

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

## Neuroanatomy

Rick Gilmore

2021-09-17 08:43:05

- Fun
- Resources
  - Harvard Brain Atlas
  - Brain anatomy through dance
- Directional terms
  - Bipeds vs. quadripeds
  - Image axes
- Supporting structures
  - Meninges (outside -> in)
  - Ventricular system
  - Blood Supply
    - Blood/brain barrier
    - Area Postrema
- Organization of the Nervous System
- Organization of the CNS
  - Hindbrain
    - Medulla oblongata
    - Cerebellum
    - Pons
  - Midbrain
    - Tectum
    - Tegmentum
  - Forebrain
    - Diencephalon ('between brain')
      - Thalamus
      - Hypothalamus
    - Telencephalon
      - Basal Ganglia
      - Hippocampus
      - Amygdala ("almond")
      - Cerebral Cortex
        - Lobes of the cerebral cortex
        - Frontal lobe
        - Temporal lobe
        - Parietal lobe

- Occipital lobe
- Insular cortex (insula)
- Brodmann Areas
- White matter pathways
  - Brainstem projections
  - Projection fiber tracts
  - Cortical white matter tracts
  - Commissural fibers
- Spinal cord
- Organization of the PNS
  - Somatic division
    - Cranial nerves
    - Spinal nerves
  - Autonomic nervous system
    - Sympathetic division
    - Parasympathetic division
    - Measures of ANS function
  - References

---

## Fun

pinky and the brain-brainstem

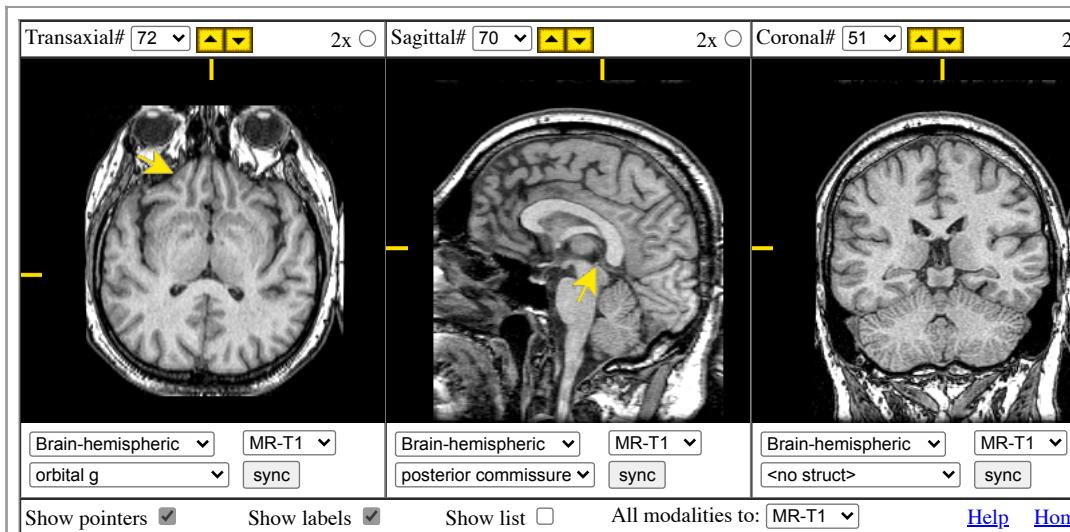


Human Body for Kids/Brain Song/Human Body Systems



## Resources

# Harvard Brain Atlas



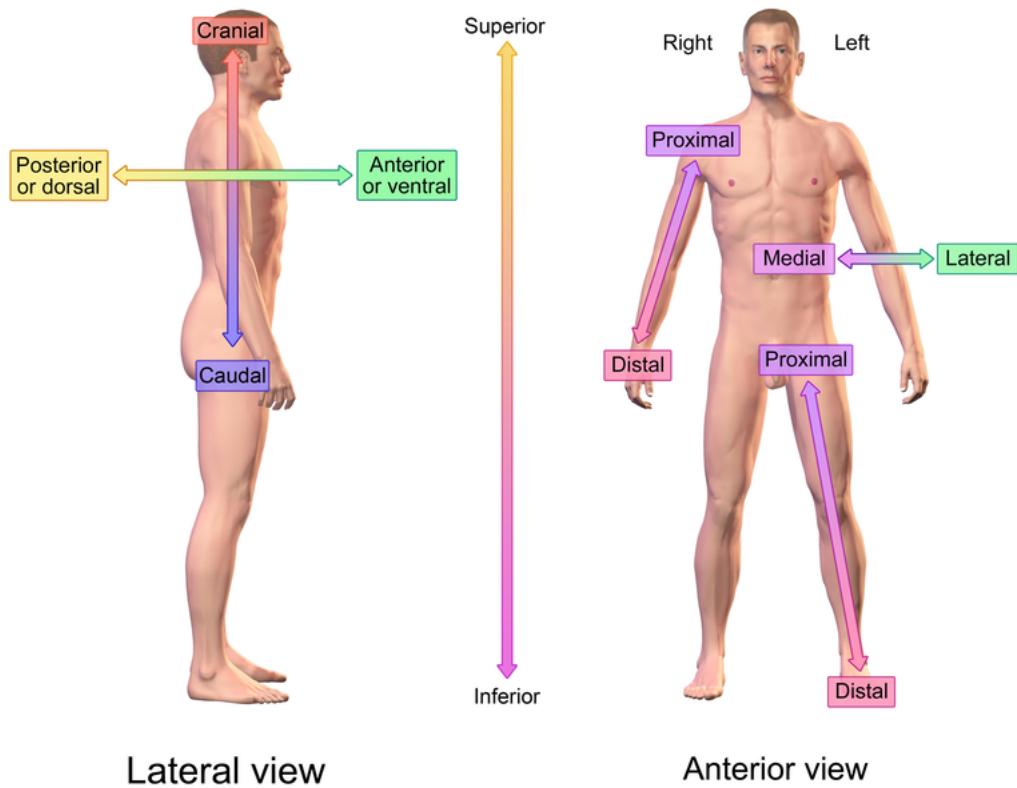
[\(http://www.med.harvard.edu/aanlib/cases/caseNA/pb9.htm\)](http://www.med.harvard.edu/aanlib/cases/caseNA/pb9.htm)

## Brain anatomy through dance

0:00 / 0:24

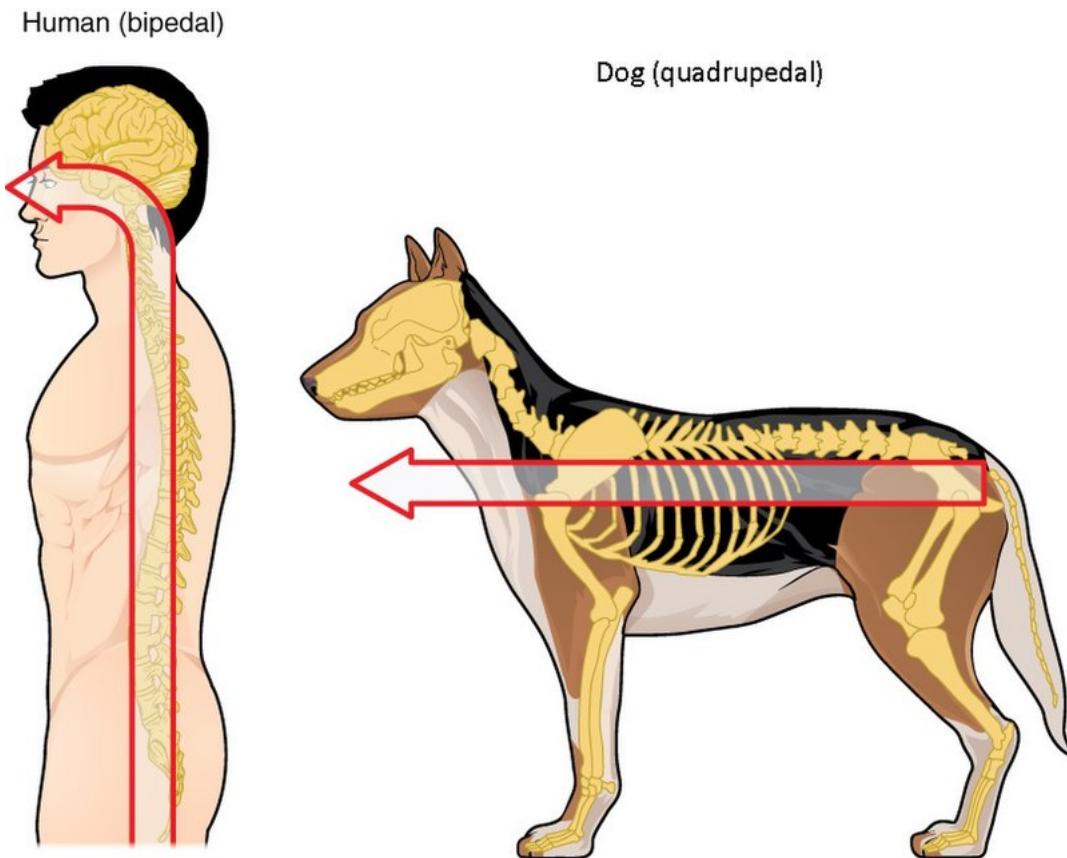
## Directional terms

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



## Directional References

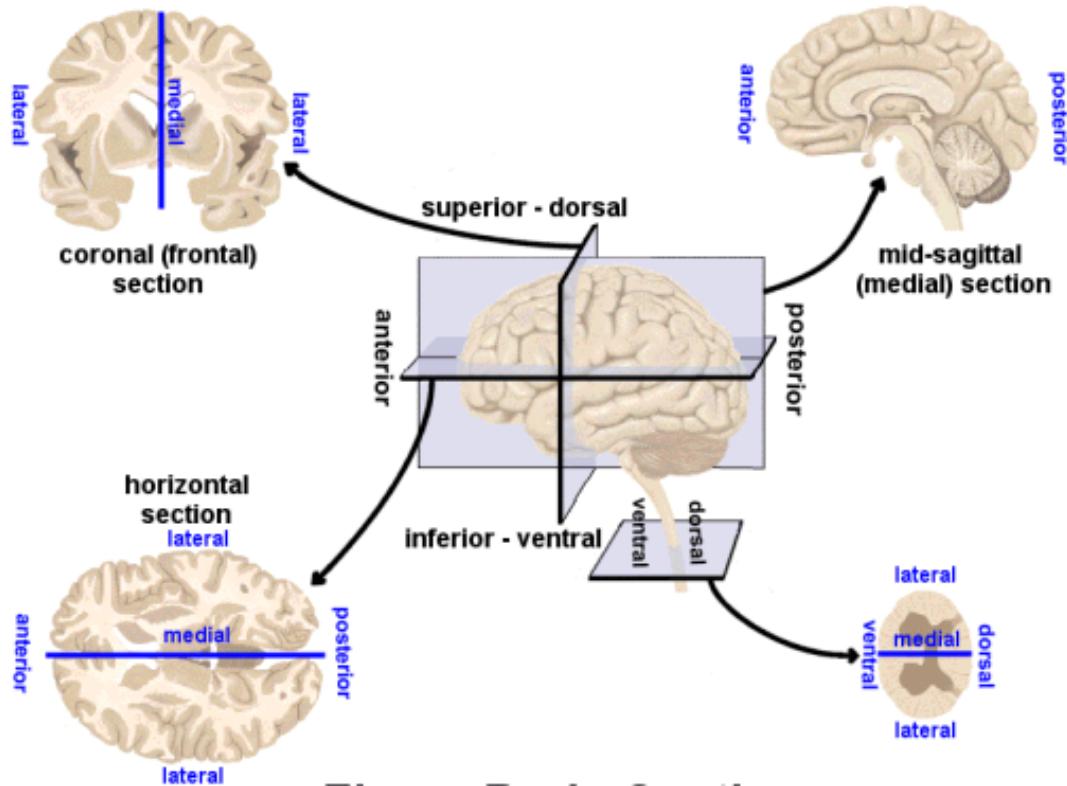
### Bipeds vs. quadrupeds



[https://upload.wikimedia.org/wikipedia/commons/thumb/0/00/1303\\_Human\\_Neuroaxis.jpg/800px-1303\\_Human\\_Neuroaxis.jpg](https://upload.wikimedia.org/wikipedia/commons/thumb/0/00/1303_Human_Neuroaxis.jpg/800px-1303_Human_Neuroaxis.jpg)  
[https://upload.wikimedia.org/wikipedia/commons/thumb/0/00/1303\\_Human\\_Neuroaxis.jpg/800px-1303\\_Human\\_Neuroaxis.jpg](https://upload.wikimedia.org/wikipedia/commons/thumb/0/00/1303_Human_Neuroaxis.jpg/800px-1303_Human_Neuroaxis.jpg)

## Image axes

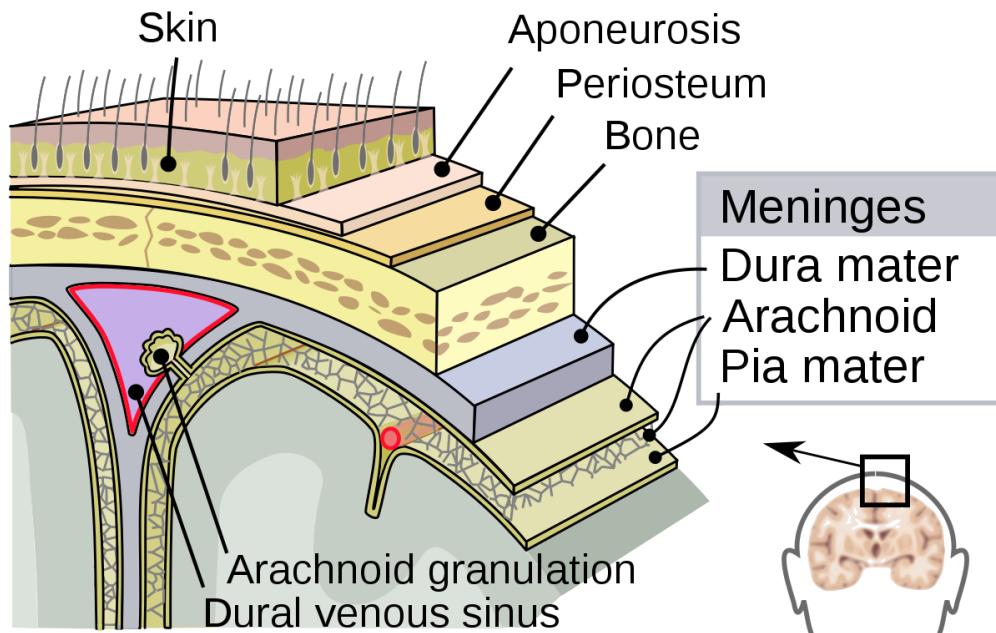
- Horizontal/Axial
- Coronal/Transverse/Frontal
- Sagittal (from the side)



## Supporting structures

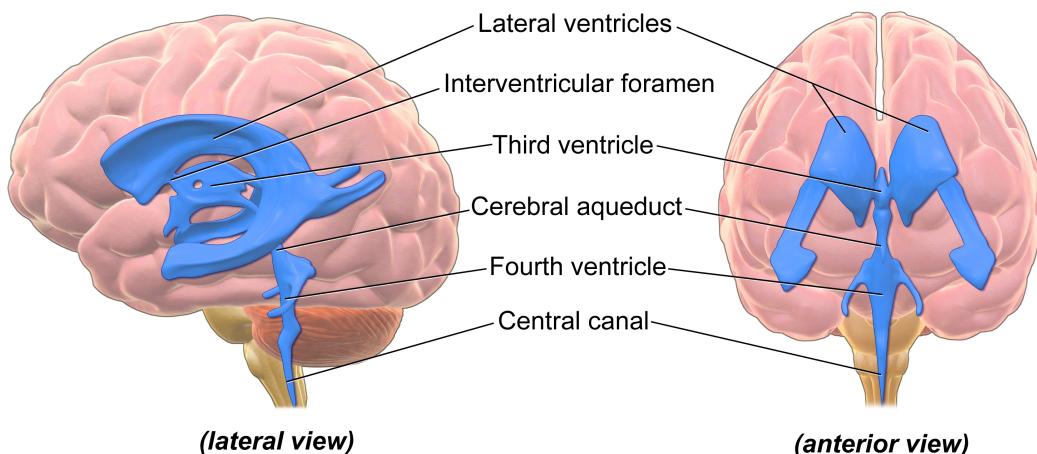
### Meninges (outside -> in)

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



## Ventricular system

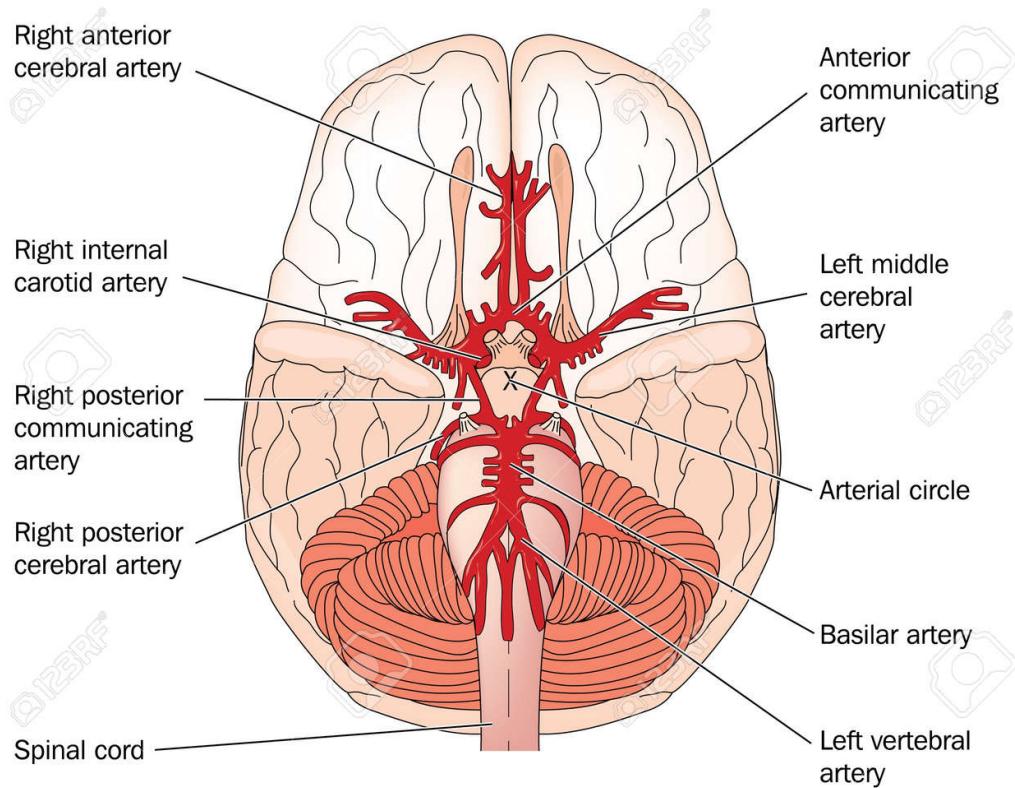
- Also known as cerebral ventricles
- Lateral (1st & 2nd)
  - Forebrain/telencephalon
- 3rd
  - Diencephalon
- Cerebral aqueduct
  - Midbrain
- 4th
  - Hindbrain



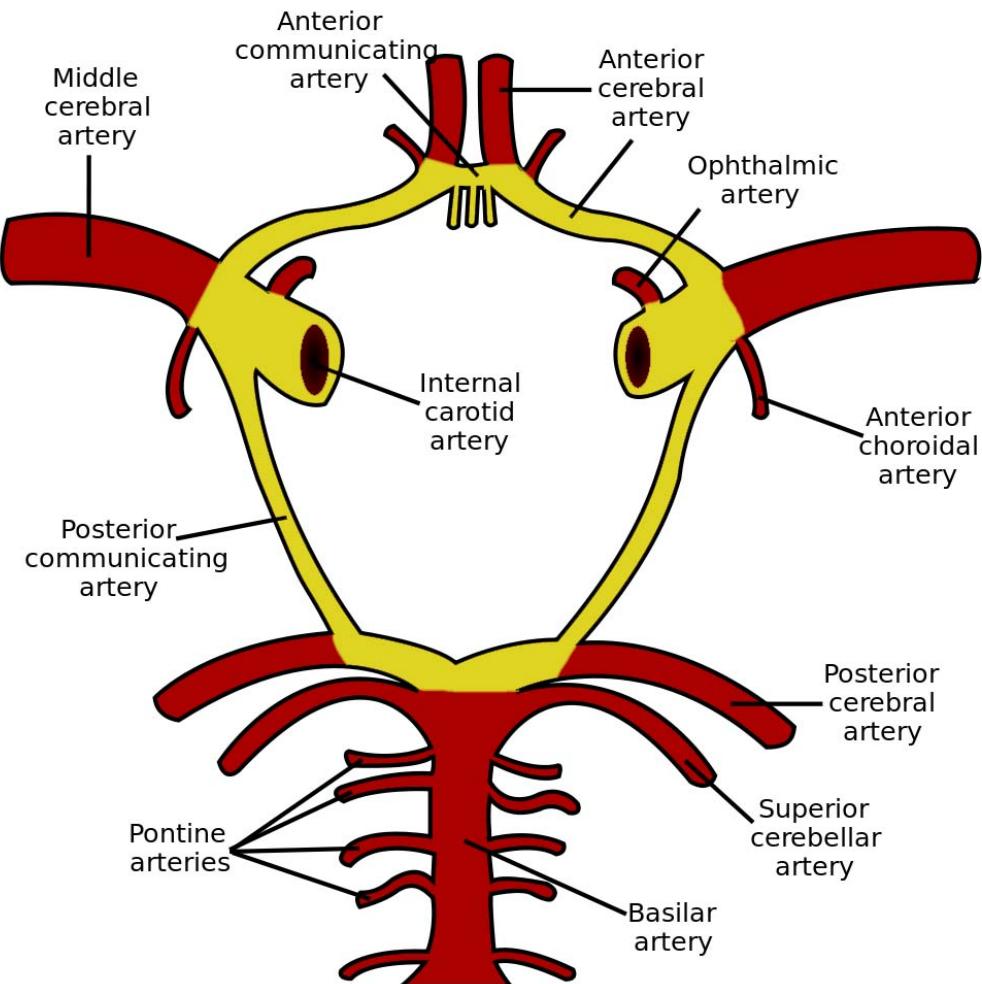
- Ventricles filled with CSF
  - CSF clears metabolites during sleep (Xie et al., 2013)?
  - Blockage of CSF flow → hydrocephalus

# Blood Supply

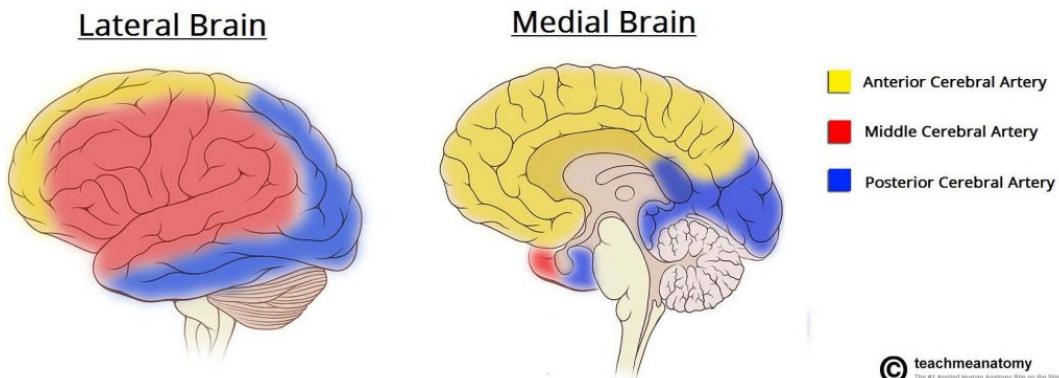
- Carotid & basilar arteries converge on Circle of Willis
- Anterior, Middle, and Posterior Cerebral arteries main output



[\(https://previews.123rf.com/images/hfsimaging/hfsimaging1208/hfsimaging120800005/14672522-drawing-of-the-blood-vessels-at-the-base-of-the-brain-called-the-circle-of-willis.jpg\)](https://previews.123rf.com/images/hfsimaging/hfsimaging1208/hfsimaging120800005/14672522-drawing-of-the-blood-vessels-at-the-base-of-the-brain-called-the-circle-of-willis.jpg)



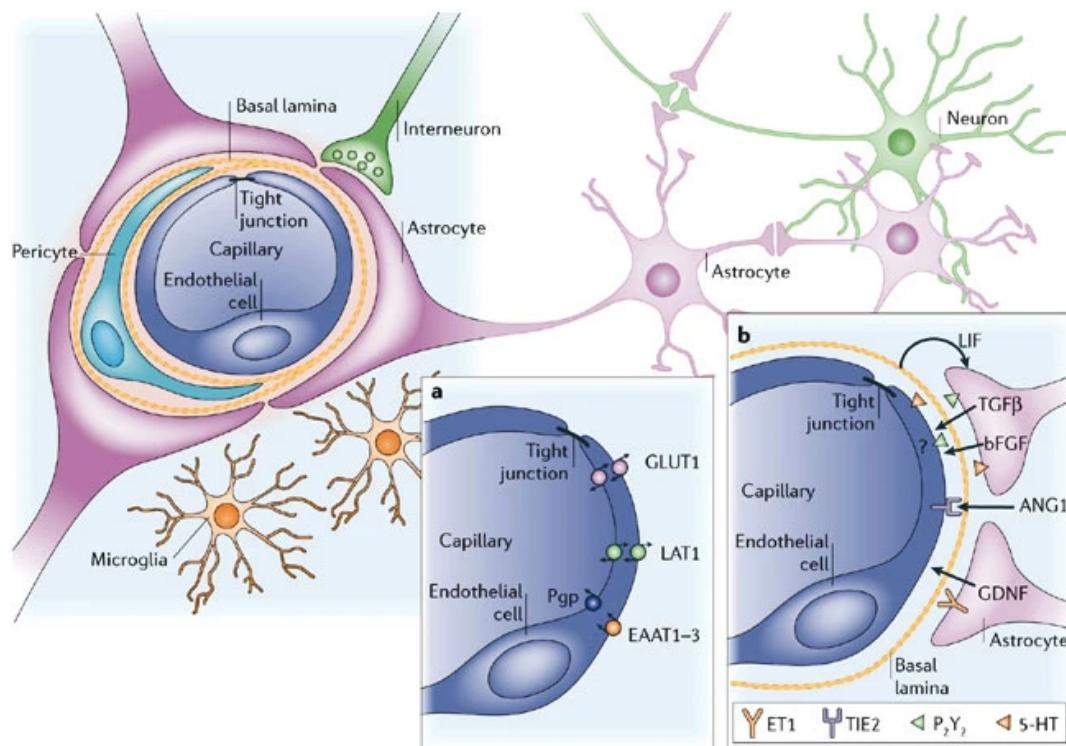
<https://teachmeanatomy.info/wp-content/uploads/Schematic-of-the-Circle-of-Willis.jpg>  
[\(https://teachmeanatomy.info/wp-content/uploads/Schematic-of-the-Circle-of-Willis.jpg\)](https://teachmeanatomy.info/wp-content/uploads/Schematic-of-the-Circle-of-Willis.jpg)



<https://teachmeanatomy.info/wp-content/uploads/Regional-Blood-Supply-to-the-Cerebrum-1024x380.jpg> (https://teachmeanatomy.info/wp-content/uploads/Regional-Blood-Supply-to-the-Cerebrum-1024x380.jpg)

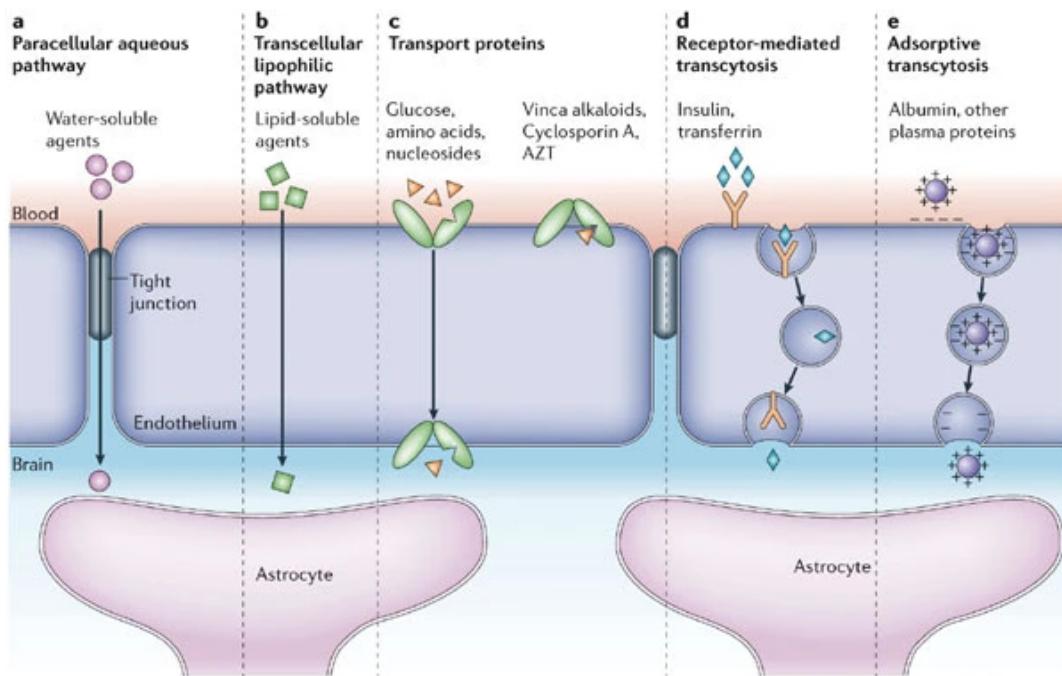
## Blood/brain barrier

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



Copyright © 2006 Nature Publishing Group  
Nature Reviews | Neuroscience

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

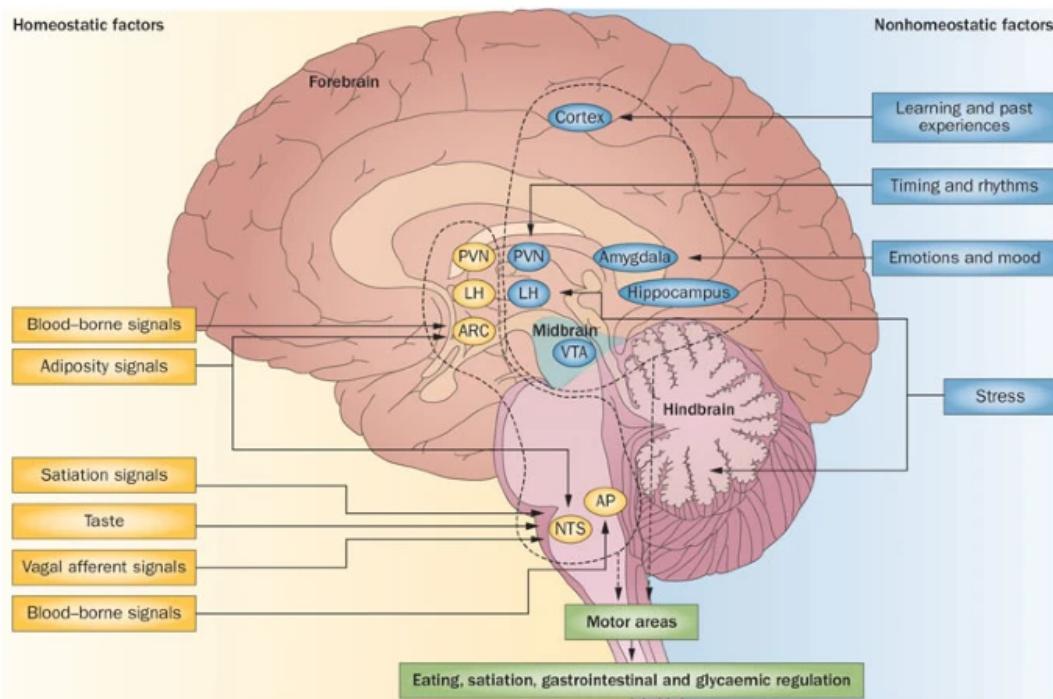


Copyright © 2005 Nature Publishing Group  
Nature Reviews | Neuroscience

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

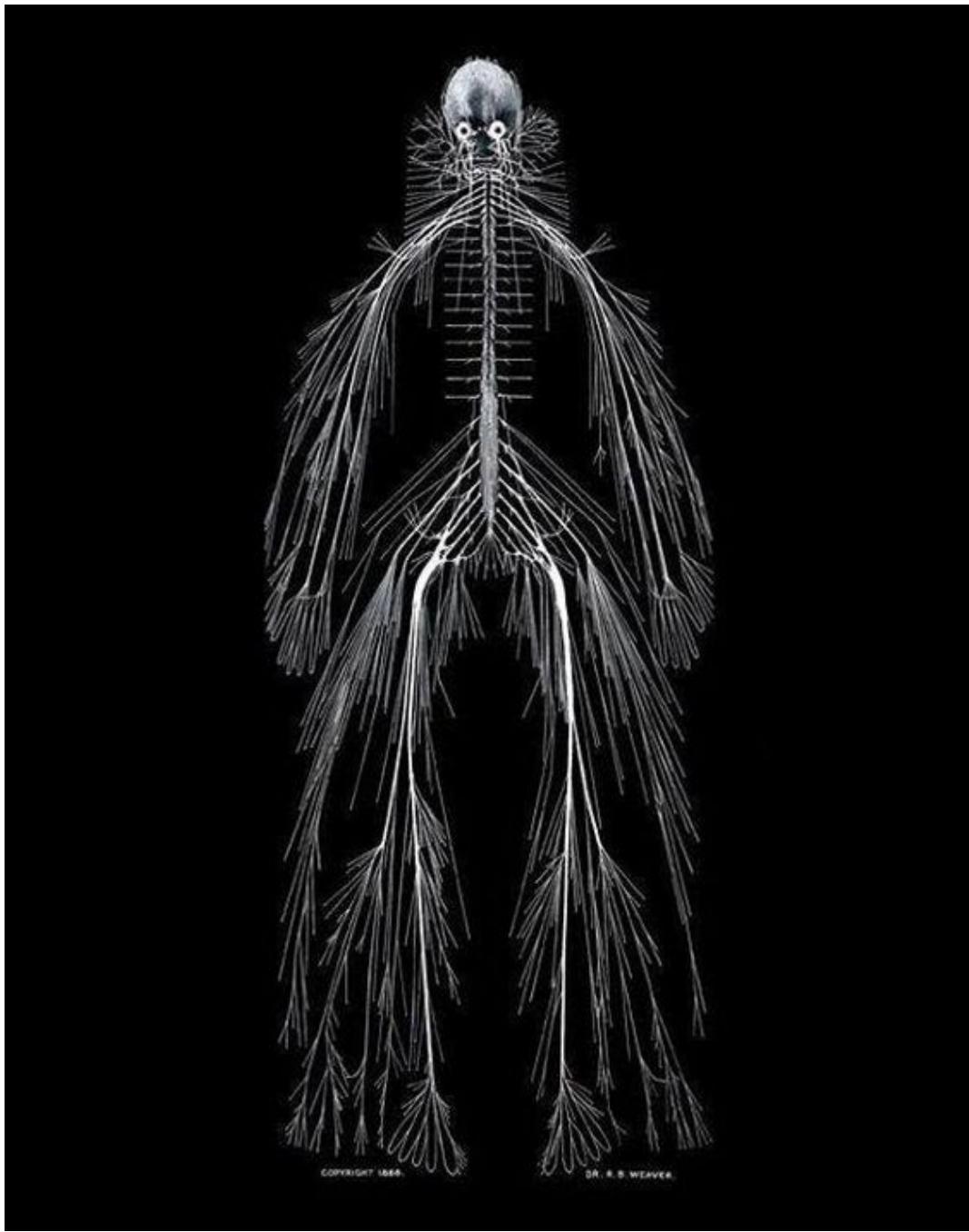
## Area Postrema

- 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



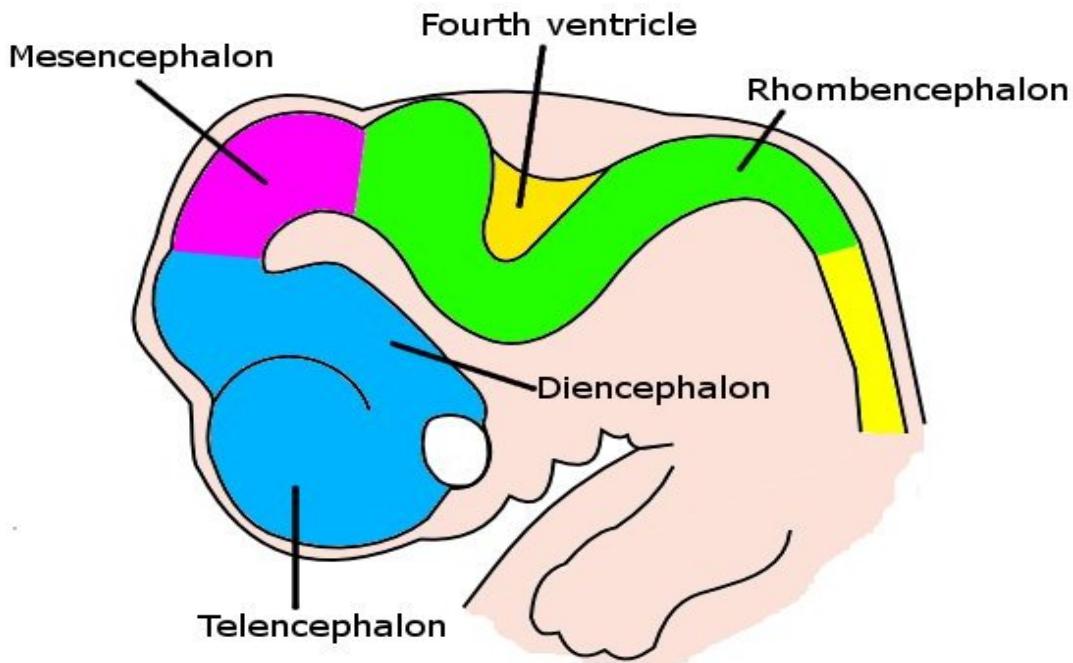
<https://www.pastmedicalhistory.co.uk/the-nervous-system-of-harriet-cole/>  
[\(https://www.pastmedicalhistory.co.uk/the-nervous-system-of-harriet-cole/\)](https://www.pastmedicalhistory.co.uk/the-nervous-system-of-harriet-cole/)

- 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

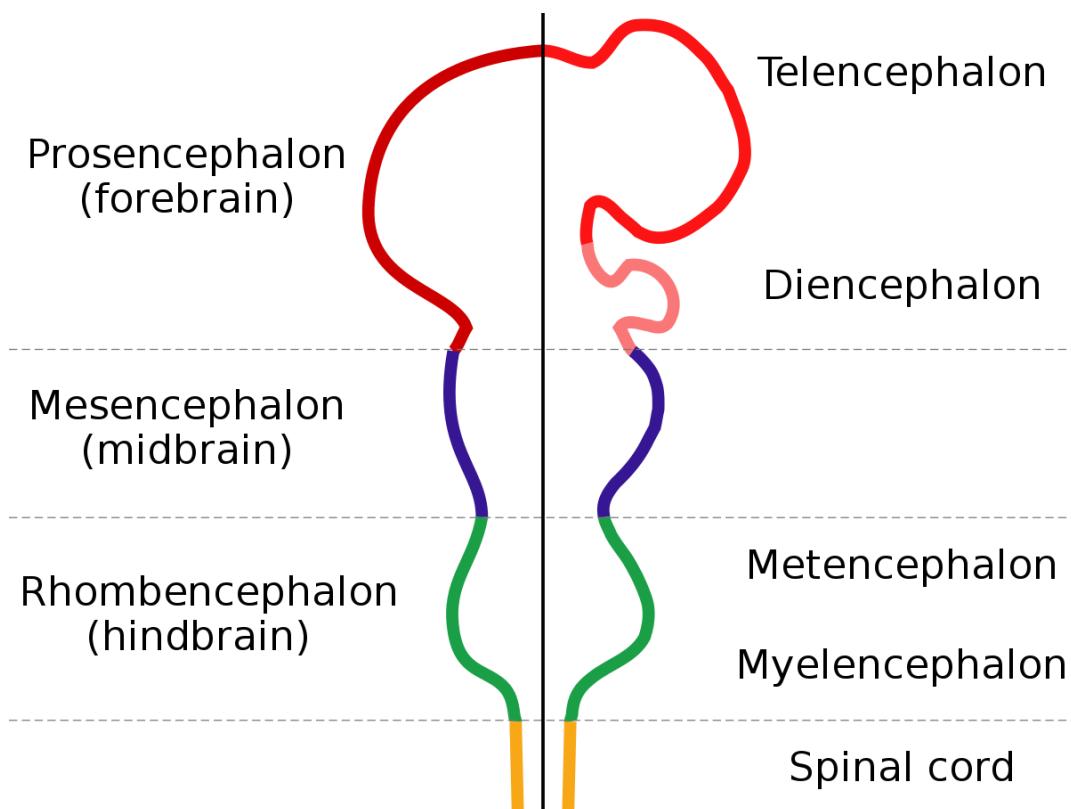
Major division	Ventricular Landmark	Embryonic Division	Structure
Forebrain	Lateral	Telencephalon	Cerebral cortex
			Basal ganglia
			Hippocampus, amygdala
Midbrain	Third	Diencephalon	Thalamus
	Cerebral Aqueduct	Mesencephalon	Tectum, tegmentum
Hindbrain	4th	Metencephalon	Cerebellum, pons
	-	Myelencephalon	Medulla oblongata

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



[https://upload.wikimedia.org/wikipedia/commons/c/c8/6\\_week\\_embryo\\_brain.jpg](https://upload.wikimedia.org/wikipedia/commons/c/c8/6_week_embryo_brain.jpg)  
[\(https://upload.wikimedia.org/wikipedia/commons/c/c8/6\\_week\\_embryo\\_brain.jpg\)](https://upload.wikimedia.org/wikipedia/commons/c/c8/6_week_embryo_brain.jpg)

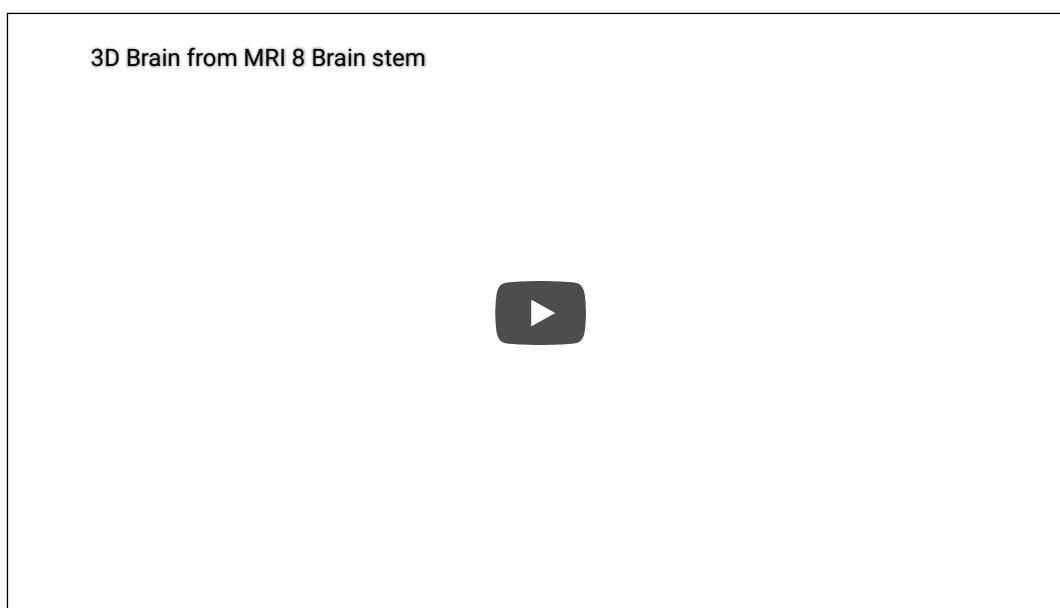
## Hindbrain

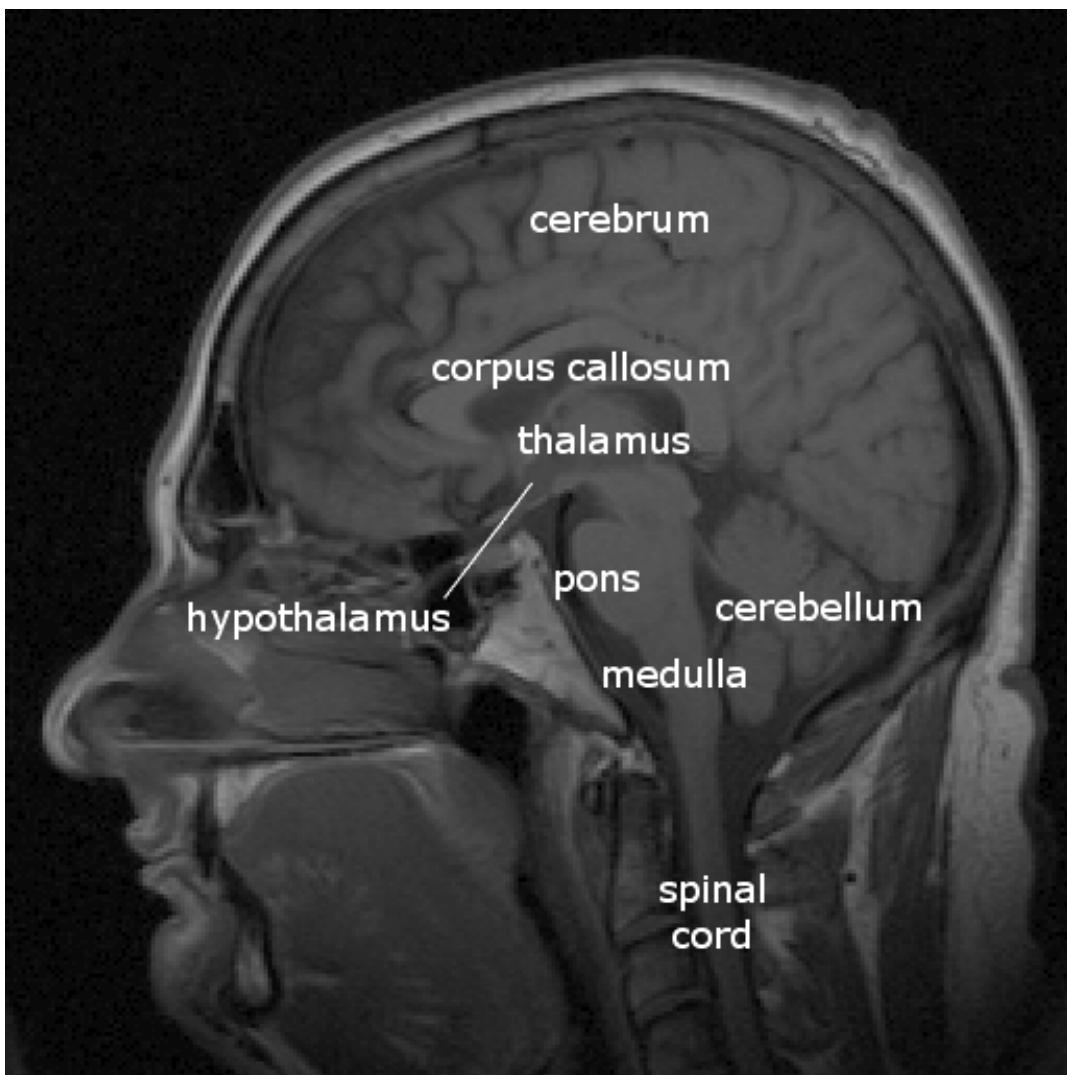
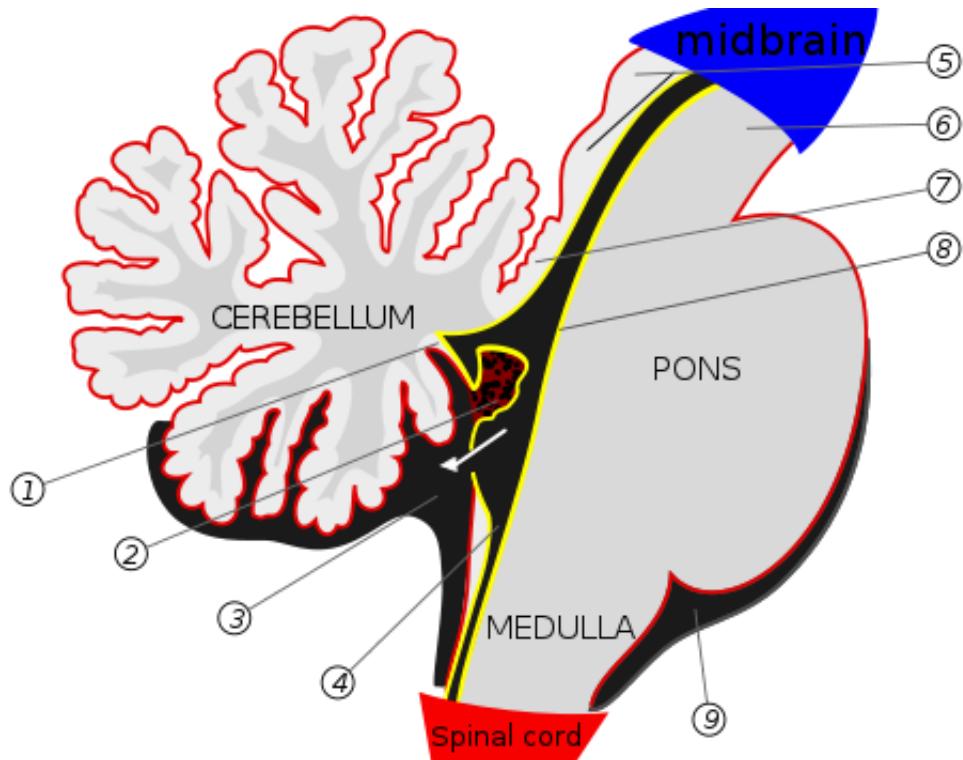


[\(https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/EmbryonicBrain.svg/1200px-EmbryonicBrain.svg.png\)](https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/EmbryonicBrain.svg/1200px-EmbryonicBrain.svg.png)

[\(https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/EmbryonicBrain.svg/1200px-EmbryonicBrain.svg.png\)](https://upload.wikimedia.org/wikipedia/commons/thumb/5/54/EmbryonicBrain.svg/1200px-EmbryonicBrain.svg.png)

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

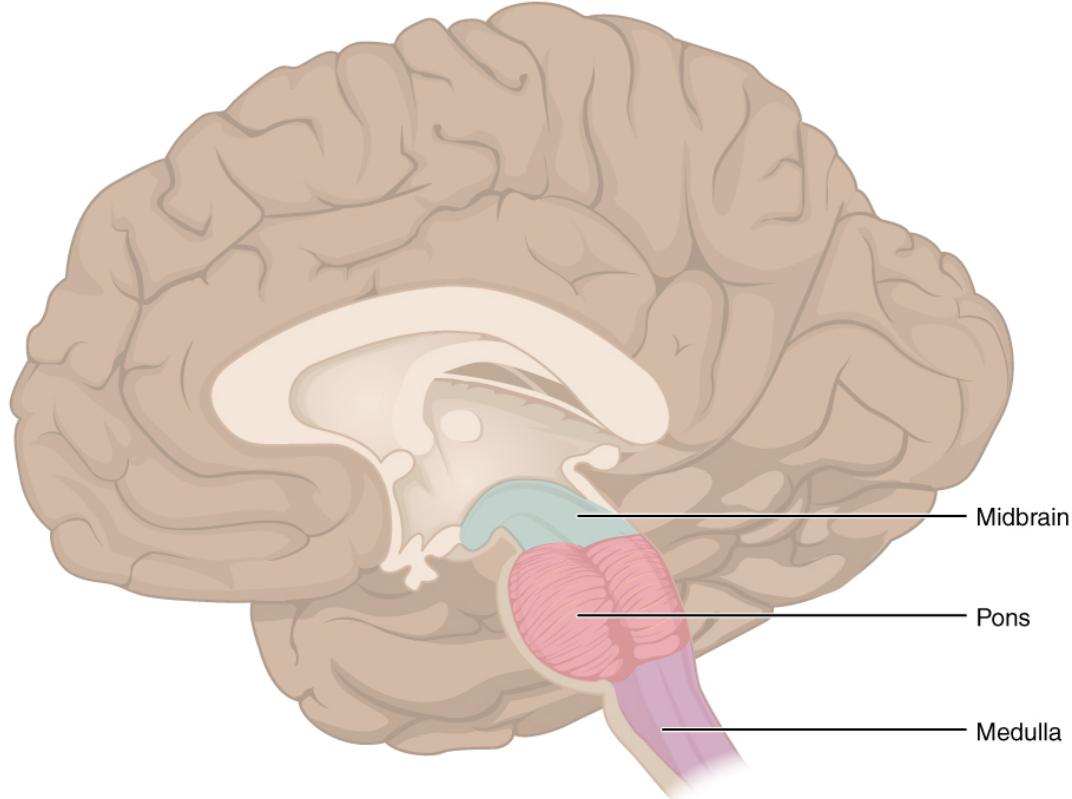




<http://webspace.ship.edu/cgboer/medial-labelled.gif>  
[\(http://webspace.ship.edu/cgboer/medial-labelled.gif\)](http://webspace.ship.edu/cgboer/medial-labelled.gif)

## Medulla oblongata ([https://en.wikipedia.org/wiki/Medulla\\_oblongata](https://en.wikipedia.org/wiki/Medulla_oblongata))

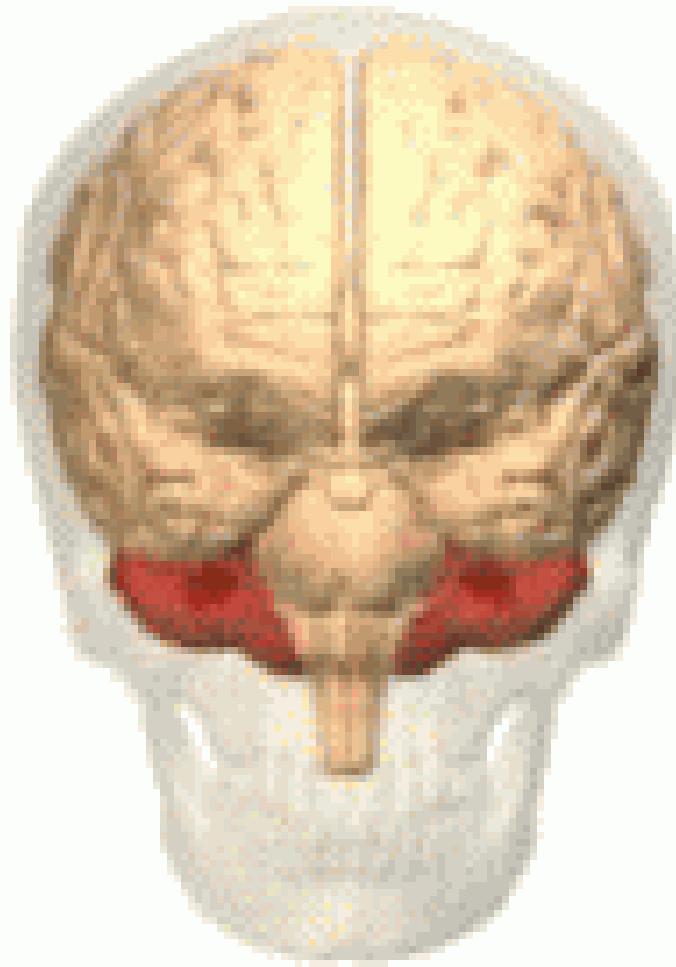
- Cardiovascular regulation
- Muscle tone
- Fibers of passage
  - Ascending fibers (from body), a.k.a. afferents
  - Descending fibers (exiting brain), a.k.a., efferents



[https://upload.wikimedia.org/wikipedia/commons/6/69/1311\\_Brain\\_Stem.jpg](https://upload.wikimedia.org/wikipedia/commons/6/69/1311_Brain_Stem.jpg)  
([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



3D Brain from MRI 9 Cerebellum



## Pons

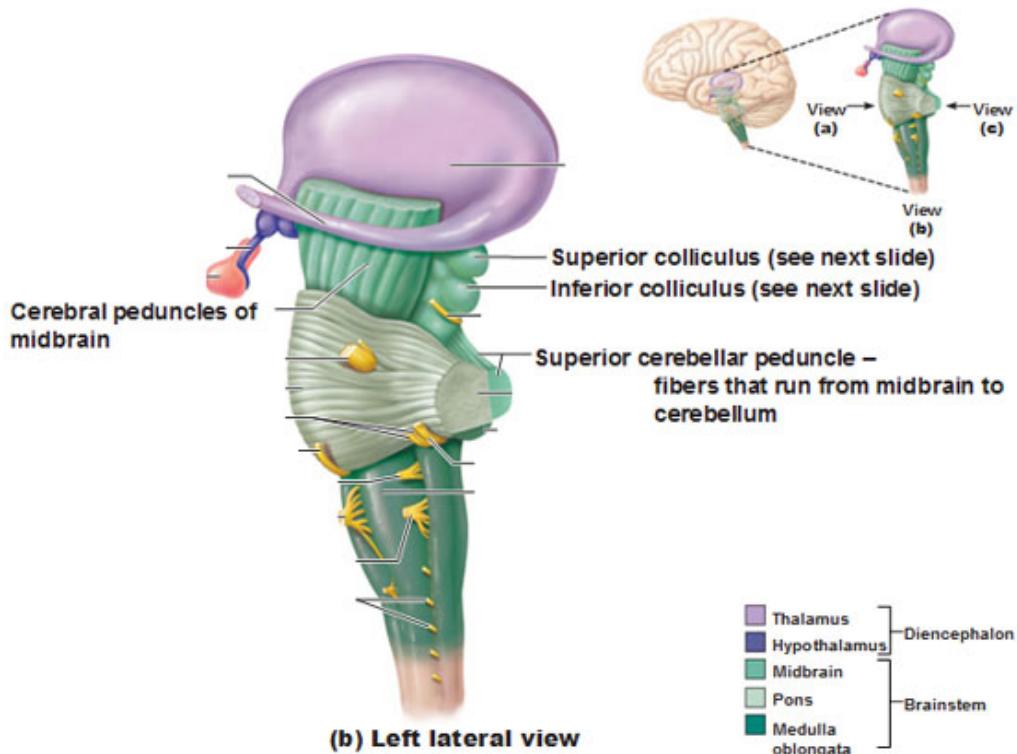
- Bulge on ventral brain stem
- Neuromodulatory nuclei
  - Nucleus (anatomically discrete cluster of neurons)

- 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

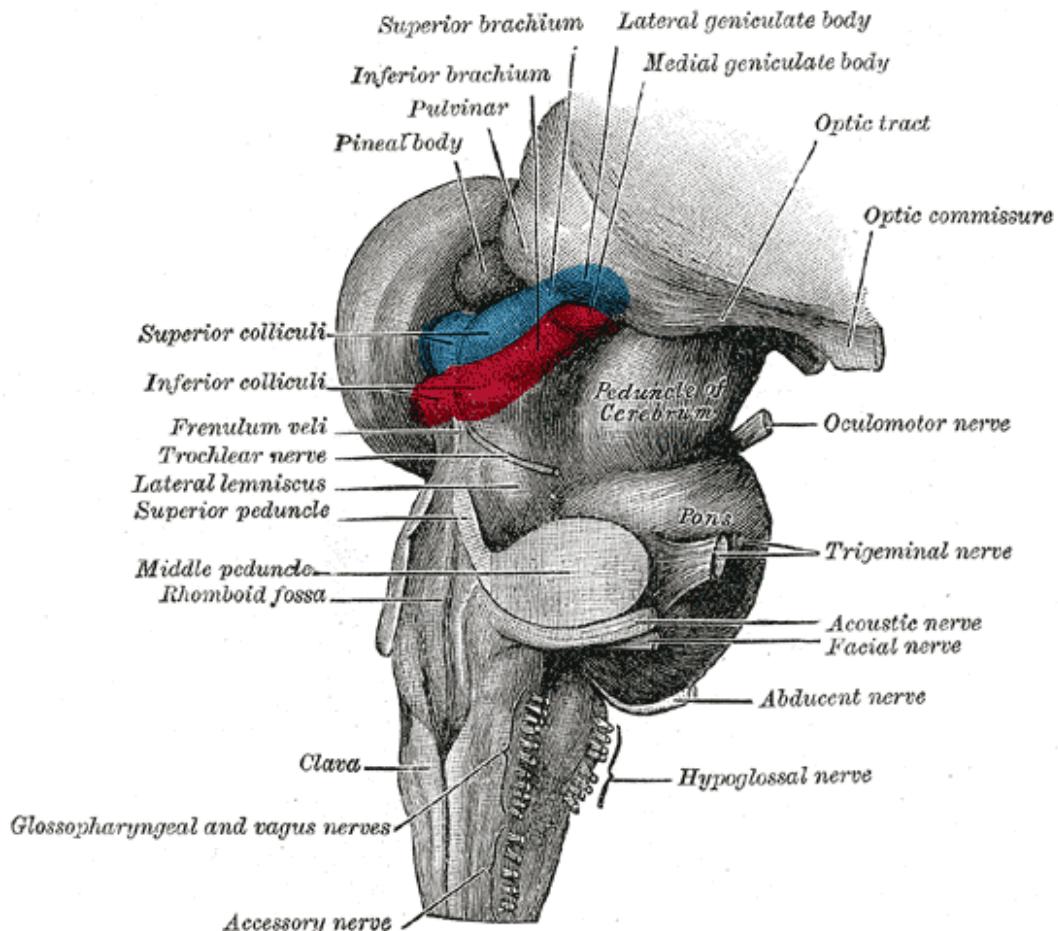
### The Brain Stem– The Midbrain

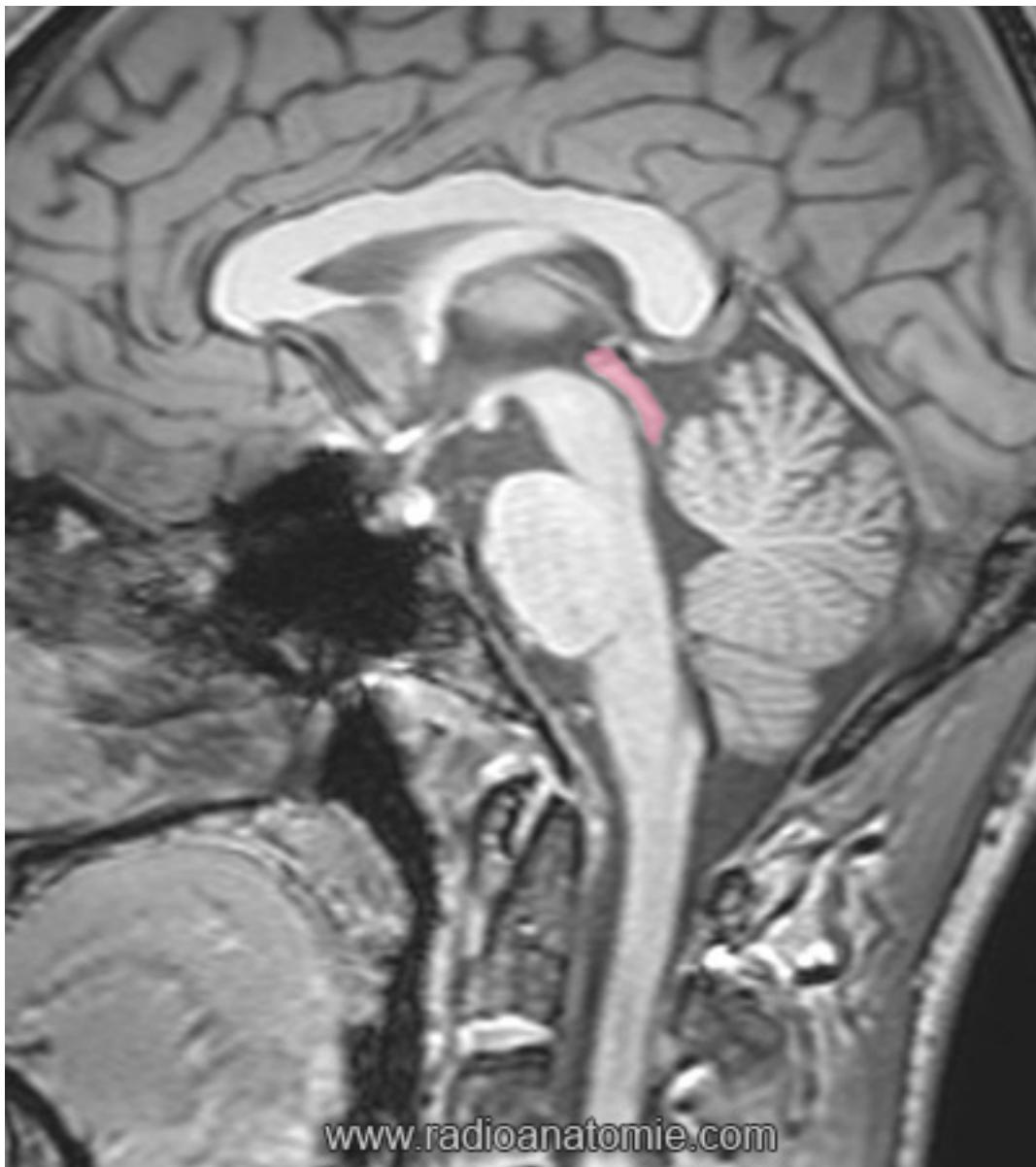


<http://antranik.org/wp-content/uploads/2011/11/the-brain-stem-mid-brain-left-lateral-view-superior-colliculus-inferior-cerebellar-peduncle.jpg> (<http://antranik.org/wp-content/uploads/2011/11/the-brain-stem-mid-brain-left-lateral-view-superior-colliculus-inferior-cerebellar-peduncle.jpg>)

## Tectum

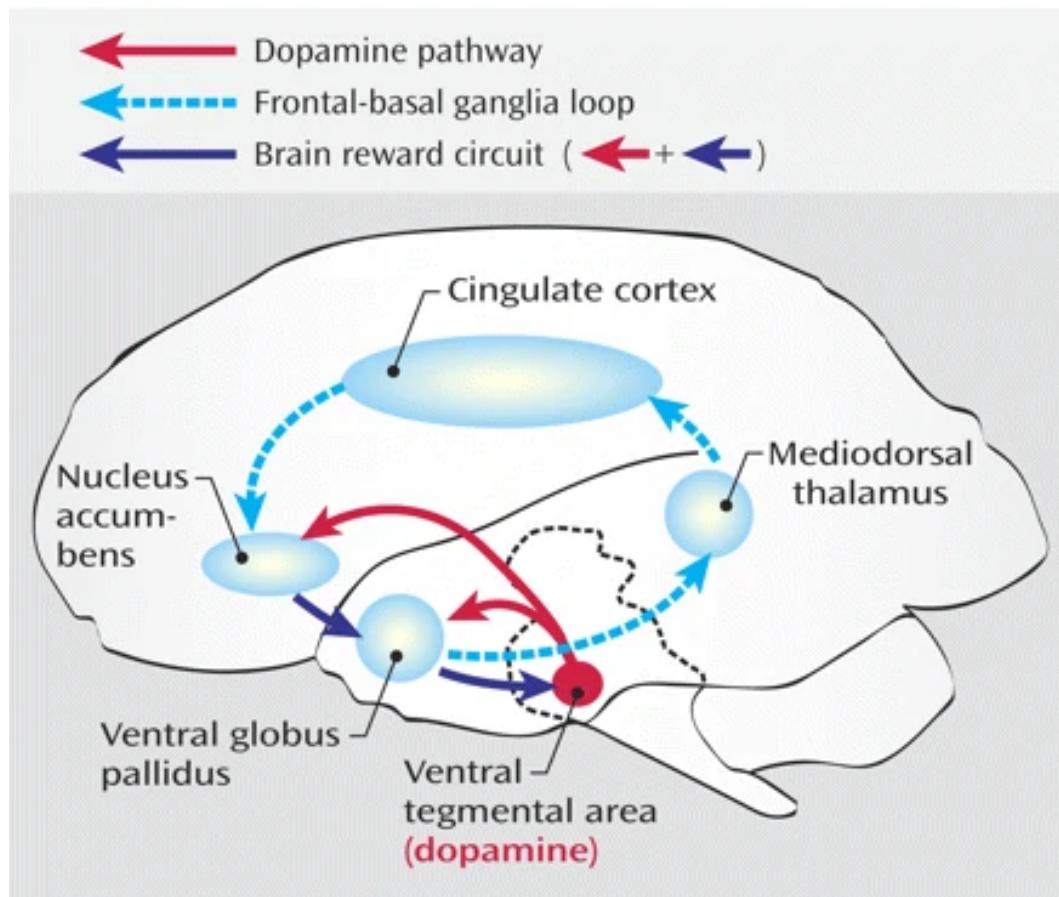
- “Roof” of the midbrain
- Superior and inferior colliculus (colliculi is plural for ‘little hill’)
- Superior colliculus: Reflexive orienting of eyes, head, ears (superior colliculi)
- Inferior colliculus: Auditory processing (from brainstem to auditory thalamus)





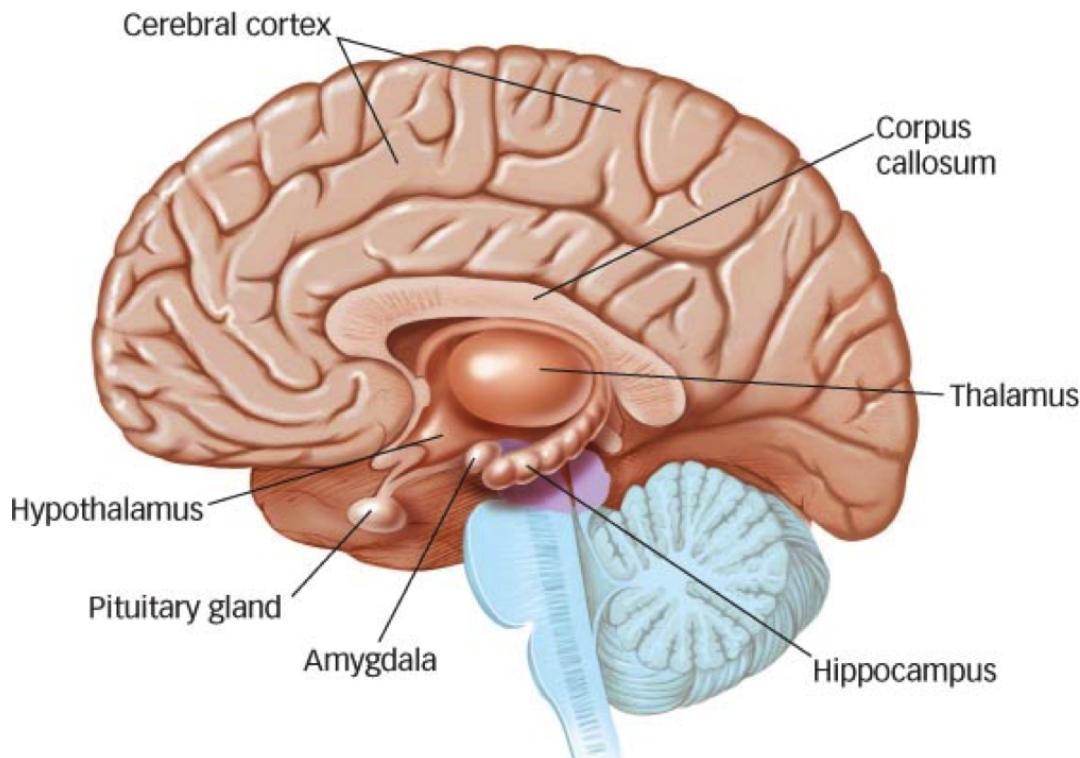
## Tegmentum

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



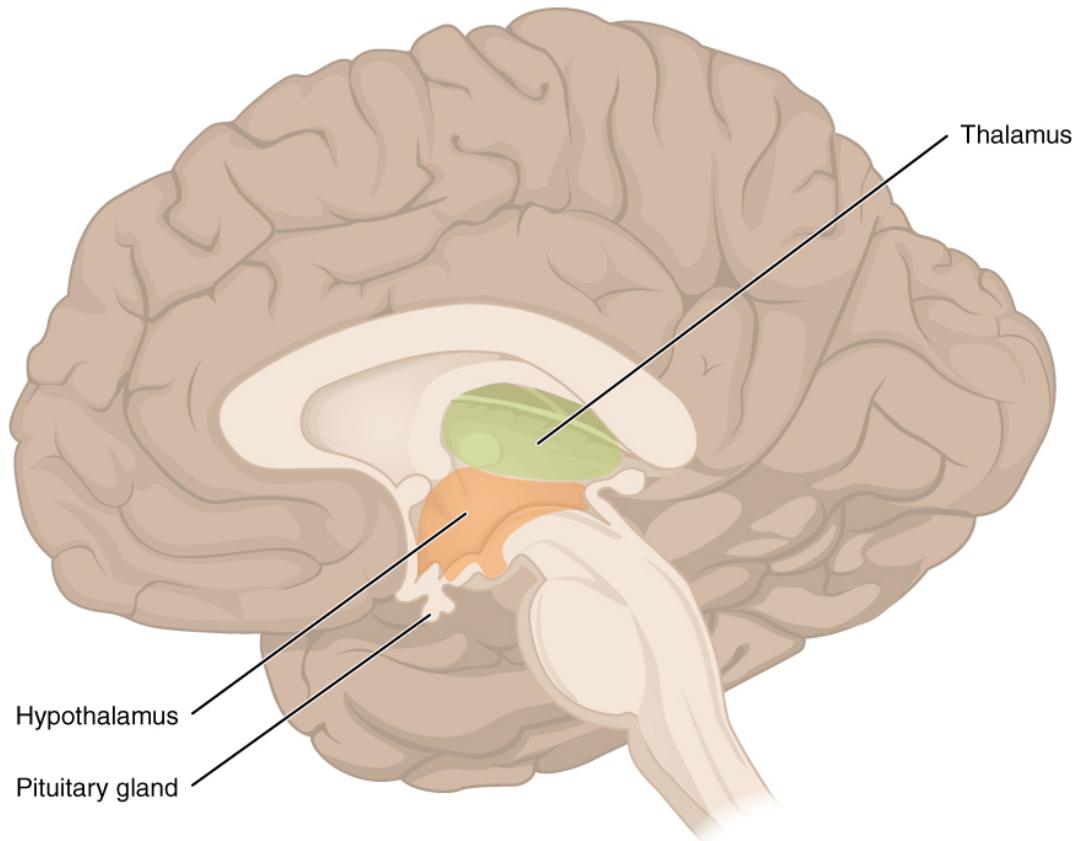
## Forebrain

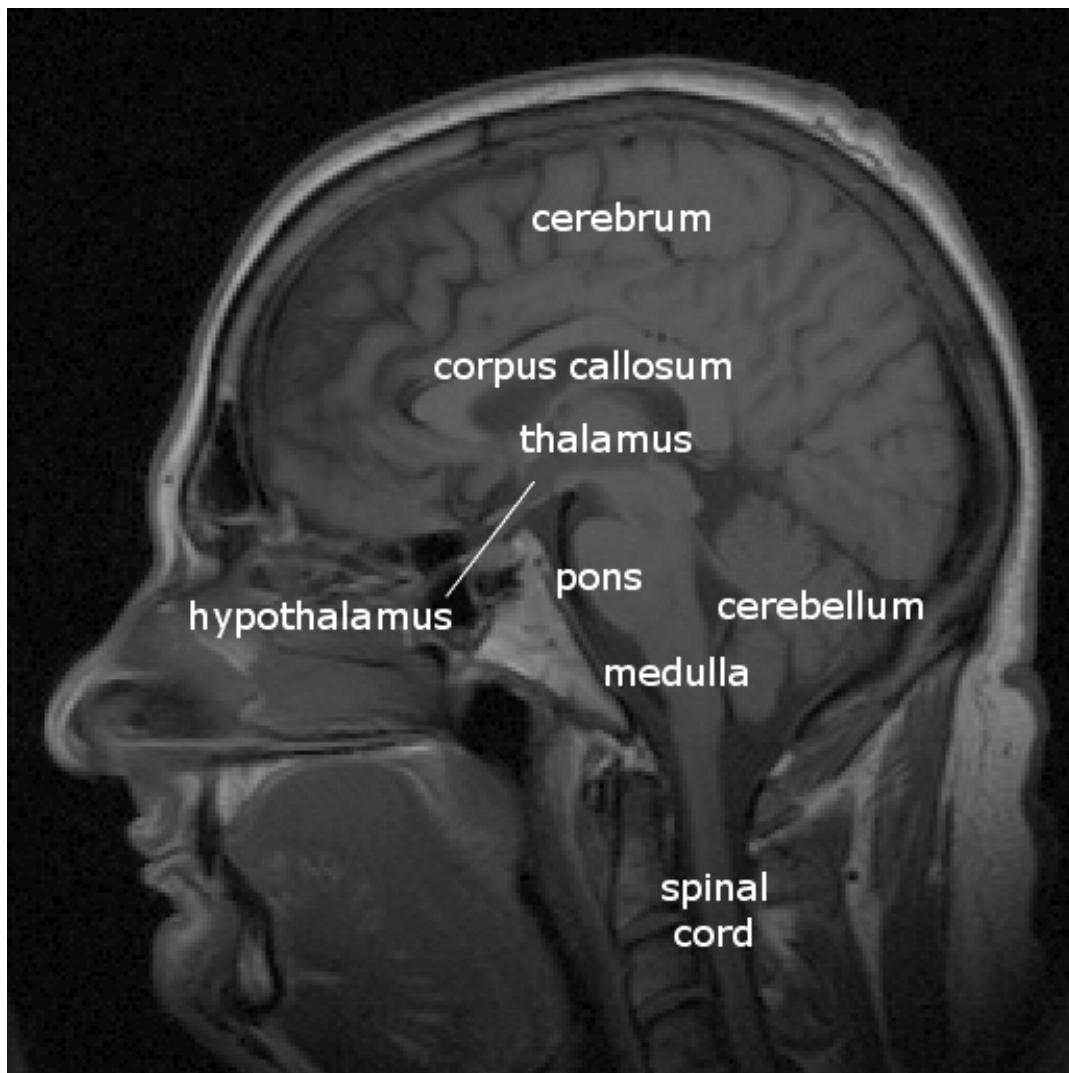
- Diencephalon
- Telencephalon



## Diencephalon ('between brain')

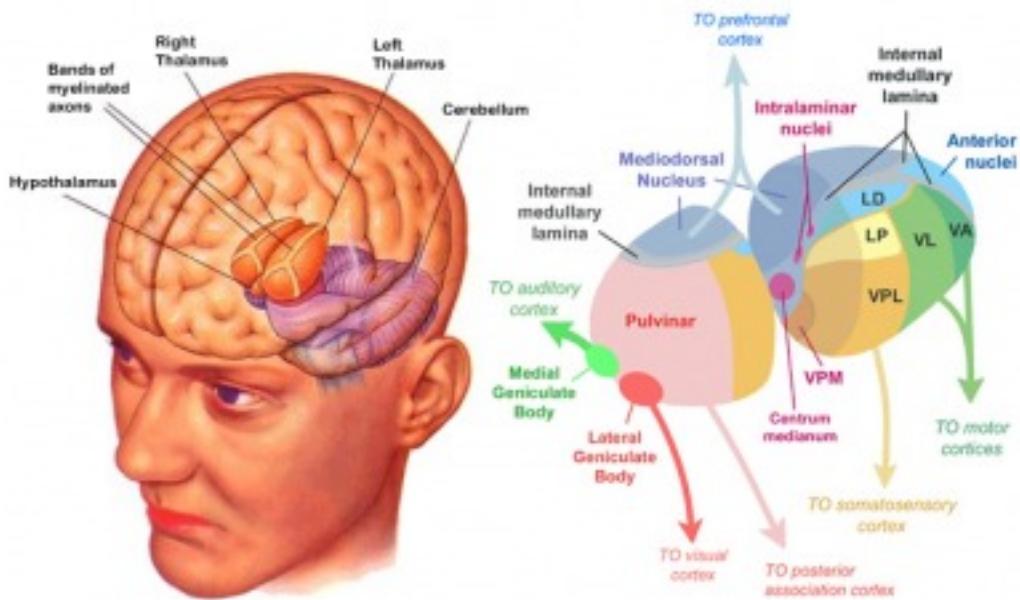
- Thalamus
- Hypothalamus





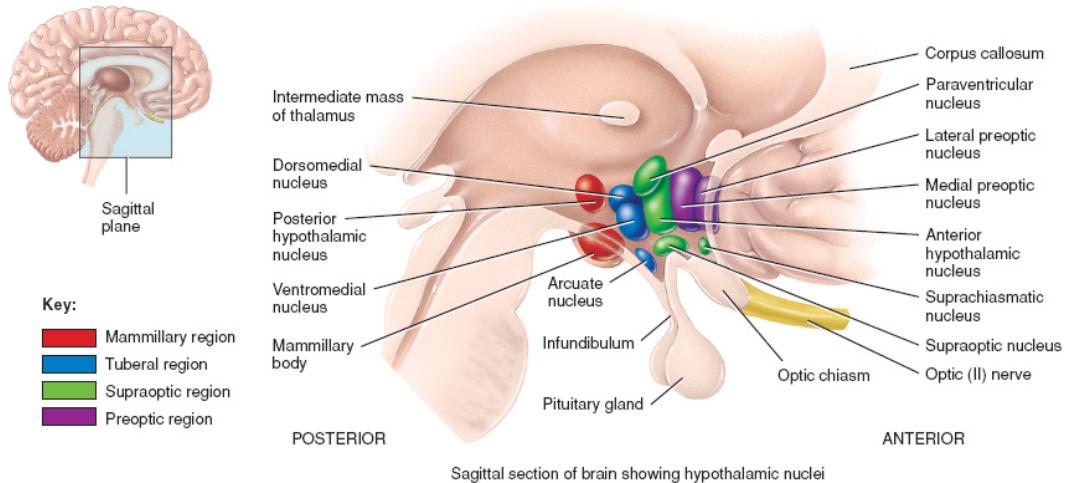
## Thalamus

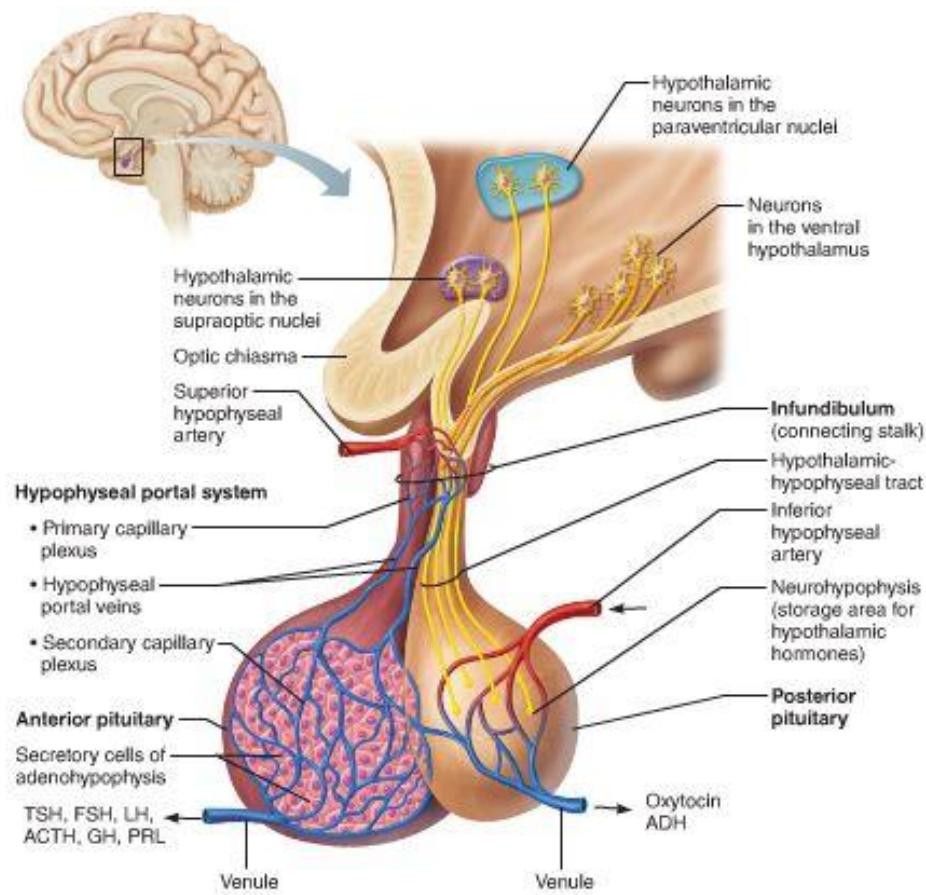
- Input to cortex
- Functionally distinct *nuclei*
  - Lateral geniculate nucleus (LGN), vision
  - Medial geniculate nucleus (MGN), audition
  - Pulvinar, attention?



## 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)



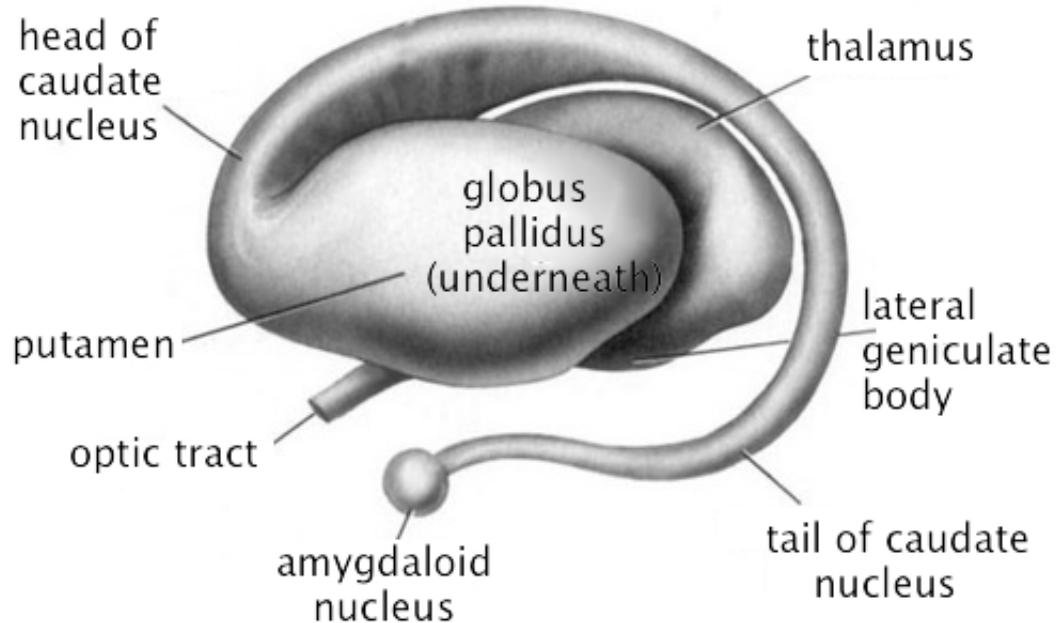


## Telencephalon

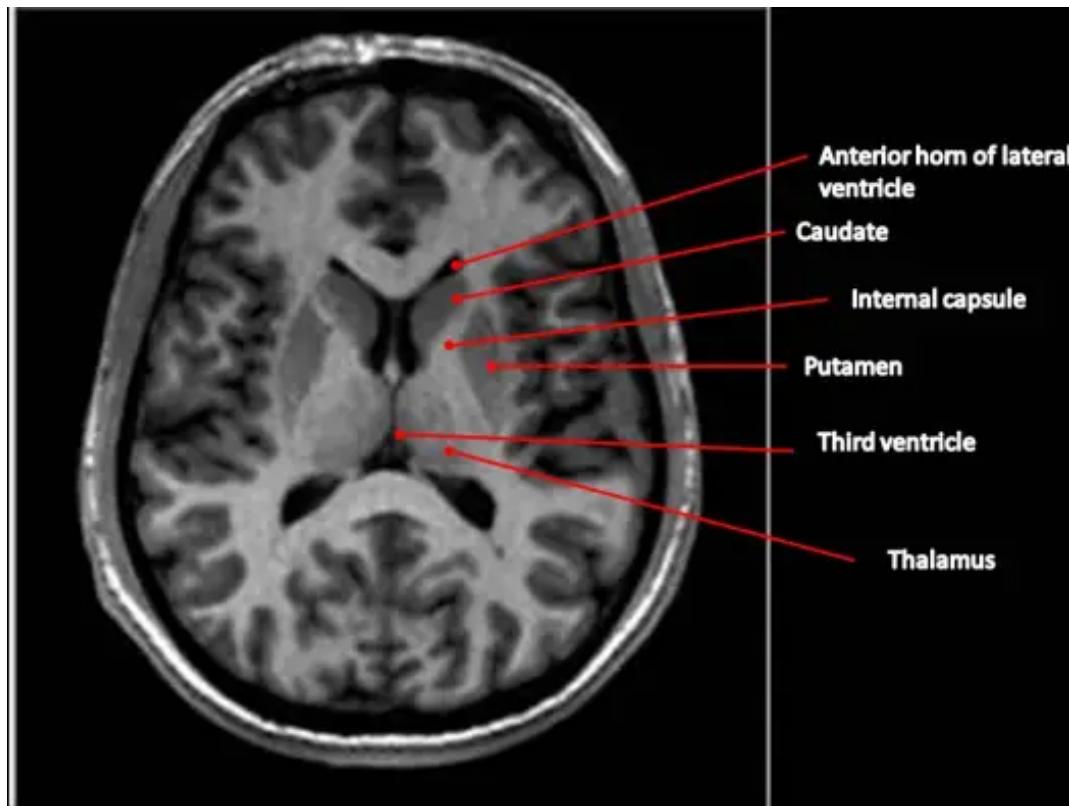
- Basal ganglia
- Hippocampus, amygdala
- Cerebral cortex

## 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)

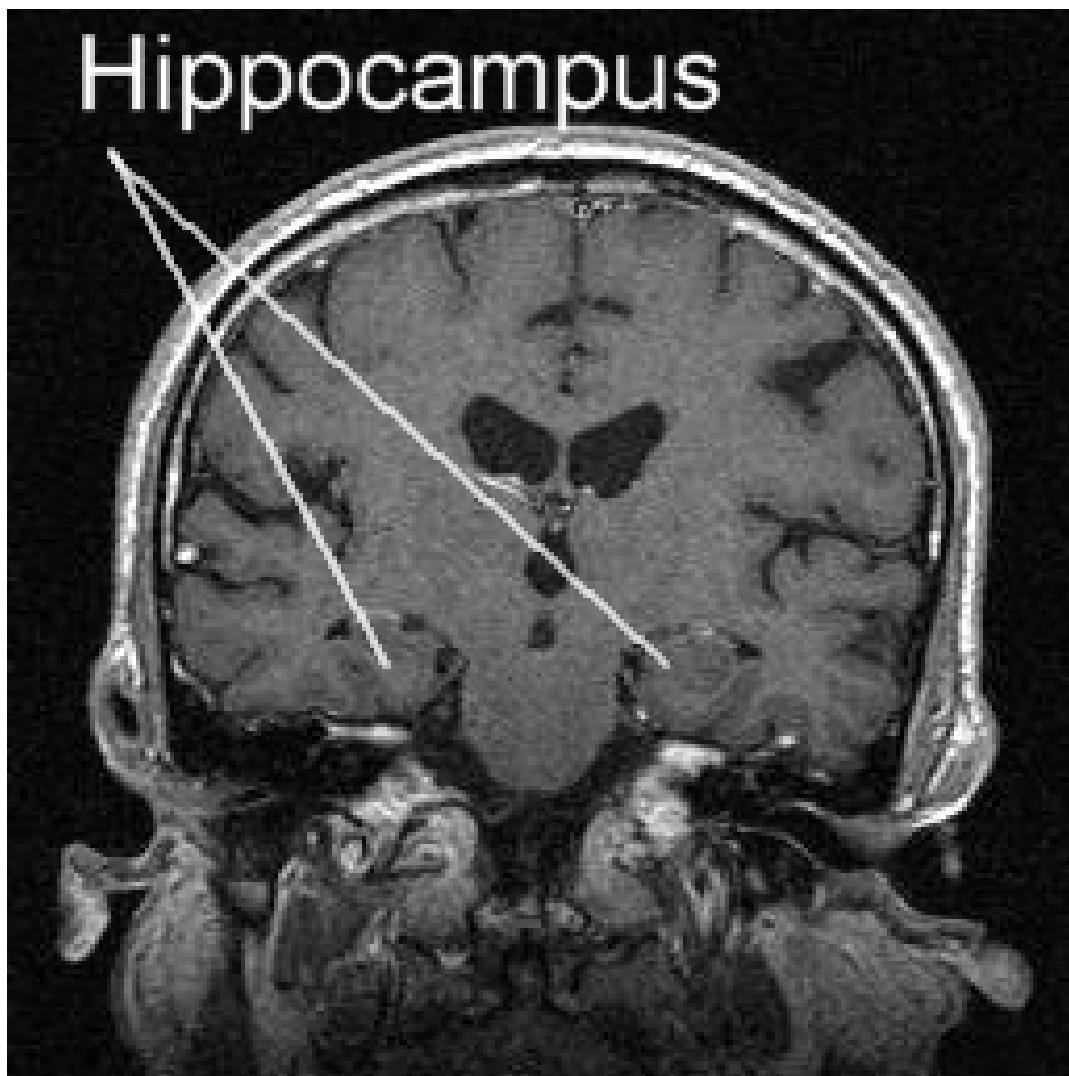


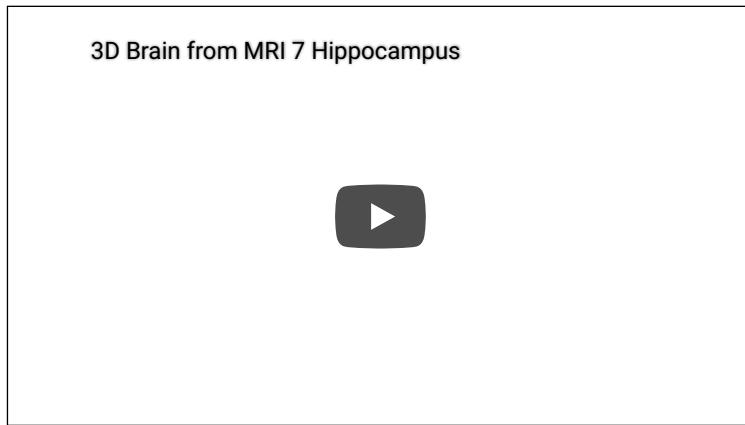
3D Brain from MRI 4 Basal ganglia



## Hippocampus

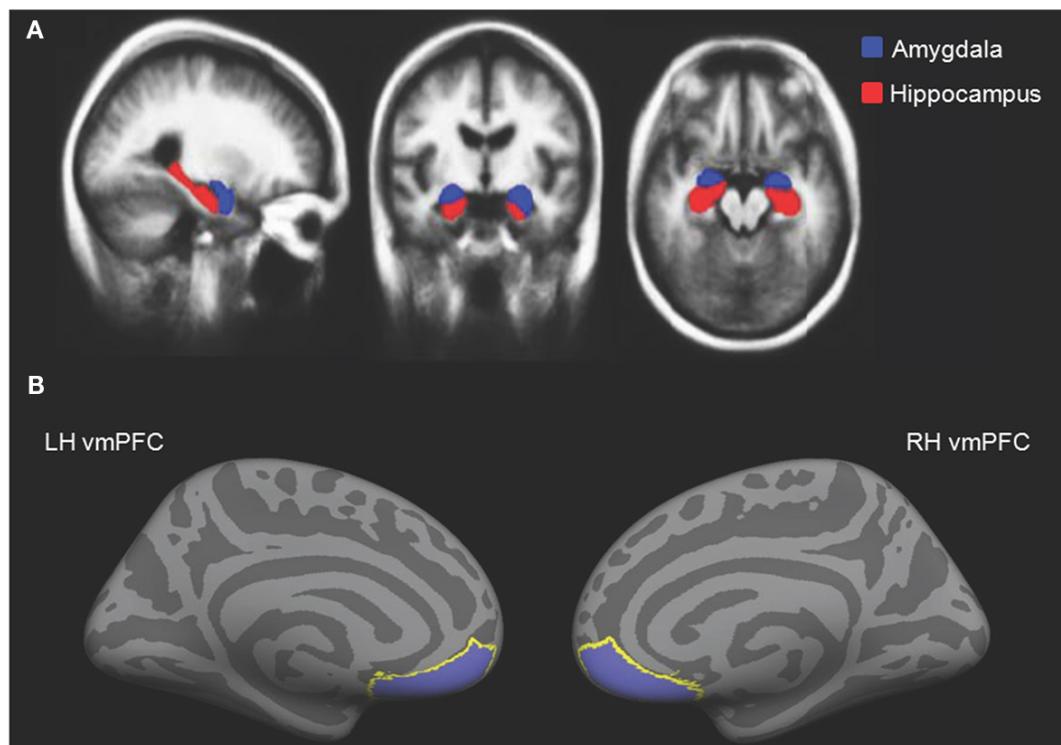
- Medial to lateral ventricles
- Memories of specific facts or events; place memory in non-human animals (& humans?)
- Fornix (axon fiber bundle) projects to (mammillary bodies of) hypothalamus





### Amygdala ("almond")

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

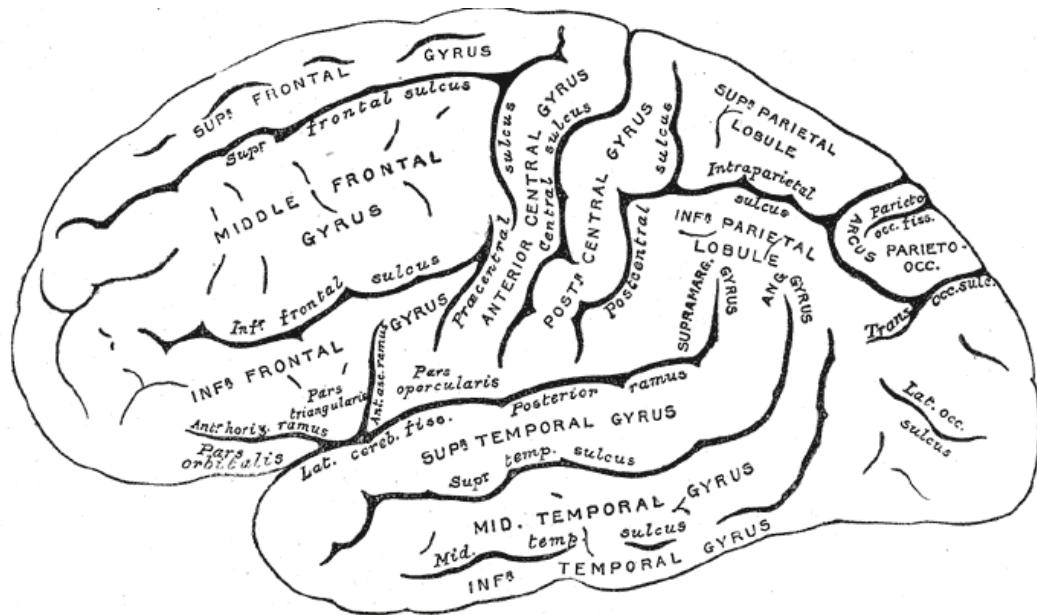


### Cerebral Cortex

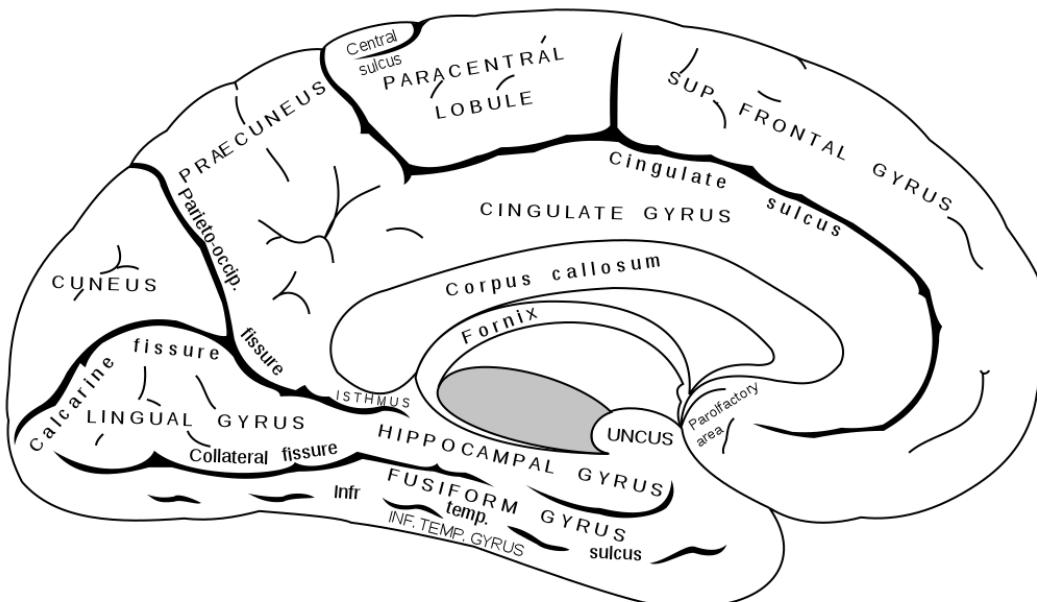
- Cerebral hemispheres

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

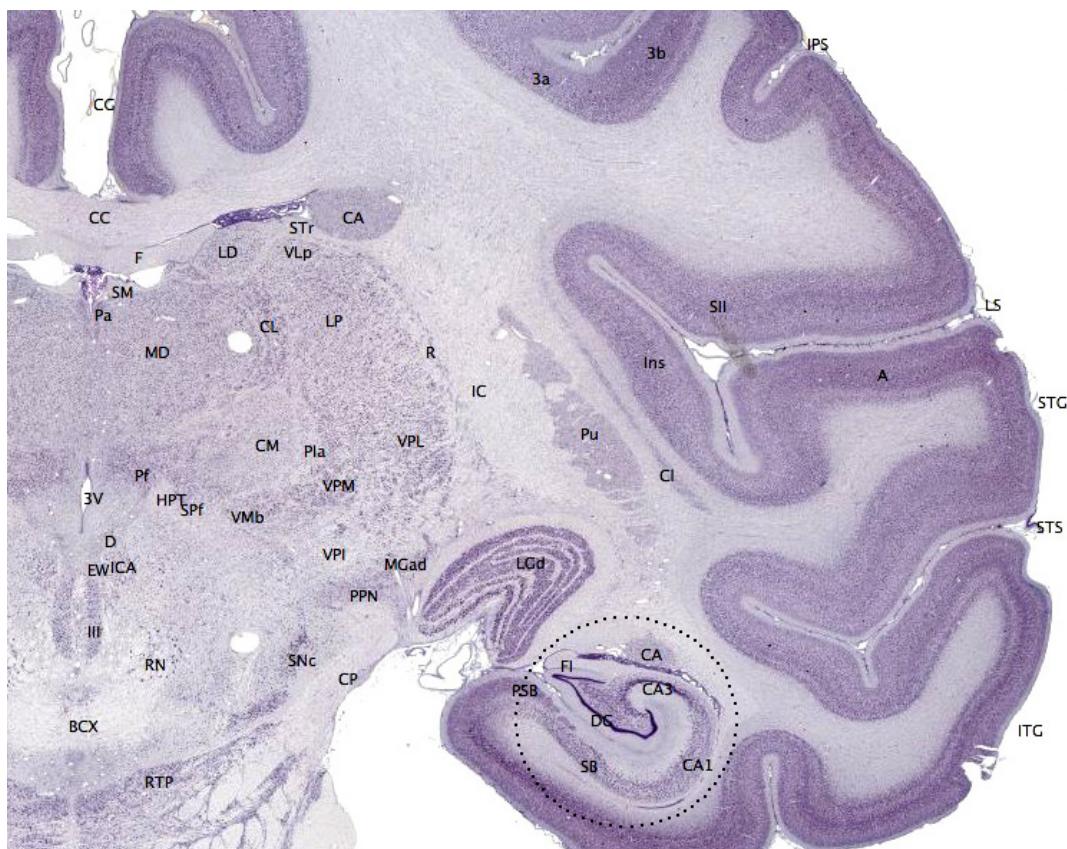
### Lateral view



### Medial view

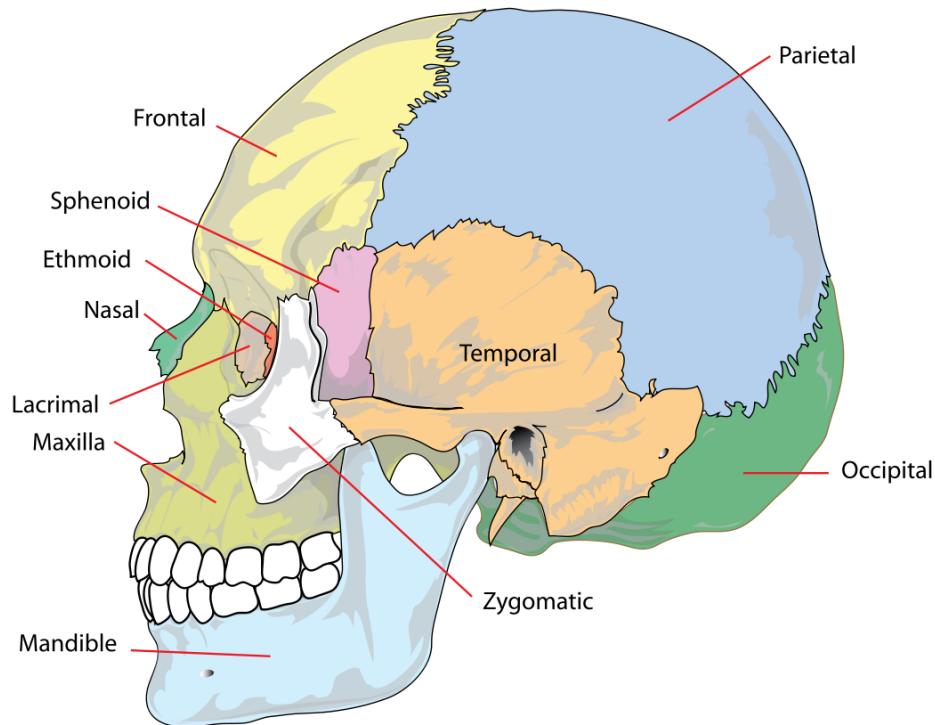


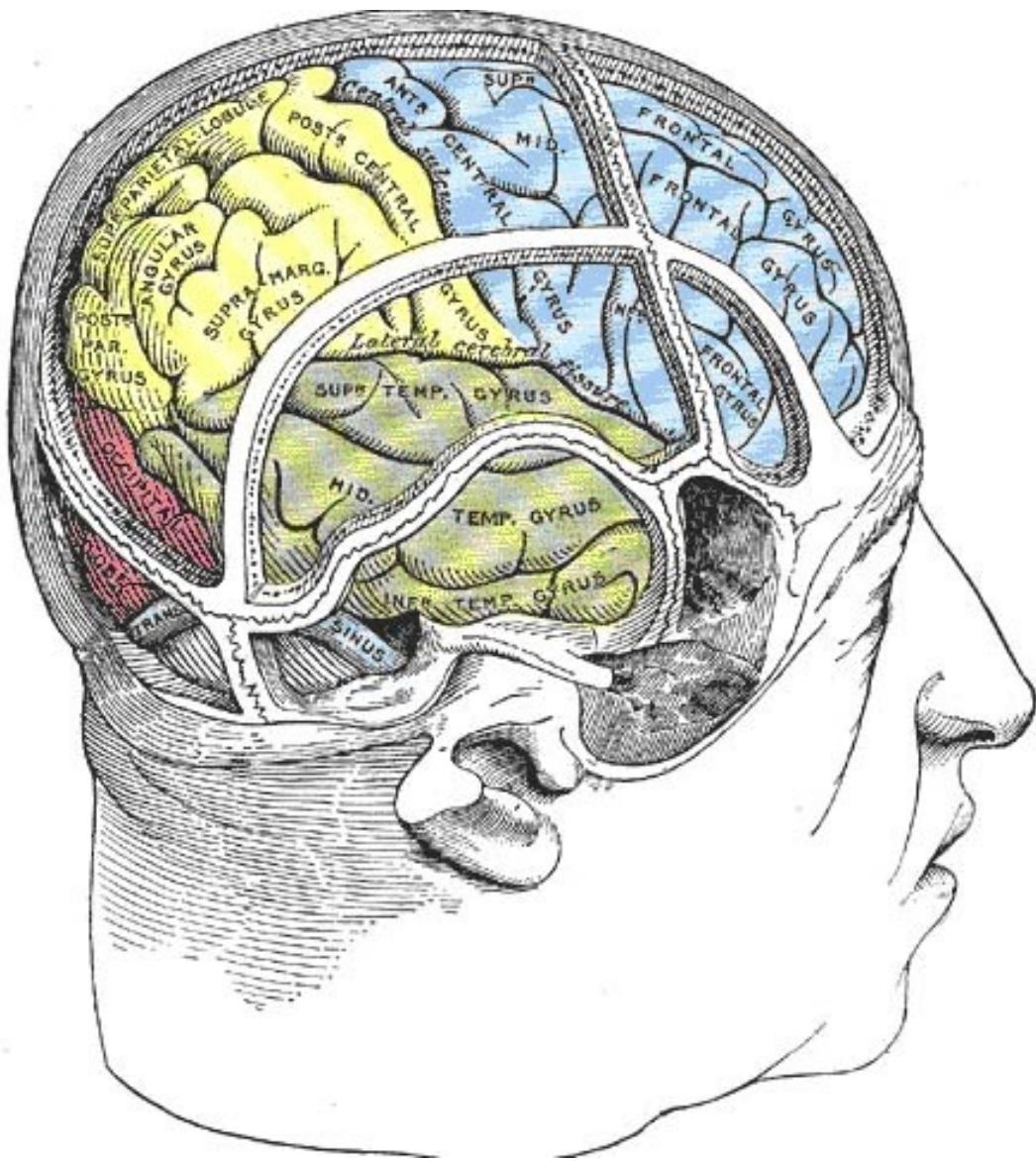
### Nissl stain



### Lobes of the cerebral cortex

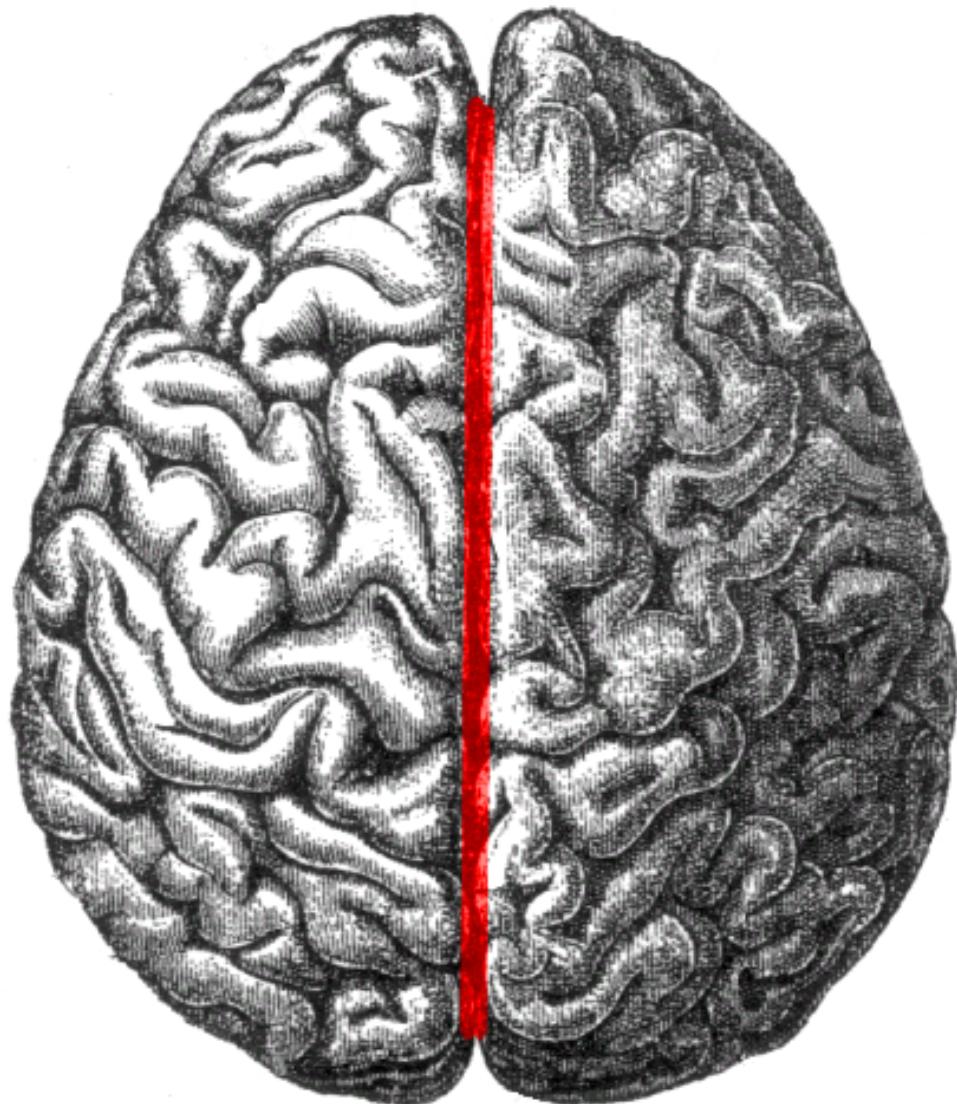
- Frontal
- Temporal
- Parietal
- Occipital
- Names derive from underlying bones of the skull





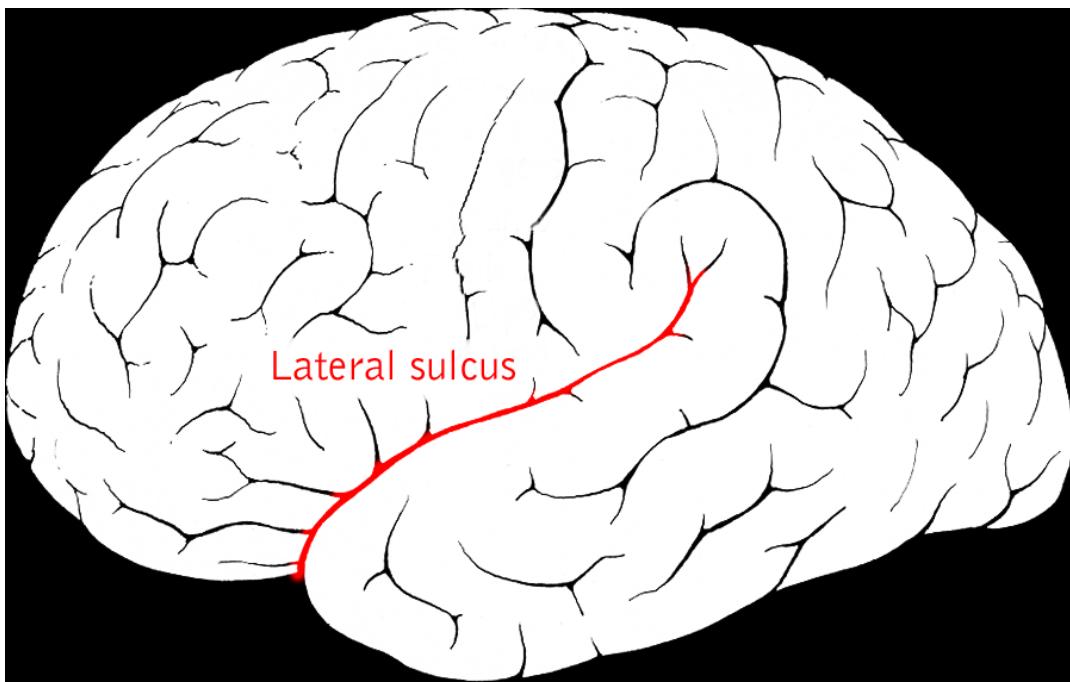
### Longitudinal fissure

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



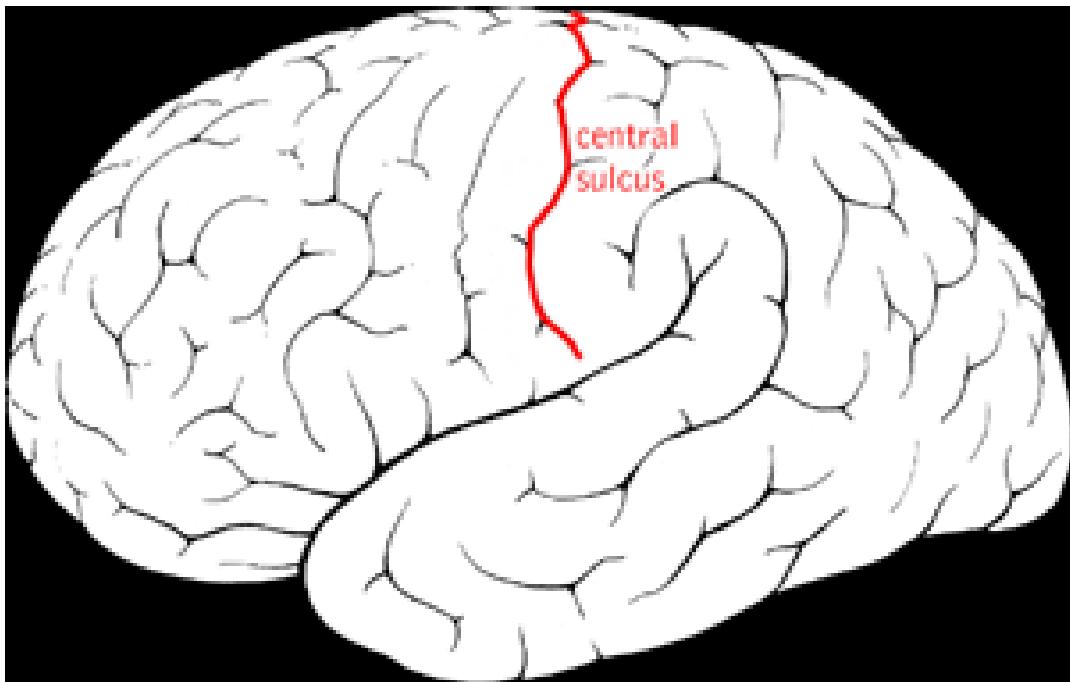
### **Lateral sulcus/fissure**

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



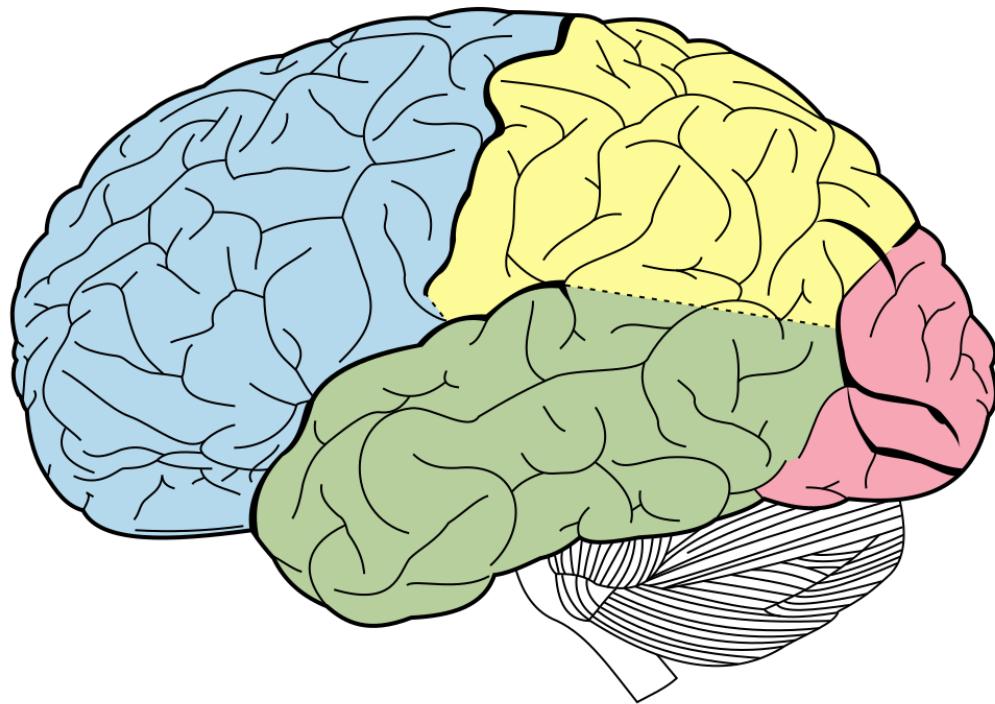
### Central sulcus

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



### Frontal lobe

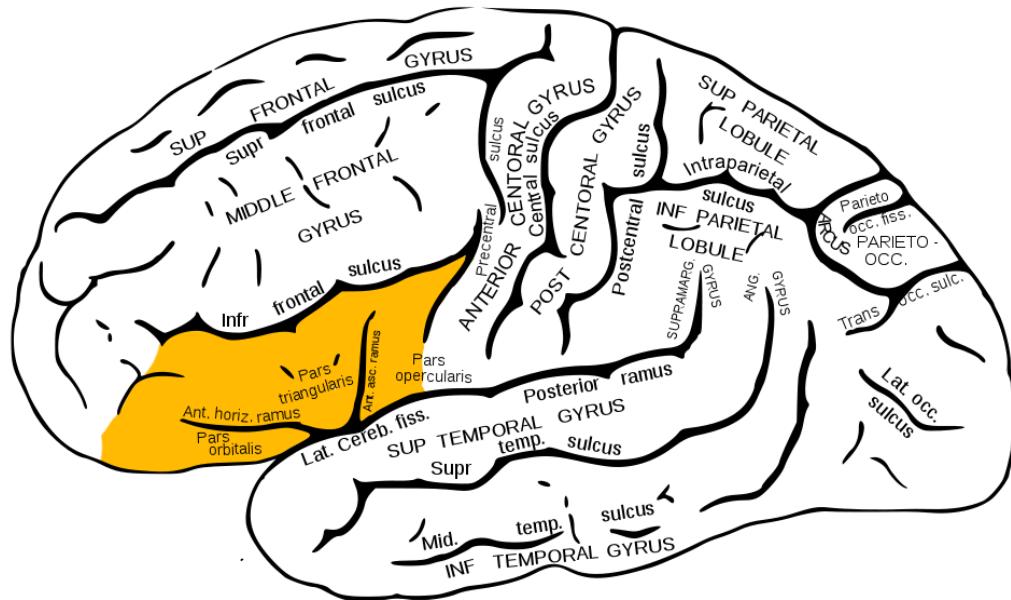
- Anterior to central sulcus
- Superior to lateral fissure
- Dorsal to temporal lobe



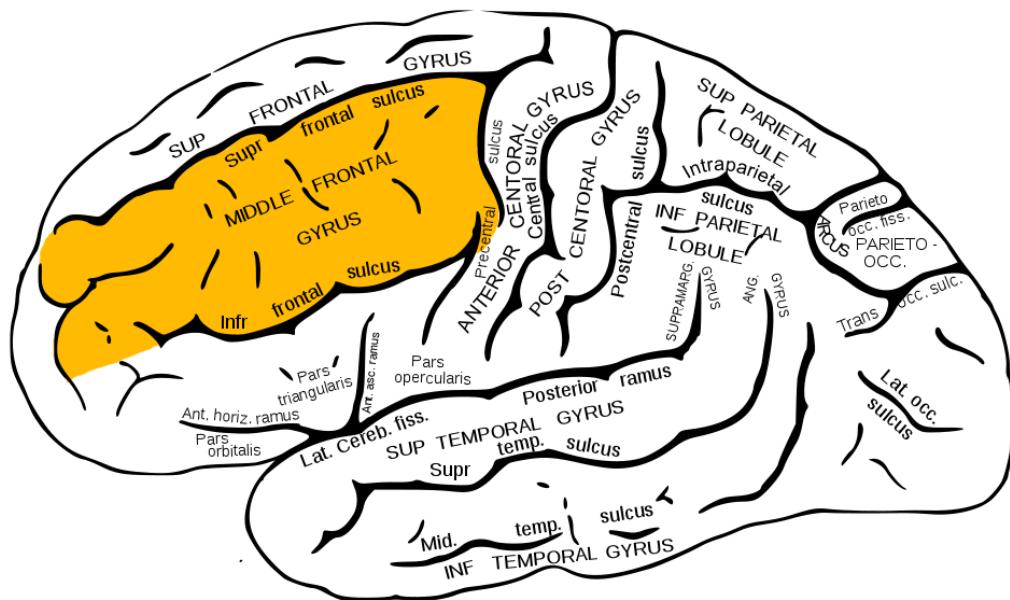
- Primary motor cortex (M1)
  - Supplementary motor cortex
  - Frontal eye fields (FEF)
- Prefrontal cortex
  - Planning, problem solving, working memory...?
- Basal forebrain
  - Nucleus accumbens (NAcc) ([https://en.wikipedia.org/wiki/Nucleus\\_accumbens](https://en.wikipedia.org/wiki/Nucleus_accumbens)), part of ventral striatum
- Anterior cingulate cortex (ACC)  
([https://en.wikipedia.org/wiki/Anterior\\_cingulate\\_cortex](https://en.wikipedia.org/wiki/Anterior_cingulate_cortex))
- Primary olfactory cortex



**Inferior Frontal Gyrus (IFG)**

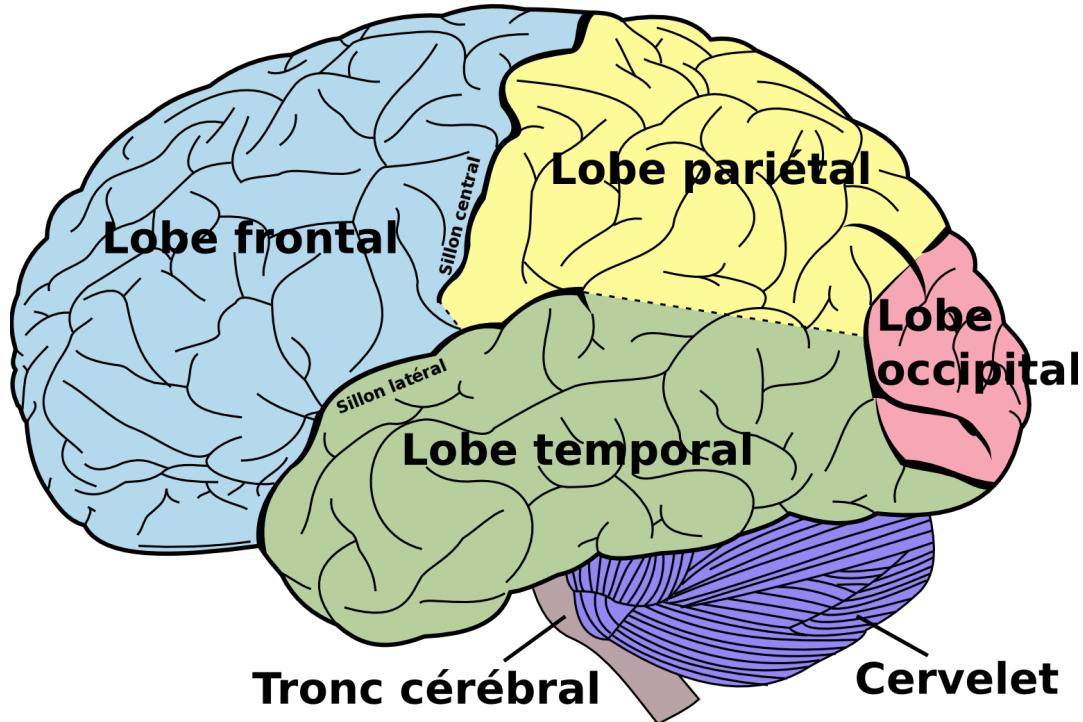


**Middle Frontal Gyrus (MFG)**



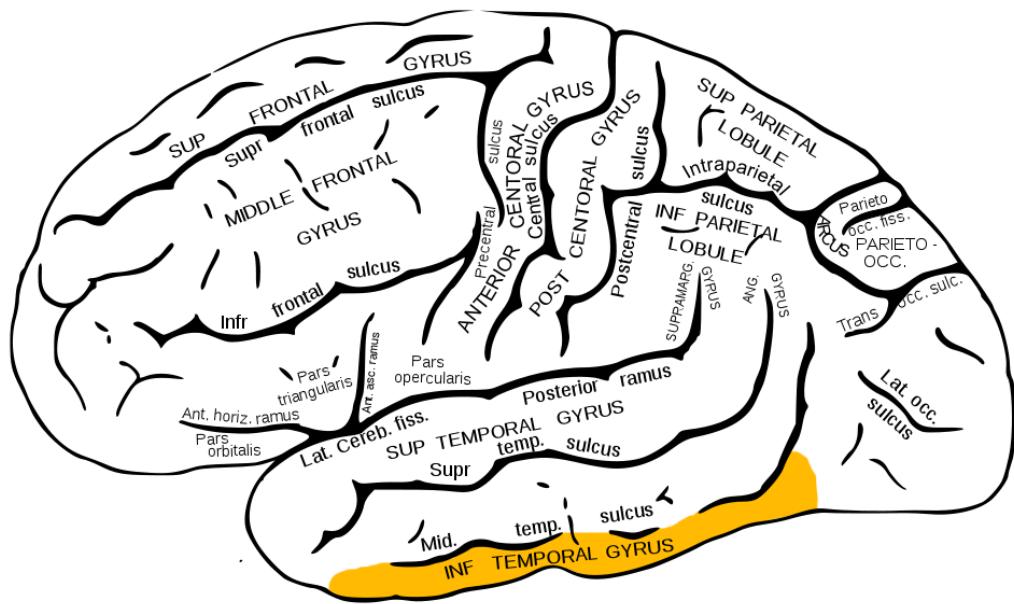
### Temporal lobe

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

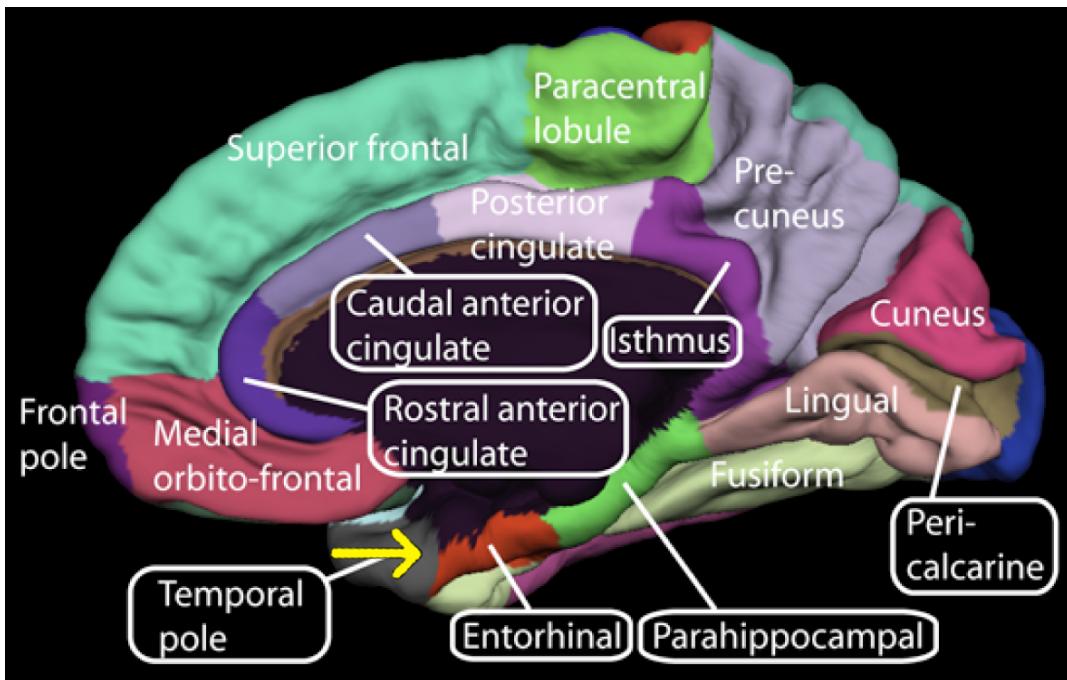


- Primary auditory cortex (A1)
- Object, face recognition
- Storage of memories about events, objects
- Amygdala, hippocampus

### Inferior Temporal Gyrus (ITG)

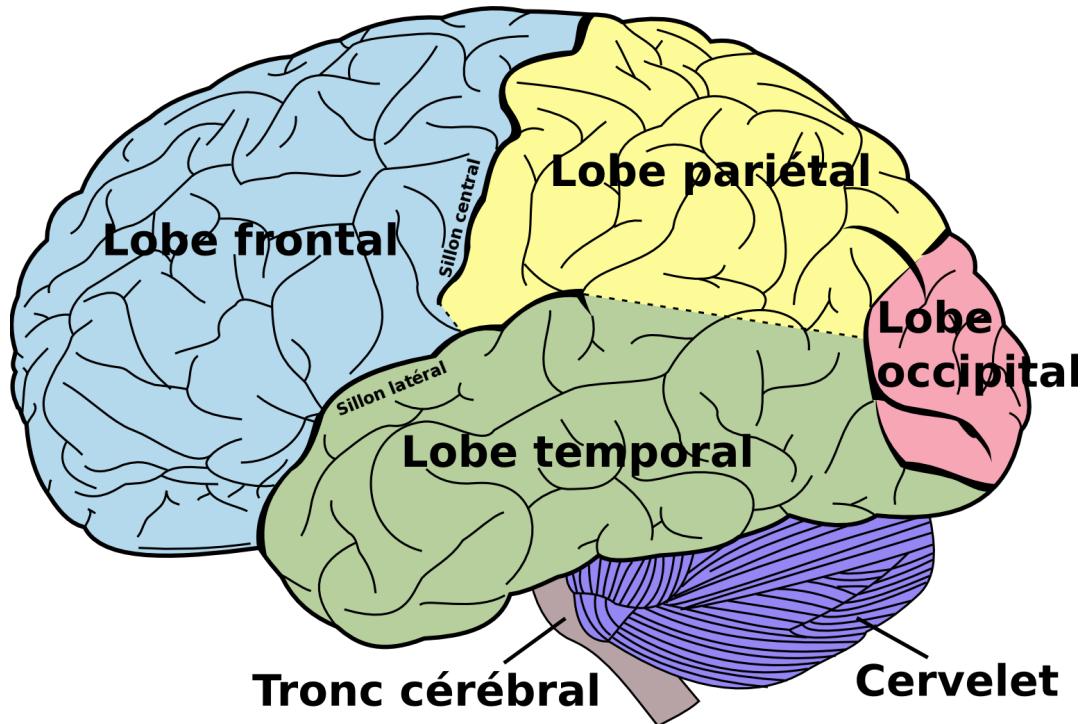


### Entorhinal Cortex (ER)



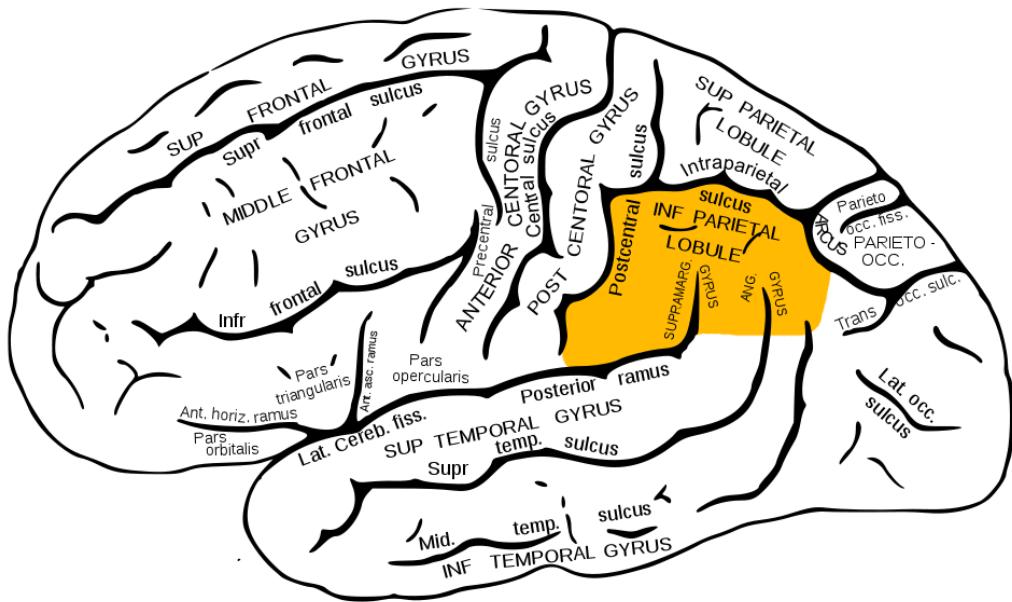
### Parietal lobe

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

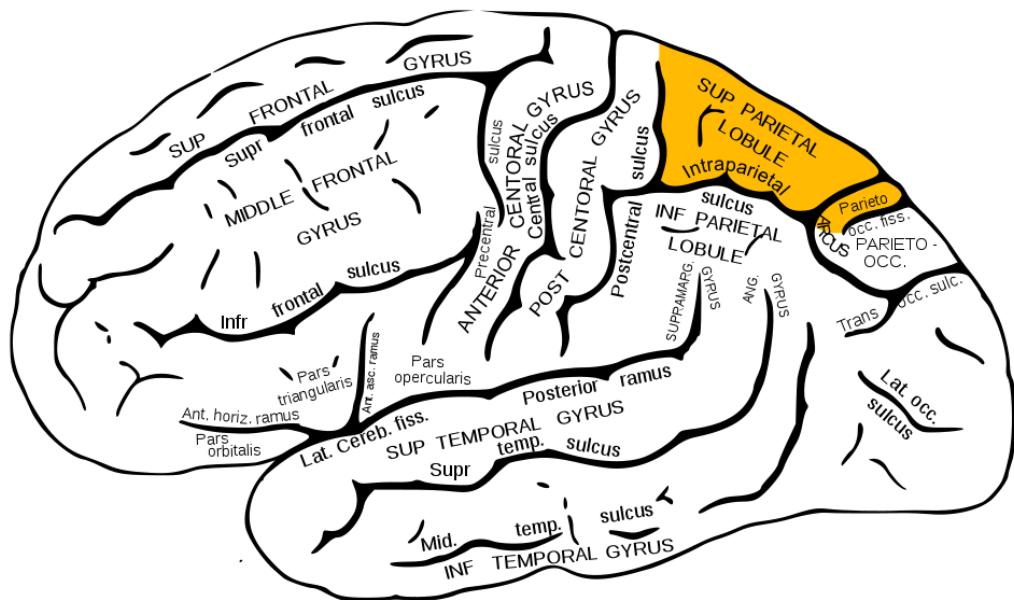


- Primary somatosensory cortex (S1)
- Perception of spatial relations, action planning

### Inferior Parietal Lobule

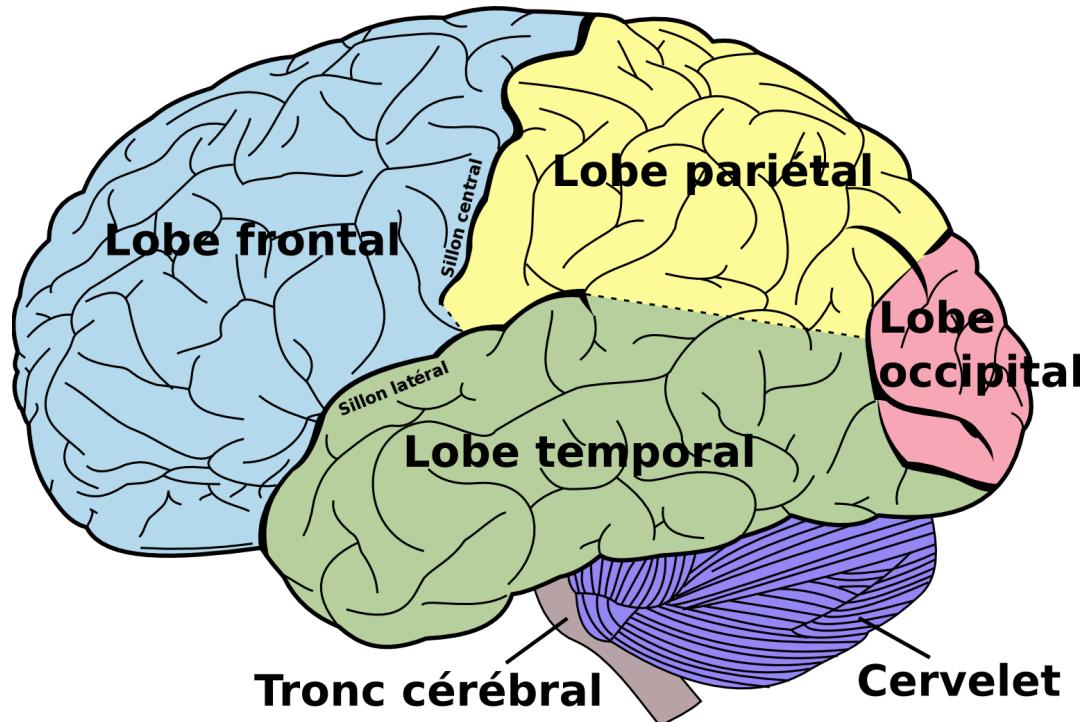


### Superior Parietal Lobule

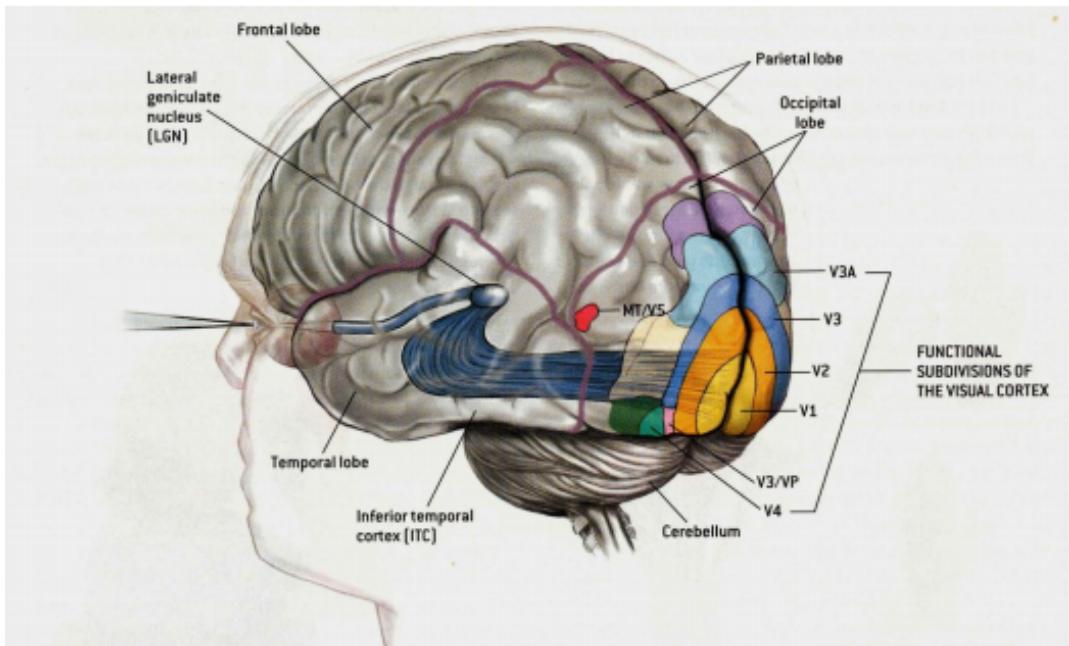


### Occipital lobe

- Caudal to parietal & temporal lobes

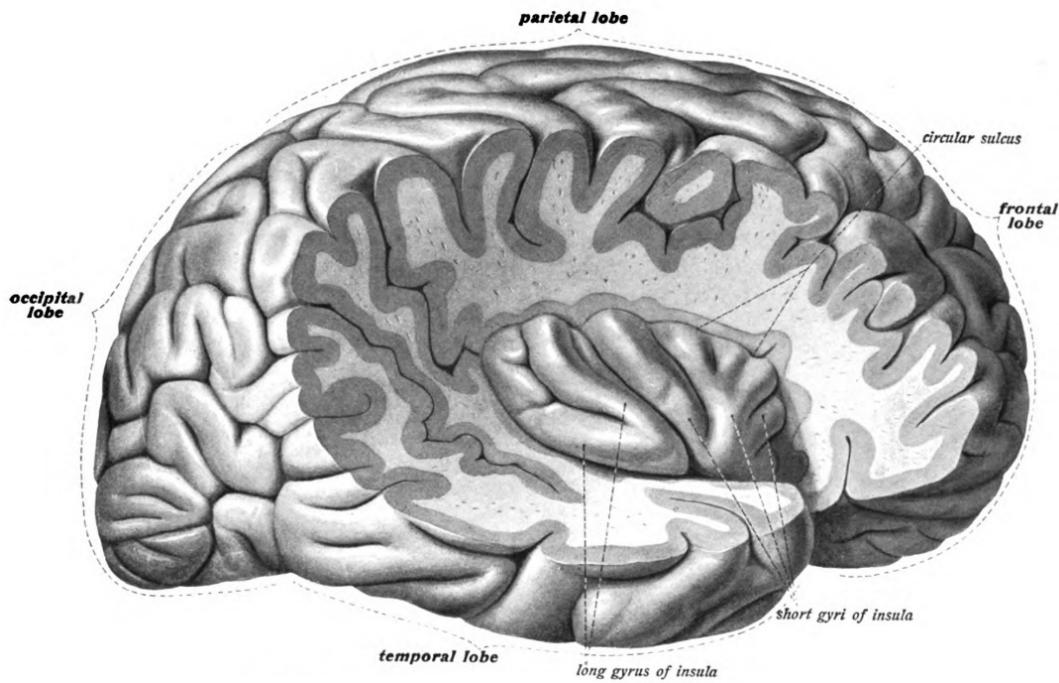


- Primary visual cortex (V1)
- Secondary visual areas (V2...V7)



### Insular cortex (insula)

- medial to temporal lobe
- deep inside lateral fissure



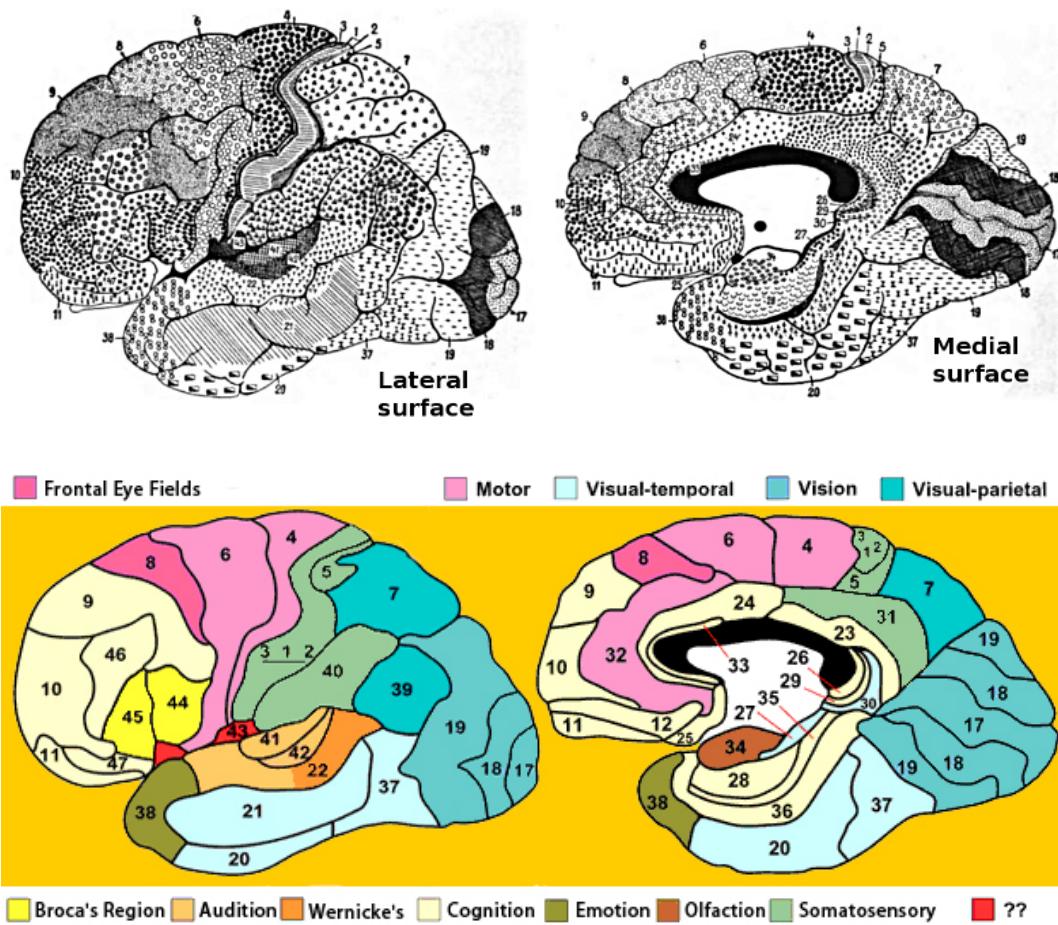
- Primary gustatory cortex
- Self-awareness, interpersonal experiences, motor control, interoception

### Brodmann Areas

- Korbinian Brodmann ([https://en.wikipedia.org/wiki/Korbinian\\_Brodmann](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

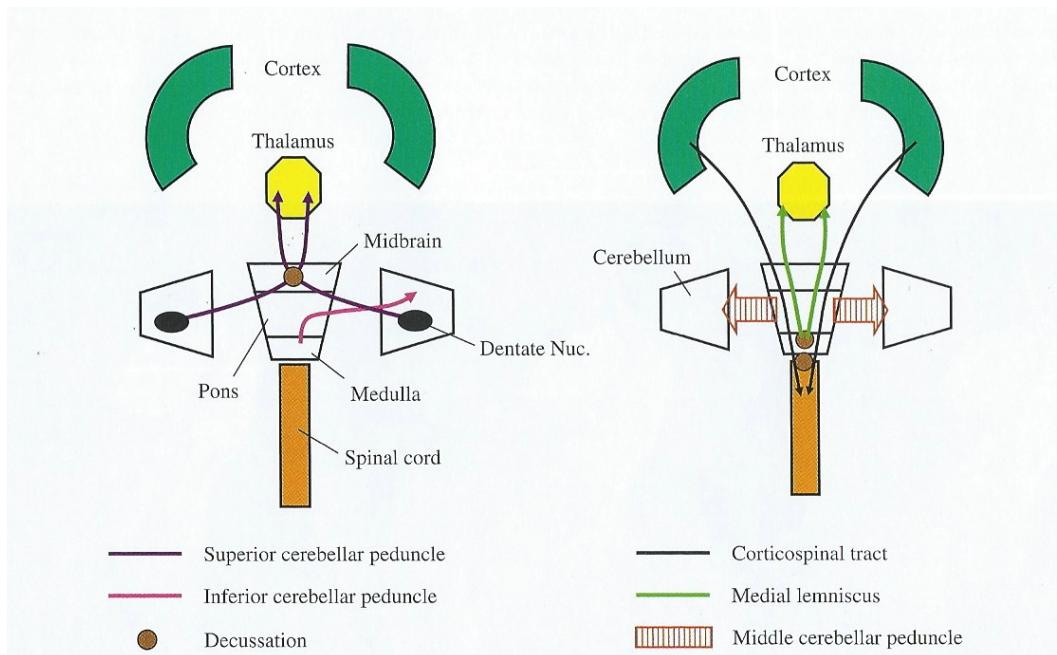


Fig. 1. Schematic diagram of the tracts in the brainstem. Decussation indicates that of the superior cerebellar peduncle.

(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=mV146F&Evap1Gr77XIw7U#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)

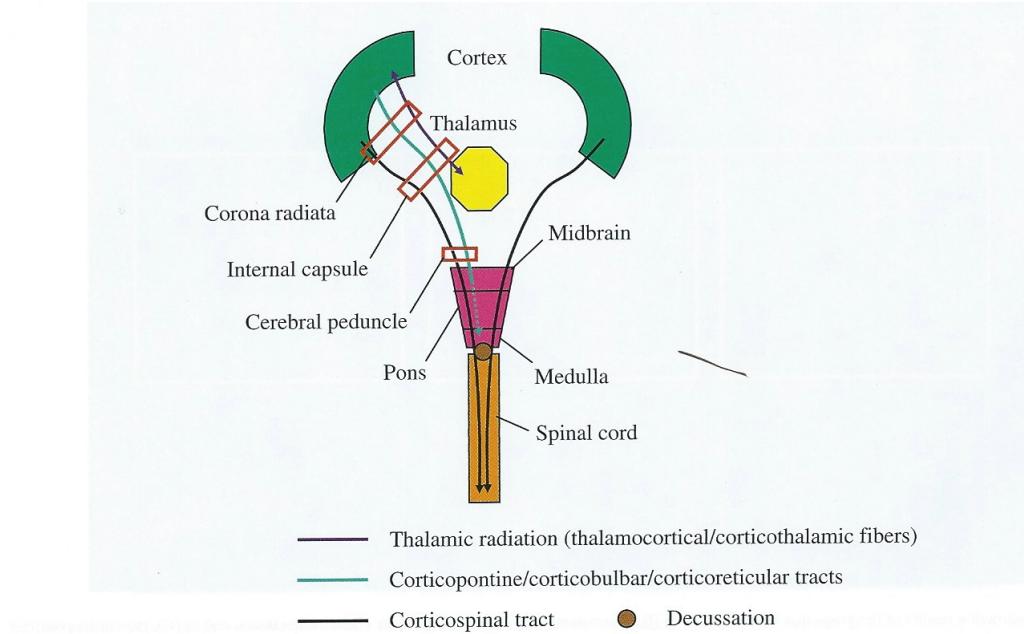


Fig. 8. A schematic diagram of trajectories of projection fibers reconstructed in this atlas. The decussation is that of the corticospinal tract.

(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=mV146F&Evap1Gr77XIw7U#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

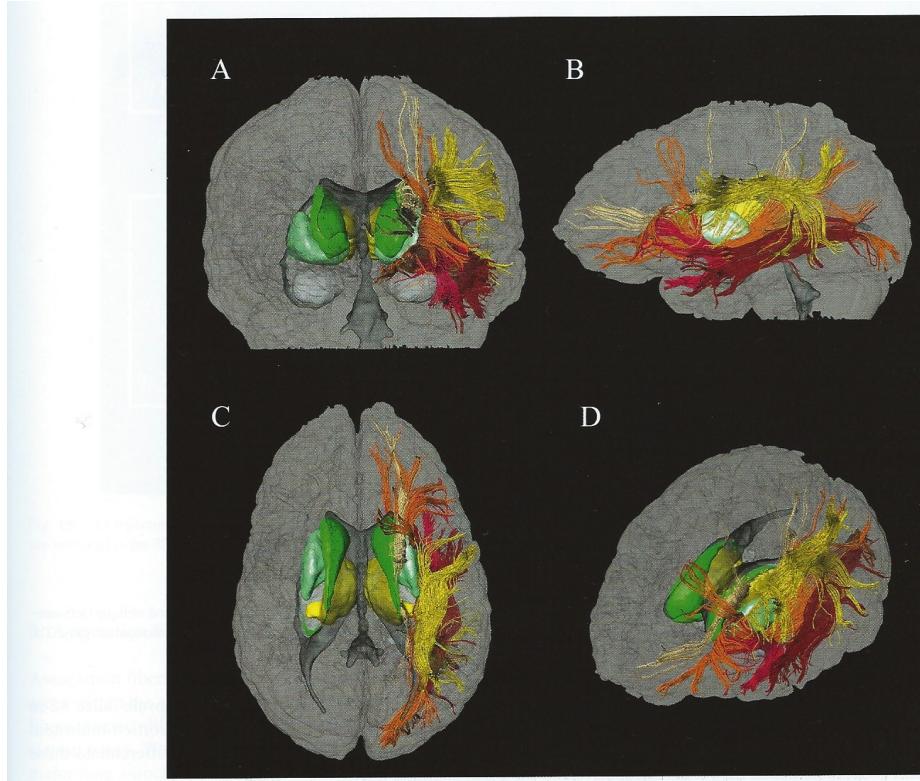
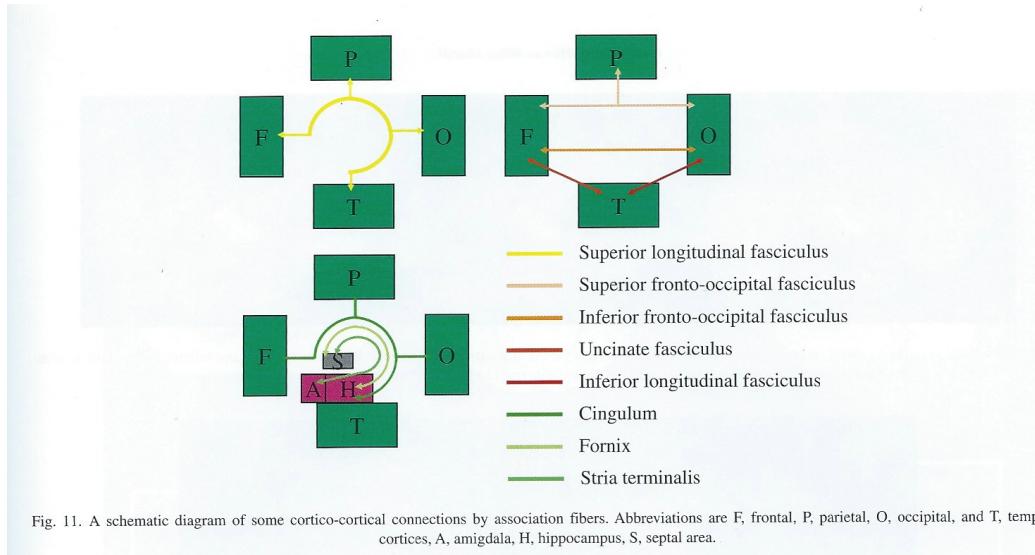


Fig. 12. 3D reconstruction results of some association fibers. Tracts are viewed from the anterior (A), left (B), superior (C), and oblique (left-antero-superior) (D) orientations. Color coding: slf is yellow, ifo is orange, unc is red, and ilf is brown. Cerebral hemispheres are delineated by semi-transparent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

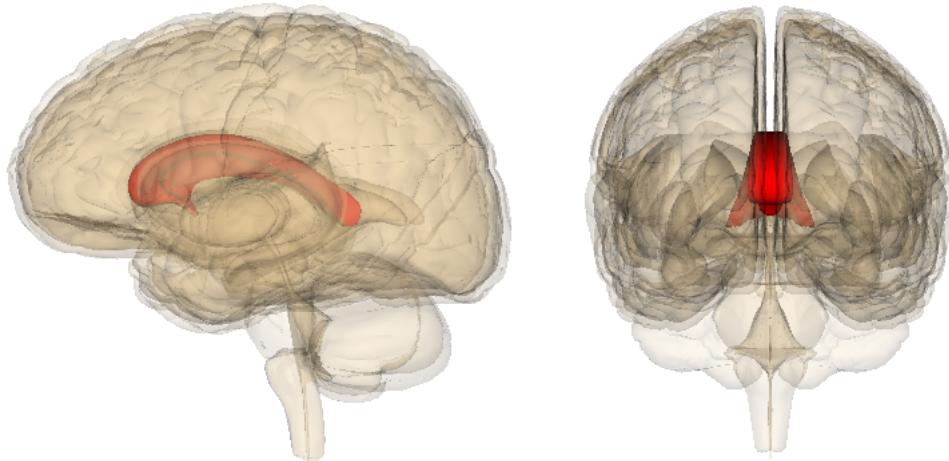
(Oishi, Faria, Zijl, & Mori, 2010) (<https://books.google.com/books?hl=en&lr=&id=v8MWjTpVUAYC&oi=fnd&pg=PT1&dq=mri+atlas+of+human+white+matter&ots=mV146F&Evap1Gr77XIw7U#v=onepage&q=mri%20atlas%20of%20human%20white%20matter&f=false>),  
Chapter 3, Figure 11.

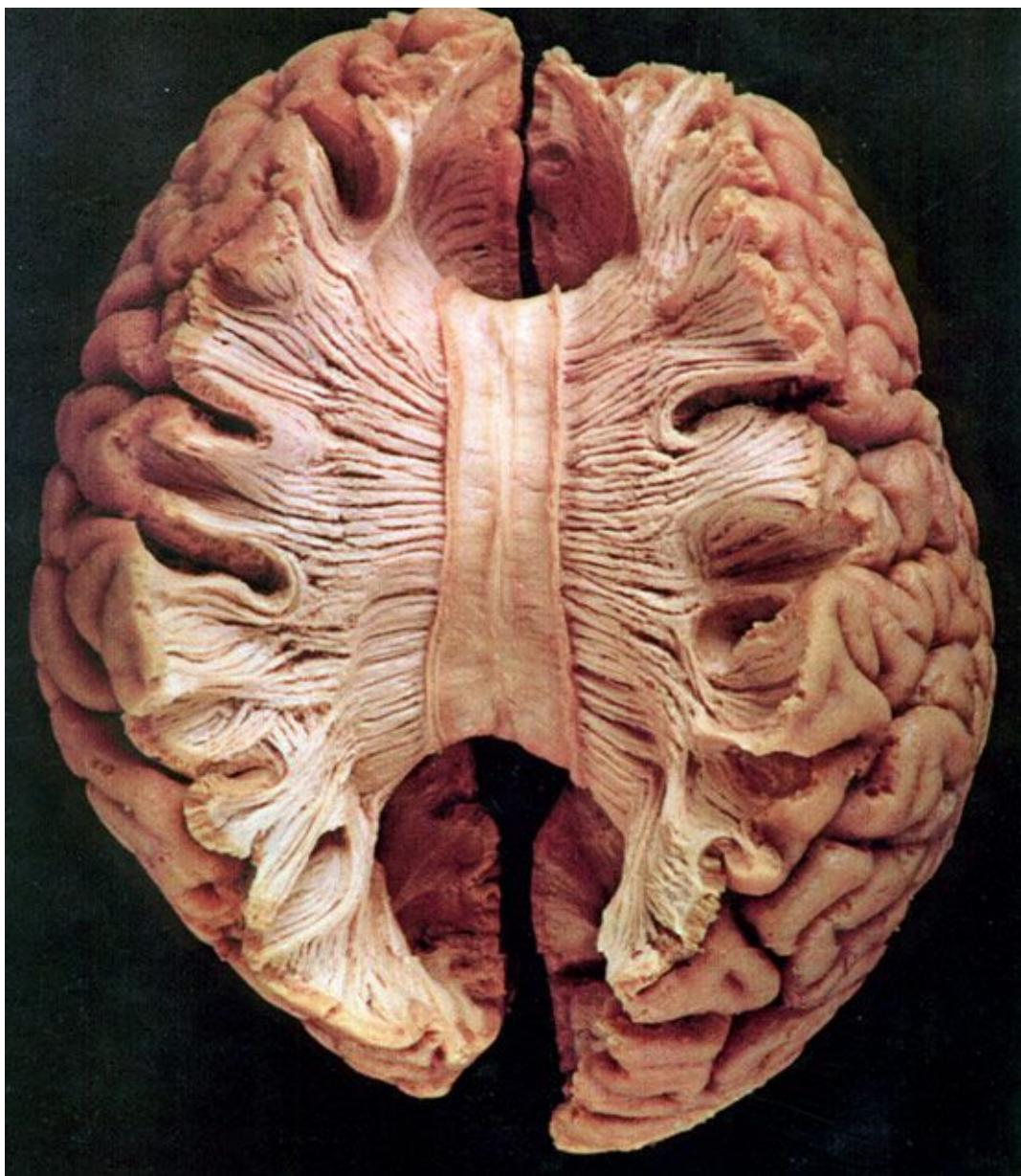
## Cortical white matter tracts

- Superior/inferior longitudinal fasciculus
  - Arcuate fasciculus ([https://en.wikipedia.org/wiki/Arcuate\\_fasciculus](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)

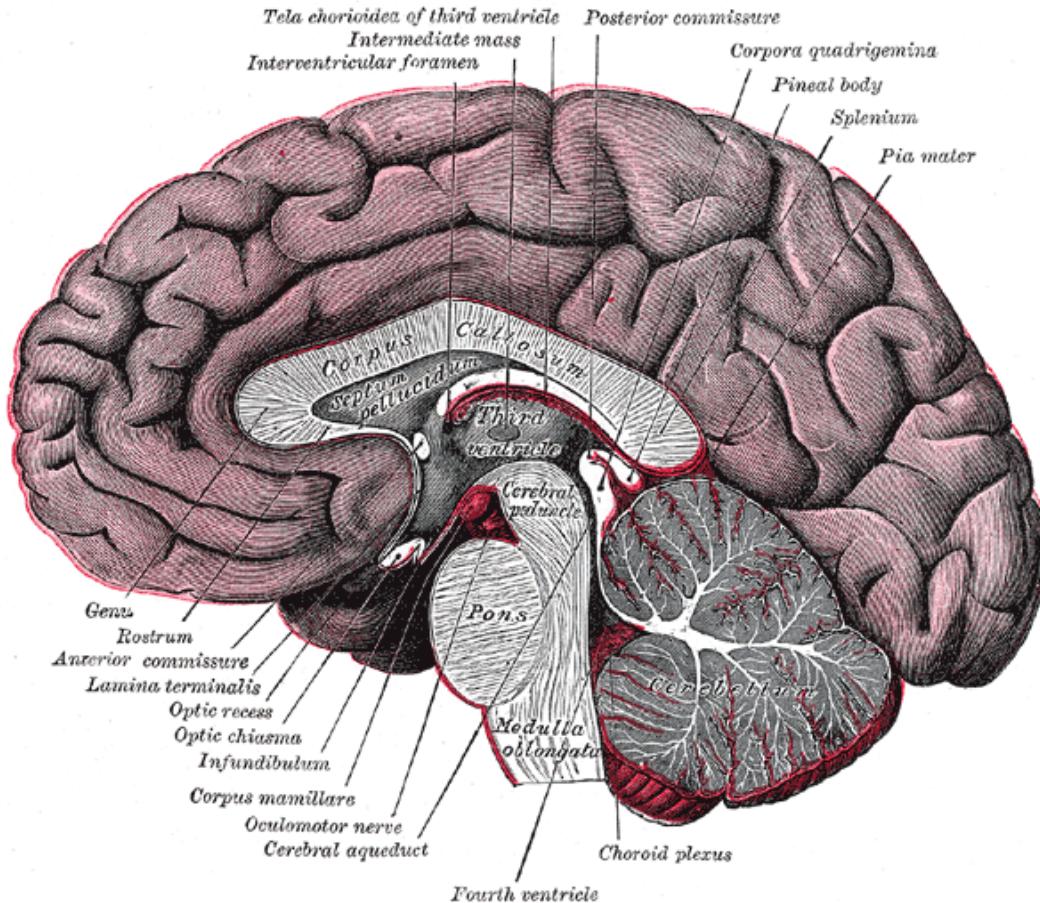
## Commissural fibers

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



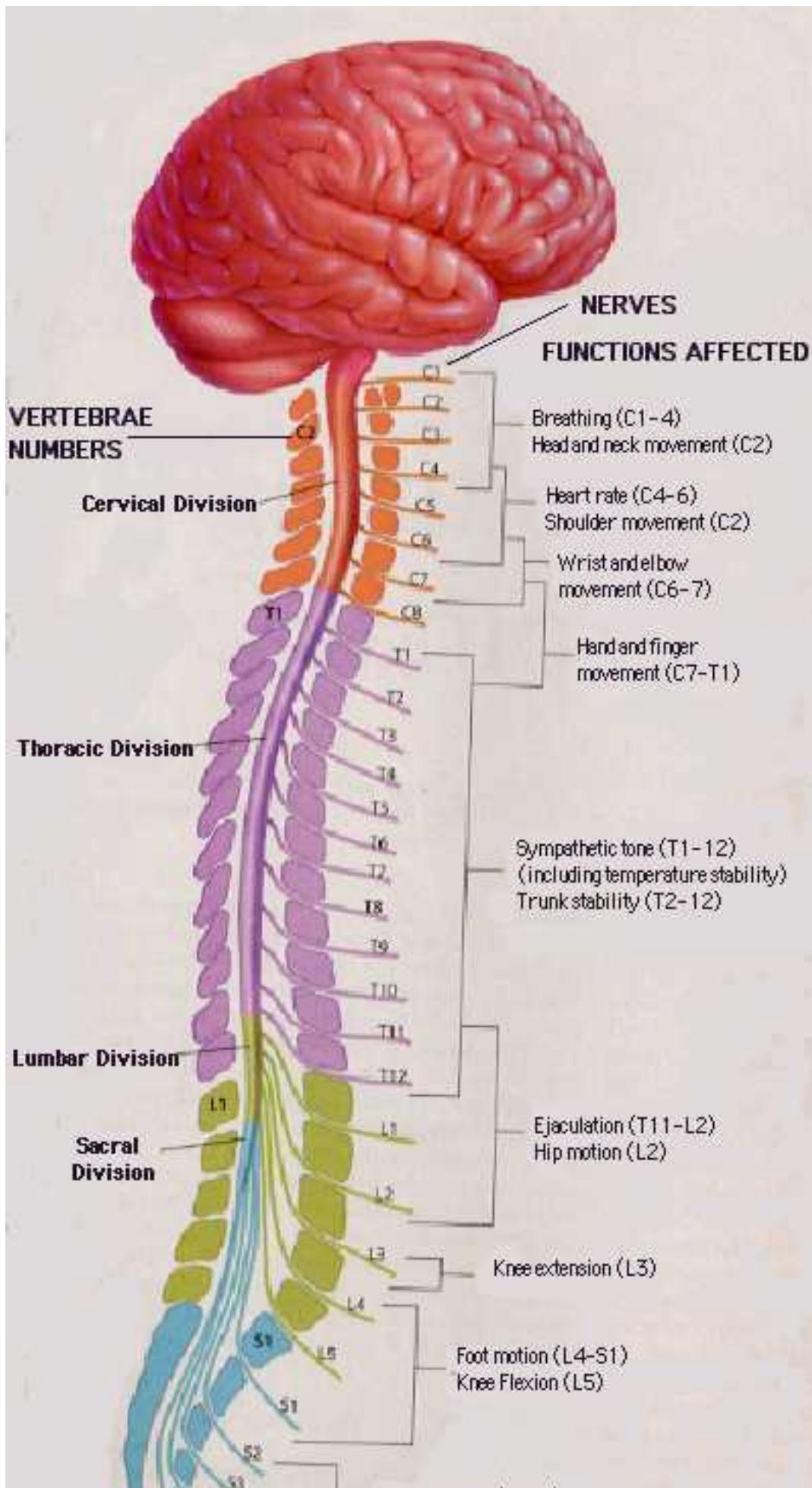


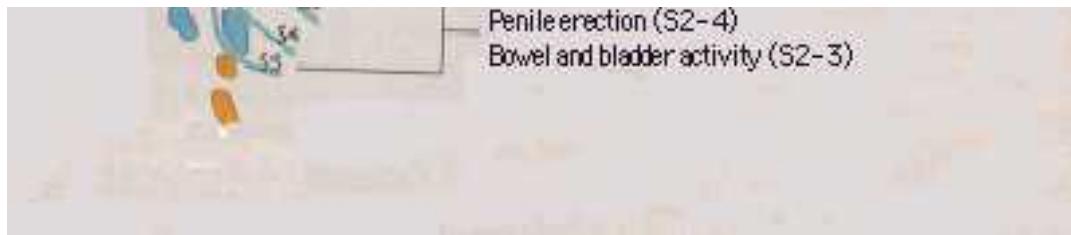
**Anterior, Posterior Commissures**



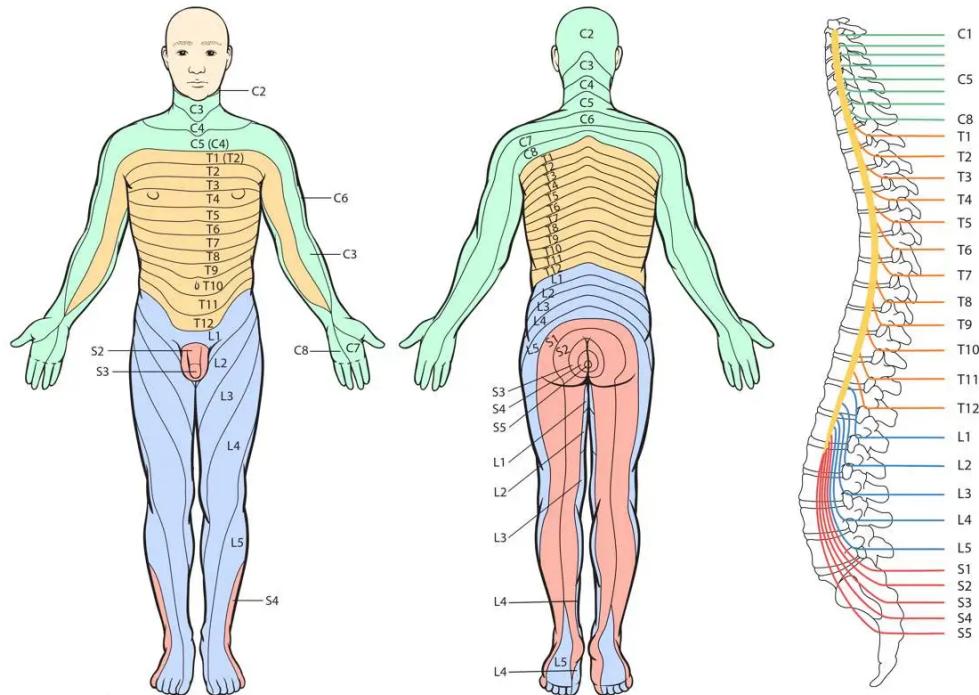
## Spinal cord

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



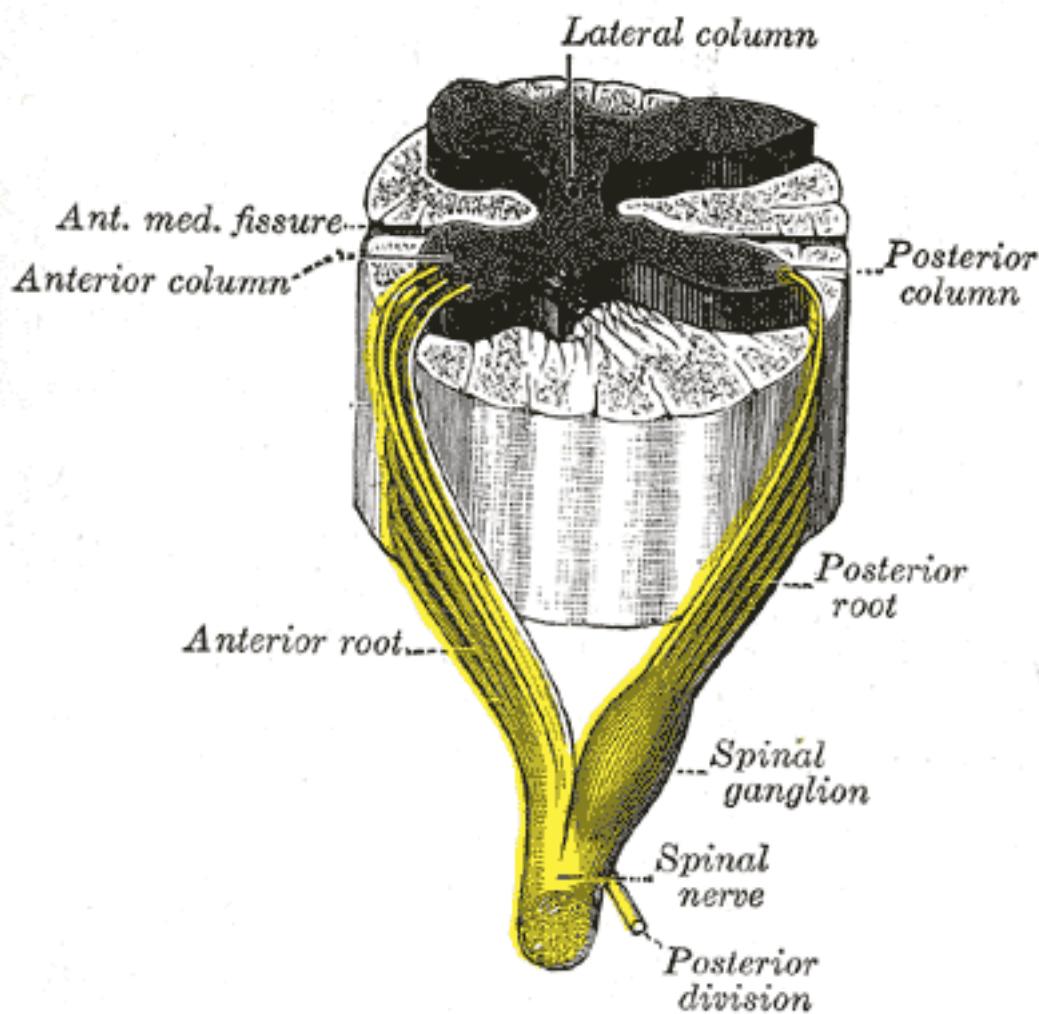
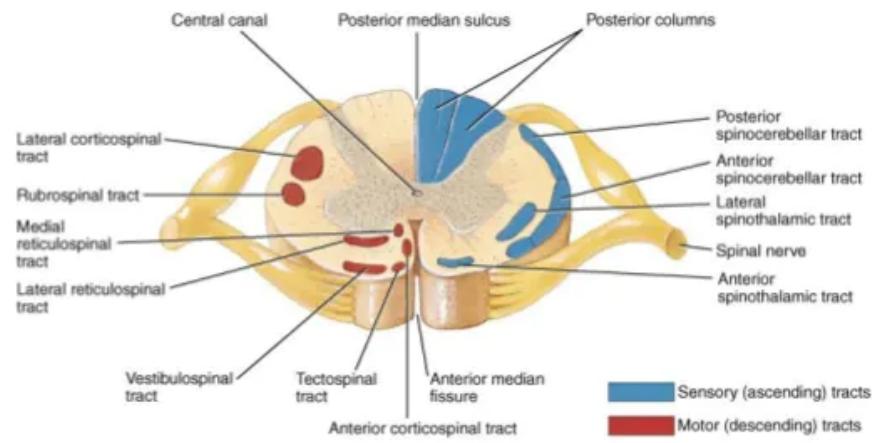


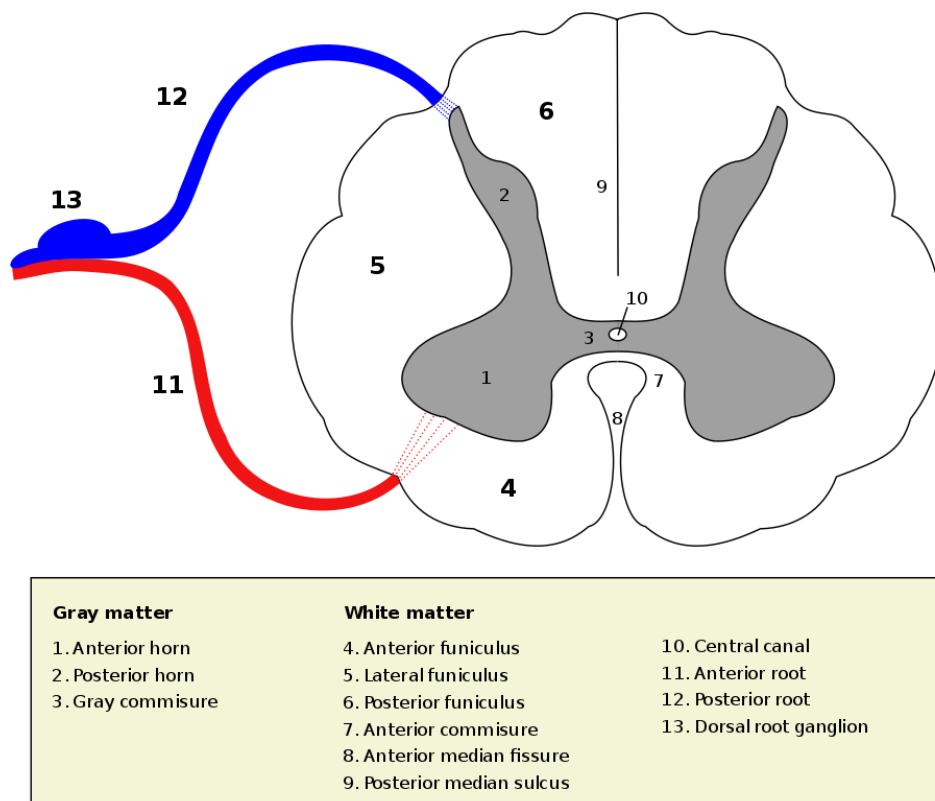
- Spinal segments (rostral to caudal) innervate specific body segments
- When focusing on the skin, these are called *dermatomes*



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

## Location of Ascending and Descending Tracts of the Spinal Cord





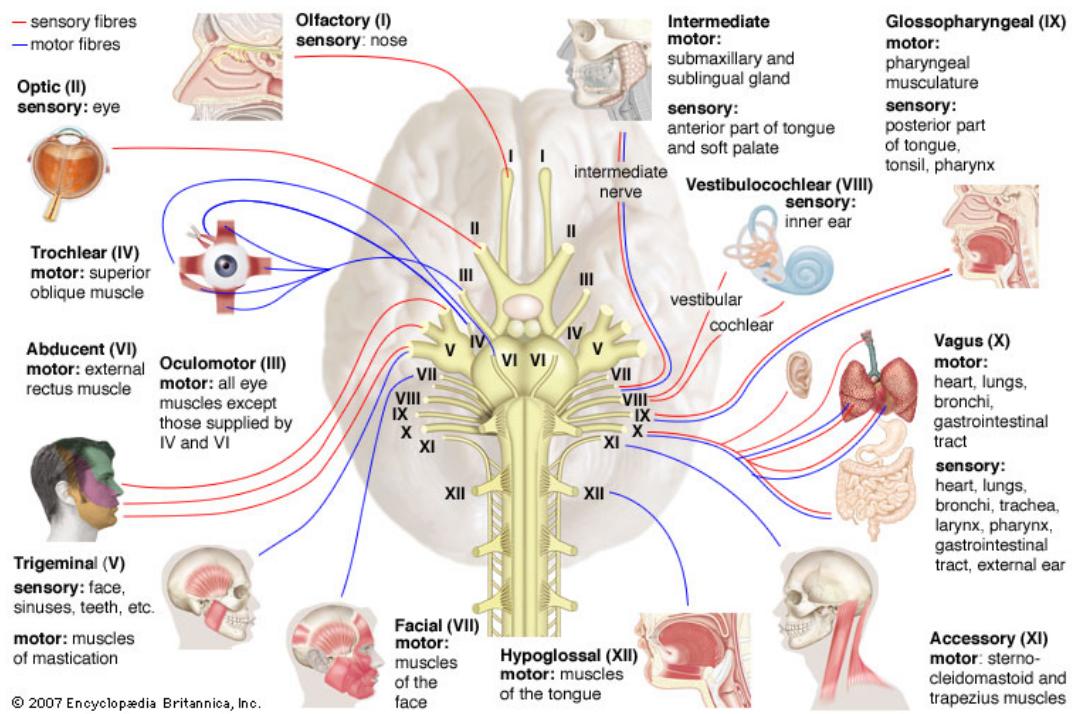
## Organization of the PNS

- Somatic division
- Autonomic division (Autonomic Nervous System)

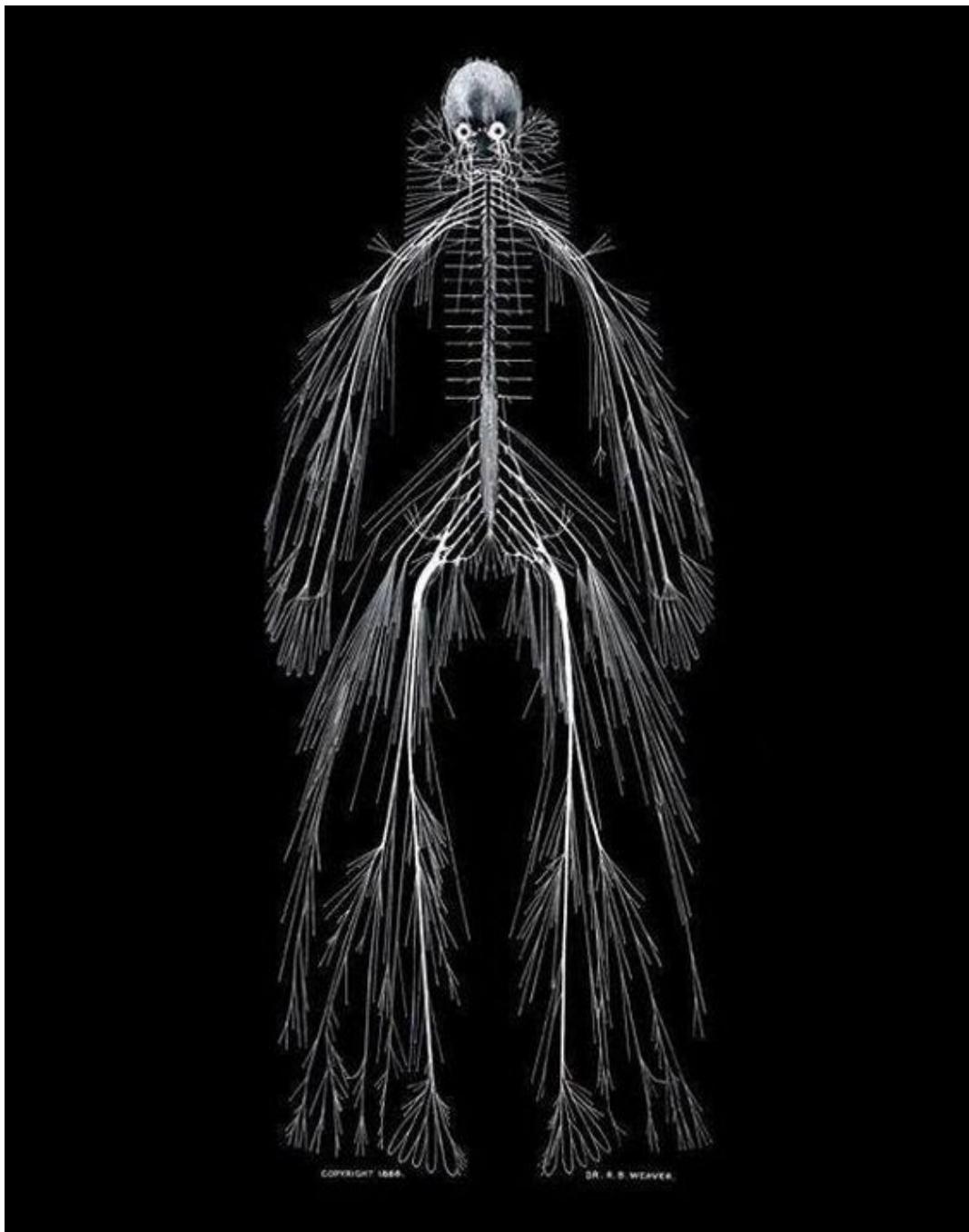
### Somatic division

#### Cranial nerves

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



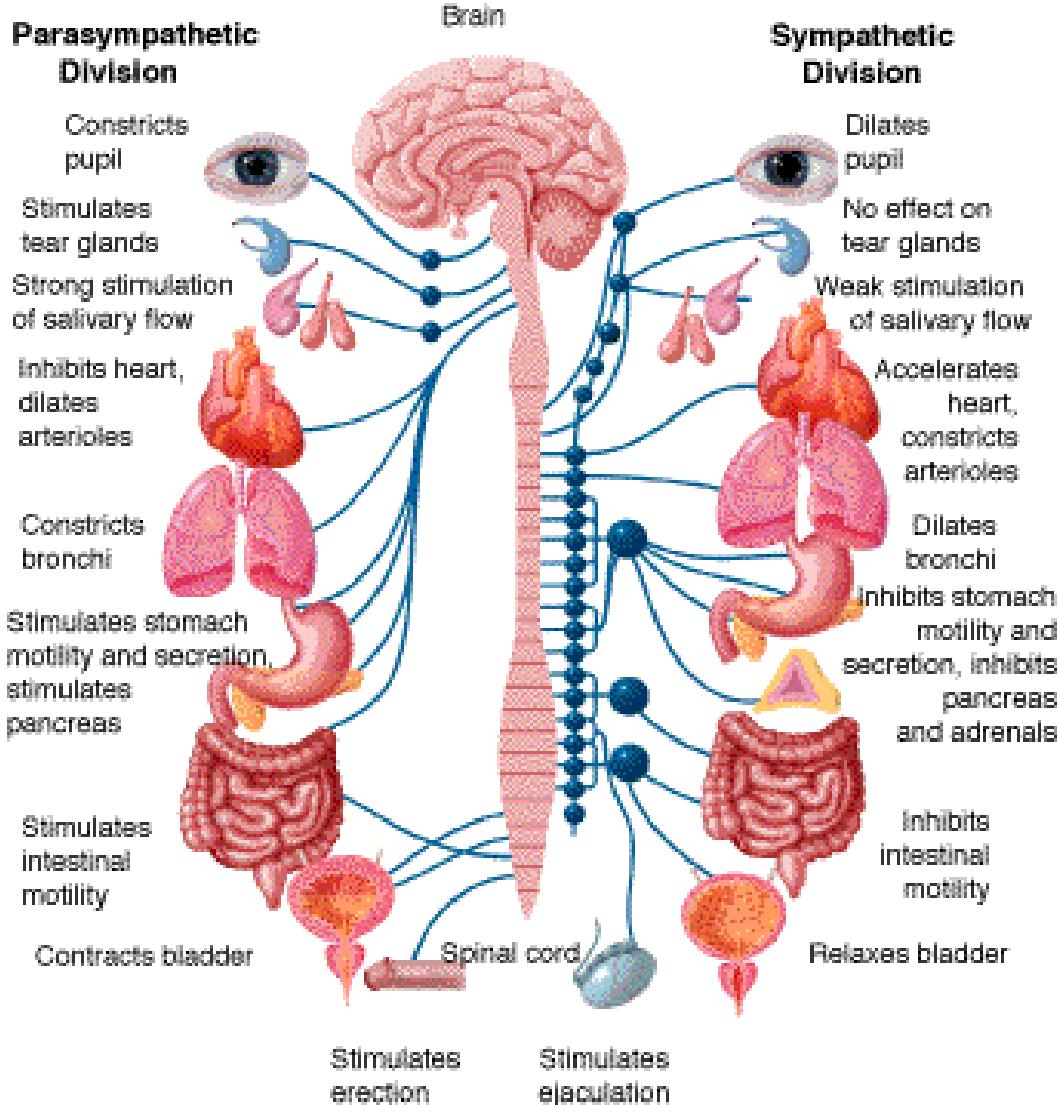
## Spinal nerves



## Autonomic nervous system

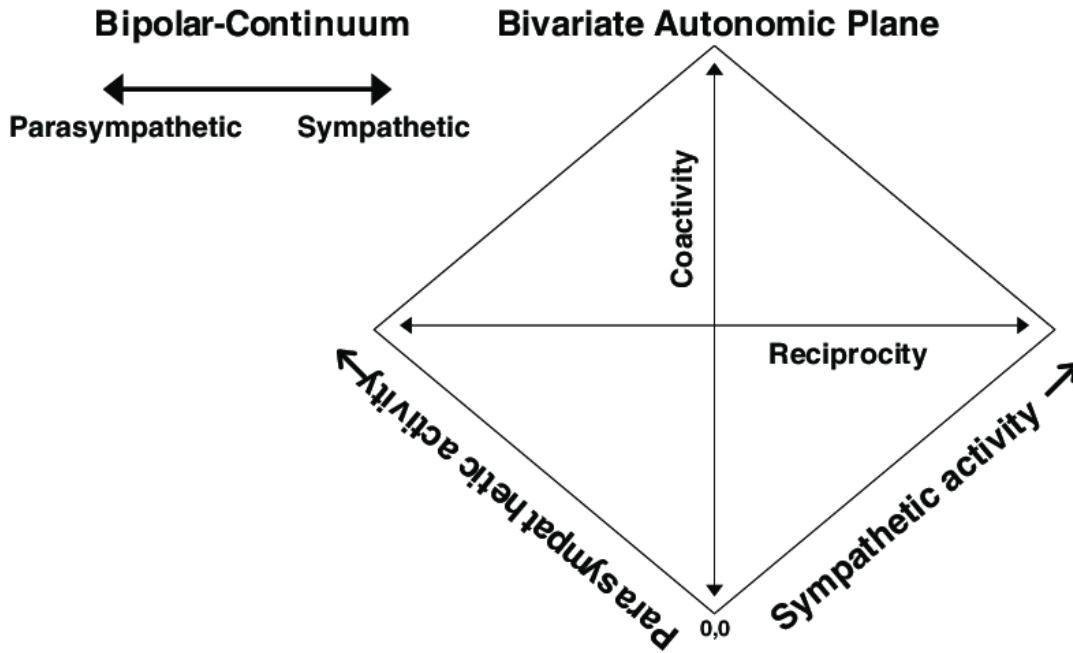
- CNS & PNS components
- Controls “vegetative functions”
  - Limited voluntary control
- Two divisions
  - Sympathetic
  - Parasympathetic

## Central Nervous System



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

## Models of Autonomic Control



### Sympathetic division

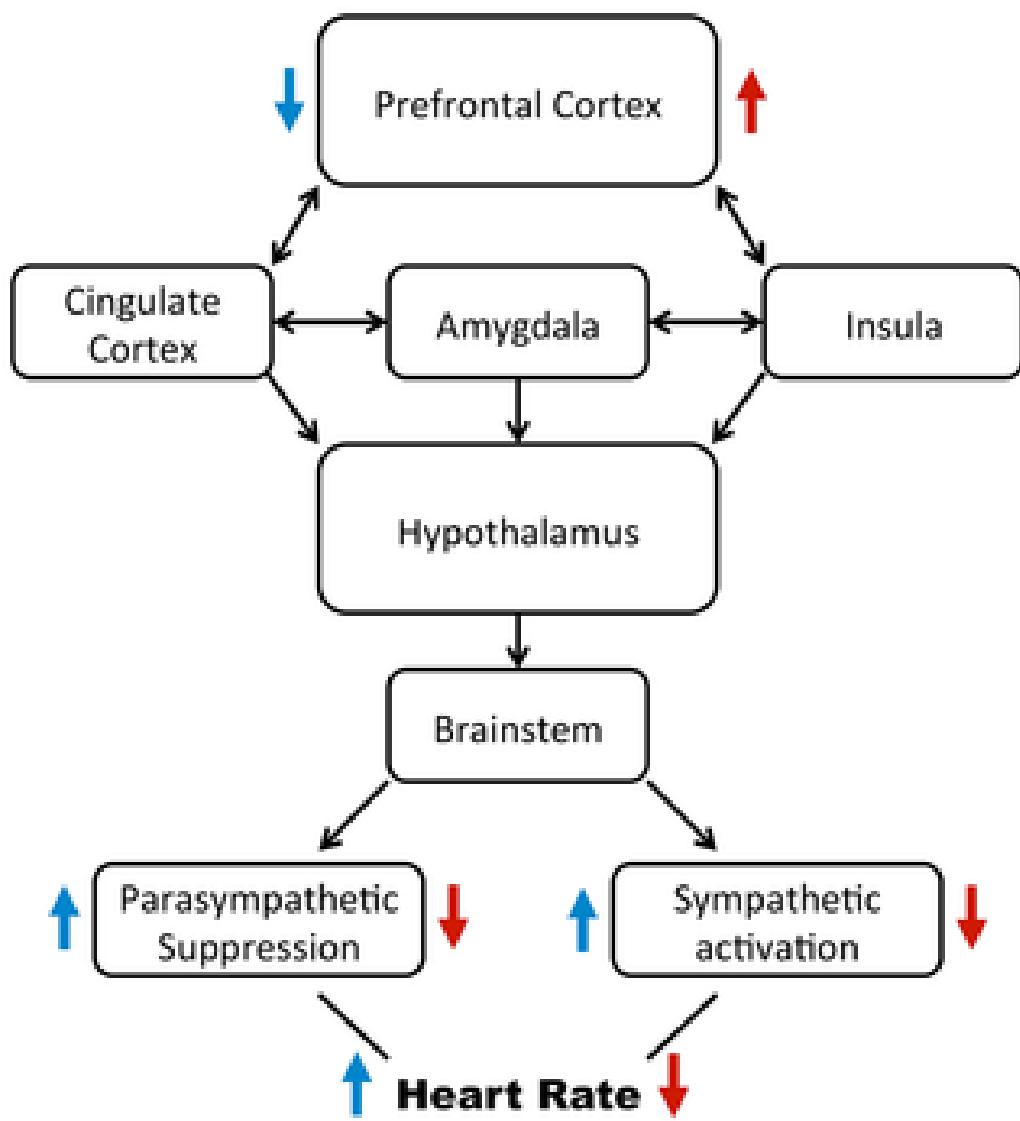
- Prepares body for action
- “Fight or flight”
- Spinal cord
  - ganglion chain along spinal column to End organs
- Neurotransmitters (NTs)
  - Preganglionic: ACh
  - Post: NE

### 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

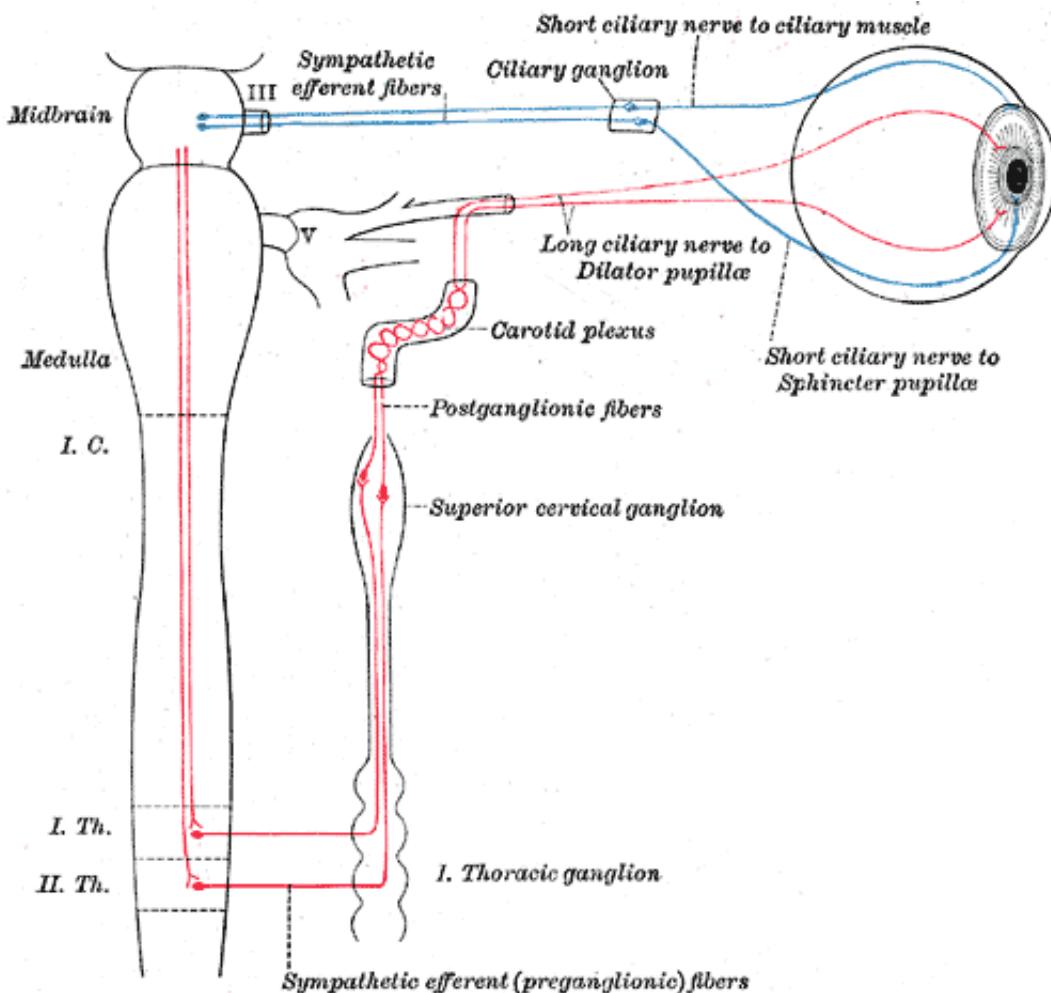


[https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral\\_integration\\_model.png](https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral_integration_model.png)

Neurovisceral\_integration\_model.png

([https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral\\_integration\\_model.png](https://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Neurovisceral_integration_model.png))  
Neurovisceral\_integration\_model.png

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



<https://upload.wikimedia.org/wikipedia/commons/a/a5/Gray840.png>  
[\(https://upload.wikimedia.org/wikipedia/commons/a/a5/Gray840.png\)](https://upload.wikimedia.org/wikipedia/commons/a/a5/Gray840.png)

## 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 [\(https://www.psychologytoday.com/blog/i-got-mind-tell-you/201508/the-amamygdala-is-not-the-brains-fear-center\)](https://www.psychologytoday.com/blog/i-got-mind-tell-you/201508/the-amamygdala-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.
- 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>)