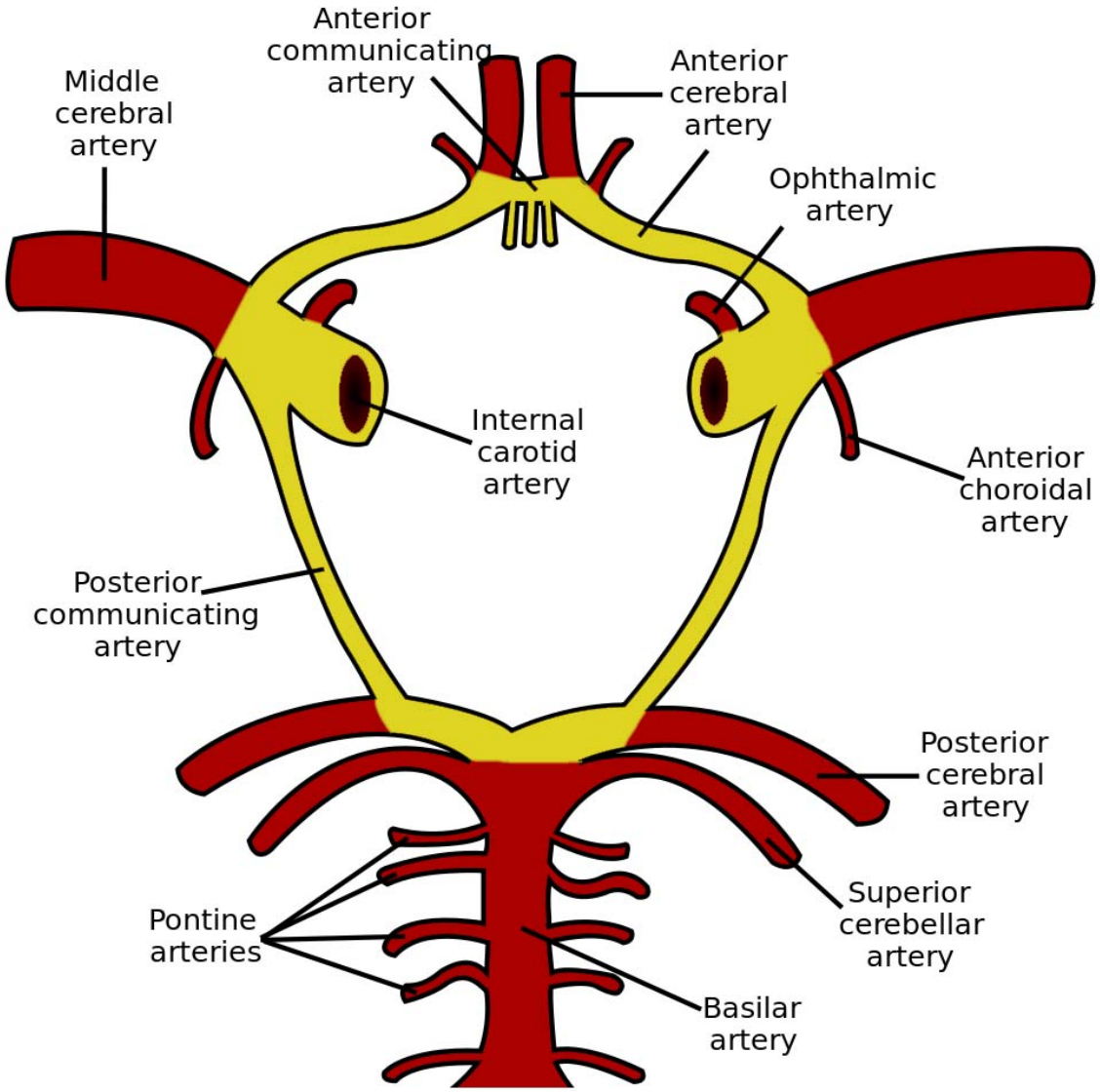

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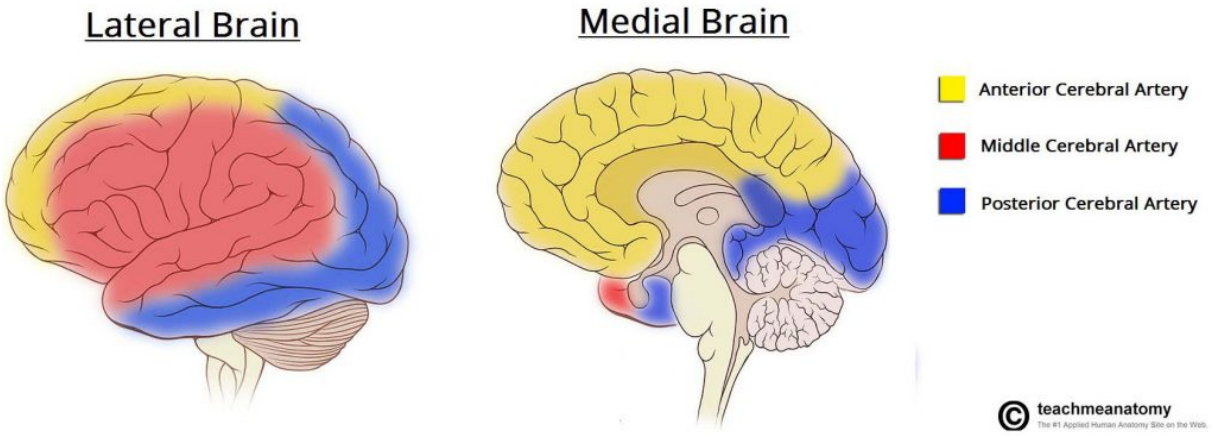

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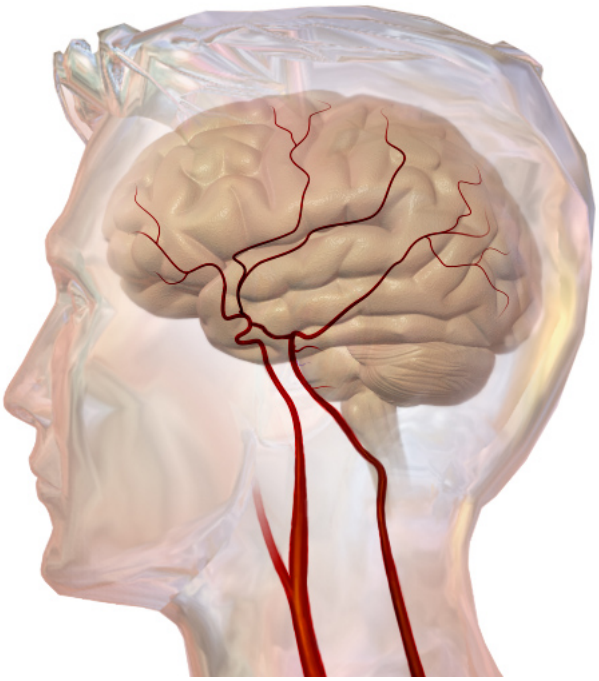

(https://commons.wikimedia.org/wiki/File:Cerebrovascular_System.png#/media/File:Cerebrovascula
By <a href="//commons.wikimedia.org/wiki/User:BruceBlaus"
title="User:BruceBlaus">BruceBlaus - Own
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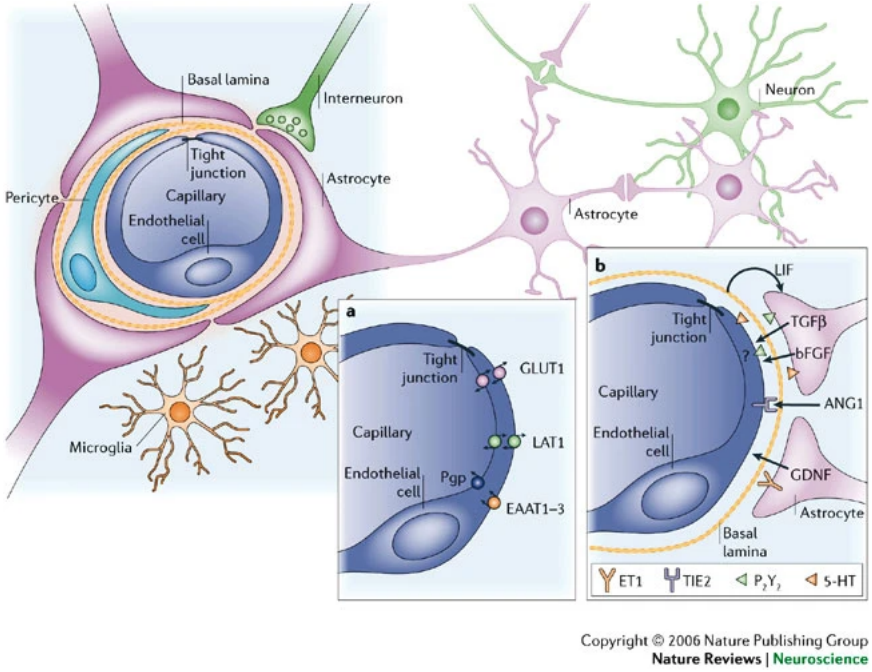
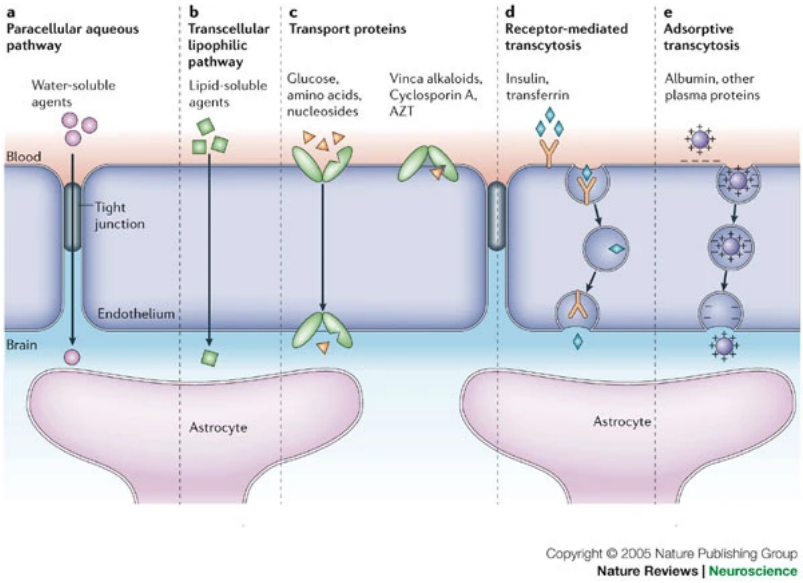
(https://commons.wikimedia.org/w/index.php?curid=51638412)

Blood/brain barrier

- Cells forming blood vessel walls tightly packed
- Active transport of molecules typically required



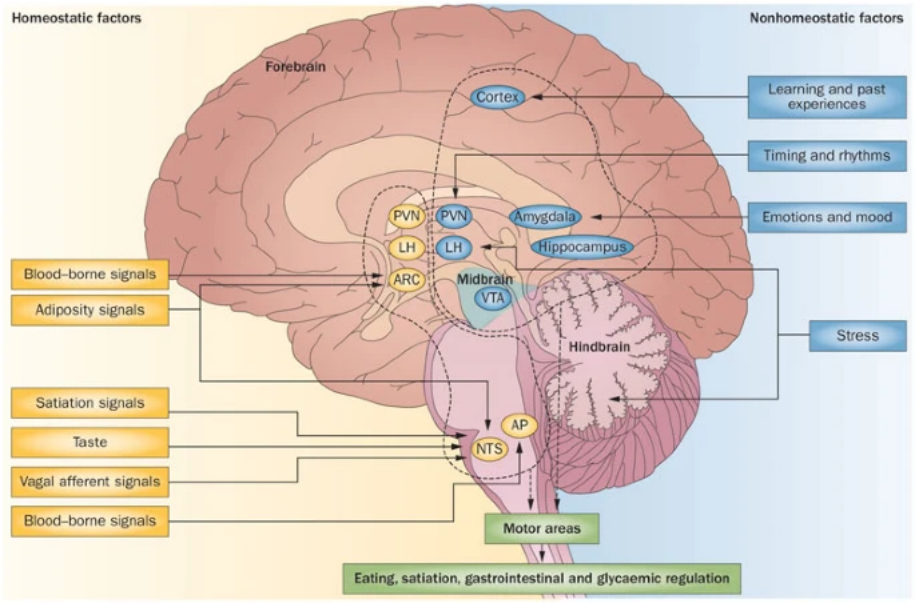
(Abbott, Rönnbäck, & Hansson, 2006) (http://dx.doi.org/10.1038/nrn1824)



(Abbott, Rönnbäck, & Hansson, 2006) (http://dx.doi.org/10.1038/nrn1824)

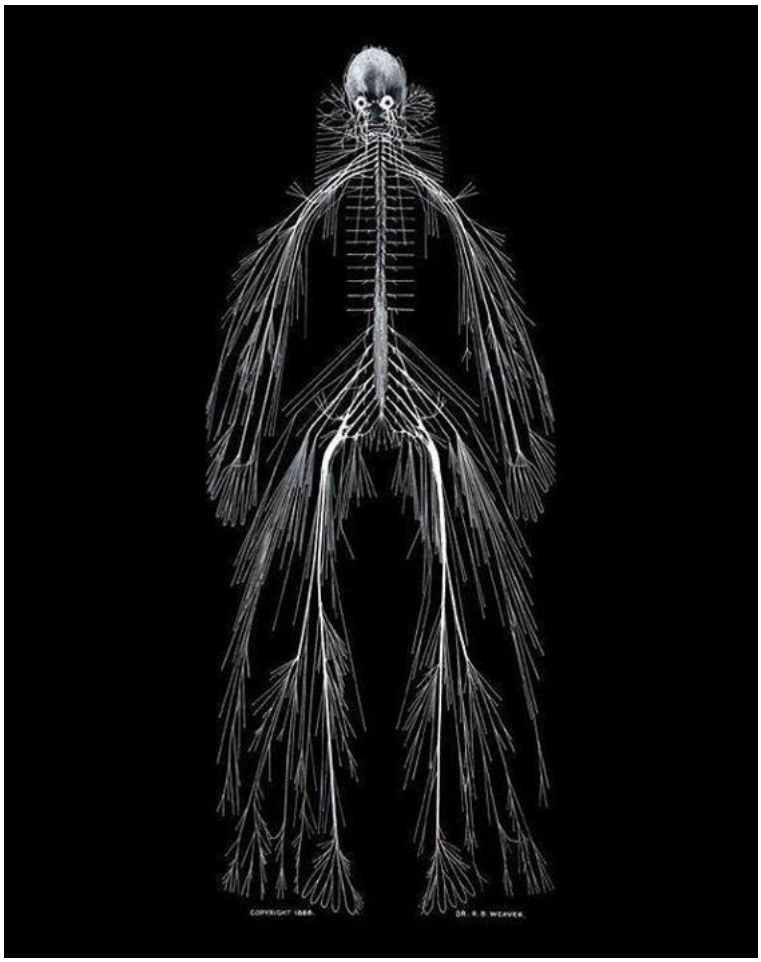
Area Postrema

- In brainstem, blood-brain barrier thin
- Chemoreceptors (chemical receptors) detect toxins, trigger emesis if necessary



(Begg & Woods, 2013) (http://dx.doi.org/10.1038/nrendo.2013.136)

Organization of the Nervous System



https://www.pastmedicalhistory.co.uk/the-nervous-system-of-harriet-cole/ (https://www.pastmedicalhistory.co.uk/the-nervous-system-of-harriet-cole/)

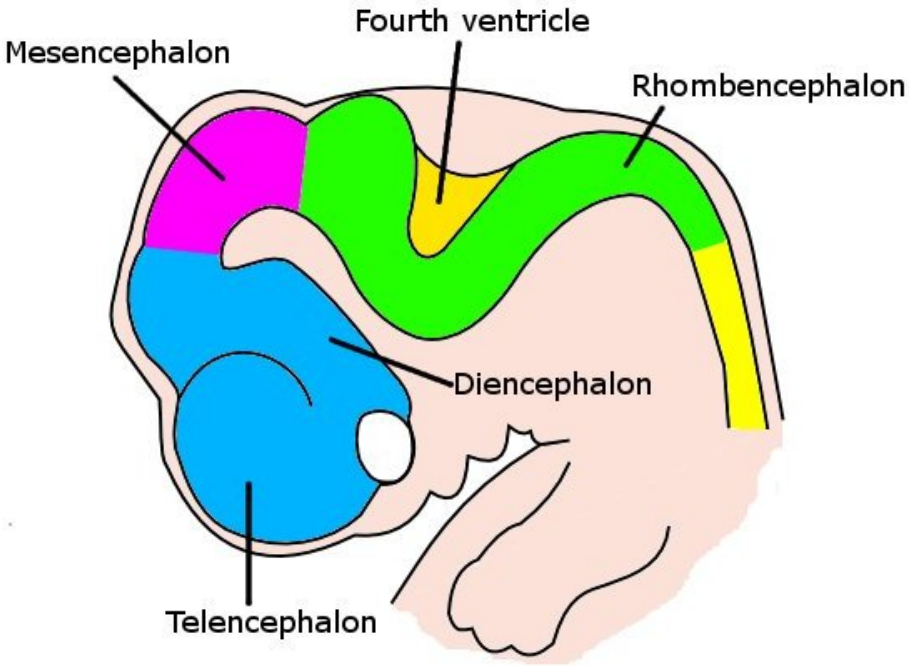
- Central Nervous System (CNS)
  - Brain
  - Spinal Cord
  - (Everything encased in bone)
- Peripheral Nervous System (PNS)
  - Somatic division
  - Autonomic division
    - Sympathetic
    - Parasympathetic

Organization of the CNS

Major division	Ventricular Landmark	Embryonic Division	Structure
Forebrain	Lateral	Telencephalon	Cerebral cortex
			Basal ganglia
			Hippocampus, amygdala
	Third	Diencephalon	Thalamus
			Hypothalamus

Major division	Ventricular Landmark	Embryonic Division	Structure
Midbrain	Cerebral Aqueduct	Mesencephalon	Tectum, tegmentum
Hindbrain	4th	Metencephalon	Cerebellum, pons
	–	Mylencephalon	Medulla oblongata

- Forebrain, midbrain, hindbrain terminology derives from embryonic stages in CNS development.



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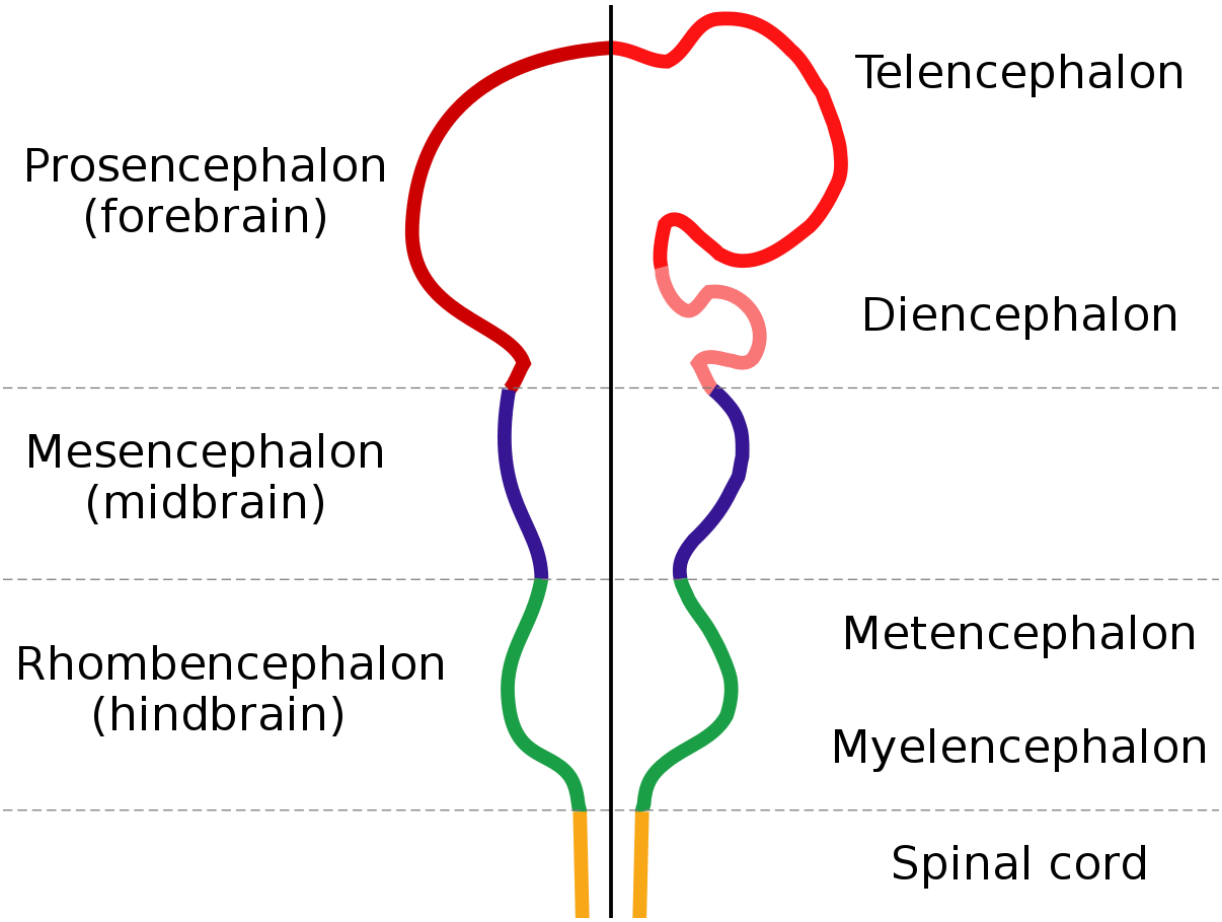
Hindbrain



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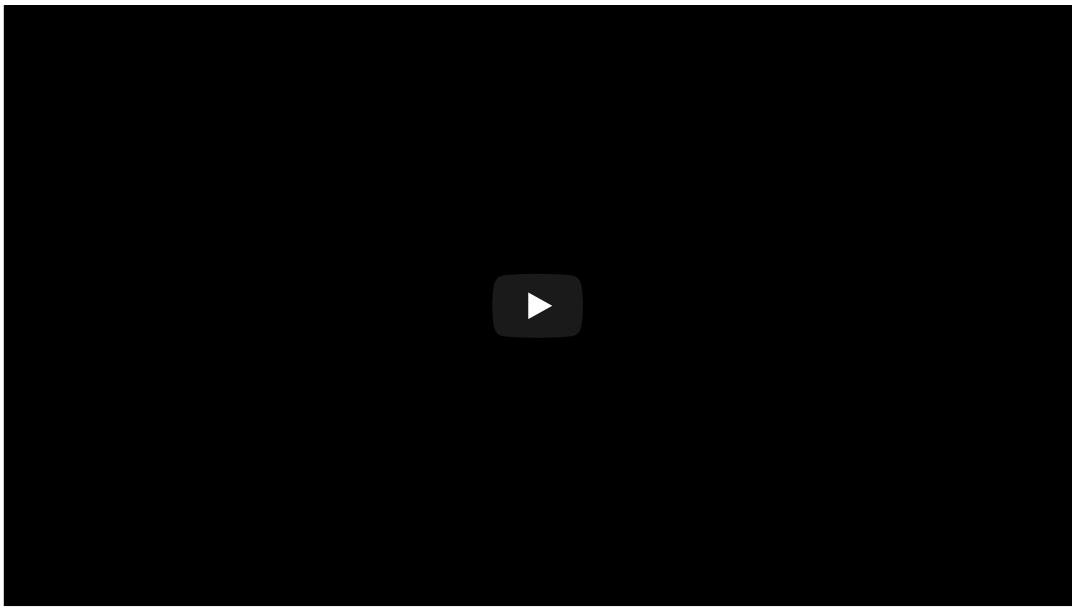
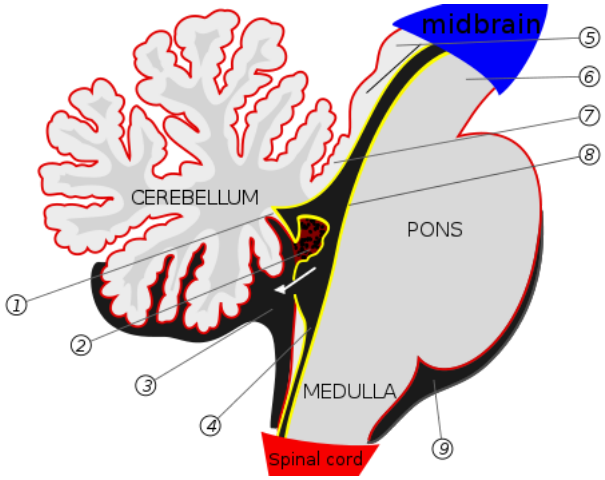
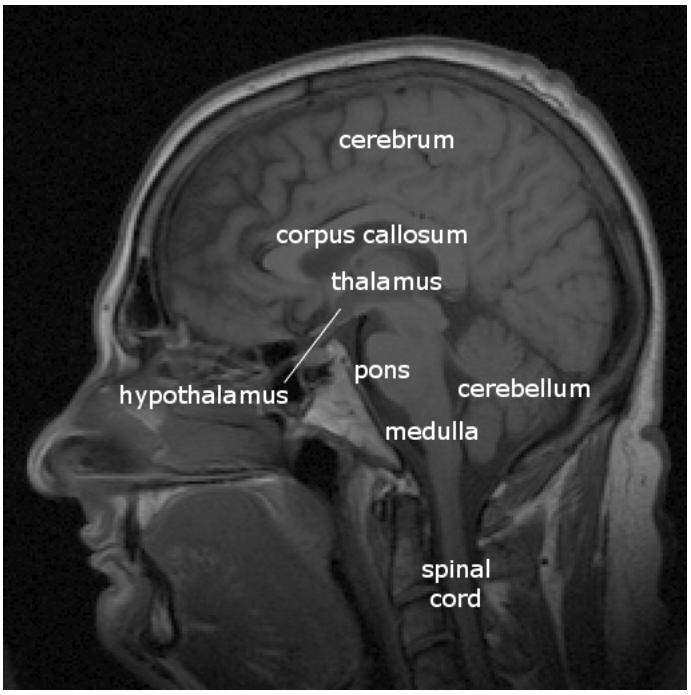
- Hindbrain: structures adjacent (or caudal to) 4th ventricle
  - Medulla oblongata
  - Cerebellum
  - Pons







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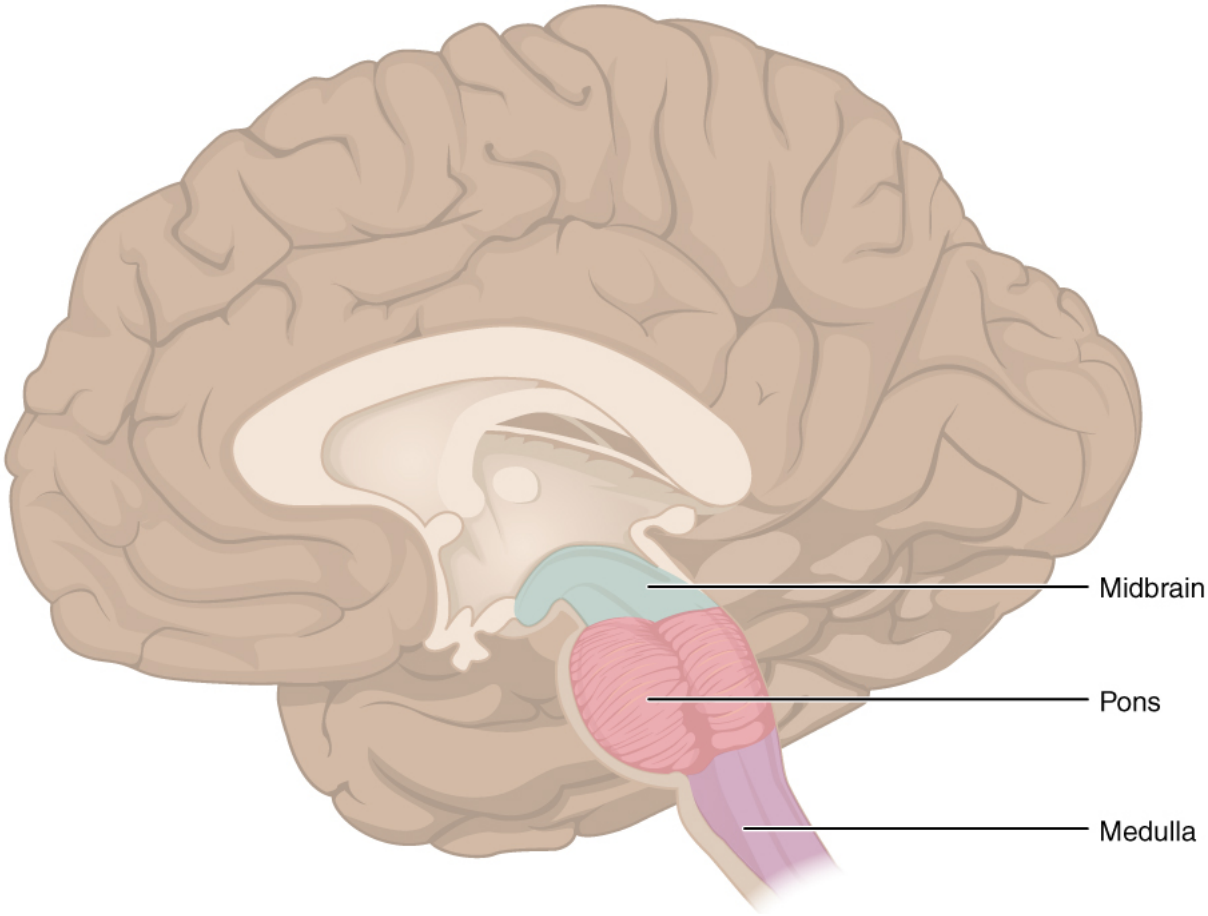
(http://webspace.ship.edu/cgboer/medial-labelled.gif)

Medulla oblongata (https://en.wikipedia.org/wiki/Medulla_oblongata)

- Cardiovascular regulation
- Muscle tone
- Fibers of passage
  - **A**scending fibers (from body), a.k.a. afferents
  - Descending fibers (**e**xiting brain), a.k.a., **e**fferents



https://upload.wikimedia.org/wikipedia/commons/6/69/1311_Brain_Stem.jpg (https://upload.wikimedia.org/wikipedia/commons/6/69/1311_Brain_Stem.jpg)

Cerebellum

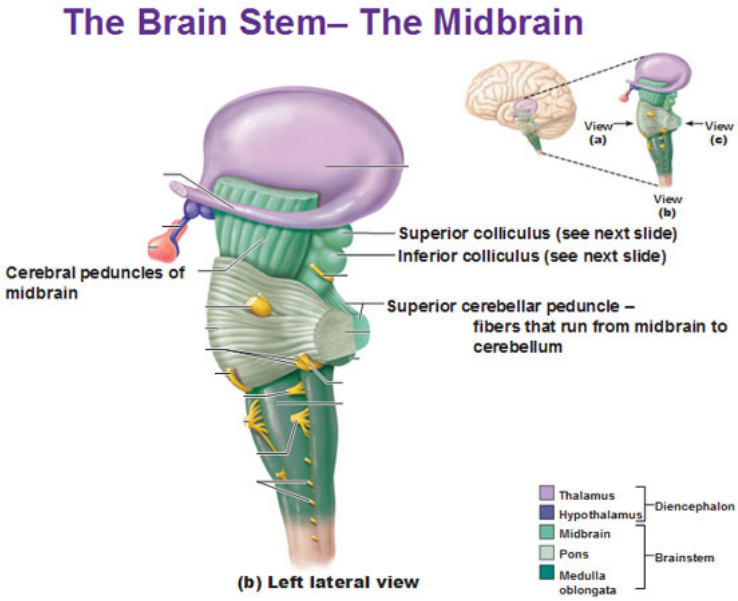
- “Little brain”
- Dorsal to pons
- Movement coordination, simple learning (classical conditioning)
- Largest number of neurons in the brain

Pons

- Bulge on ventral brain stem
- Neuromodulatory nuclei
  - Nucleus (anatomically discrete cluster of neurons
  - Neuromodulators: neurotransmitters that modulate/alter function of other neurons
  - e.g., Serotonin (5-HT), norepinephrine (NE), acetylcholine (ACh), dopamine (DA)
- Relay to cerebellum

Midbrain

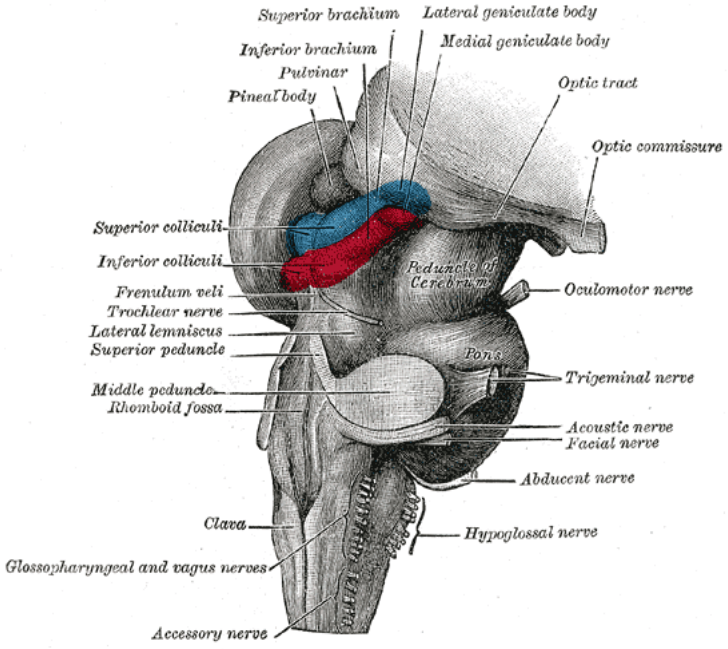
- Tectum (roof), dorsal
- Tegmentum (floor), ventral

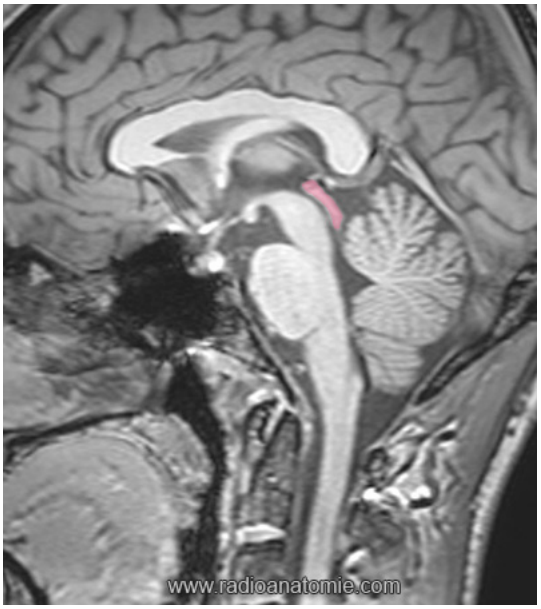


http://antranik.org/wp-content/uploads/2011/11/the-brain-stem-mid-brain-left-lateral-view-superior-colliculus-inferior-cerebellar-peduncle.jpg (http://antranik.org/wp-content/uploads/2011/11/the-brain-stem-mid-brain-left-lateral-view-superior-colliculus-inferior-cerebellar-peduncle.jpg)

Tectum

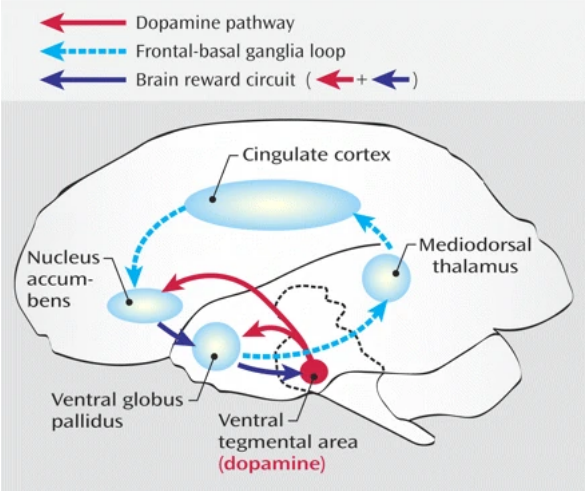
- “Roof” of the midbrain
- Superior and inferior colliculus (colliculi is plural for ‘little hill’)
- Superior colliculus: Reflexive orienting of eyes, head, ears (superior colliculi)
  - Input from FEF, parietal lobe
  - Output to cranial nerve nuclei (III, IV, VI) in tegmentum, pons
- Inferior colliculus: Auditory processing (from brainstem to auditory thalamus)





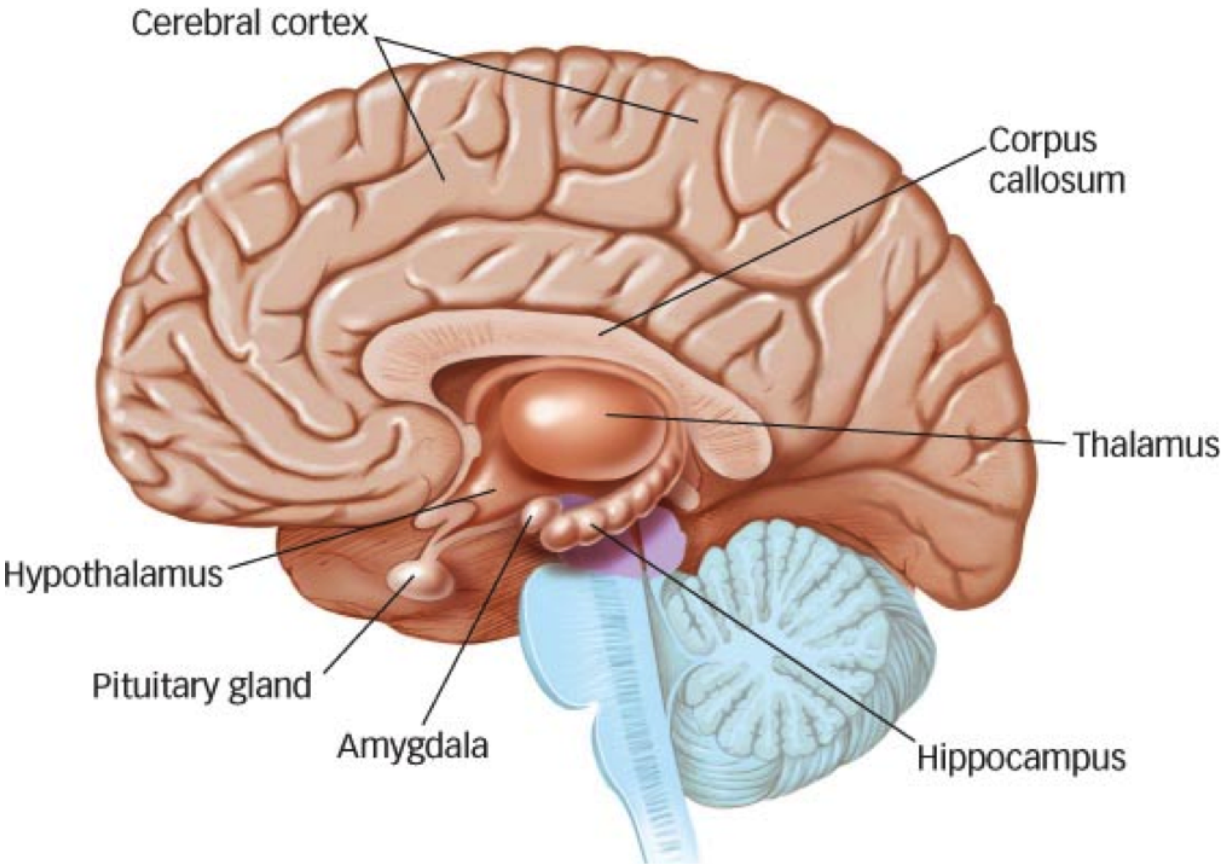
Tegmentum

- “Floor” of the midbrain
- Species-typical movement sequences
- Neuromodulatory nuclei
  - Norepinephrine (NE)
  - Serotonin (5-HT)
  - Dopamine (DA) – from *ventral tegmental area (VTA)*



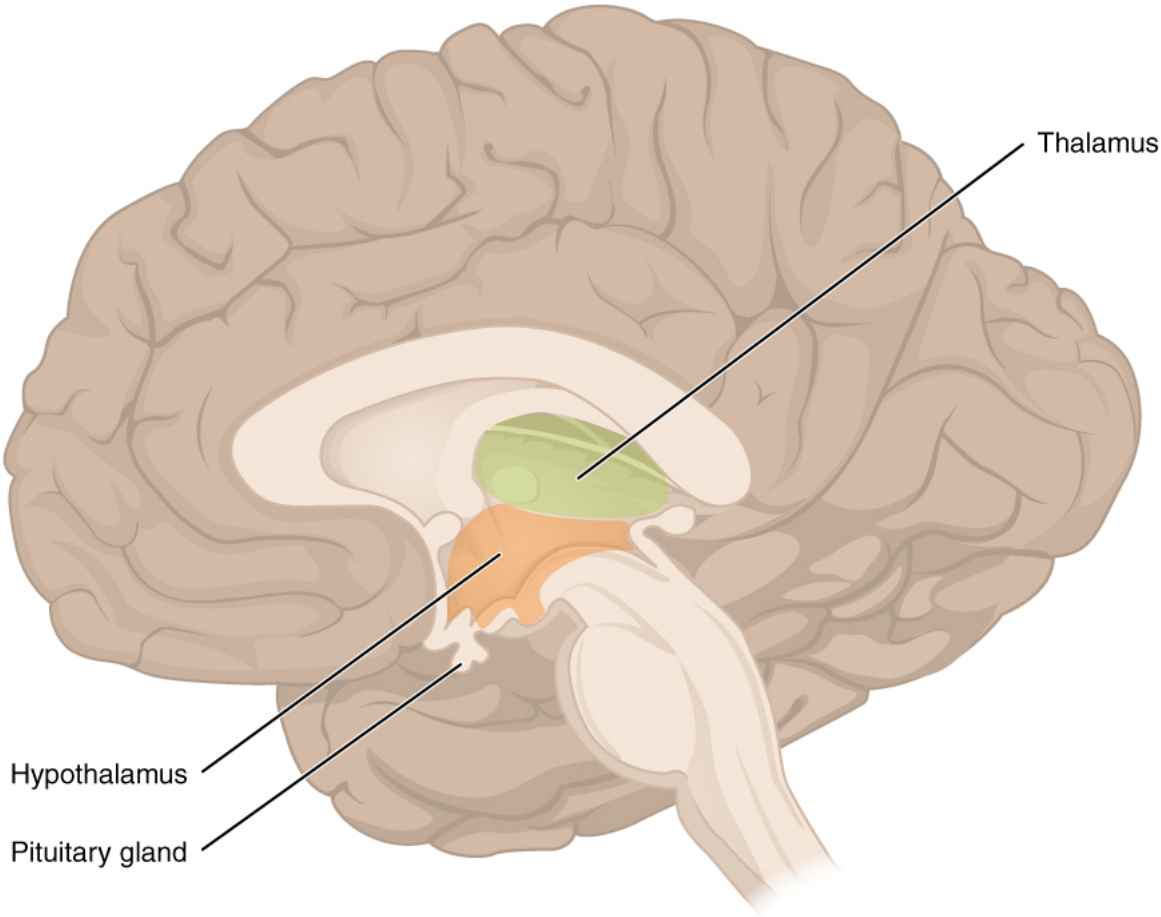
Forebrain

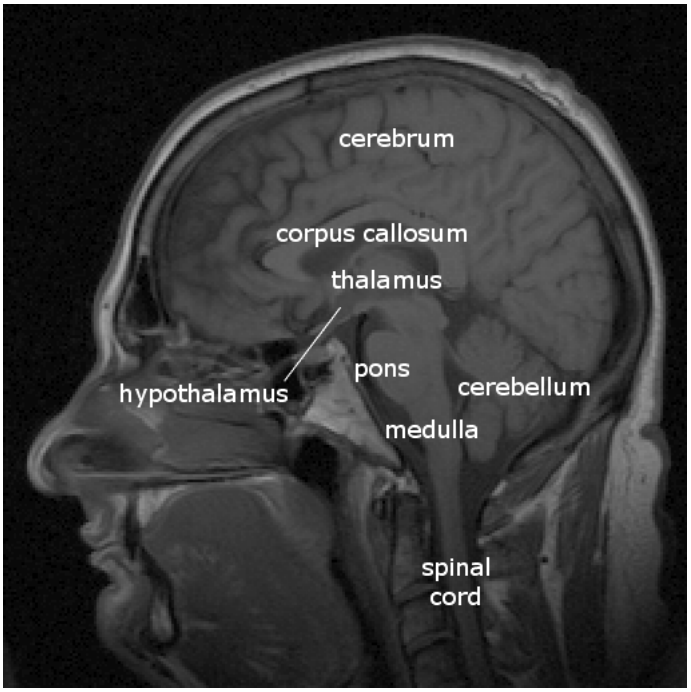
- Diencephalon
- Telencephalon



Diencephalon (‘between brain’)

- Thalamus
- Hypothalamus

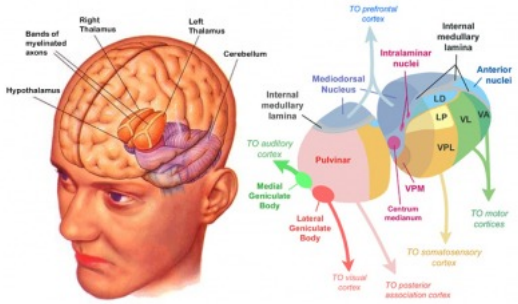




Thalamus

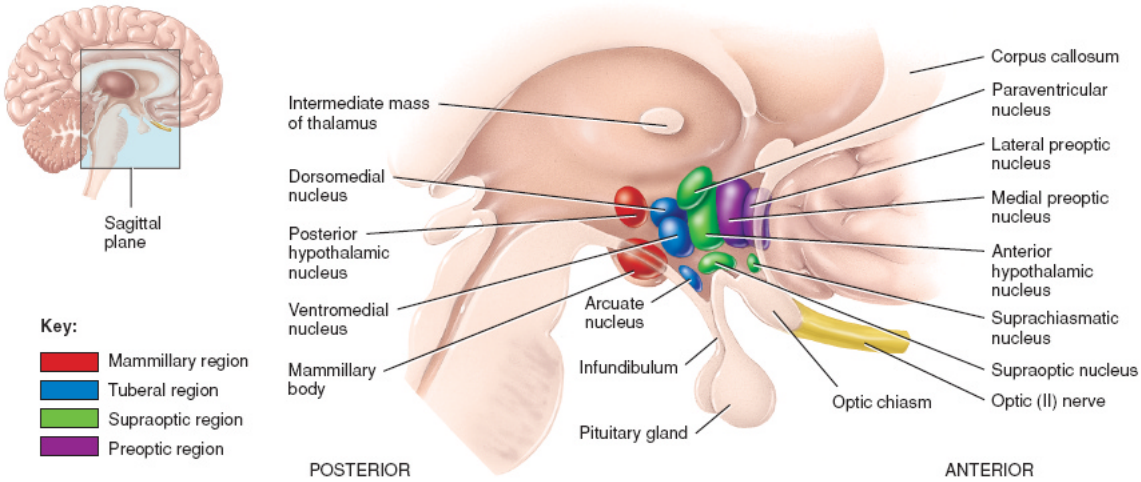
- Input to cortex
- Functionally distinct *nuclei*
  - Lateral geniculate nucleus (LGN), vision

- Medial geniculate nucleus (MGN), audition
- Pulvinar, attention?

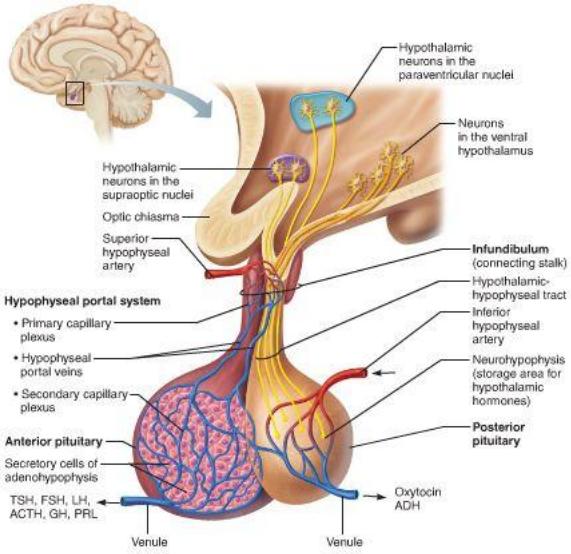


Hypothalamus

- Five Fs: fighting, fleeing/freezing, feeding, and reproduction
- Controls pituitary gland (“master” gland)
  - Anterior pituitary (indirect release of hormones)
    - e.g., Corticotropin Releasing Hormone (CRH) -> release of cortisol from Adrenal Cortex (adjacent to kidney)
  - Posterior pituitary (direct release of hormones)
    - Oxytocin
    - Vasopressin (aka, Arginine Vasopressin – AVP; Anti-diuretic Hormone – ADH)



Sagittal section of brain showing hypothalamic nuclei

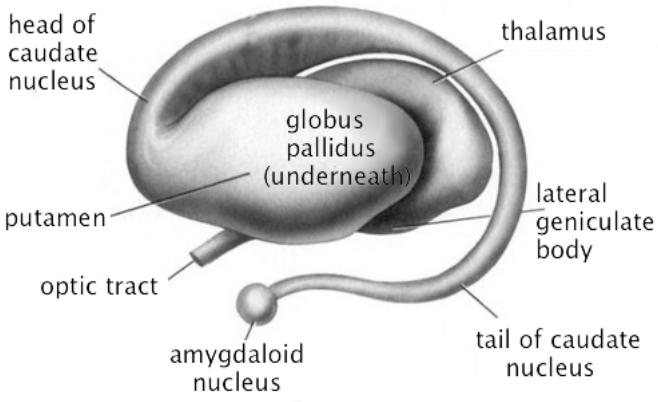


Telencephalon

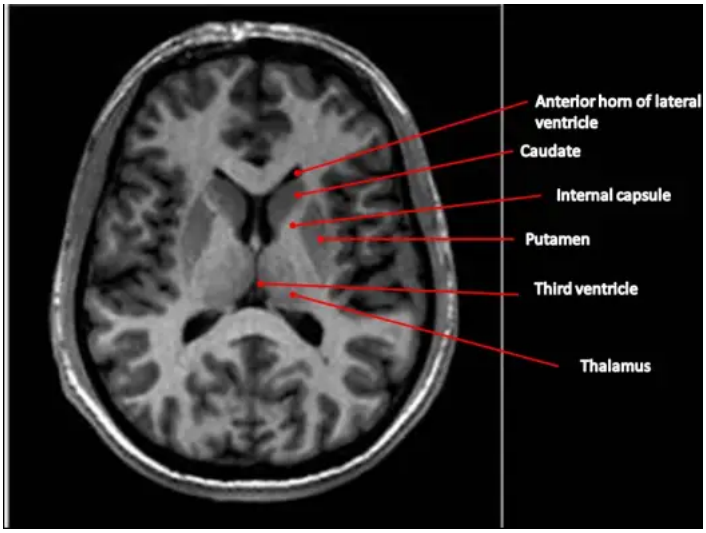
- Basal ganglia
- Hippocampus, amygdala
- Cerebral cortex

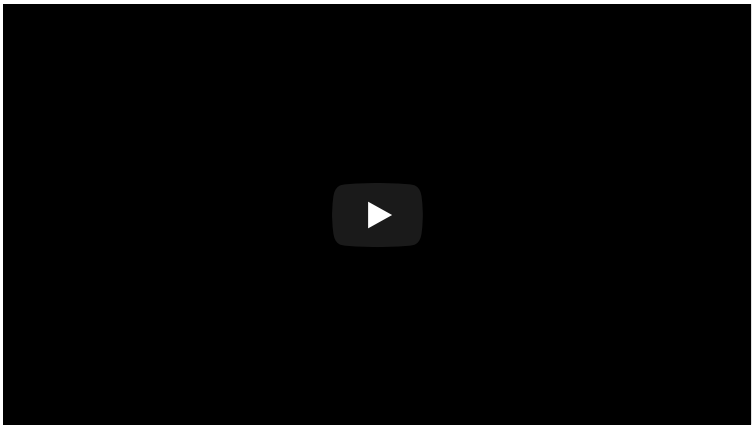
Basal Ganglia

- Skill and habit learning
- Linked to Tourette syndrome, obsessive-compulsive disorder (OCD), addiction, movement disorders
- Example: Parkinson's Disease



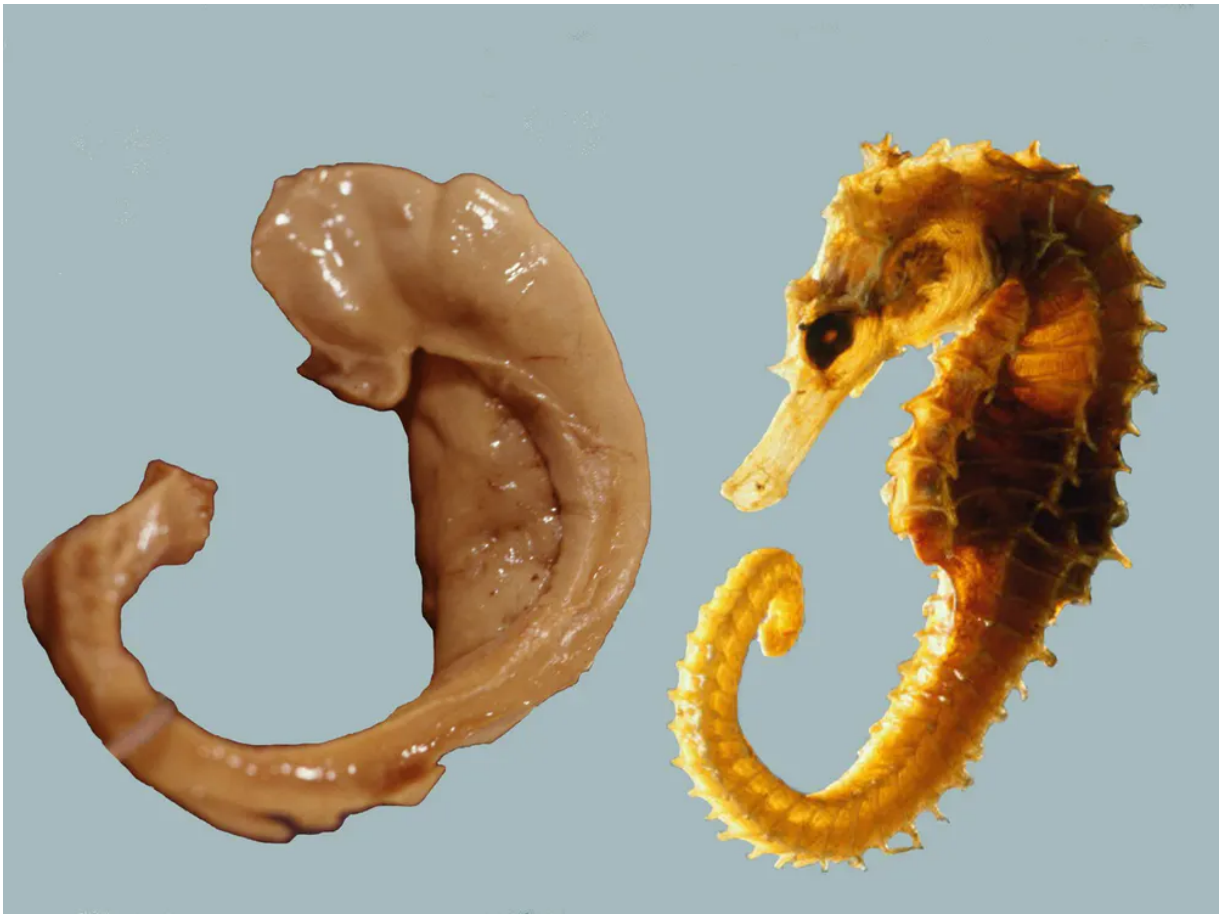
- Striatum
  - Caudate nucleus
  - Putamen
- Globus pallidus
- Subthalamic nucleus
- Substantia nigra (tegmentum)





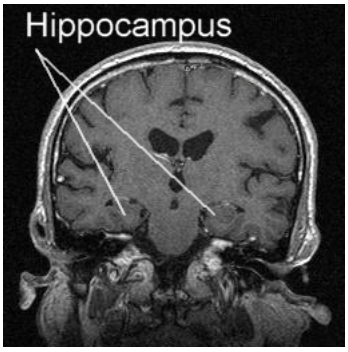
Hippocampus

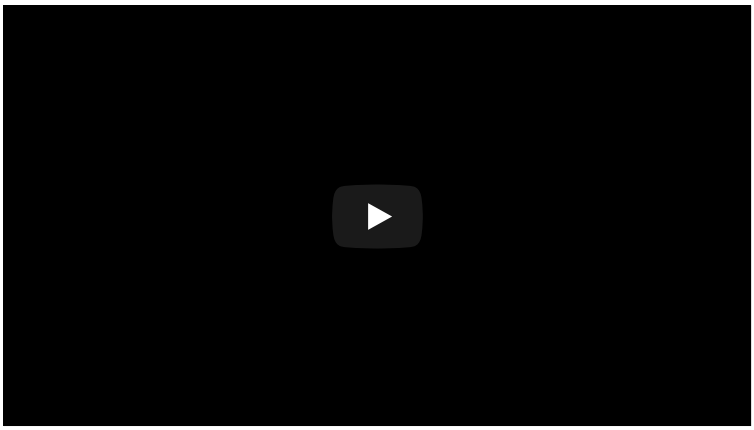
- Hippocampus means “sea horse”



https://theconversation.com/explainer-what-happens-in-the-hippocampus-32589 (https://theconversation.com/explainer-what-happens-in-the-hippocampus-32589)

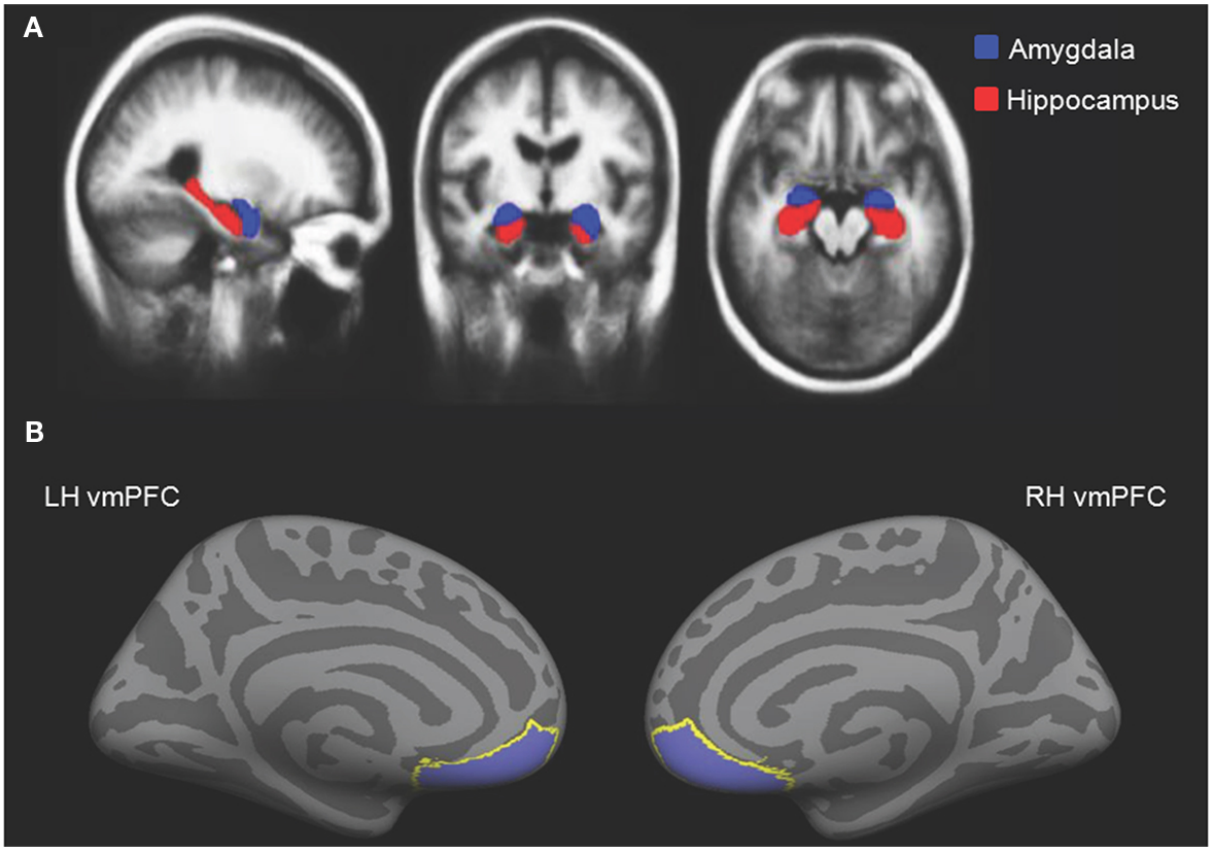
- Medial to lateral ventricles
- Store memories of specific facts (semantic memory) or events (episodic memory)
- Place memory in non-human animals (& humans?)
- Fornix (axon fiber bundle) projects to (mammillary bodies of) hypothalamus

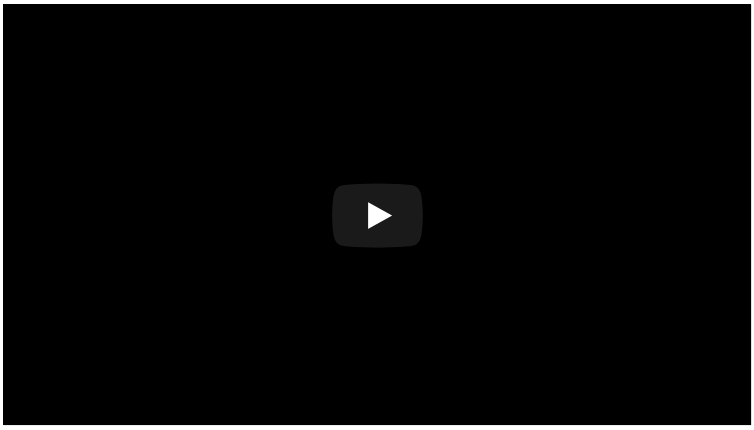




Amygdala (“almond”)

- Physiological state, behavioral readiness, affect
- NOT the fear center! (LeDoux, 2015).
- Projection to hypothalamus

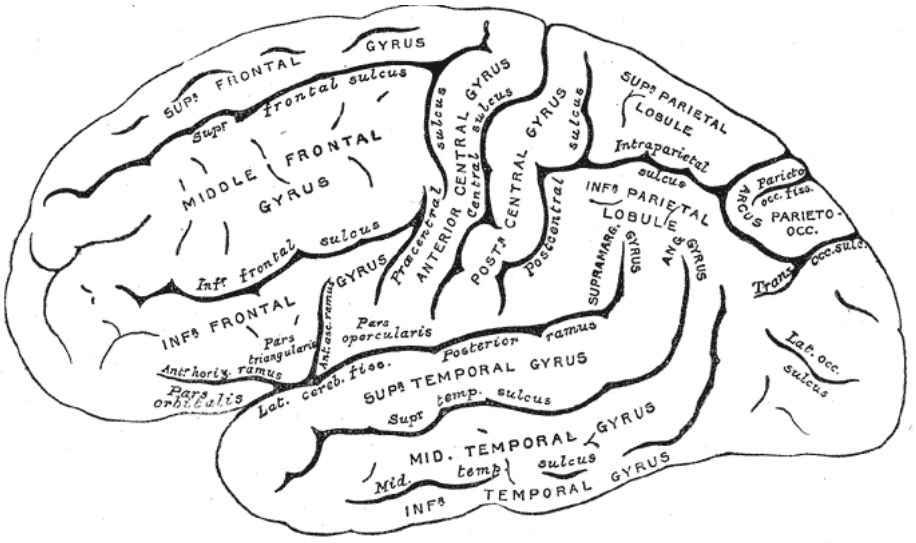




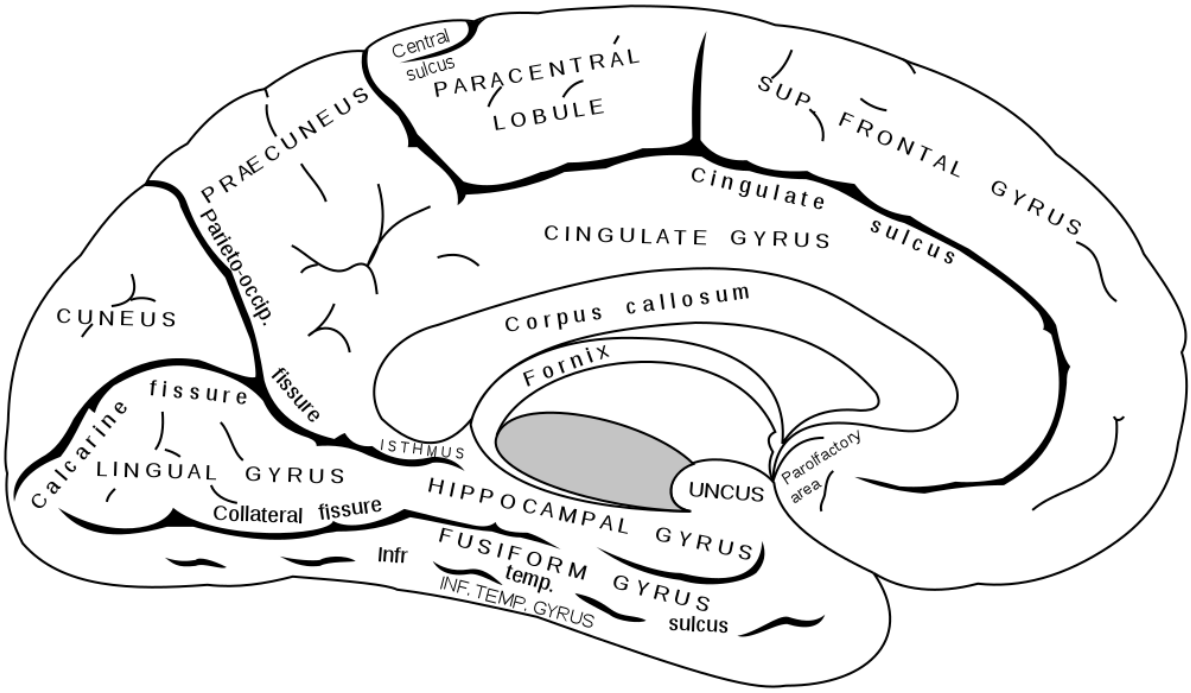
Cerebral Cortex

- Cerebral hemispheres
- Groove (sulcus or sulci)
- Bumps (gyrus or gyri)
- Grey vs. white matter
- Lobes

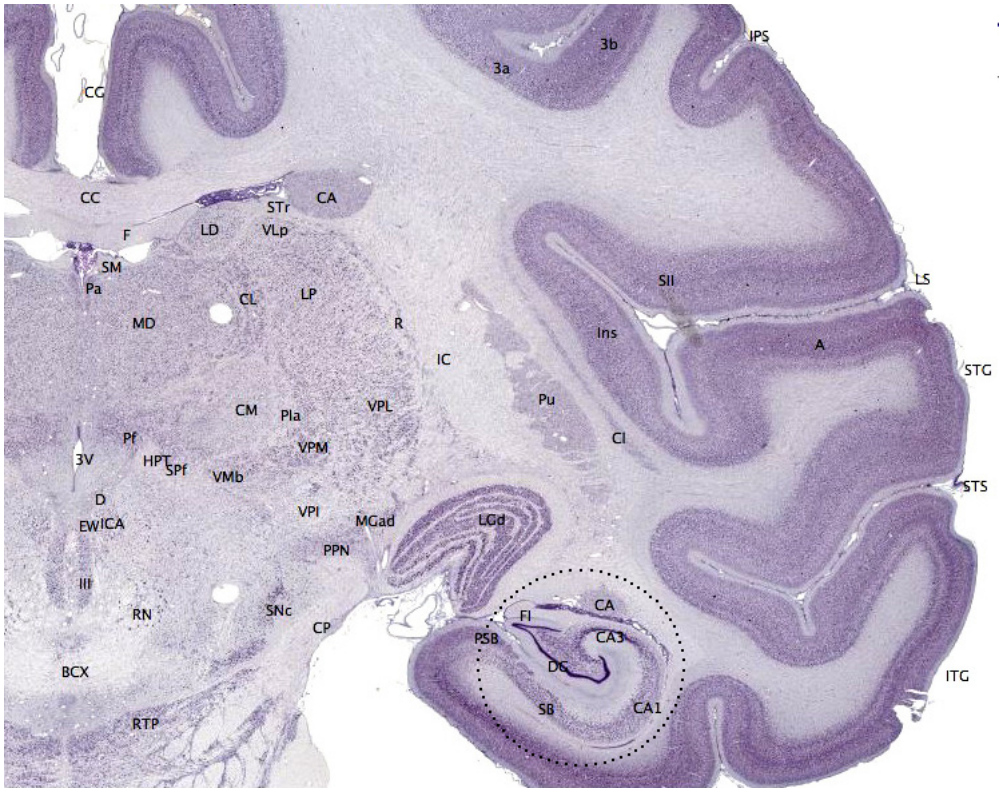
Lateral view



Medial view

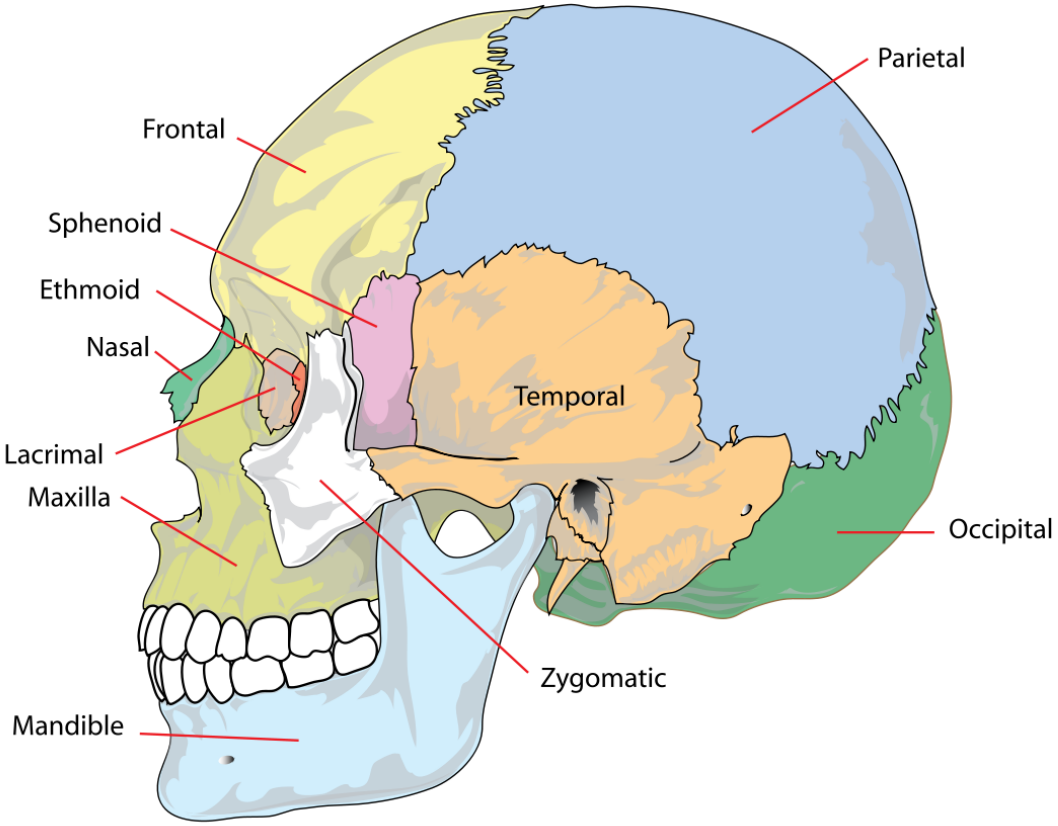


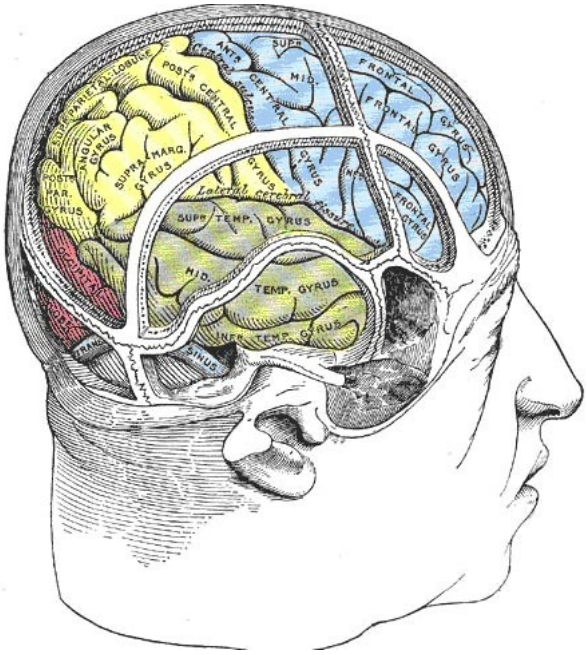
Nissl stain



Lobes of the cerebral cortex

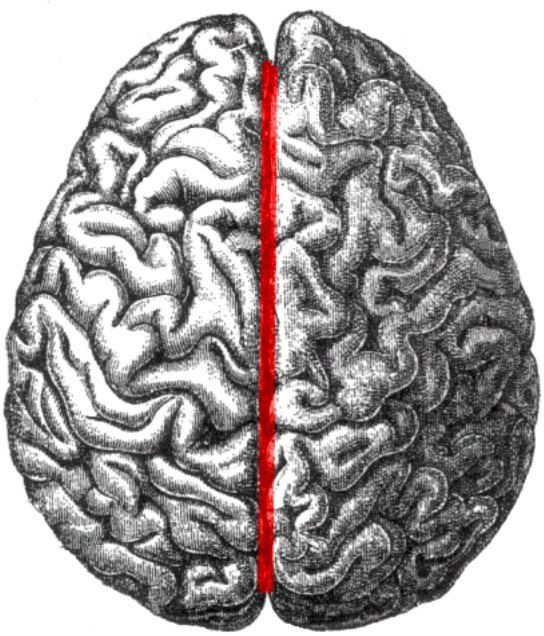
- Frontal
- Temporal
- Parietal
- Occipital
- Names derive from underlying bones of the skull





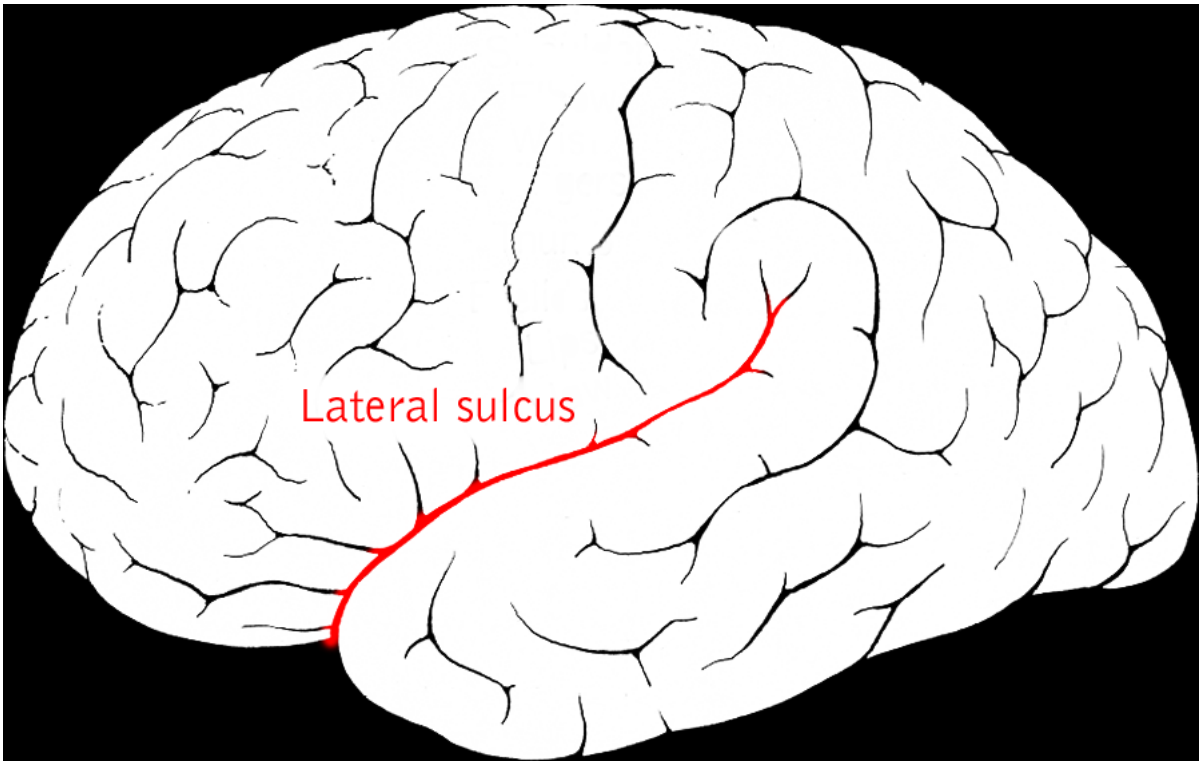
Longitudinal fissure

- Also known as superior longitudinal fissure
- Divides the cerebral hemispheres



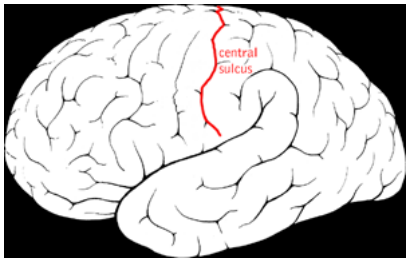
Lateral sulcus/fissure

- Also known as Sylvian Fissure
- Divides frontal from temporal lobe



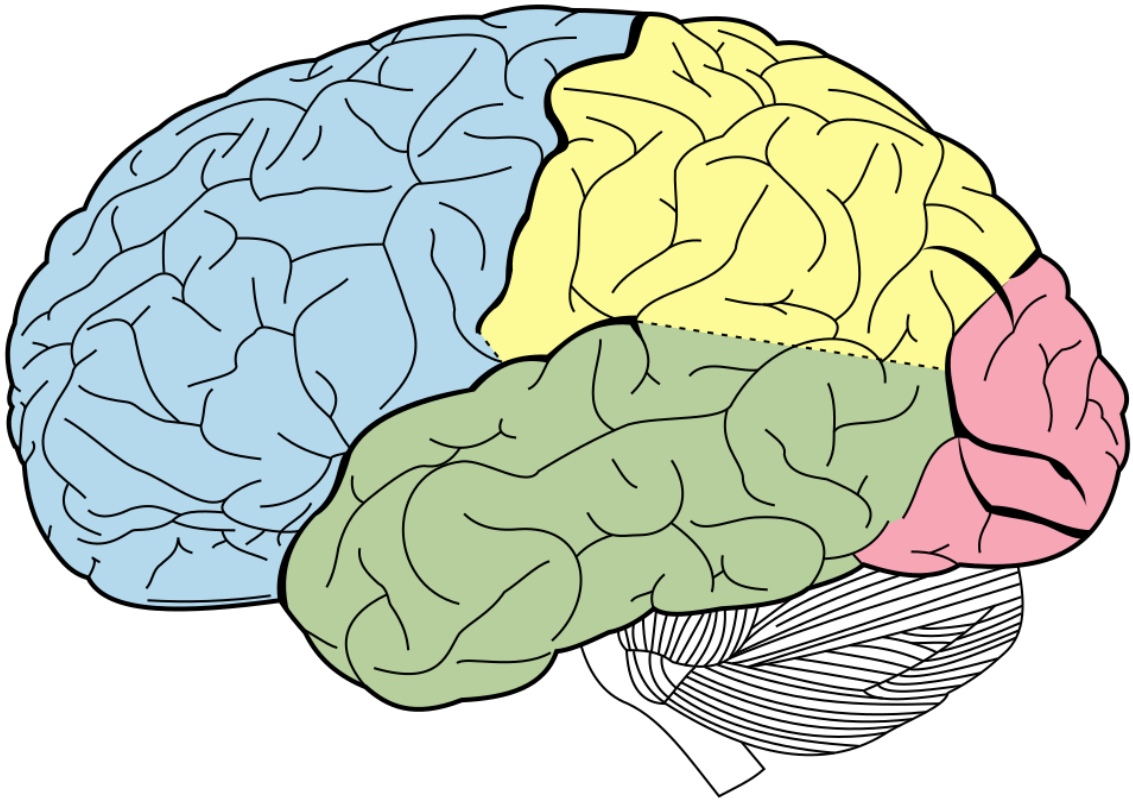
Central sulcus

- Also known as Rolandic Fissure or Fissure of Rolando
- Divides frontal from parietal lobe



Frontal lobe

- Anterior to central sulcus
- Superior to lateral fissure
- Dorsal to temporal lobe

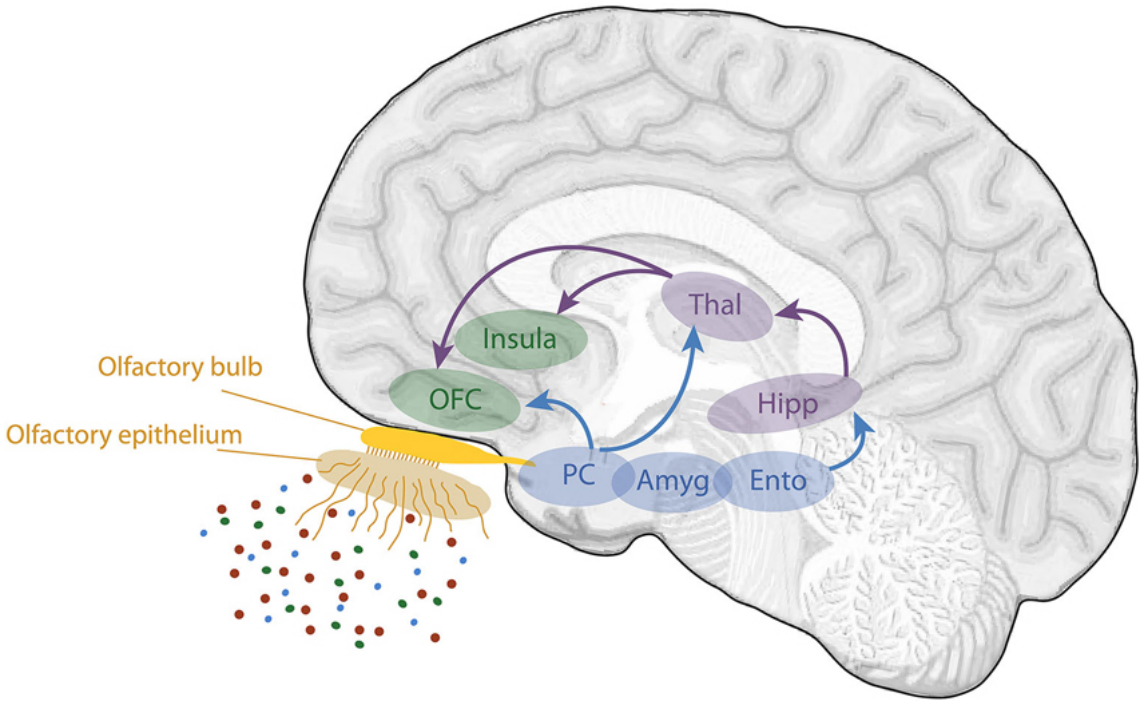


- Primary motor cortex (M-I or M1)
  - Precentral gyrus

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

https://en.wikipedia.org/wiki/Precentral_gyrus
(https://en.wikipedia.org/wiki/Precentral_gyrus)

- Secondary motor areas
  - Supplementary motor cortex (SMC)
  - Frontal eye fields (FEF)
- Prefrontal cortex
  - Planning, problem solving, working memory…?
- Secondary olfactory cortex



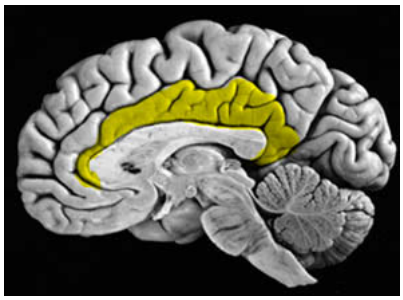
(Saive, Royet, & Plailly, 2014) (http://doi.org/10.3389/fnbeh.2014.00240)

Figure 1. Schematic view of the human olfactory system. The primary and secondary olfactory cortices are represented in blue and green, respectively. Amyg, amygdala; Ento, entorhinal cortex; Hipp, hippocampus; OFC, orbitofrontal cortex; PC, piriform cortex; Thal, thalamus (adapted from Royet et al., 2014).

(Saive, Royet, & Plailly, 2014) (http://doi.org/10.3389/fnbeh.2014.00240)

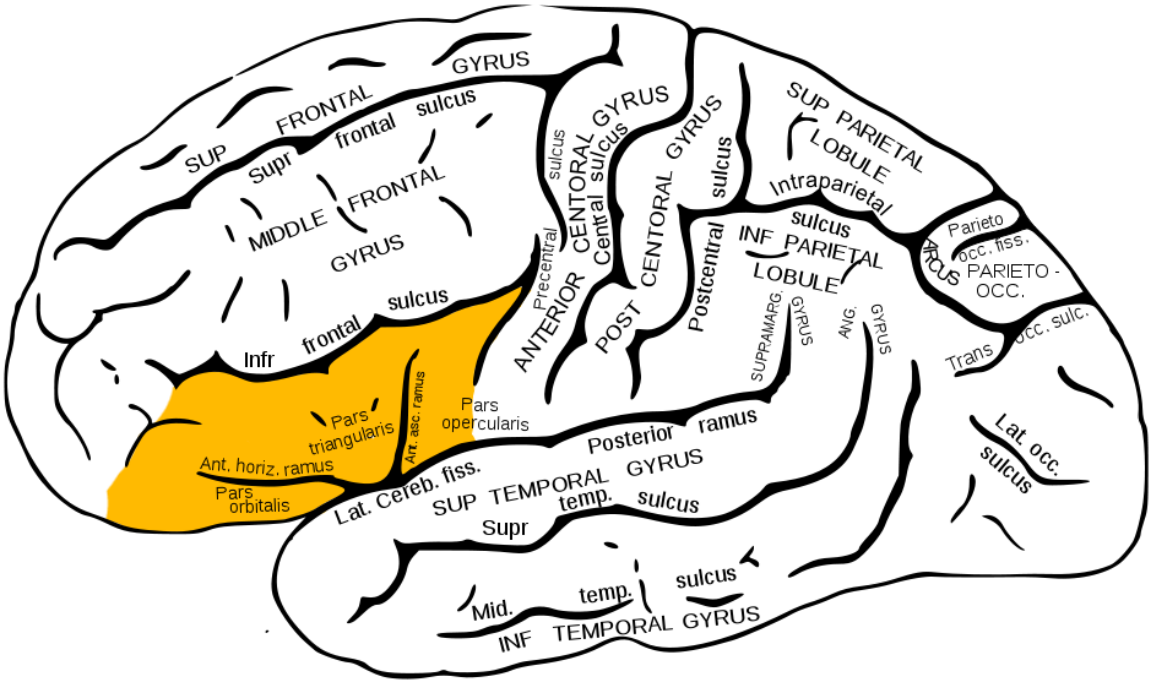
- Basal forebrain
  - Nucleus accumbens (NAcc) (https://en.wikipedia.org/wiki/Nucleus_accumbens), part of ventral striatum

Cingulate Gyrus



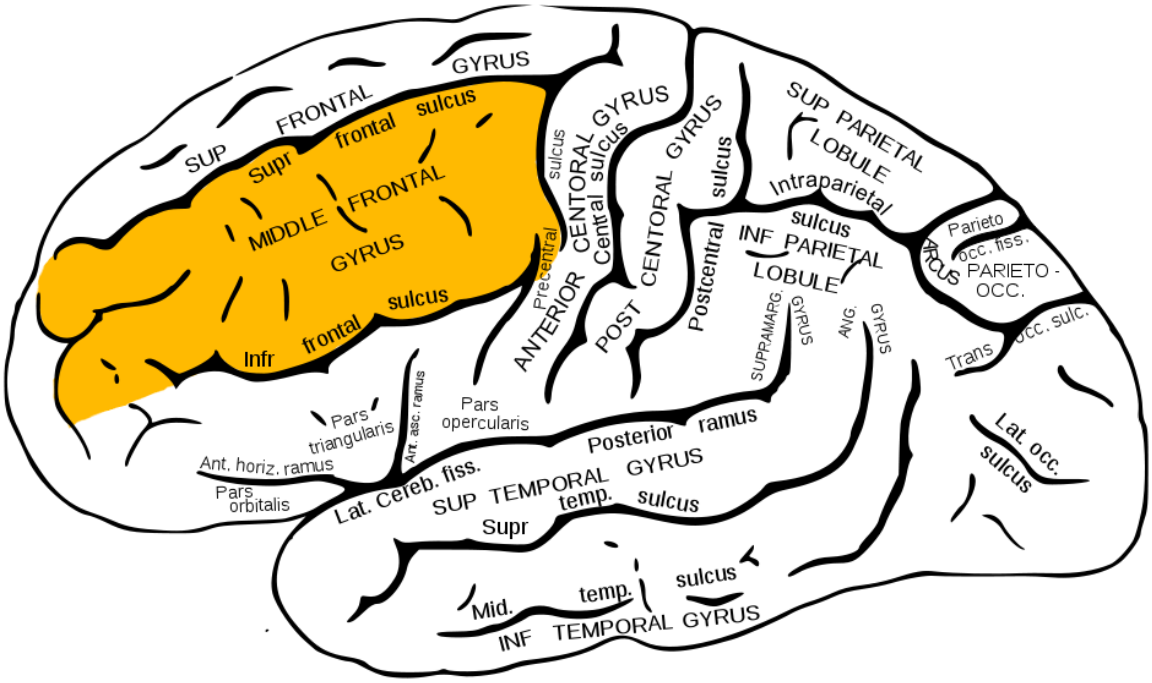
- Anterior cingulate cortex (ACC) (https://en.wikipedia.org/wiki/Anterior_cingulate_cortex)

Inferior Frontal Gyrus (IFG)



- Home to Broca's Area

Middle Frontal Gyrus (MFG)



- Home to Dorsolateral Prefrontal Cortex (DLPFC (https://en.wikipedia.org/wiki/Dorsolateral_prefrontal_cortex))

Superior Frontal Gyrus (SFG)

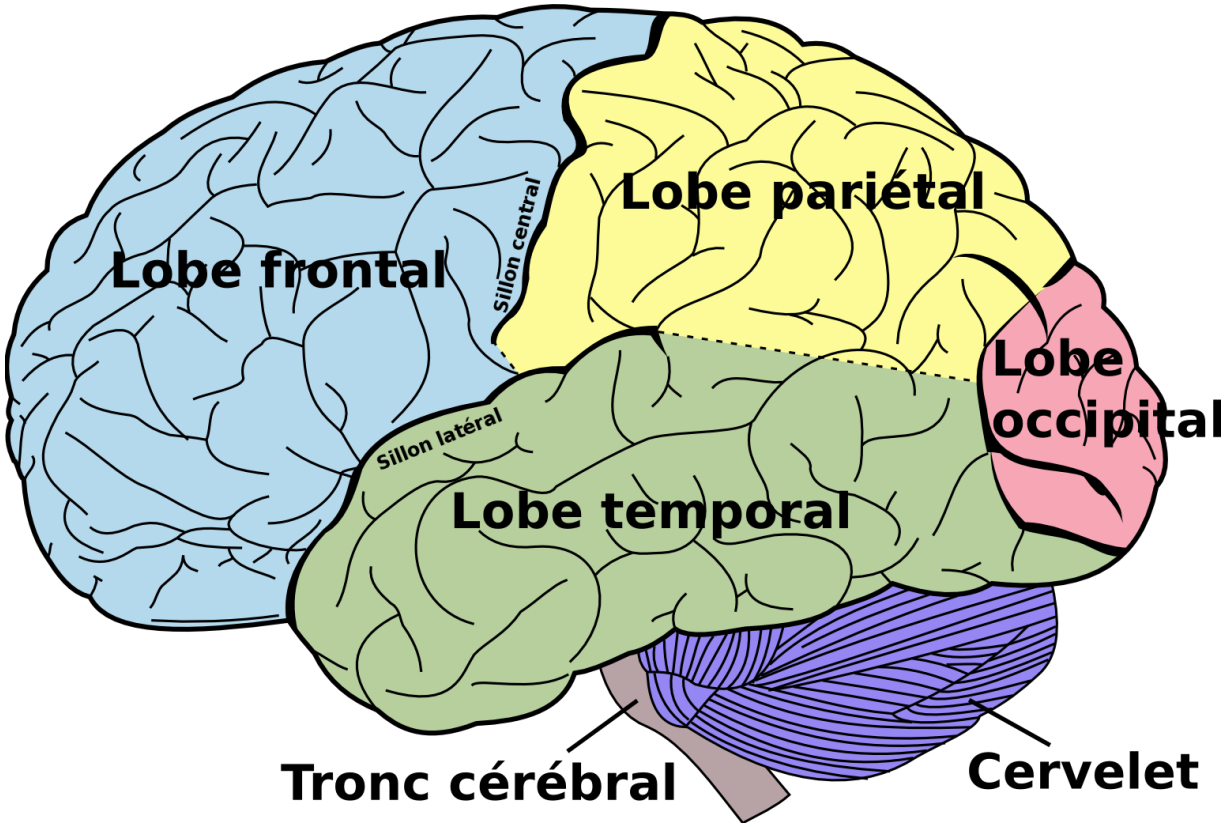
- Brodmann Area 8
- Frontal Eye Fields (FEF)

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

https://en.wikipedia.org/wiki/Frontal_eye_fields
(https://en.wikipedia.org/wiki/Frontal_eye_fields)

Temporal lobe

- Ventral to frontal, parietal lobes
- Inferior to lateral fissure



- Primary auditory cortex (A-I or A1)

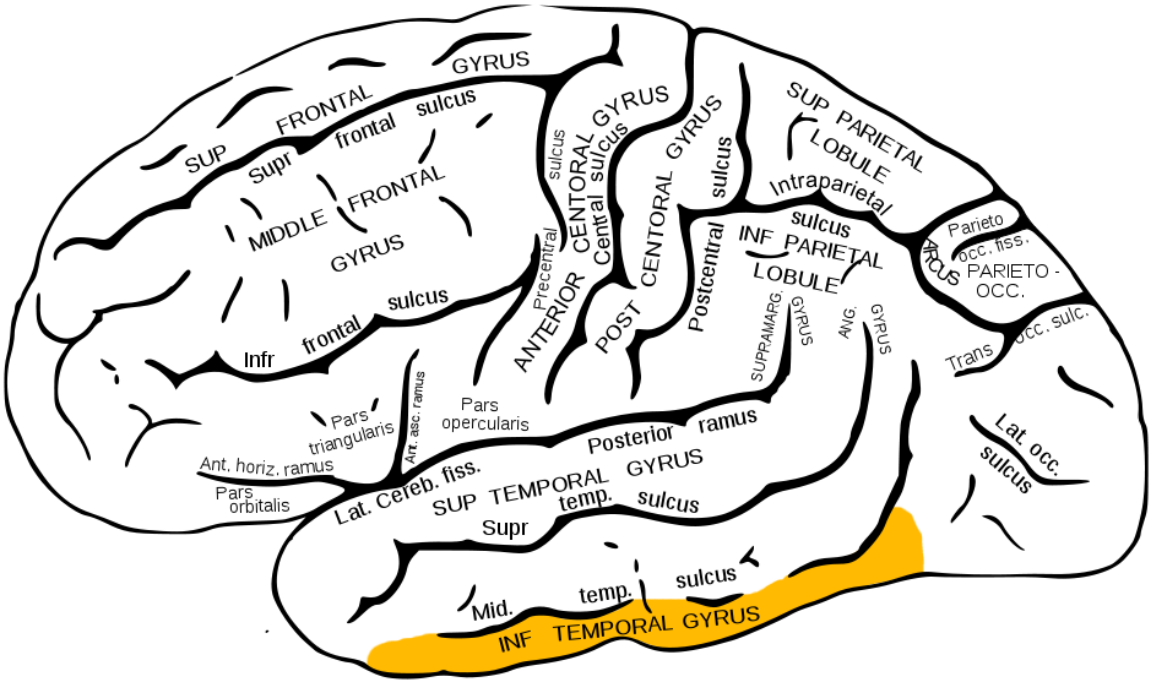
https://en.wikipedia.org/wiki/Auditory_cortex

https://en.wikipedia.org/wiki/Auditory_cortex
(https://en.wikipedia.org/wiki/Auditory_cortex)

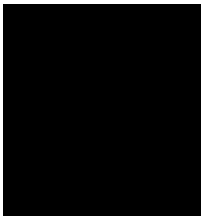
Superior Temporal Sulcus

- Object, face recognition; biological motion processing
- Language processing

Inferior Temporal Gyrus (ITG)

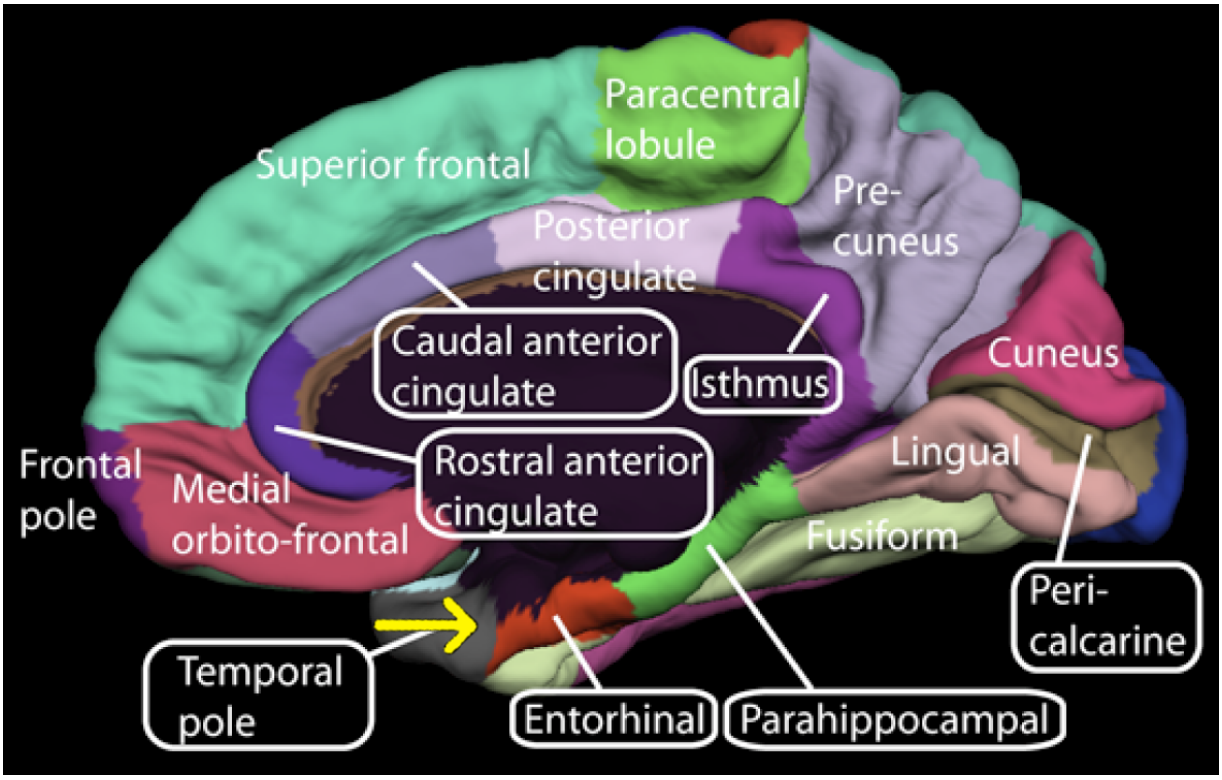


- Continuation of ventral visual processing stream



https://en.wikipedia.org/wiki/Inferior_temporal_gyrus
(https://en.wikipedia.org/wiki/Inferior_temporal_gyrus)

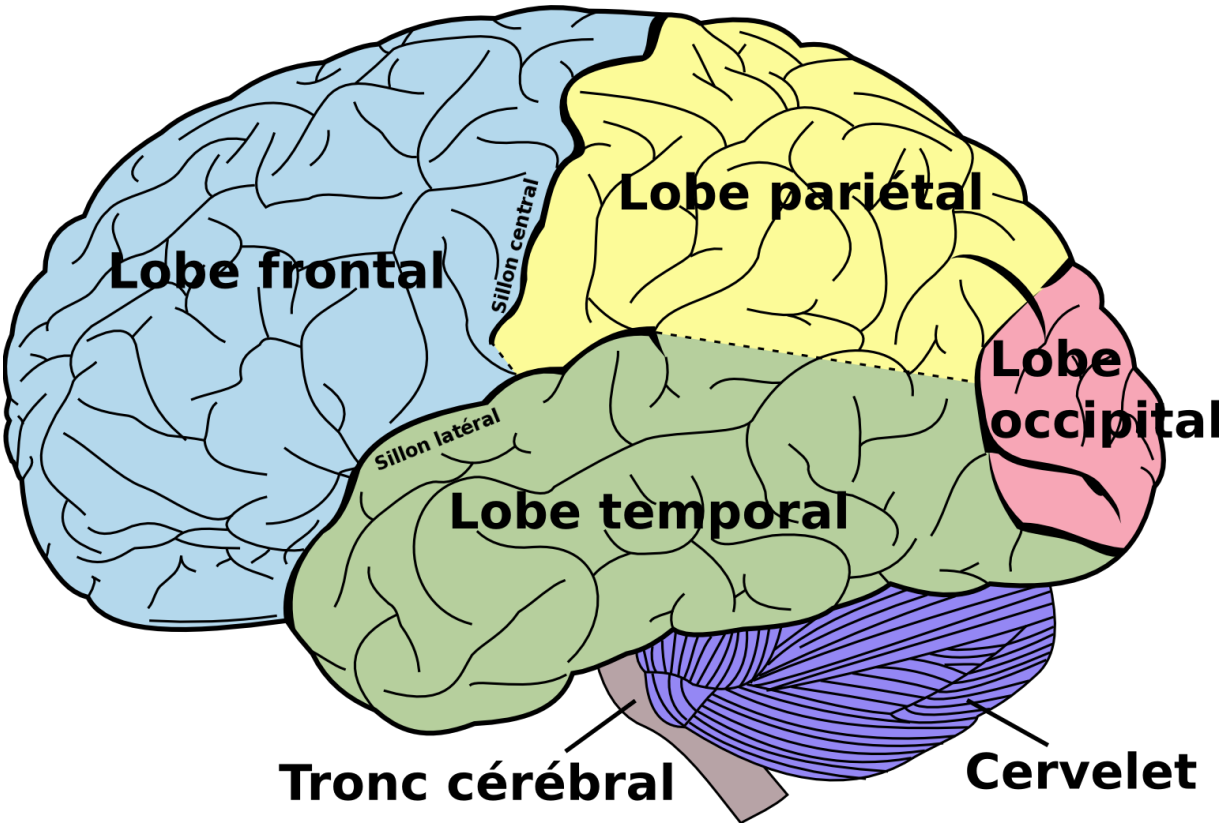
Entorhinal Cortex (ER)



- Storage of memories about events, objects
- Amygdala, hippocampus

Parietal lobe

- Caudal to frontal lobe
- Dorsal to temporal lobe
- Posterior to central sulcus



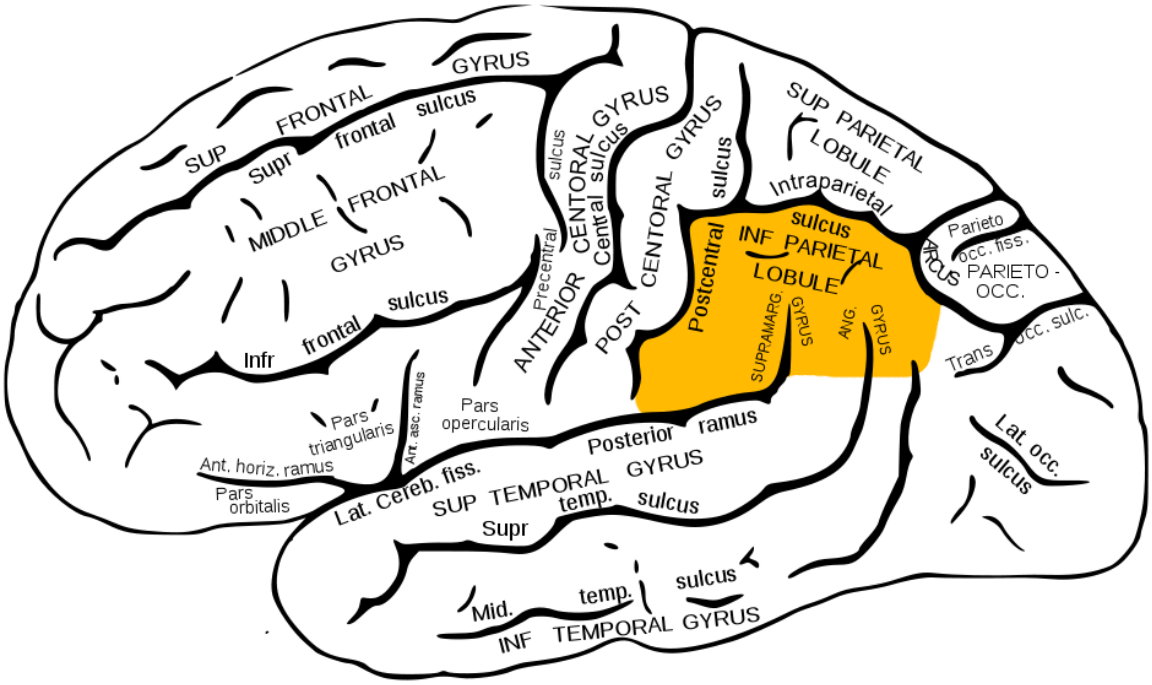
- Primary somatosensory cortex (S-I or S1)
    - information from sensors in skin, muscles, tendons, joints and viscera
- Post-central gyrus

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

https://en.wikipedia.org/wiki/Postcentral_gyrus
(https://en.wikipedia.org/wiki/Postcentral_gyrus)

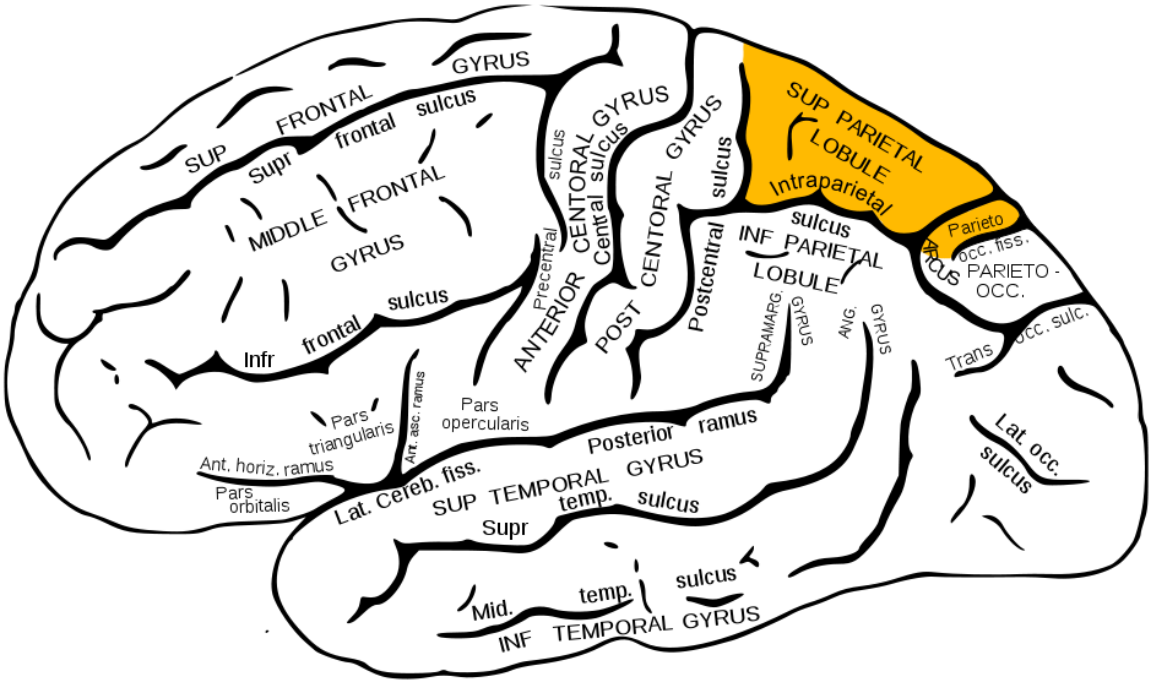
- Perception of spatial relations, action planning

Inferior Parietal Lobule



- e.g., language, mathematical operations, body image, etc.

Superior Parietal Lobule

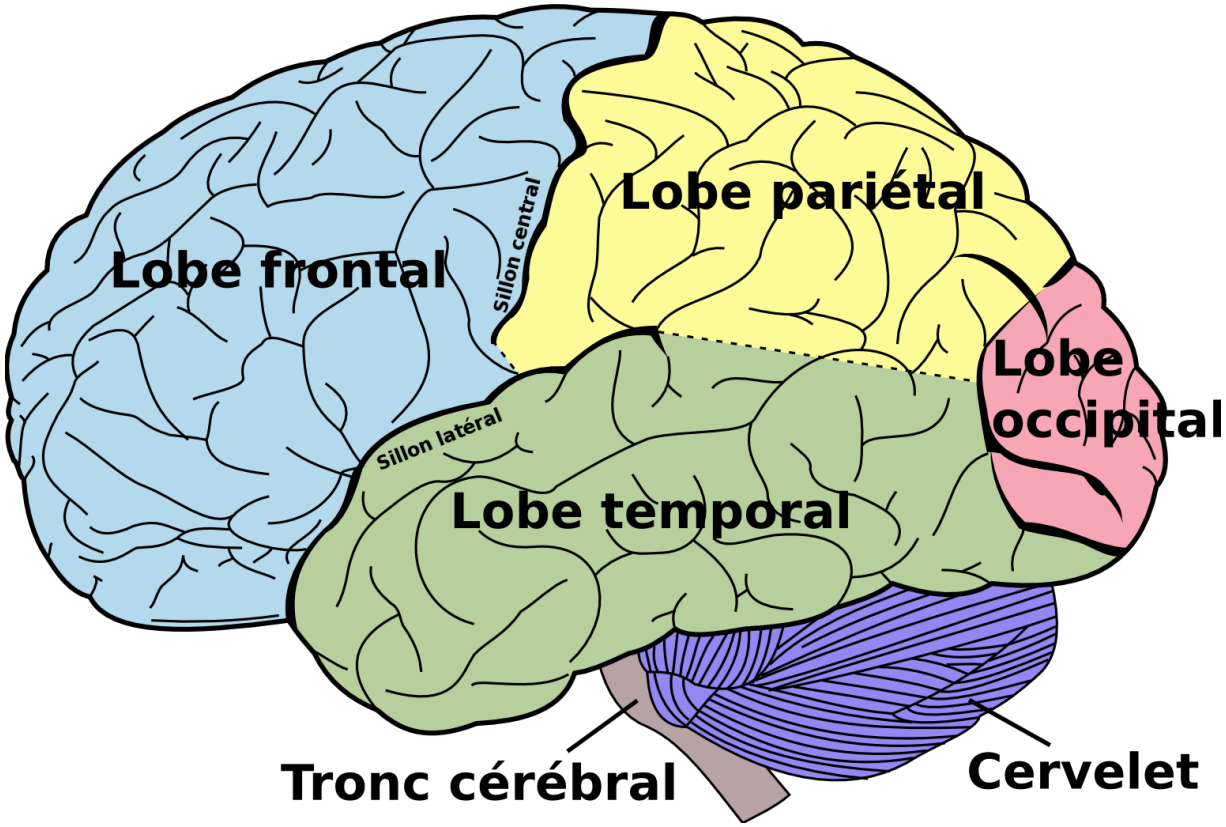


- damage to can cause spatial hemi-neglect

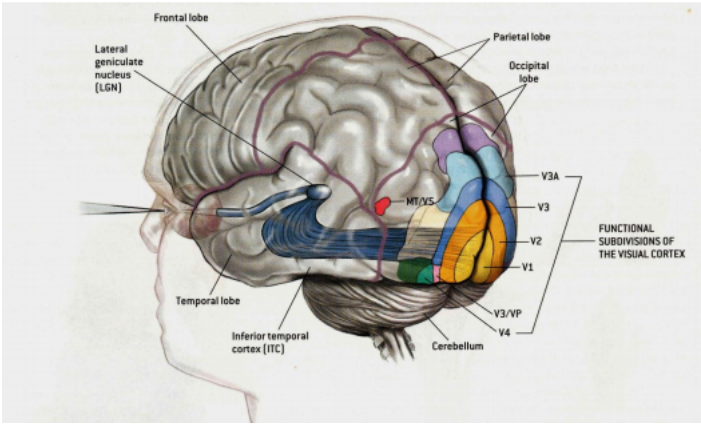
https://en.wikipedia.org/wiki/Superior_parietal_lobule (https://en.wikipedia.org/wiki/Superior_parietal_lobule)

Occipital lobe

- Caudal to parietal & temporal lobes

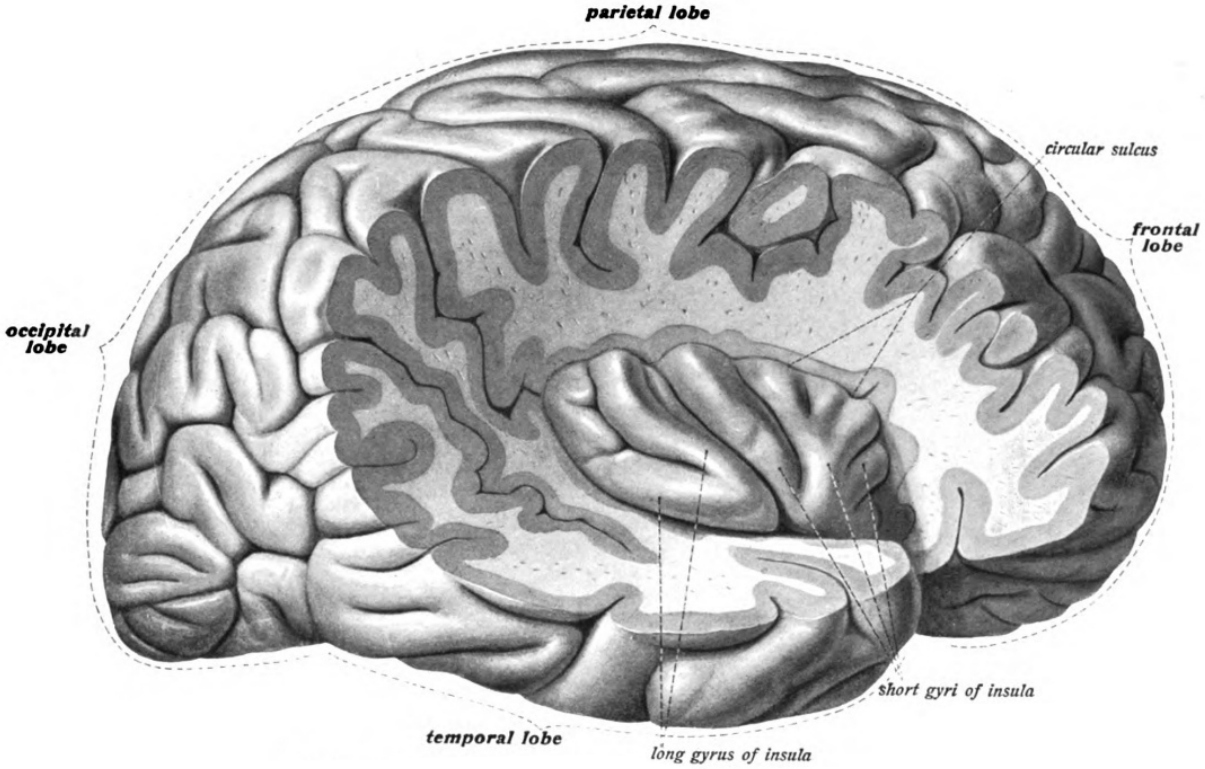


- Primary visual cortex (V1)
- Secondary visual areas (V2…V7)



Insular cortex (insula)

- medial to temporal lobe
- deep inside lateral fissure

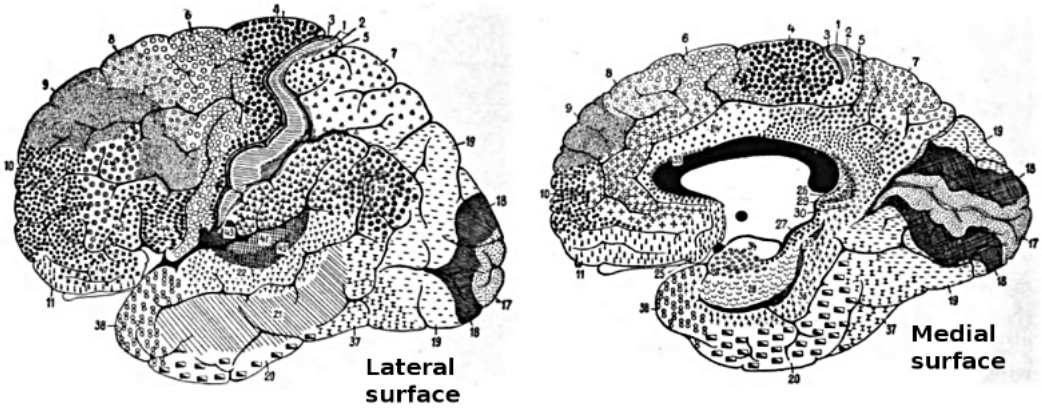


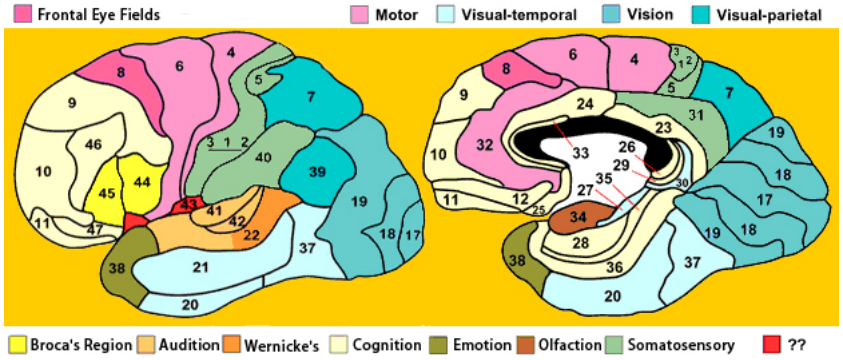
- Primary gustatory cortex
- Self-awareness, interpersonal experiences, motor control, interoception

Brodmann Areas

- Korbinian Brodmann (https://en.wikipedia.org/wiki/Korbinian_Brodmann)

- Cytoarchitectonic (cellular architecture) differences in cerebral cortex
- Numbered areas, e.g. V1 == Area 17





White matter pathways

- Brainstem
- Projection fibers
- Association fibers
- Commissural fibers

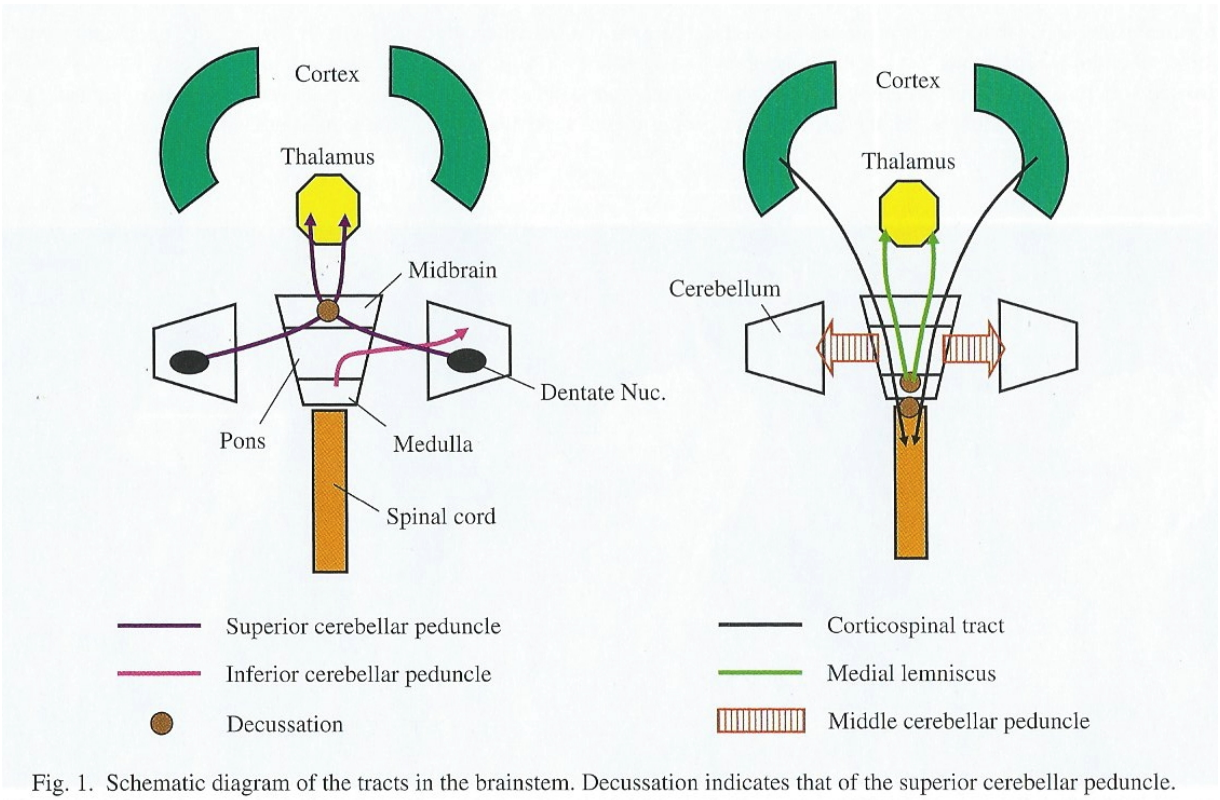


Fig. 1. Schematic diagram of the tracts in the brainstem. Decussation indicates that of the superior cerebellar peduncle.

(Oishi, Faria, Zijl, & Mori, 2010) (https://books.google.com/books?hl=en&lr=&id=v8MWjTpVUAYC&oi=fnd&pg=PT1&dq=mri+atlas+of+human+white+matter&ots=mV146FEVap1Gr77XIw7U#v=onepage&q=mri%20atlas%20of%20human%20white%20matter&f=false), Chapter 3, Figure 1.

Brainstem projections

- Corticospinal tract (descending/efferent)
- Dorsal column/medial lemniscus (ascending/afferent)
- Superior/inferior cerebellar peduncles (from/to cerebellum)

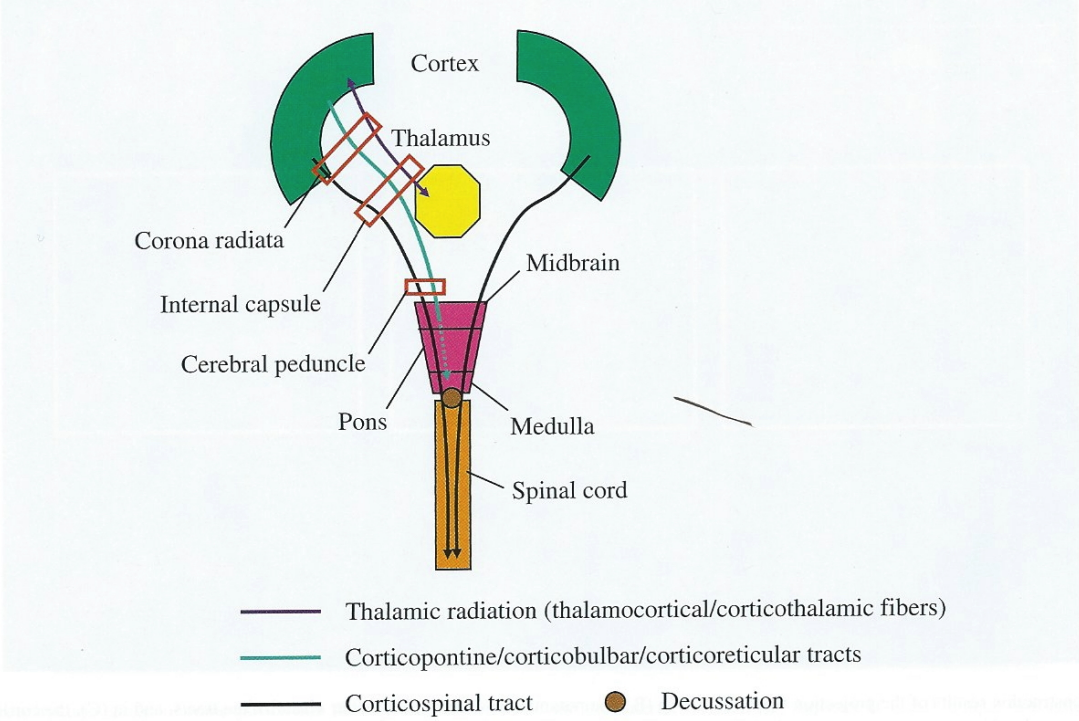


Fig. 8. A schematic diagram of trajectories of projection fibers reconstructed in this atlas. The decussation is that of the corticospinal tract.

(Oishi, Faria, Zijl, & Mori, 2010) (https://books.google.com/books?hl=en&lr=&id=v8MWjTpVUAYC&oi=fnd&pg=PT1&dq=mri+atlas+of+human+white+matter&ots=mV146FEVap1Gr77XIw7U#v=onepage&q=mri%20atlas%20of%20human%20white%20matter&f=false), Chapter 3, Figure 8.

Projection fiber tracts

- Internal capsule
  - Thalamic radiation
  - Cortico-{pontine, bulbar, reticular} tracts

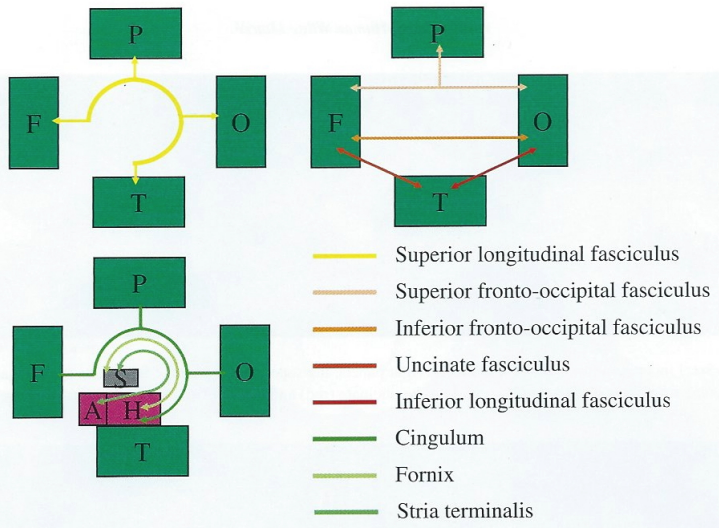


Fig. 11. A schematic diagram of some cortico-cortical connections by association fibers. Abbreviations are F, frontal, P, parietal, O, occipital, and T, temporal cortices, A, amigdala, H, hippocampus, S, septal area.

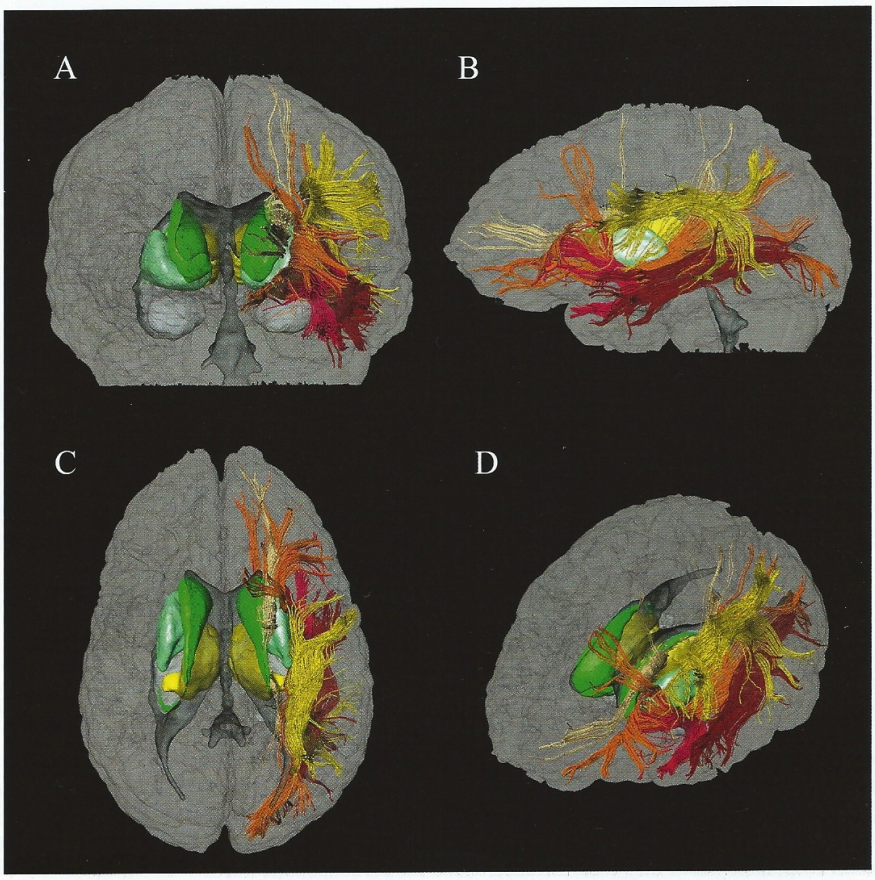


Fig. 12. 3D reconstruction results of some association fibers. Tracts are viewed from the anterior (A), left (B), superior (C), and oblique (left-antero-superior) (D) orientations. Color coding: slf is yellow, ifo is orange, unc is red, and ilf is brown. Cerebral hemispheres are delineated by semi-transparent gray. Thalami are yellow, ventricles are gray, caudate nuclei are green and lentiform nuclei are light green.

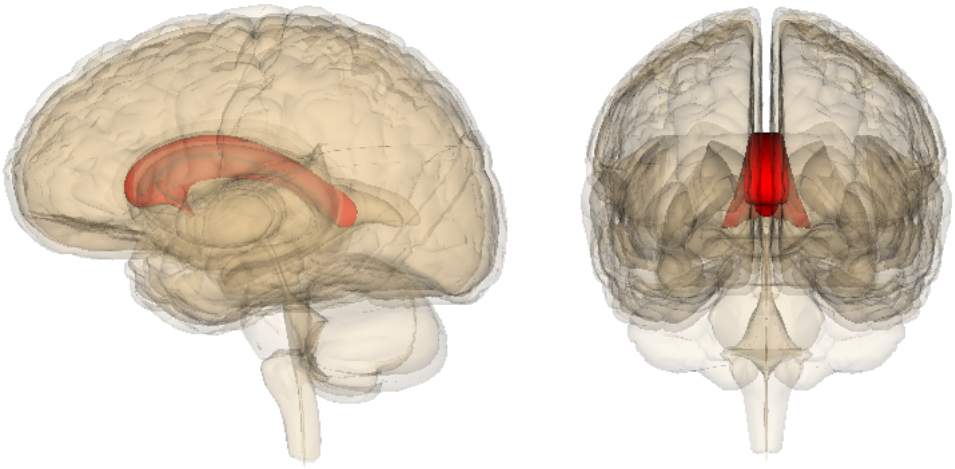
(Oishi, Faria, Zijl, & Mori, 2010) (https://books.google.com/books?hl=en&lr=&id=v8MWjTpVUAYC&oi=fnd&pg=PT1&dq=mri+atlas+of+human+white+matter&ots=mV146FEVap1Gr77XIw7U#v=onepage&q=mri%20atlas%20of%20human%20white%20matter&f=false), Chapter 3, Figure 11.

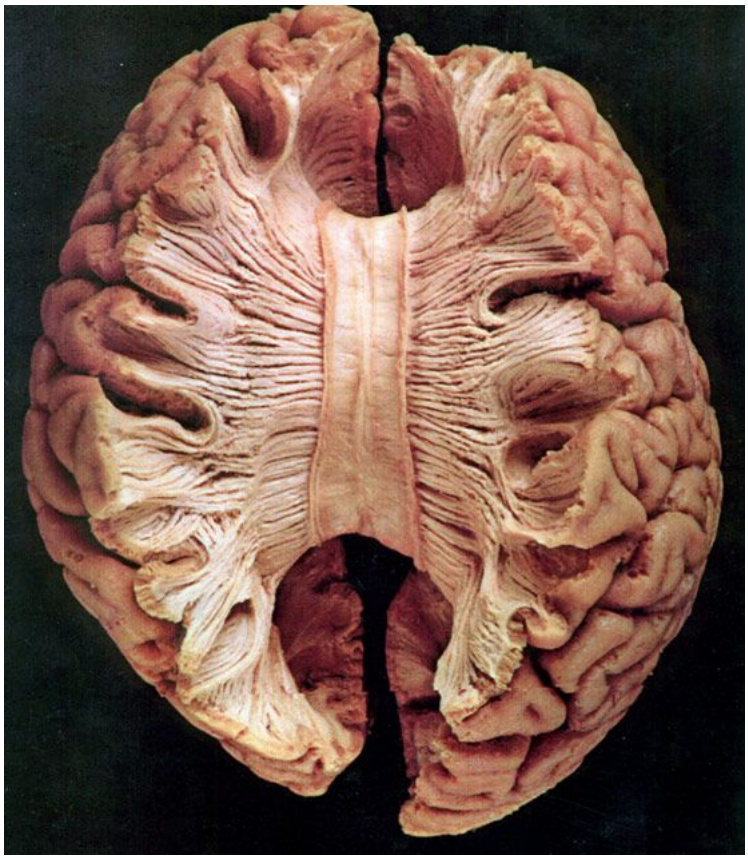
Cortical white matter tracts

- Superior/inferior longitudinal fasciculus
  - Arcuate fasciculus (https://en.wikipedia.org/wiki/Arcuate_fasciculus) part of sup. long. f.
- Superior/inferior fronto-occipital fasciculus
- Cingulum, fornix (hyp-hip), stria terminalis (hyp-amyg)

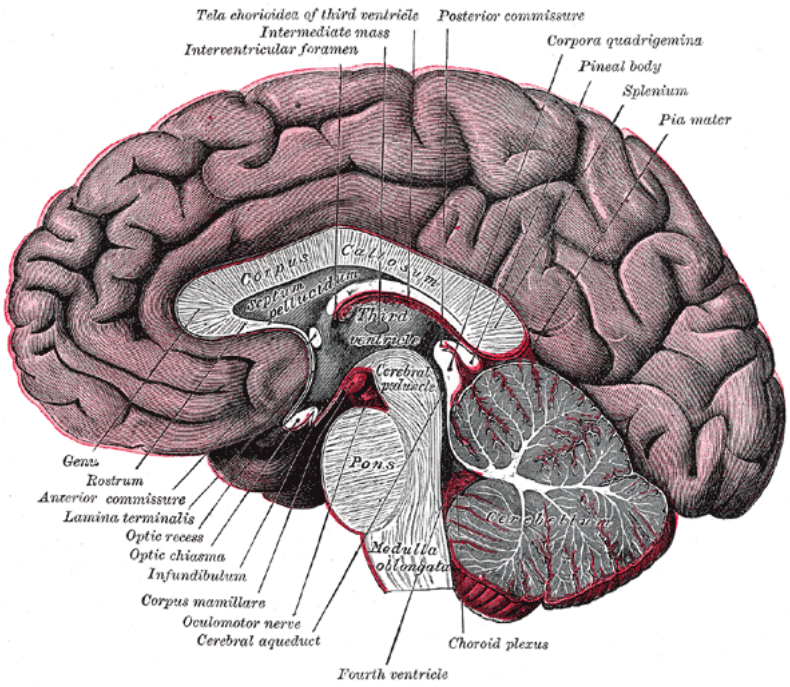
Commissural fibers

- Corpus callosum
- Anterior commissure (AC)
- Posterior commissure (PC)



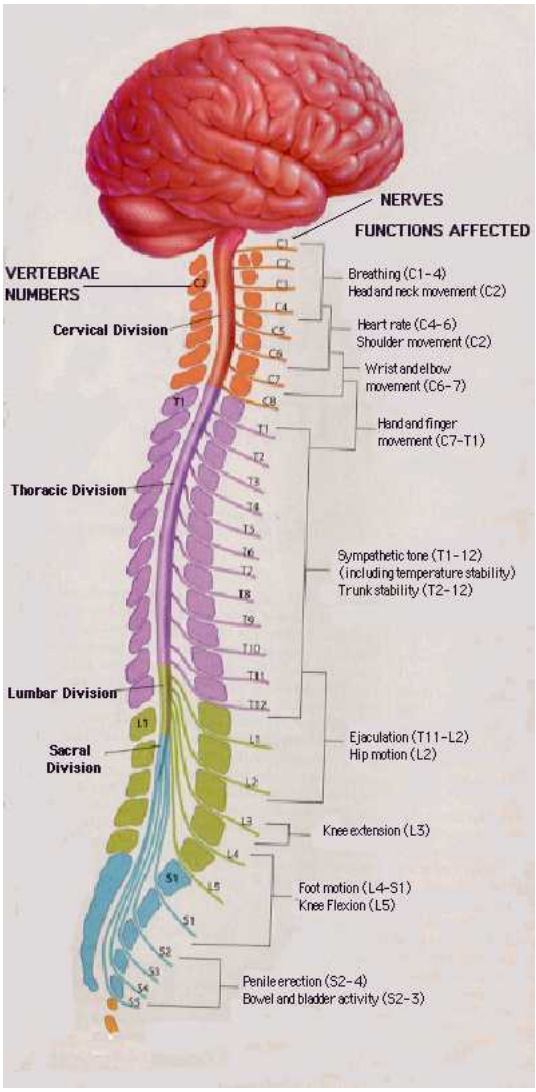


Anterior, Posterior Commissures

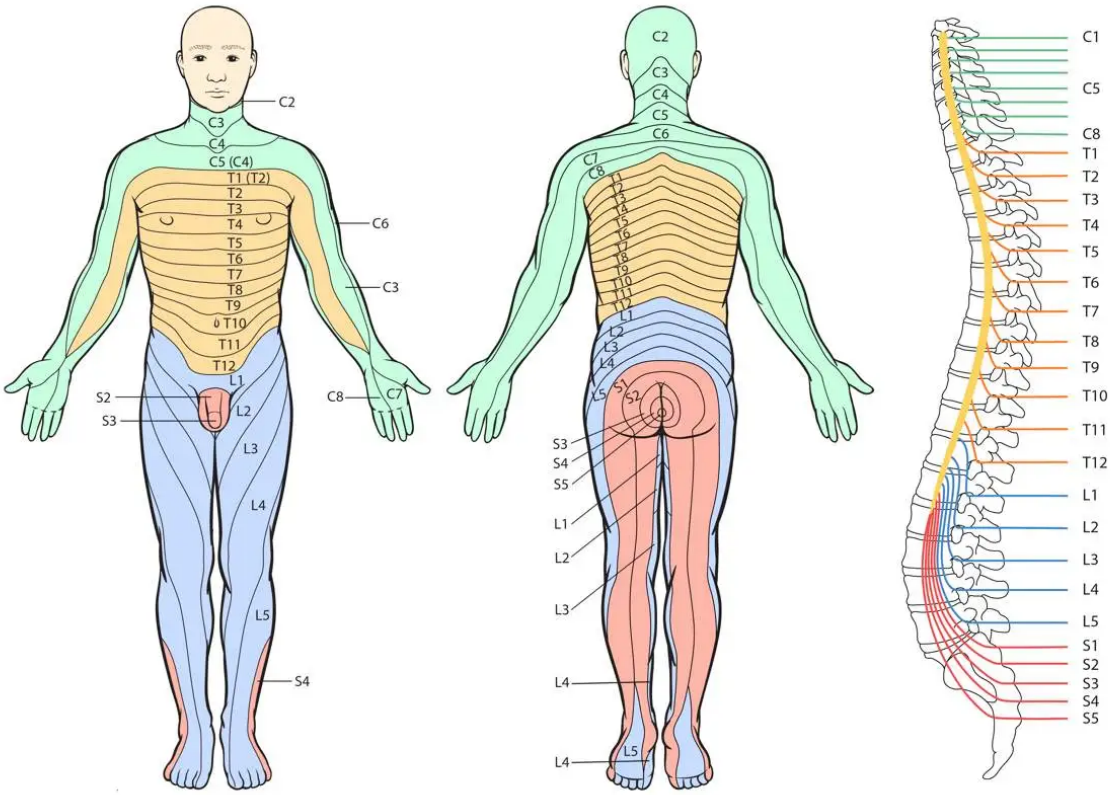


Spinal cord

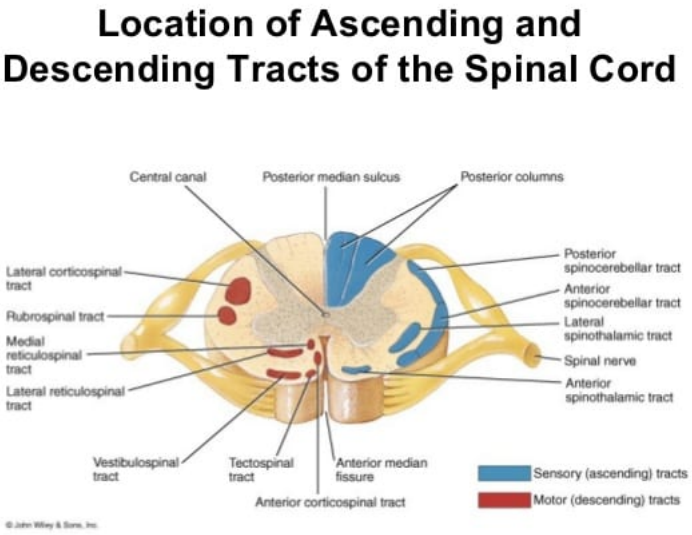
- Spinal column w/ vertebrae
- Moving rostral -> caudal…
- Cervical (8), thoracic (12), lumbar (5), sacral (5), coccygeal (1)
- Spinal segments & 31 nerve pairs
- Cauda equina

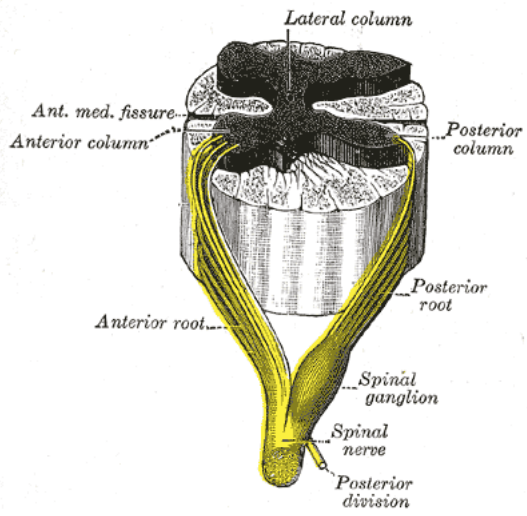


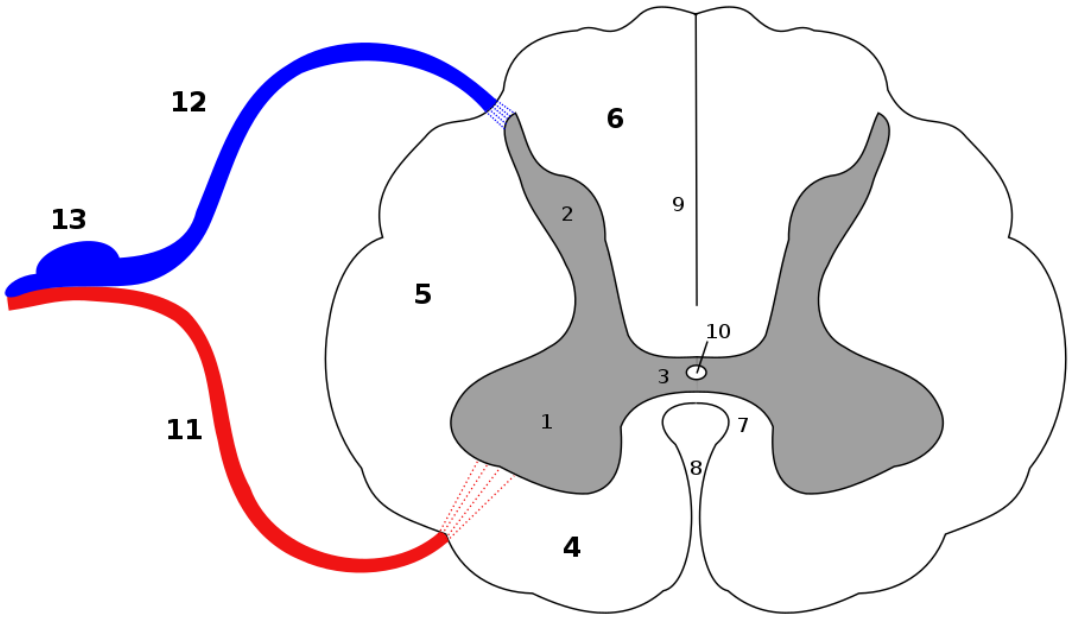
- Spinal segments (rostral to caudal) ennervate specific body segments
- When focusing on the skin, these are called *dermatomes*



- Dorsal/Ventral
  - Dorsal root (sensory)
  - Ventral root (mostly motor)
- Grey (interior) vs. white matter (exterior)
  - Cerebral cortex opposite (grey exterior, white interior)







Gray matter	White matter	
1. Anterior horn	4. Anterior funiculus	10. Central canal
2. Posterior horn	5. Lateral funiculus	11. Anterior root
3. Gray commisure	6. Posterior funiculus	12. Posterior root
	7. Anterior commisure	13. Dorsal root ganglion
	8. Anterior median fissure	
	9. Posterior median sulcus	

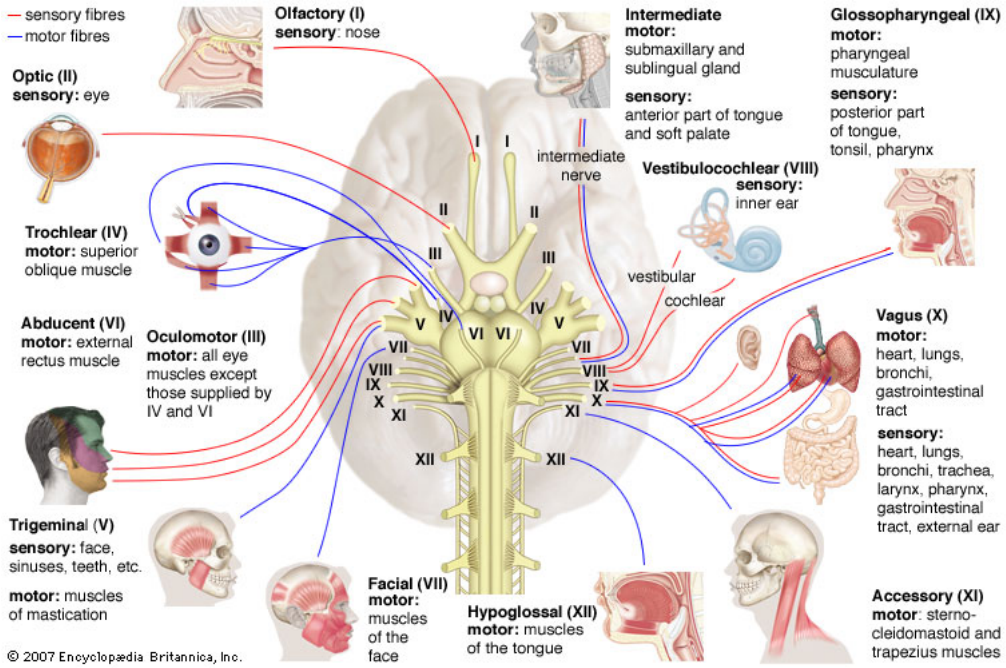
Organization of the PNS

- Somatic division
- Autonomic division (Autonomic Nervous System)

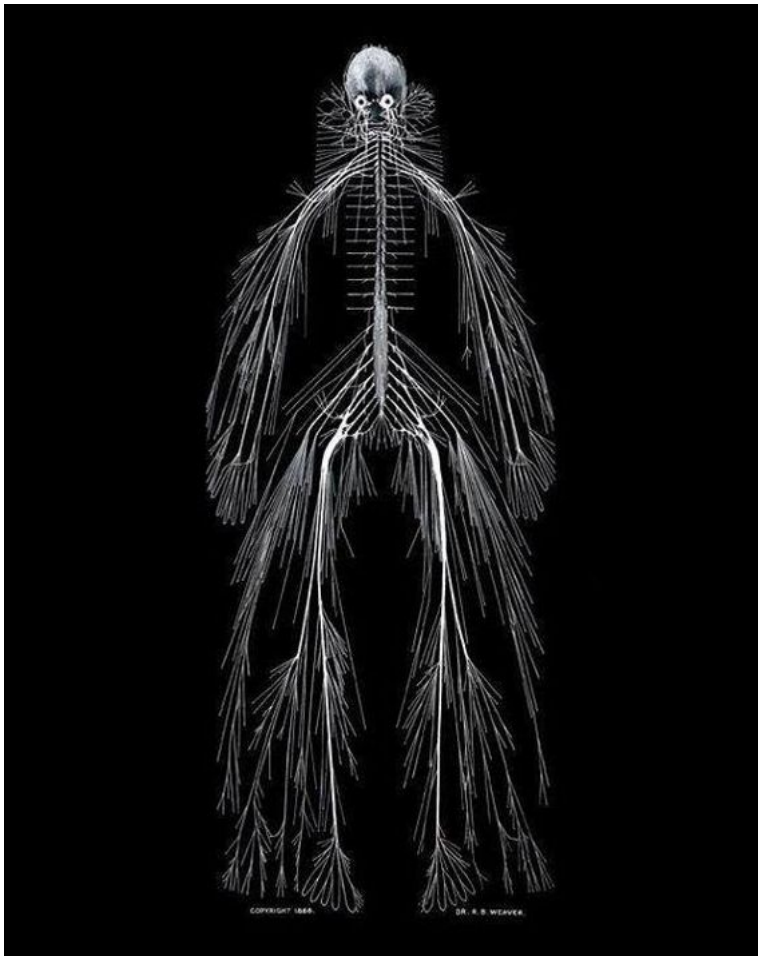
Somatic division

Cranial nerves

- Afferents (input), efferents (output), or mixed
- Innervate head and neck
- Olfactory (I), optic (II), (VIII) auditory, vagus (X), etc.
- Spinal nerves

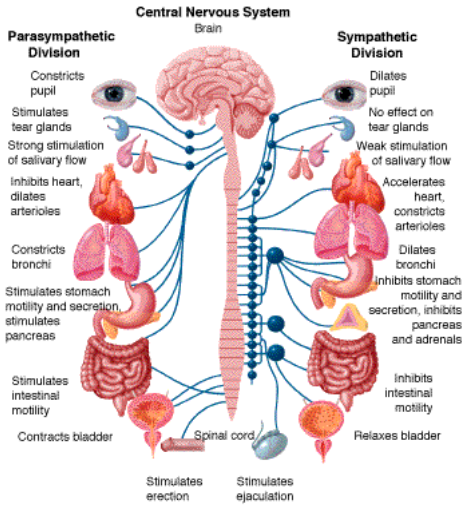


Spinal nerves

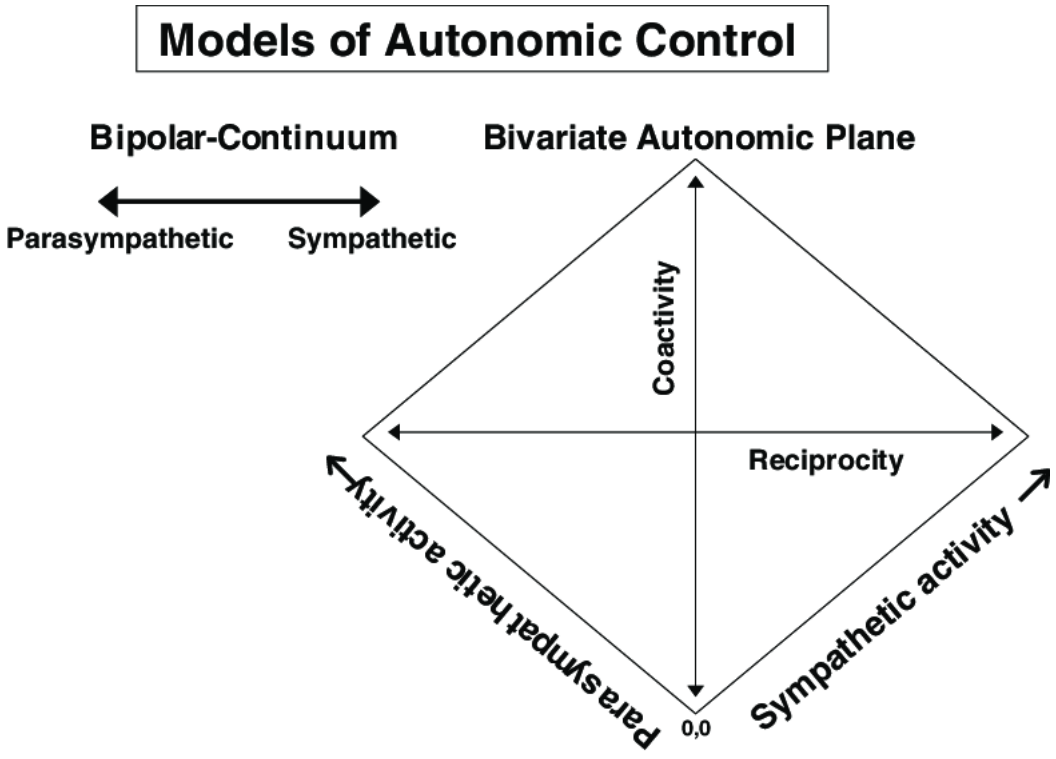


Autonomic nervous system

- CNS & PNS components
- Controls “vegetative functions”
  - Limited voluntary control
- Two divisions
  - Sympathetic
  - Parasympathetic



- Bipolar (continuum) vs. bivariate autonomic space (Berntson, Cacioppo, & Quigley, 1991) (https://www.ncbi.nlm.nih.gov/pubmed/1660159)



Sympathetic division

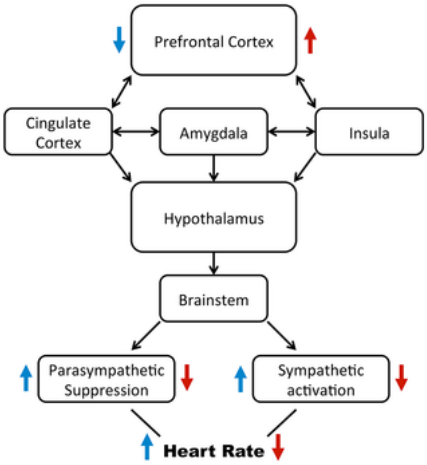
- Prepares body for action
- “Fight or flight”
- Spinal cord
  - ganglion chain along spinal column to End organs
- Neurotransmitters (NTs)
  - Preganglionic: ACh
  - Post: NE

Parasympathetic division

- “Around” sympathetic
- Restorative function
- “Rest & digest”
- Spinal cord (or Vagus n. from Xth cranial n.) -> ganglia near end organs -> end organ
  - NT: ACh

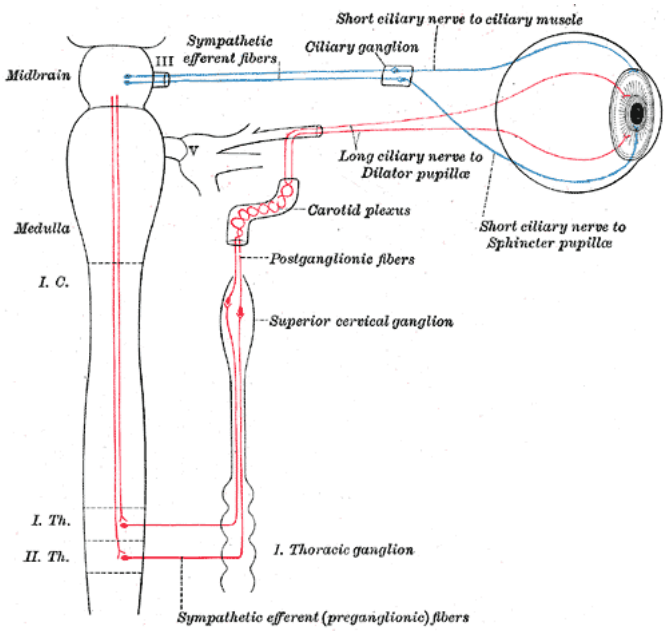
Measures of ANS function

- Heart rate variability



https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral_integration_model.pn
Neurovisceral_integration_model.png
(https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral_integration_model.p
Neurovisceral_integration_model.png)

- Galvanic skin response (GSR)
- Pupillary response (https://en.wikipedia.org/wiki/Pupillary_response)



https://upload.wikimedia.org/wikipedia/commons/a/a5/Gray840.png
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References

Abbott, N. J., Rönnbäck, L., & Hansson, E. (2006). Astrocyte-endothelial interactions at the blood-brain barrier. *Nature Reviews. Neuroscience*, *7*(1), 41–53. https://doi.org/10.1038/nrn1824 (https://doi.org/10.1038/nrn1824)

Begg, D. P., & Woods, S. C. (2013). The endocrinology of food intake. *Nature Reviews. Endocrinology*, *9*(10), 584–597. https://doi.org/10.1038/nrendo.2013.136 (https://doi.org/10.1038/nrendo.2013.136)

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1991). Autonomic determinism: The modes of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological Review*, *98*(4), 459–487. https://doi.org/10.1037/0033-295X.98.4.459 (https://doi.org/10.1037/0033-295X.98.4.459)

LeDoux, J. (2015, August 10). The Amygdala Is NOT the Brain's Fear Center. *Psychology Today*. Retrieved from https://www.psychologytoday.com/blog/i-got-mind-tell-you/201508/the-amygdala-is-not-the-brains-fear-center (https://www.psychologytoday.com/blog/i-got-mind-tell-you/201508/the-amygdala-is-not-the-brains-fear-center)

Oishi, K., Faria, A. V., Zijl, P. C. van, & Mori, S. (2010). *MRI atlas of human white matter*. Academic Press.

Saive, A.-L., Royet, J.-P., & Plailly, J. (2014). A review on the neural bases of episodic odor memory: From laboratory-based to autobiographical approaches. *Frontiers in Behavioral Neuroscience*, *8*, 240. https://doi.org/10.3389/fnbeh.2014.00240 (https://doi.org/10.3389/fnbeh.2014.00240)

Xie, L., Kang, H., Xu, Q., Chen, M. J., Liao, Y., Thiyagarajan, M., … others. (2013). Sleep drives metabolite clearance from the adult brain. *Science*, *342*(6156), 373–377. https://doi.org/10.1126/science.1241224 (https://doi.org/10.1126/science.1241224)