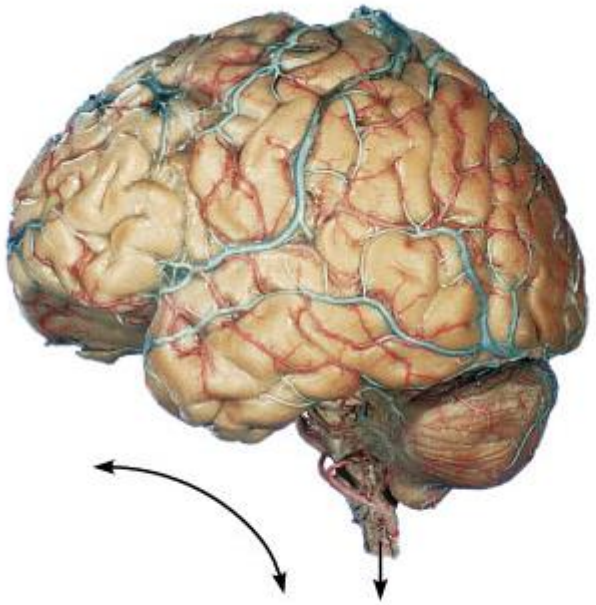
Human Anatomy & Physiology

Central Nervous System:
"CNS"

Spinal Cord

Brain



Objectives.

- **Outline the functions of 4 types of neuroglial cells**
- **Describe the structure of the meninges**
- **Describe the flow of cerebrospinal fluid in the brain**
- **List the functions of cerebrospinal fluid.**

Neuroglia

- **Neuroglia**
- **Astrocytes**
- **Oligodendrocytes**
  - Myelination in CNS
- **Microglia**
  - derived from monocytes; are Phagocytic
- **Ependymal cells**
  - Form the epithelial lining of the ventricles of the brain and the central canal of the spinal cord.

Membranes covering the brain and spinal cord (the meninges)

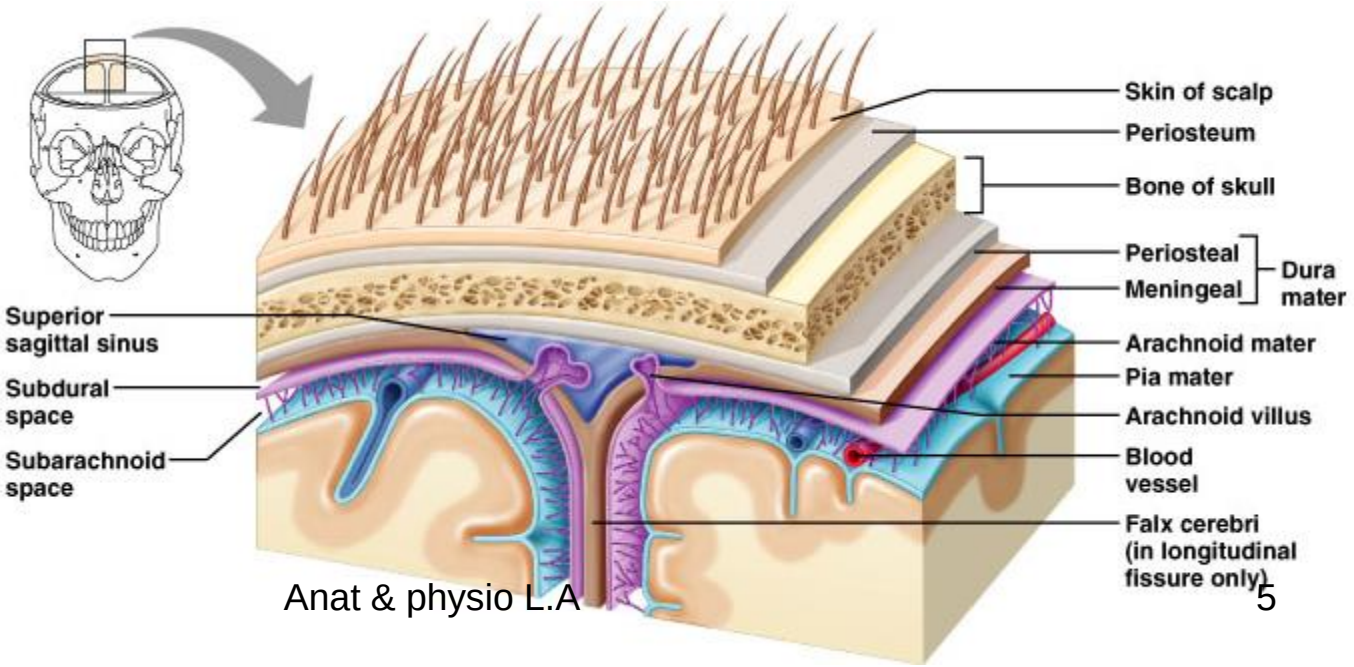
From outwards inwards:

- Dura Mater
- Arachnoid Mater
- Pia Mater

Meninges

1. ***Dura mater***: 2 layers of fibrous connective tissue, fused except for dural sinuses
   - Periosteal layer attached to bone
   - Meningeal layer - proper brain covering
2. ***Arachnoid mater***
3. ***Pia mater***

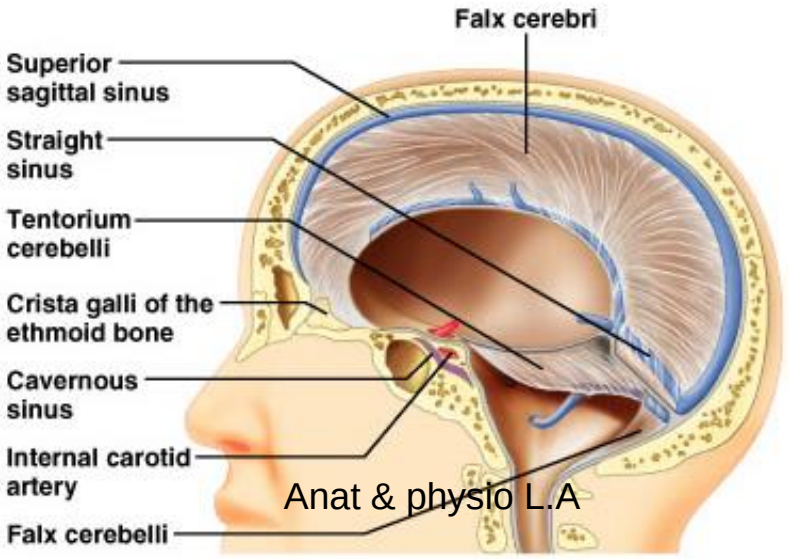
Note superior sagittal sinus

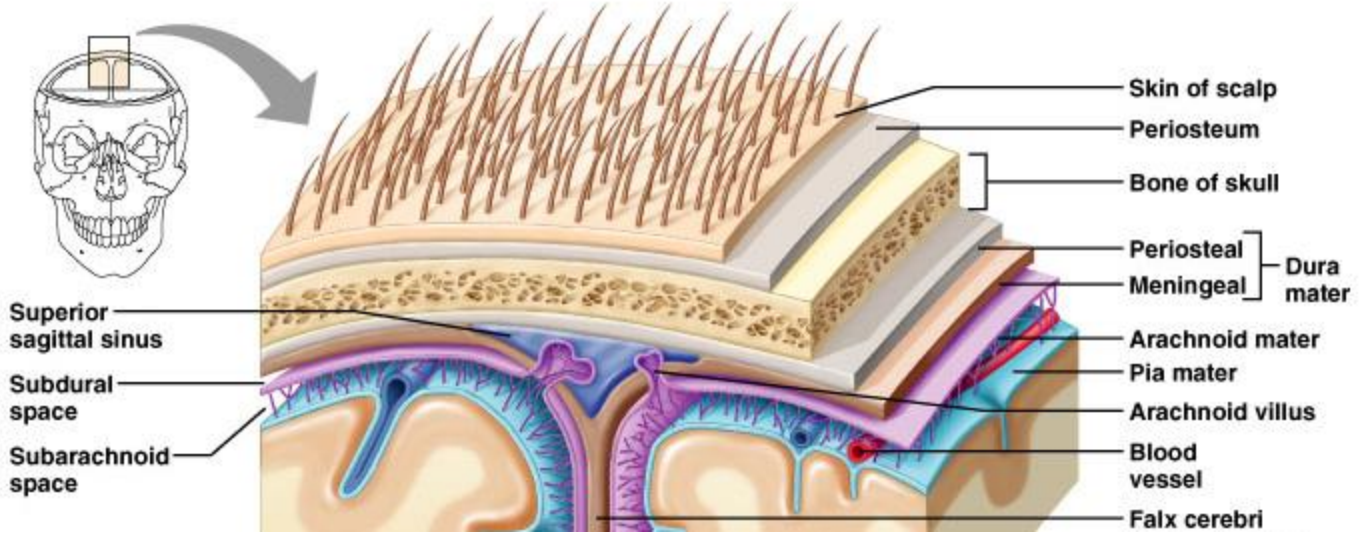


Dura mater - dural partitions

Subdivide cranial cavity & limit movement of brain

- Falx cerebri
  - In longitudinal fissure; attaches to crista galli of ethmoid bone
- Falx cerebelli
  - Runs vertically along vermis of cerebellum
- Tentorium cerebelli
  - Sheet in transverse fissure between cerebrum & cerebellum





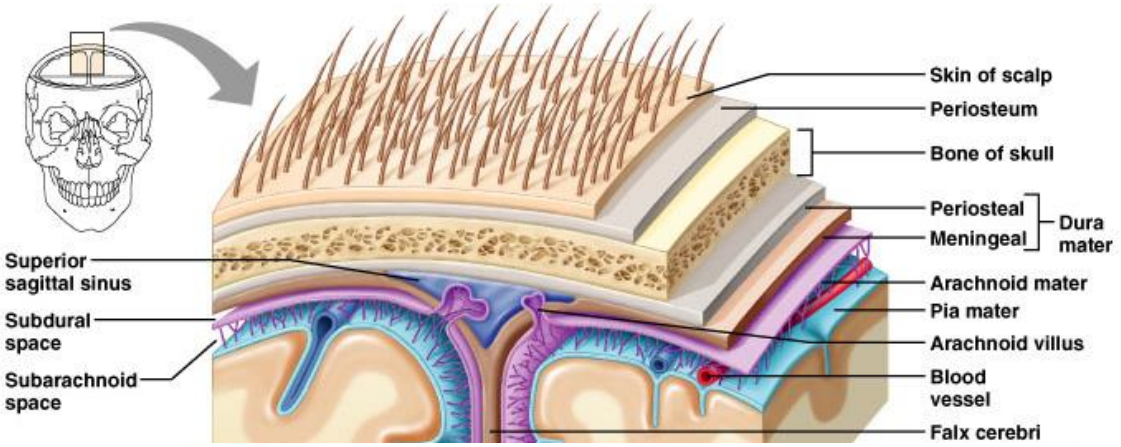
- Arachnoid mater
  - Between dura and arachnoid: ***subdural space***
  - Dura and arachnoid cover brain loosely
  - Deep to arachnoid is ***subarachnoid space***
    - Filled with CSF
    - Lots of vessels run through (susceptible to tearing)
  - Superiorly, forms arachnoid villi: CSF valves
    - Allow draining into dural blood sinuses
- Pia mater
  - Delicate, clings to brain following convolutions

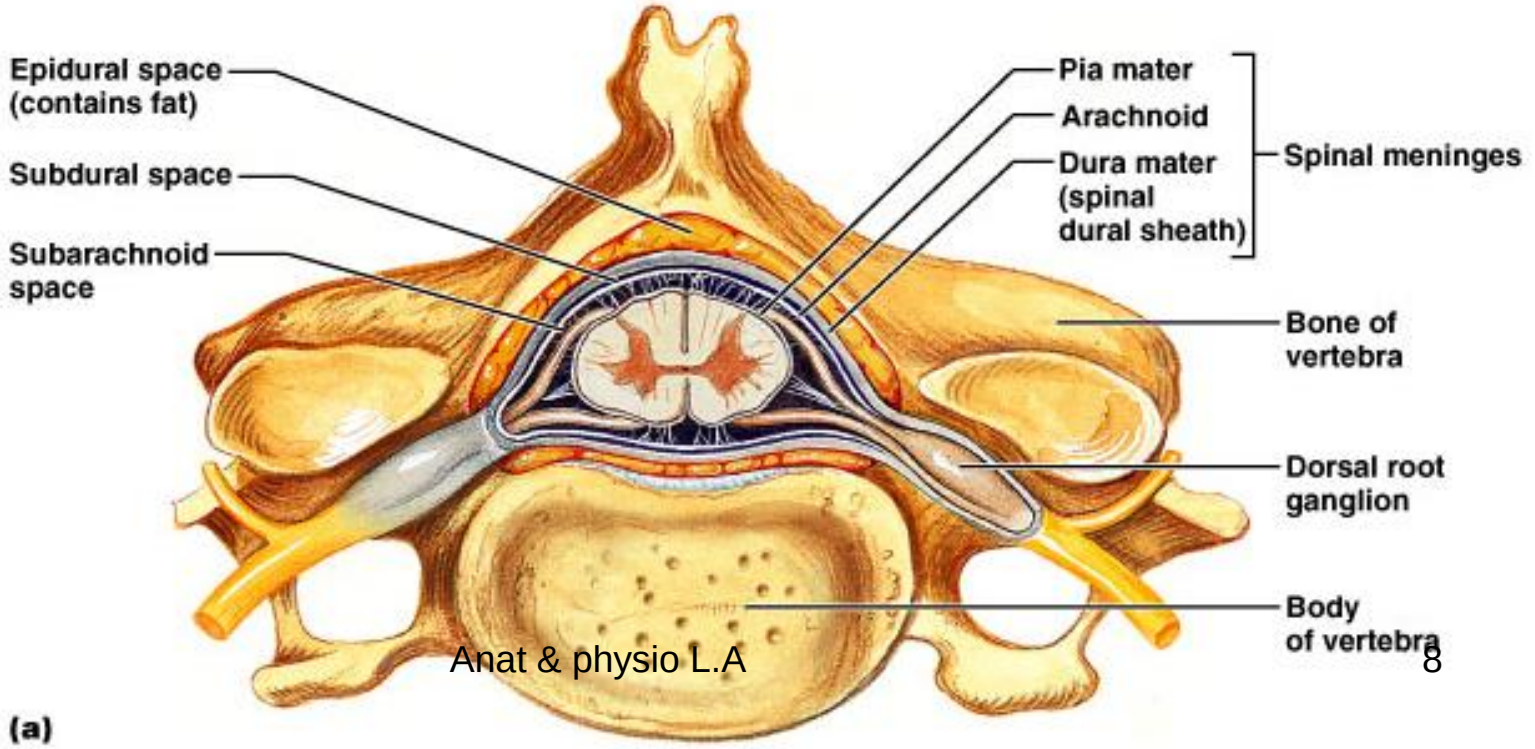
Protection:

Bone
Meninges
CSF (cerebrospinal fluid)

3 meninges:
- dura mater (outer)
- arachnoid mater (middle)
- pia mater (inner)

3 potential spaces
- epidural: outside dura
- subdural: between dura & arachnoid
- subarachnoid: deep to arachnoid





Meninges

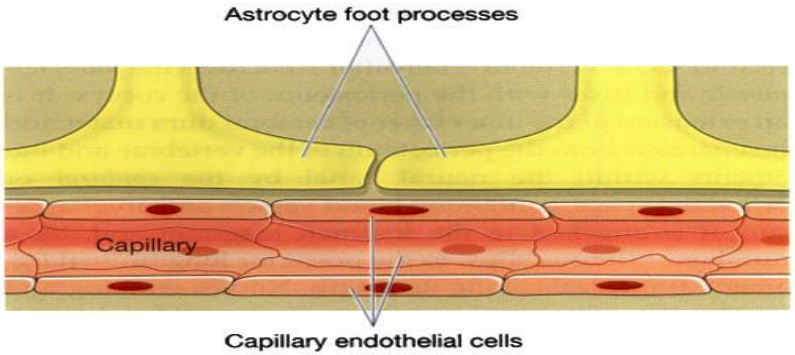
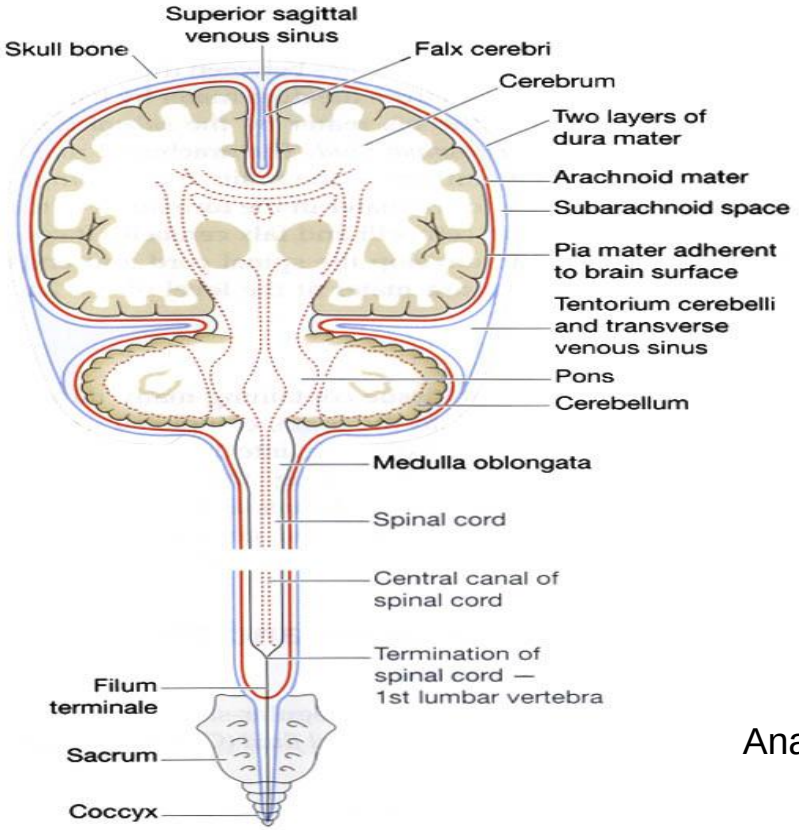
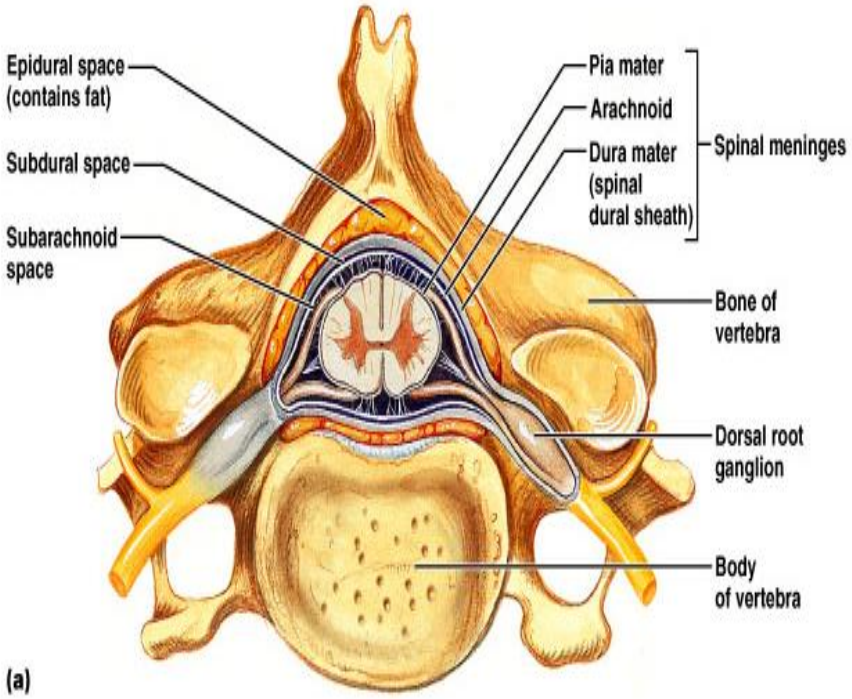


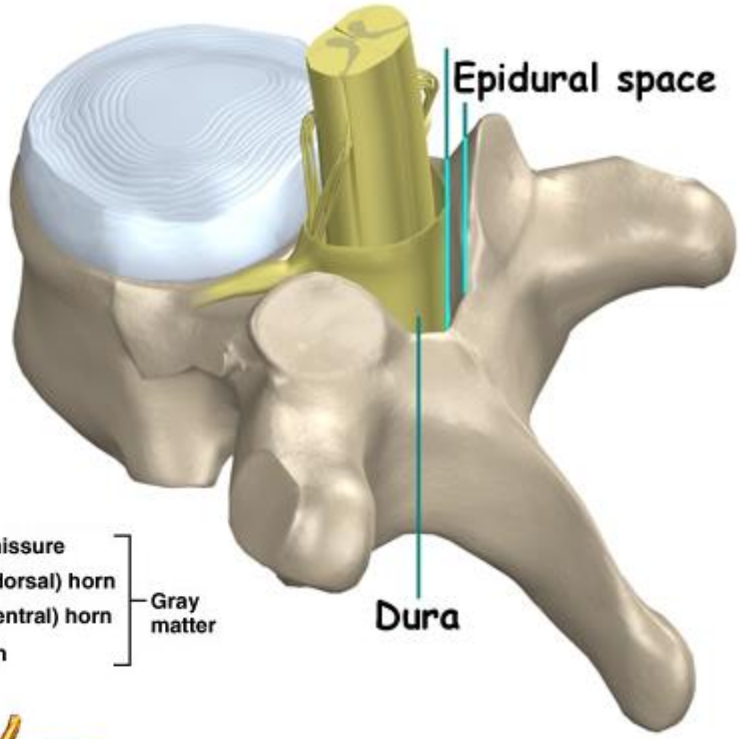
Figure 7.11 Blood–brain barrier.

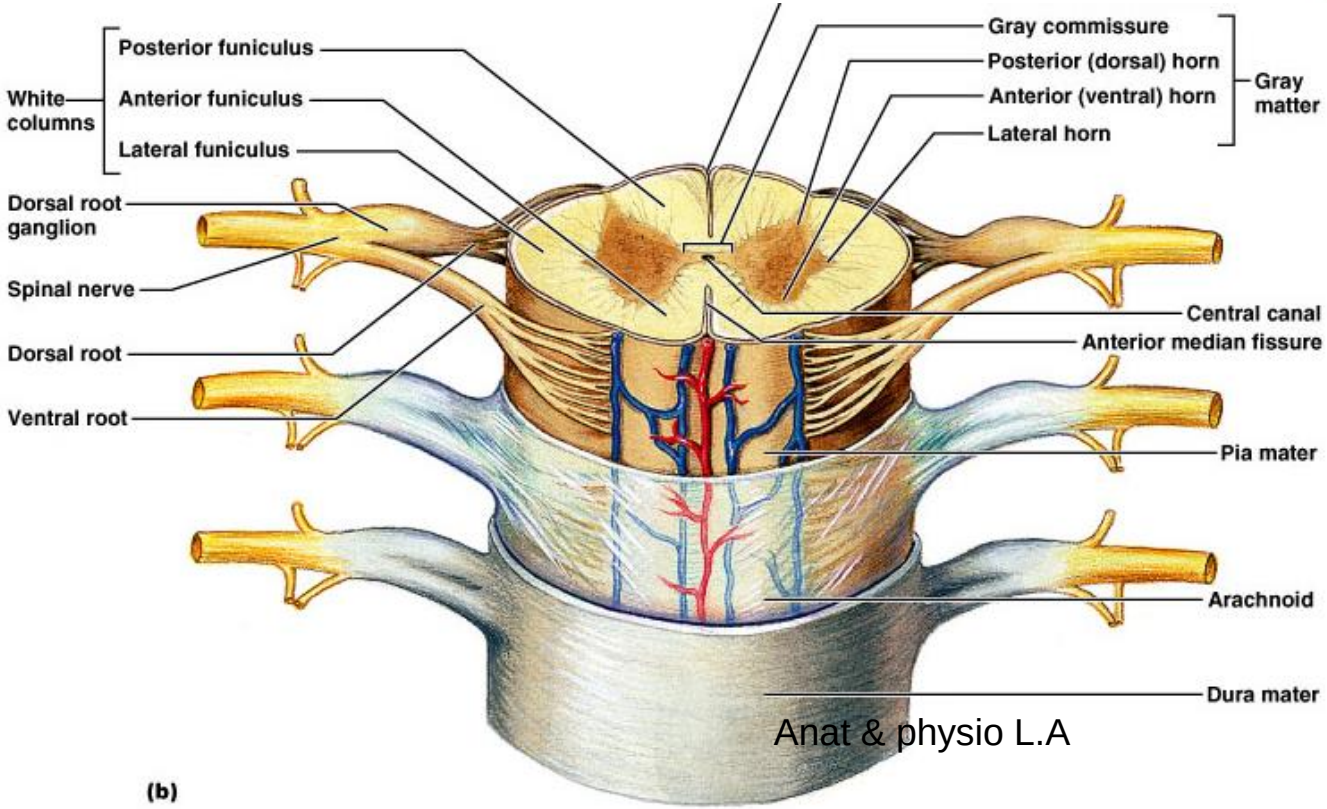




Spinal cord coverings and spaces

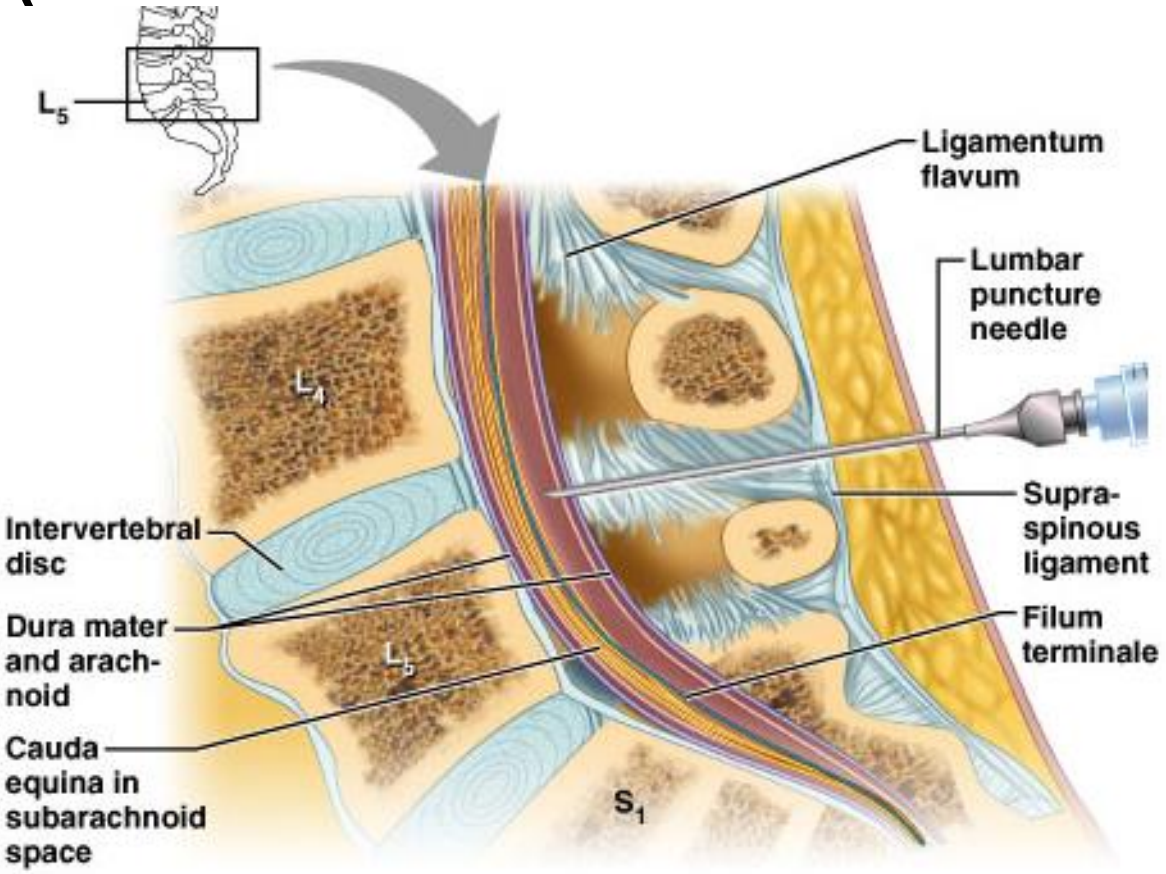
http://www.eorthopod.com/images/ContentImages/pm/pm_general_esi/pmp_general_esi_epidural_space.jpg





LP (lumbar puncure) = spinal tap

*(needle introduced into **subdural** space to collect CSF)*

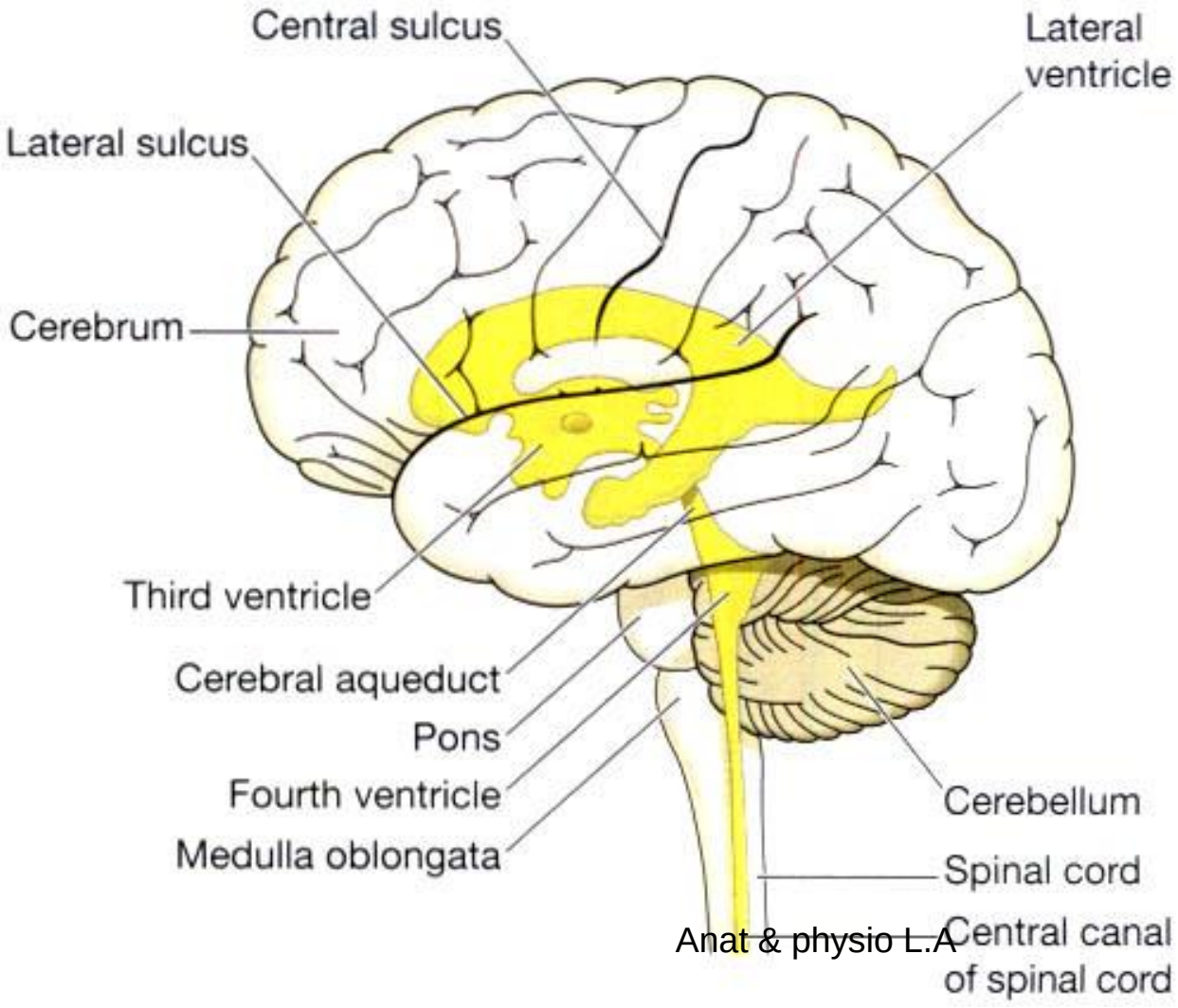


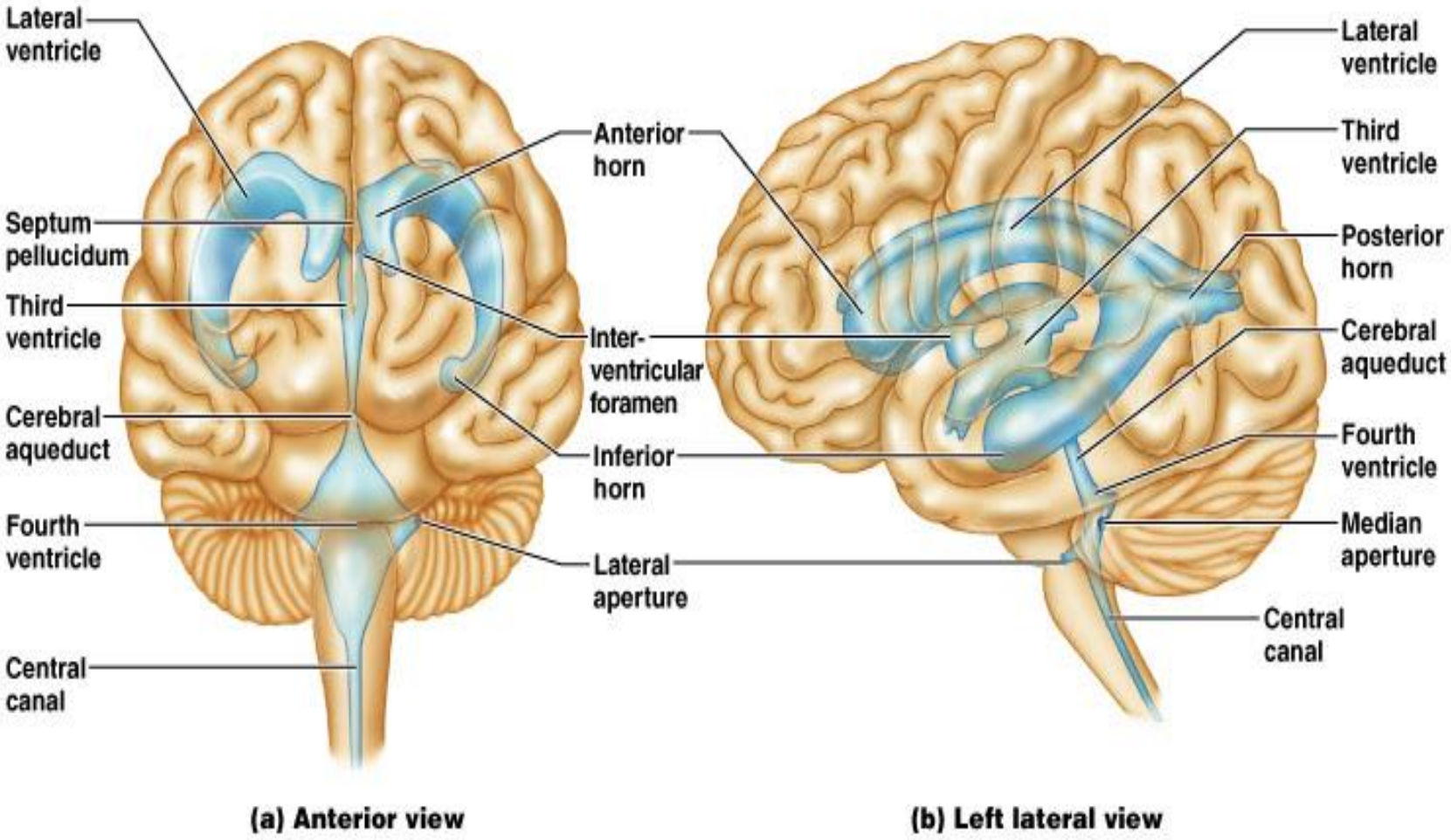
Lumbar spine needs to be flexed so can go between spinous processes

Ventricles of the brain and the cerebrospinal fluid

- Four irregular-shaped cavities, or *ventricles,* containing *cerebrospinal fluid* (CSF
  - right and left lateral ventricles
  - third ventricle
  - fourth ventricle.

The positions of the ventricles of the brain

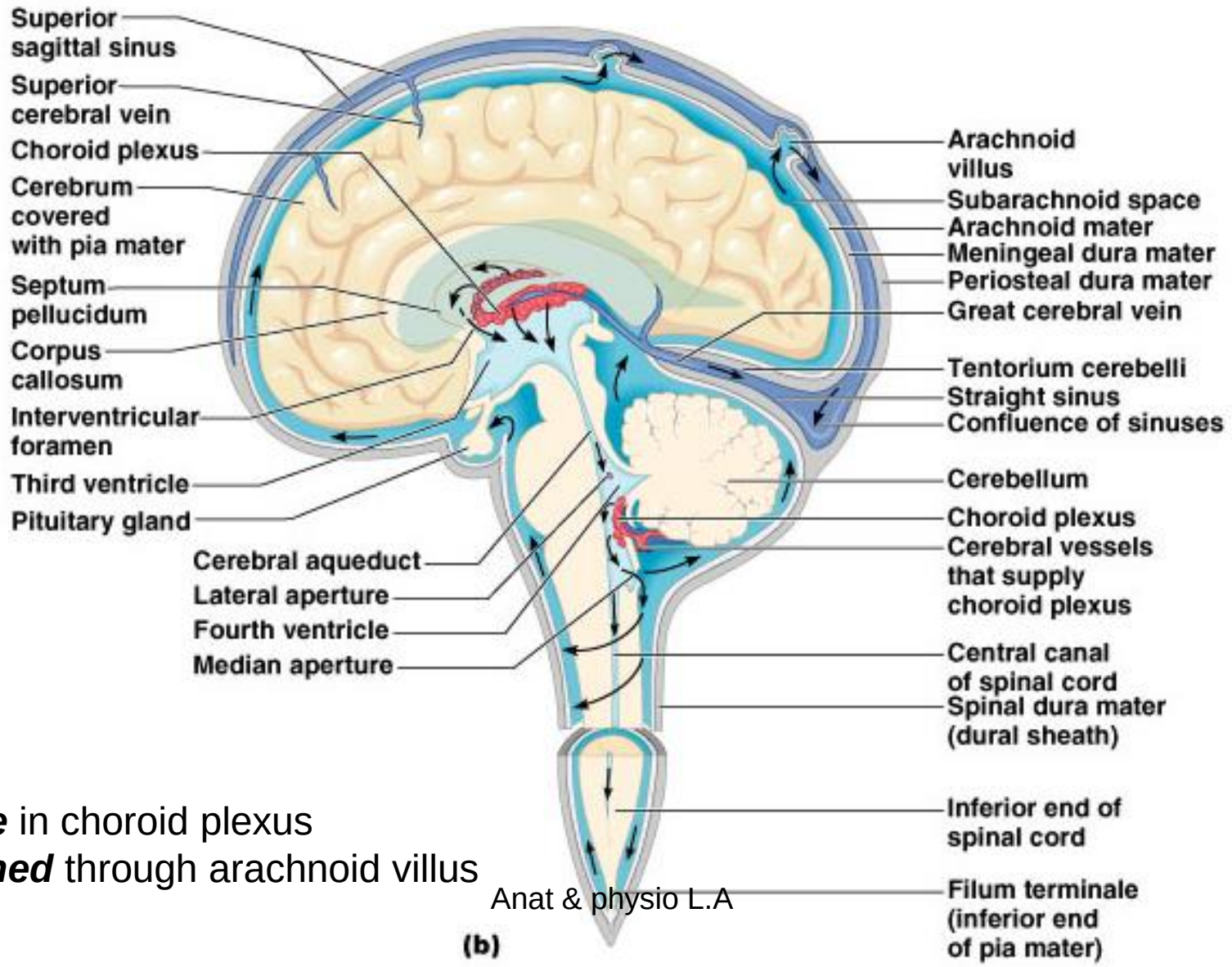



Lateral ventricle
Septum pellucidum
Third ventricle
Cerebral aqueduct
Fourth ventricle
Central canal
Anterior horn
Inter-ventricular foramen
Inferior horn
Lateral aperture
(a) Anterior view
Lateral ventricle
Third ventricle
Posterior horn
Cerebral aqueduct
Fourth ventricle
Median aperture
Central canal
(b) Left lateral view

Cerebrospinal fluid (CSF)

- Secreted into each ventricle of the brain by *choroid plexuses*
- clear, slightly alkaline fluid
- Rate: 0.5 ml/minute, i.e. 720 ml/day
- CSF pressure:
  - 10 cmH_2O when the individual is lying on his side
  - 30 cmH_2O when sitting up

CSF circulation: through ventricles, median and lateral apertures, subarachnoid space, arachnoid villi, and into the blood of the superior sagittal sinus



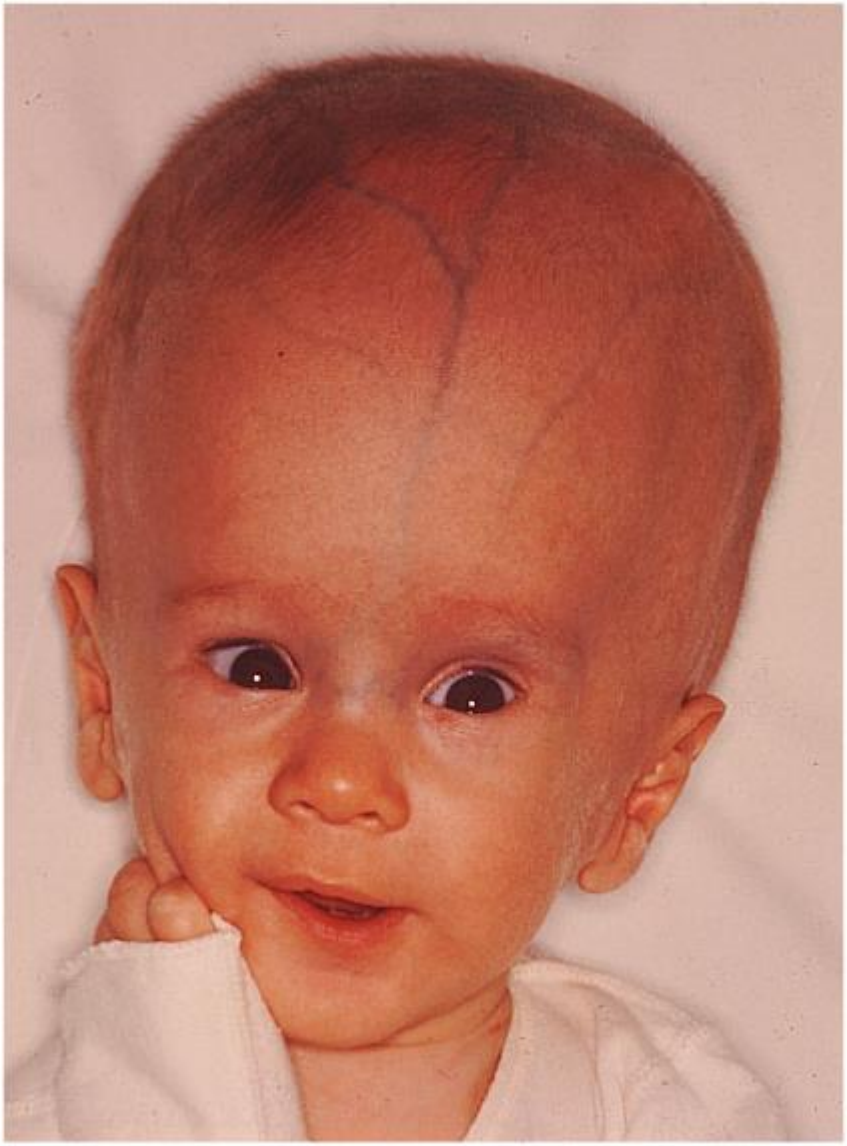
CSF:

-***Made*** in choroid plexus

-***Drained*** through arachnoid villus

CSF composition

- Water
- Mineral salts
- Glucose
- Plasma proteins: small amounts of albumin and
- Globulin
- Creatinine
- Urea
- A few leukocytes.



Hydrocephalus

Functions of cerebrospinal fluid

- Support/protection of CNS
- It maintains a uniform pressure around these delicate structures.
- Cushion and shock absorber
- Moistens brain & spinal cord
- Interchange of substances between CSF and nerve cells
    - Nutrients
    - Waste products.

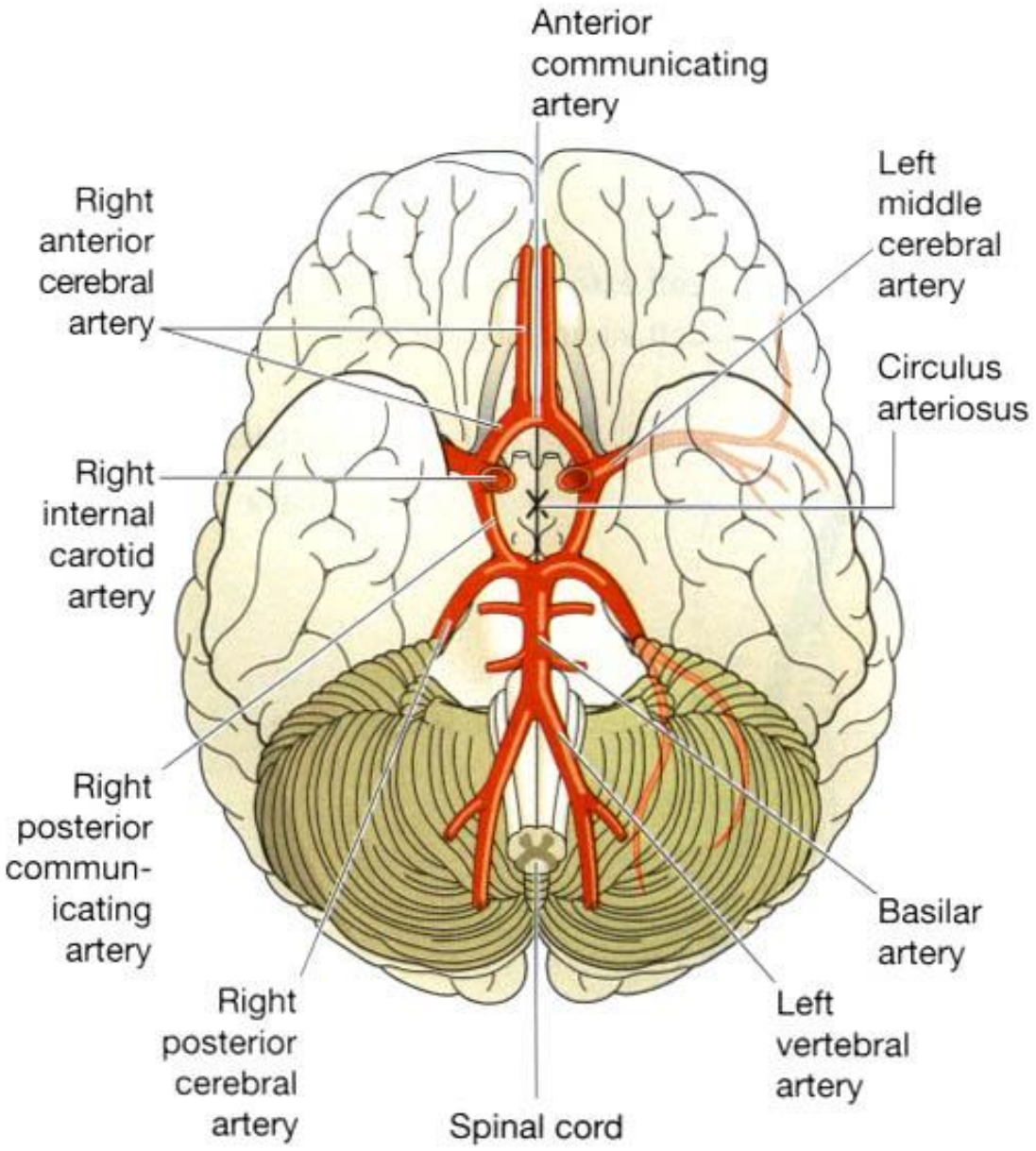
Brain.

- **Objectives**
  - By the end of the topic, learners will be able to:
    - Describe the blood supply to the brain
    - Name the lobes and sulci of the brain
    - Outline the functions of the cerebrum
    - Identify the main sensory and motor areas of the cerebrum

Blood supply to the brain…

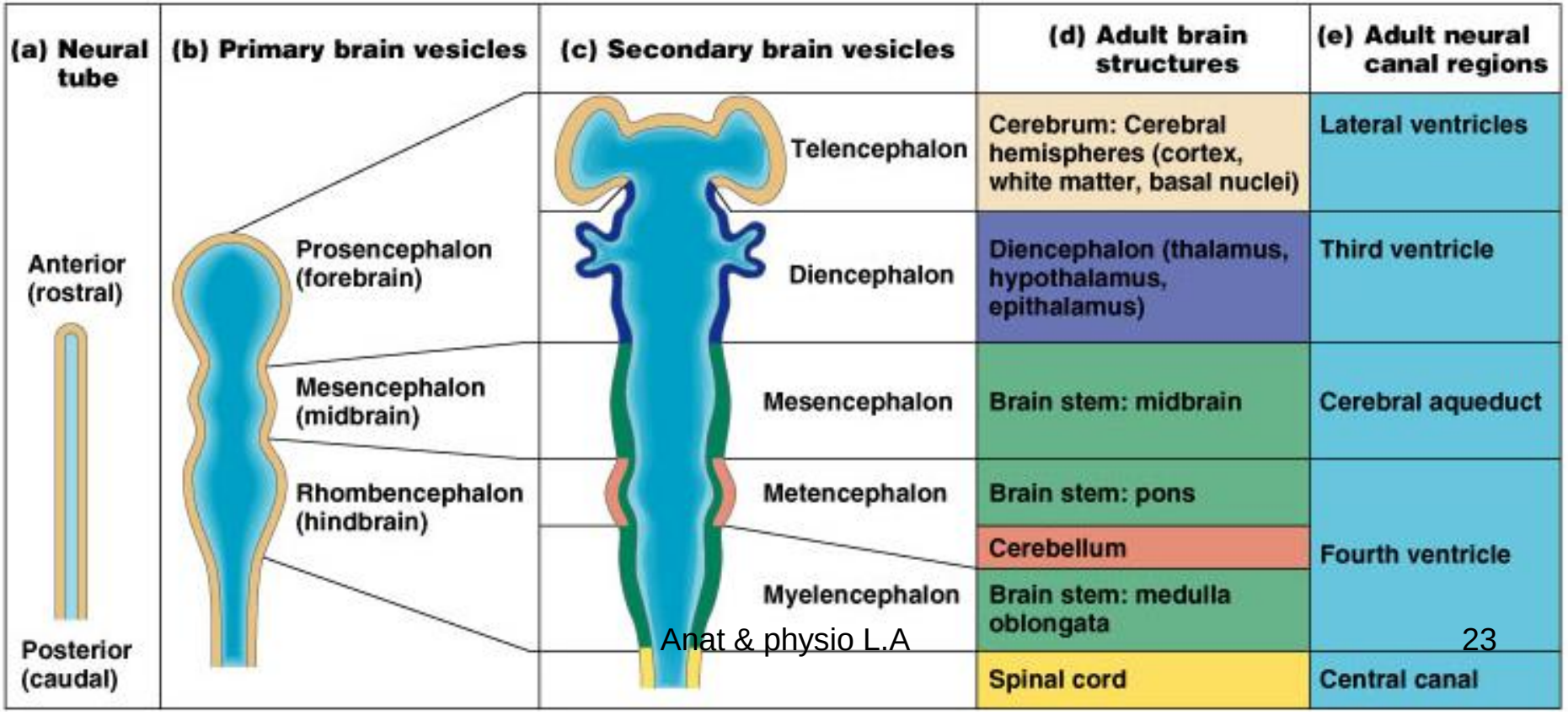
- Refer to the circle of Willis

Circulus arteriosus (circle of Willis).



- **2 anterior cerebral arteries**
- **2 internal carotid arteries**
- **1 anterior communicating artery**
- **2 posterior communicating arteries**
- **2 posterior cerebral arteries**
- **1 basilar artery.**

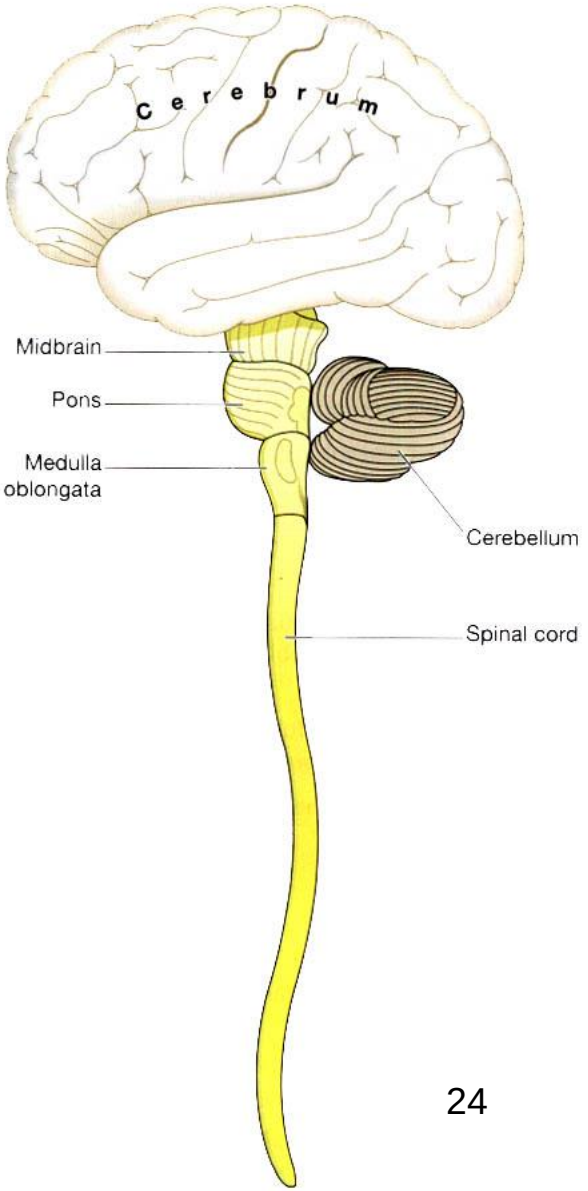
Brain development



Introduction

- Parts of the brain:
  - Cerebrum
  - Midbrain
  - Pons
  - Medulla oblongata
  - Cerebellum.

Brain stem



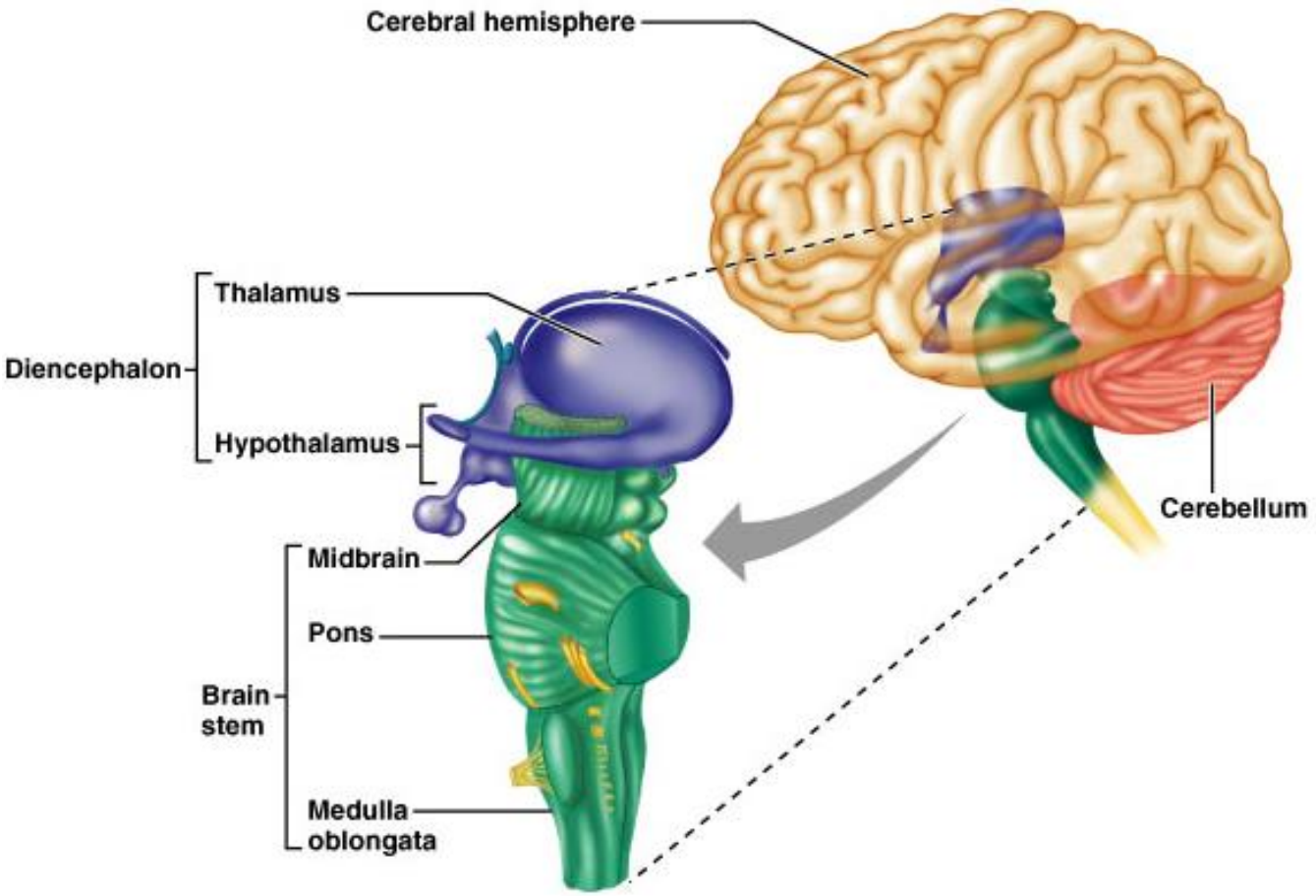
Parts of Brain

Cerebrum

Diencephalon

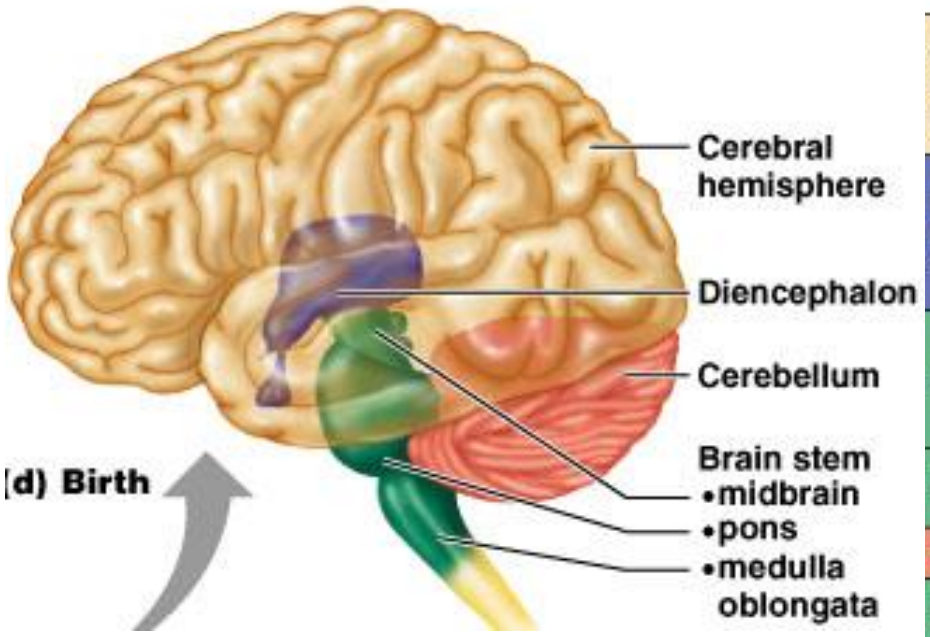
Brainstem

Cerebellum



Anatomical classification

- Cerebral hemispheres
- Diencephalon
  - Thalamus
  - Hypothalamus
- Brain stem
  - Midbrain
  - Pons
  - Medulla
- Cerebellum
- Spinal cord



(d) Adult brain structures
Cerebrum: Cerebral hemispheres (cortex, white matter, basal nuclei)
Diencephalon (thalamus, hypothalamus, epithalamus)
Brain stem: midbrain
Brain stem: pons
Cerebellum
Brain stem: medulla oblongata
Spinal cord

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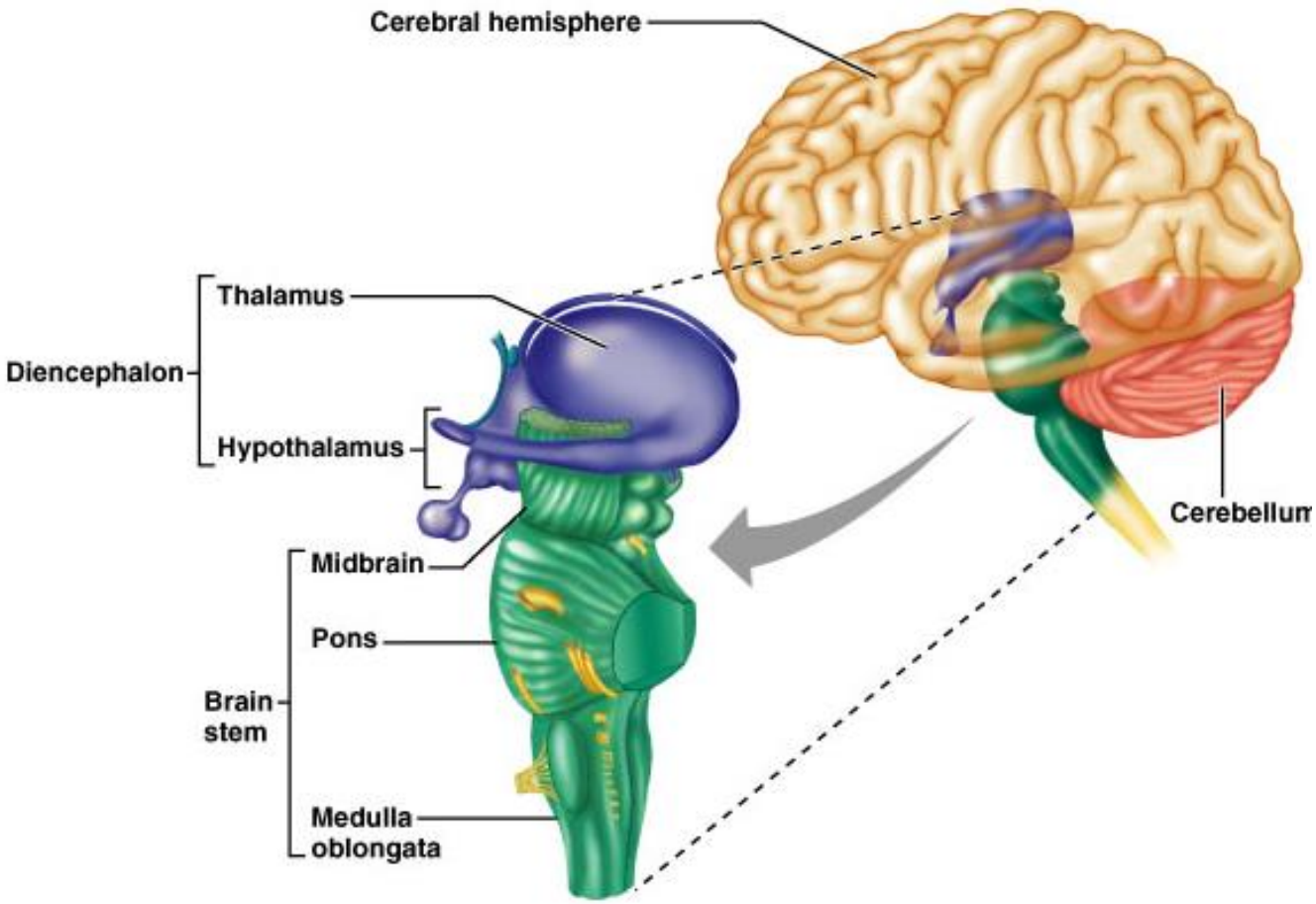
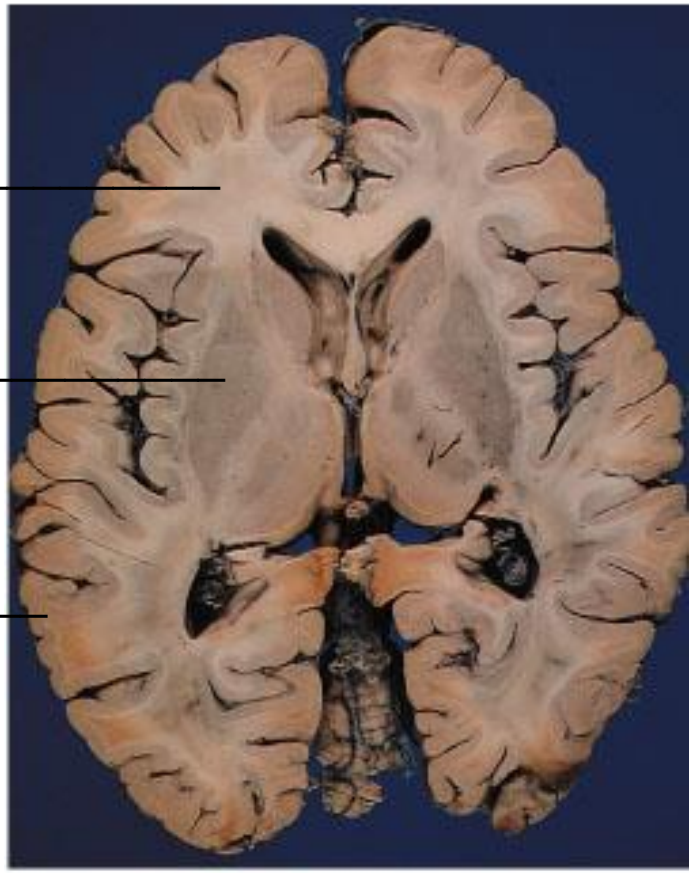
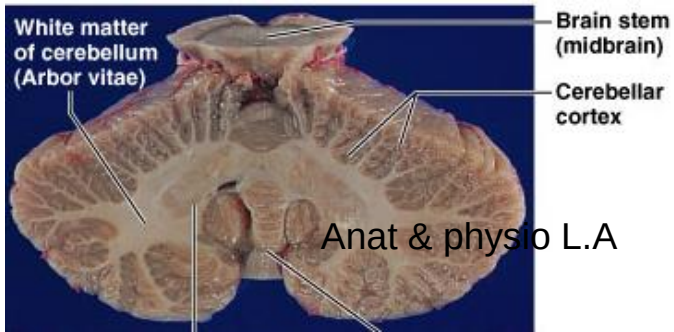


Cerebrum
Diencephalon
Brainstem
Cerebellum

Usual pattern of gray/white in CNS

- White exterior to gray
- Gray surrounds hollow central cavity
- Two regions with additional gray called "cortex"
  - Cerebrum: "cerebral cortex"
  - Cerebellum: "cerebellar cortex"

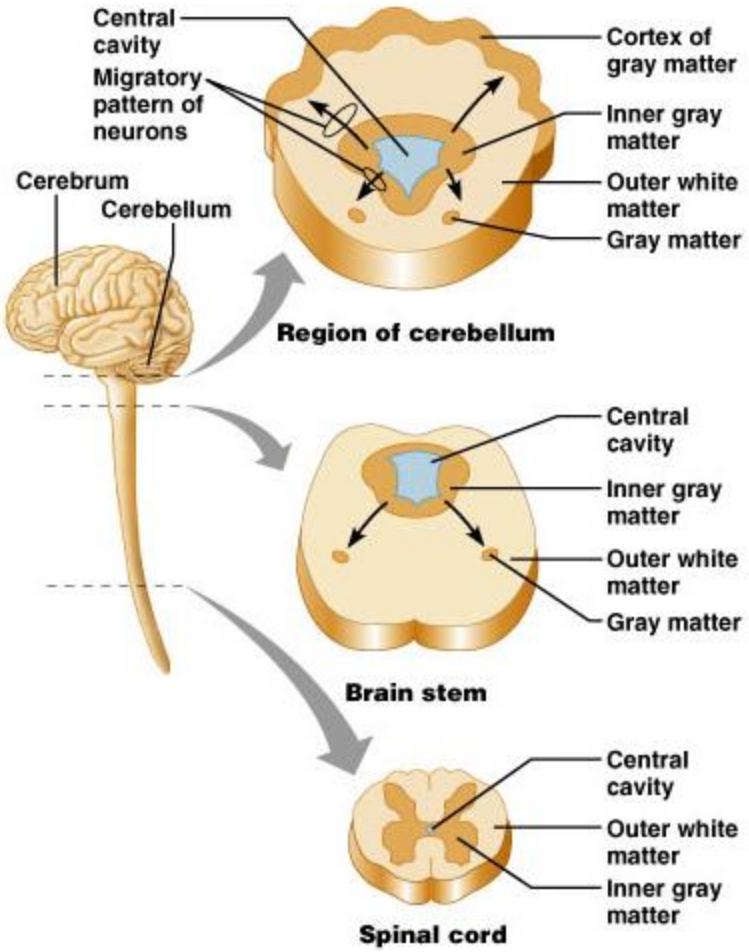




Gray and White Matter

- Like spinal cord but with another layer of gray outside the white
  - Called **cortex**
  - Cerebrum and cerebellum have
- Inner gray: "**brain nuclei**" (not cell nuclei)
  - Clusters of cell bodies

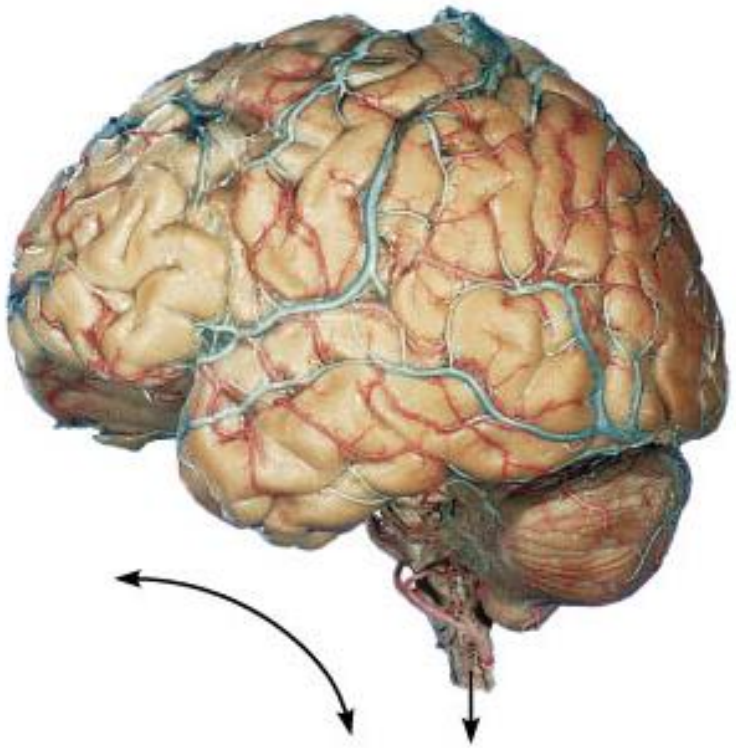
Remember, in PNS clusters of cell bodies were called "ganglia"



More words: brains stem is ***caudal*** (toward tail) to the more **rostral** (noseward) cerebrum

Surface anatomy

- ***Gyri*** (plural of ***gyrus***)
  - Elevated ridges
  - Entire surface
- Grooves separate gyri
  - A ***sulcus*** is a shallow groove (plural, ***sulci***)
  - Deeper grooves are ***fissures***



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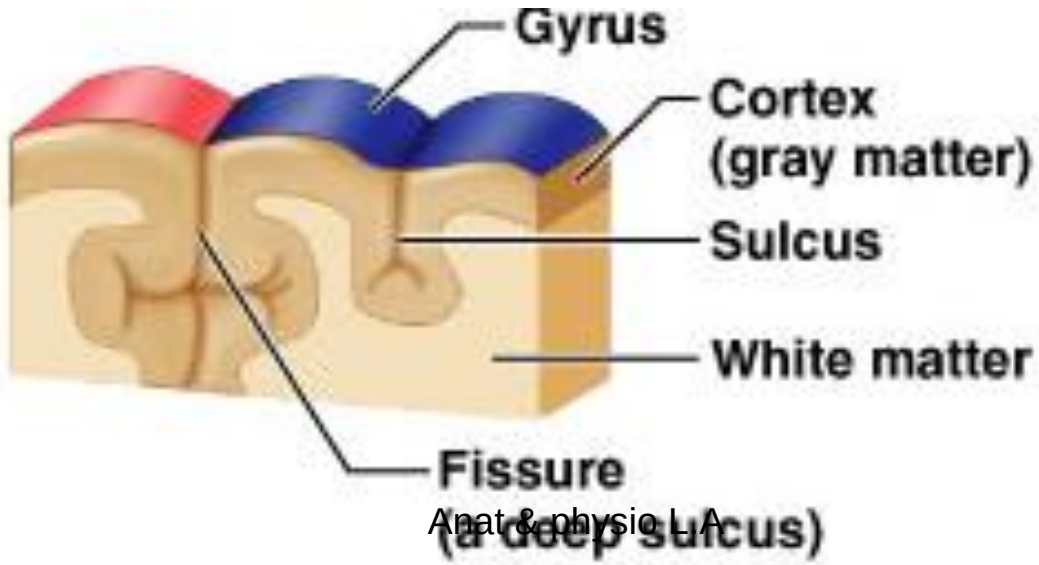
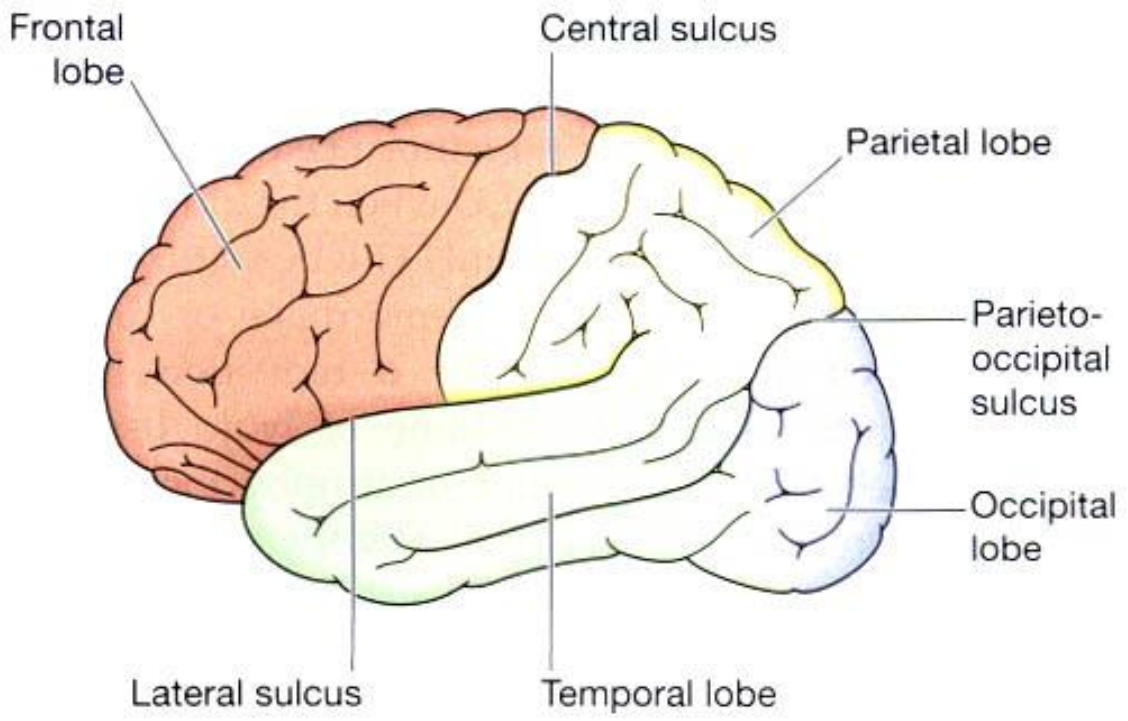


Cerebral hemispheres

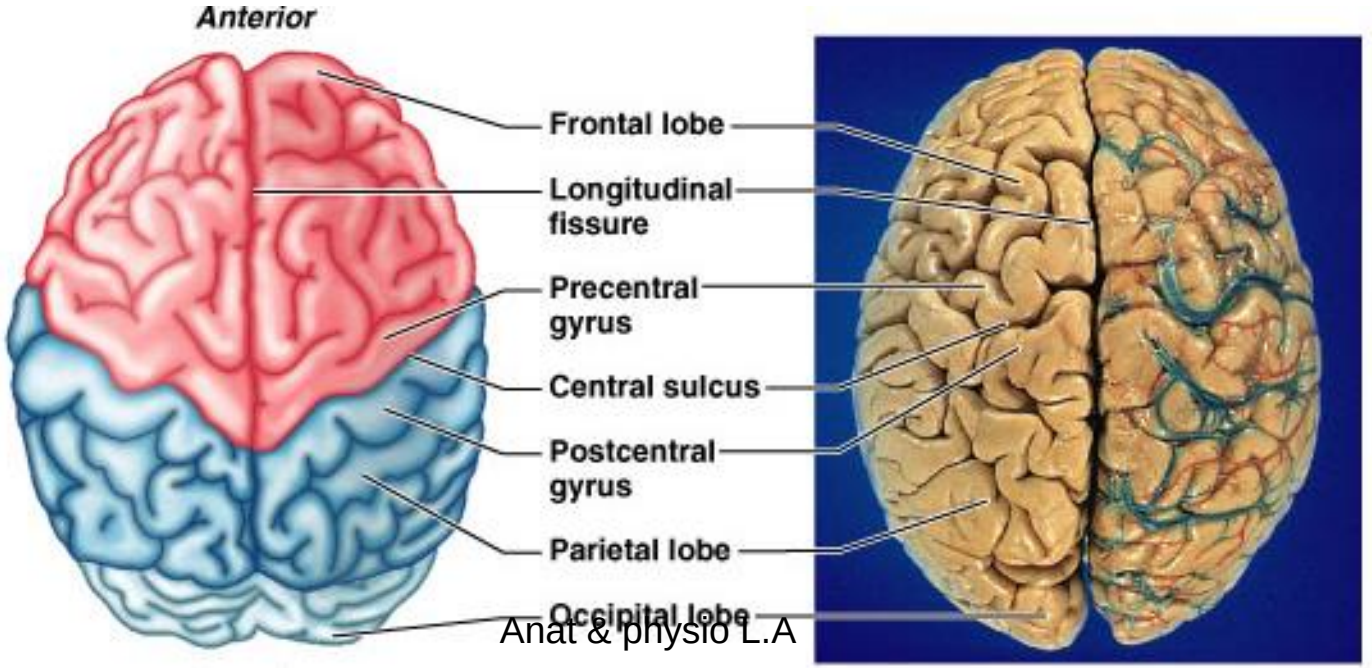
- Lobes: under bones of same name
  - Frontal
  - Parietal
  - Temporal
  - Occipital



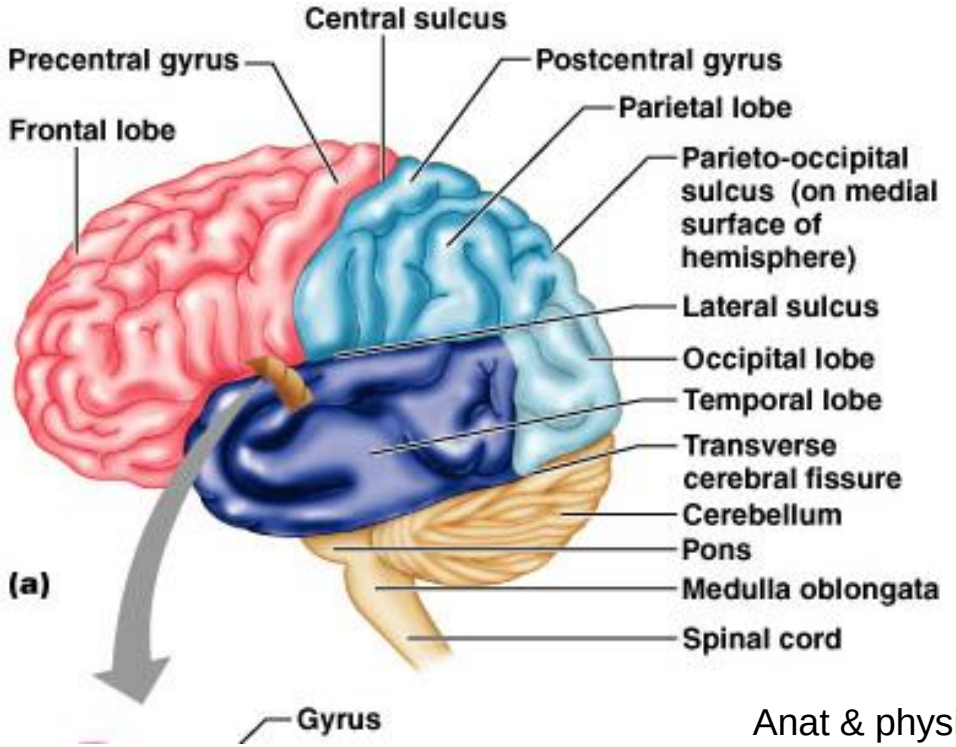
  - Plus: Insula (buried deep in lateral sulcus)

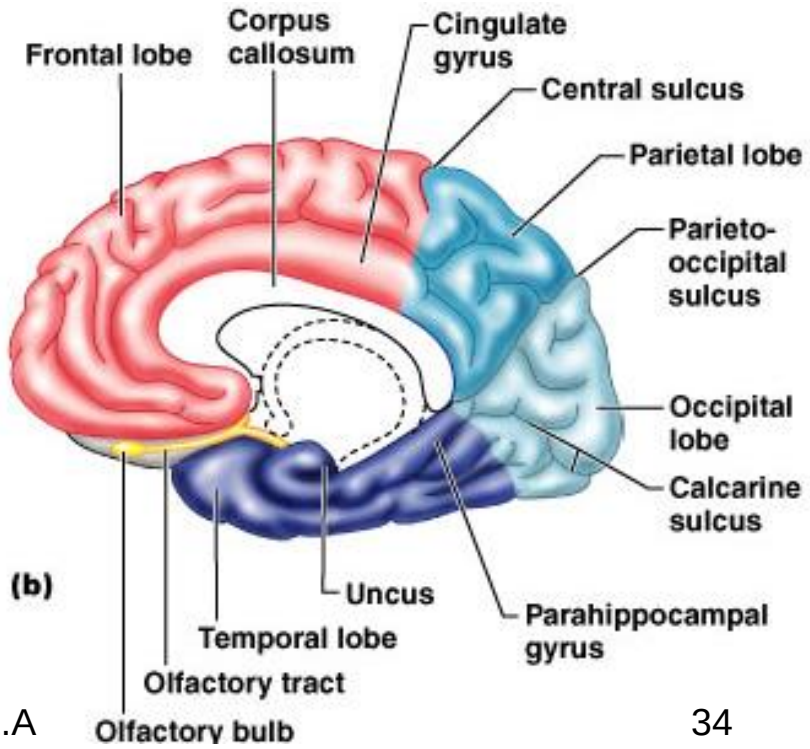
Cerebral hemispheres: note lobes

- Divided by ***longitudinal fissure*** into right & left sides
- ***Central sulcus*** divides frontal from parietal lobes



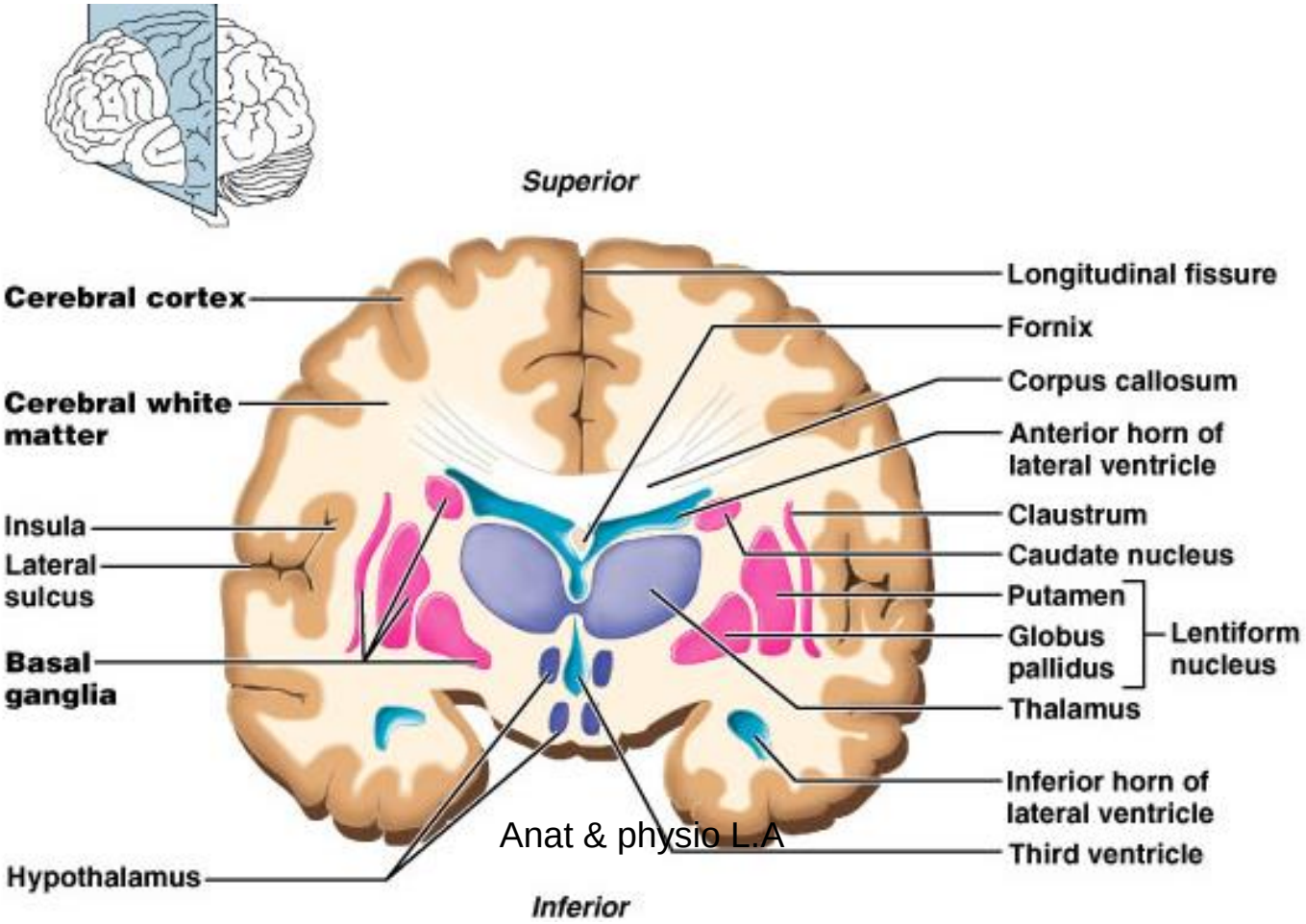
- ***Lateral sulcus*** separates temporal lobe from parietal lobe
- ***Parieto-occipital sulcus*** divides occipital and parietal lobes (not seen from outside)
- ***Transverse cerebral fissure*** separates cerebral hemispheres from cerebellum





coronal section

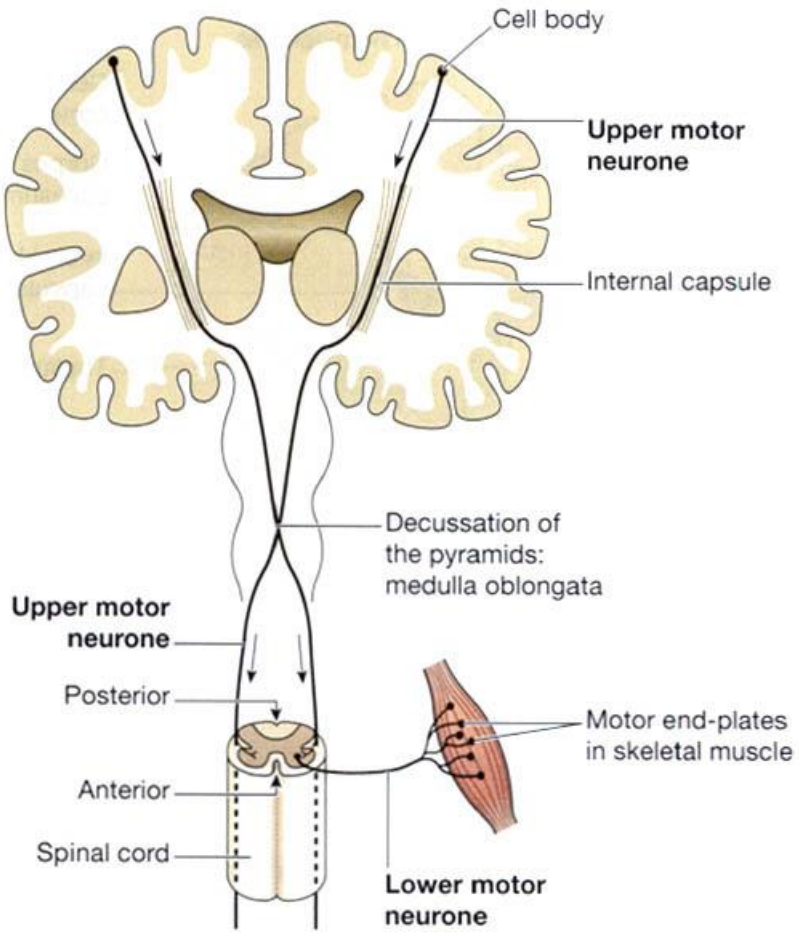
- Note: longitudinal fissure, lateral sulcus, insula
- Note: cerebral cortex (external sheet of gray), cerebral white, deep gray (basal ganglia)



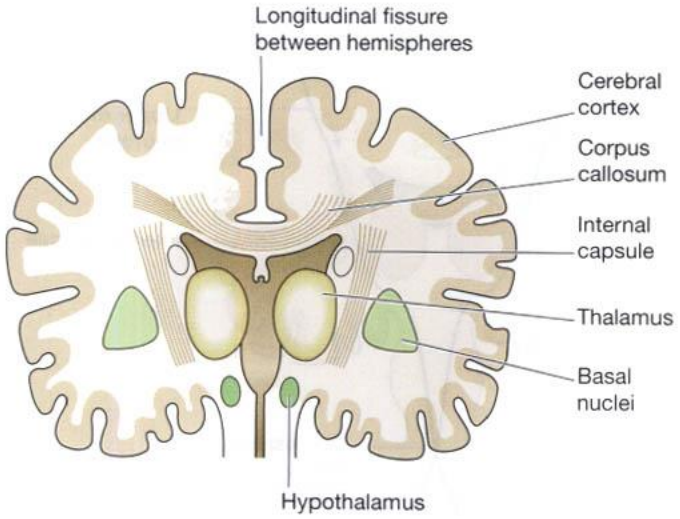
Cerebral cortex

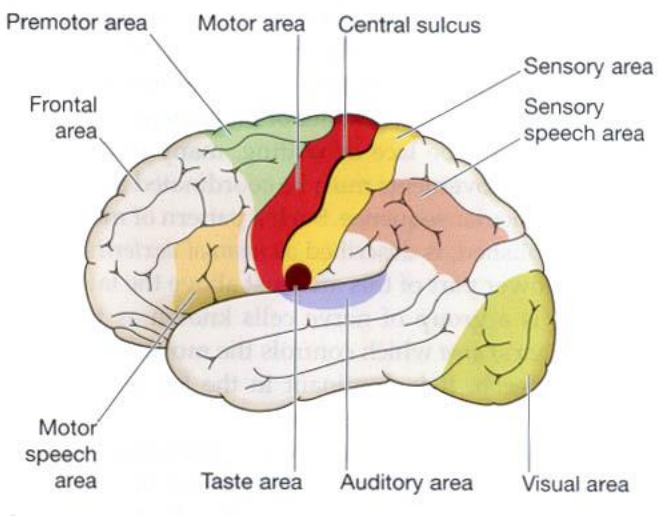
- Three kinds of functional areas
  - ***Motor*** areas: movement
  - ***Sensory*** areas: perception
  - ***Association*** areas: integrate diverse information to enable purposeful action

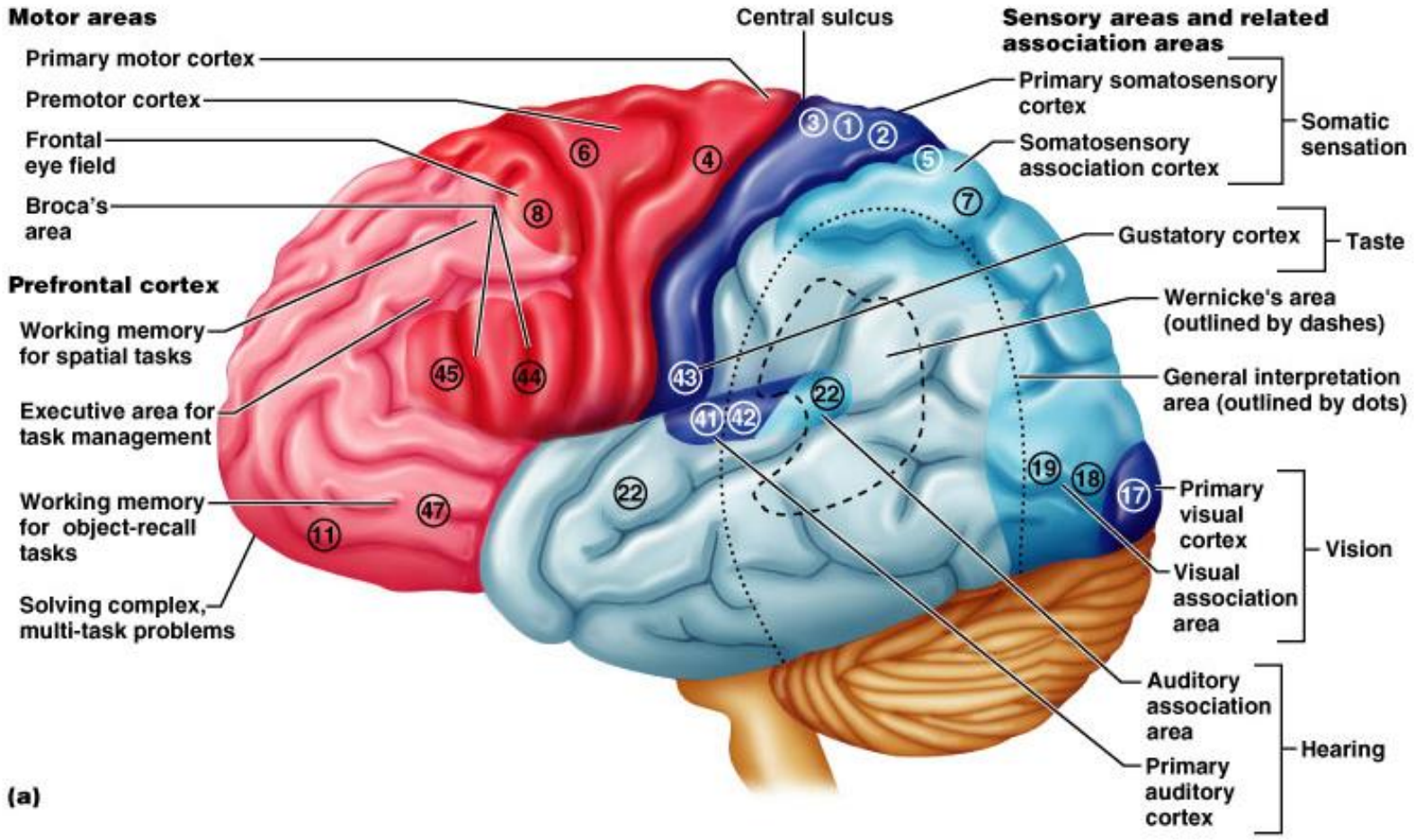
The motor nerve pathways: upper and lower motor neurones.



Functional areas of the cerebrum



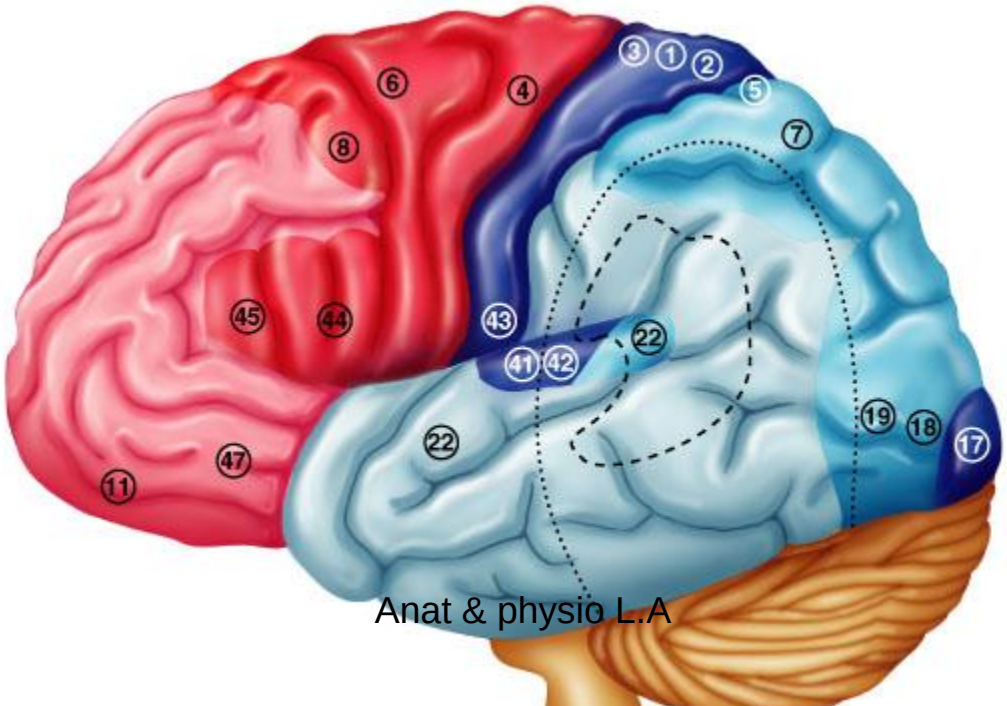




Motor areas

Anterior to central sulcus

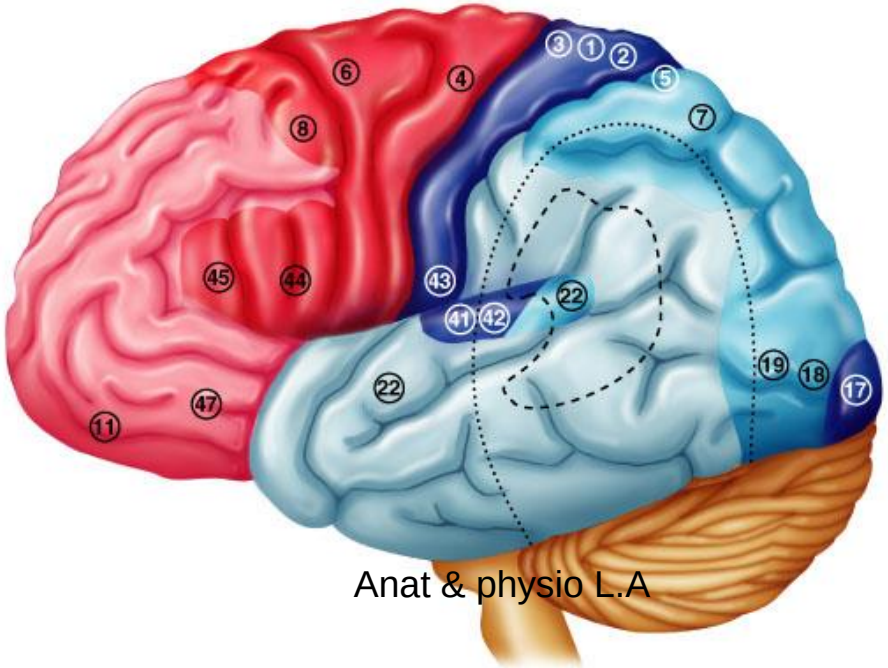
- Primary motor area
  - Precentral gyrus of frontal lobe (4)
  - Conscious or voluntary movement of skeletal muscles



- Primary motor area continued
  - Precentral gyrus of frontal lobe
  - Precise, conscious or voluntary movement of skeletal muscles
  - Large neurons called ***pyramidal cells***
  - Their axons: form massive ***pyramidal*** or ***corticospinal tracts***
    - Decend through brain stem and spinal cord
    - **Cross to contralateral (the other) side** in brainstem
    - Therefore: ***right side of the brain controls the left side of the body, and the left side of the brain controls the right side of the body***

Motor areas – continued

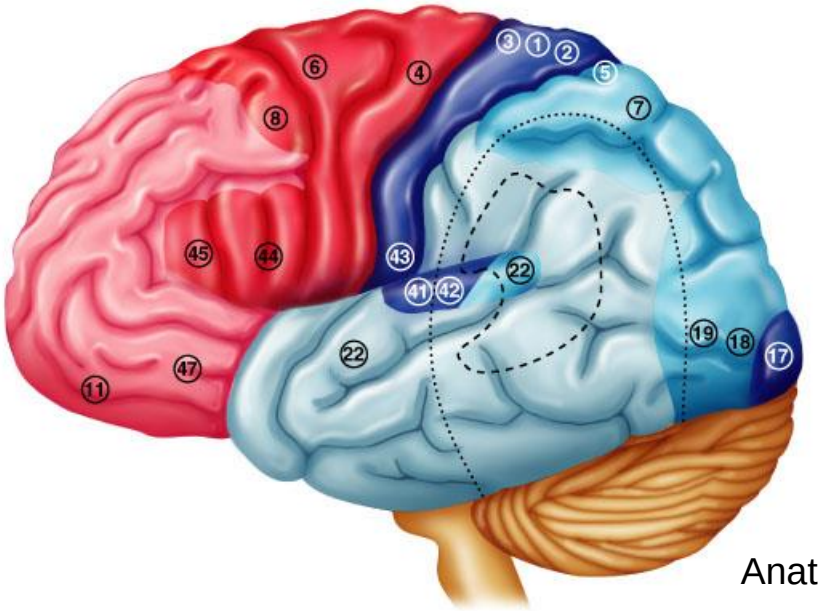
- Broca's area (44): specialized motor speech area
  - Base of precentral gyrus just above lateral sulcus in only one hemisphere, usually left
  - Word articulation: the movements necessary for speech
  - Damage: can understand but can't speak

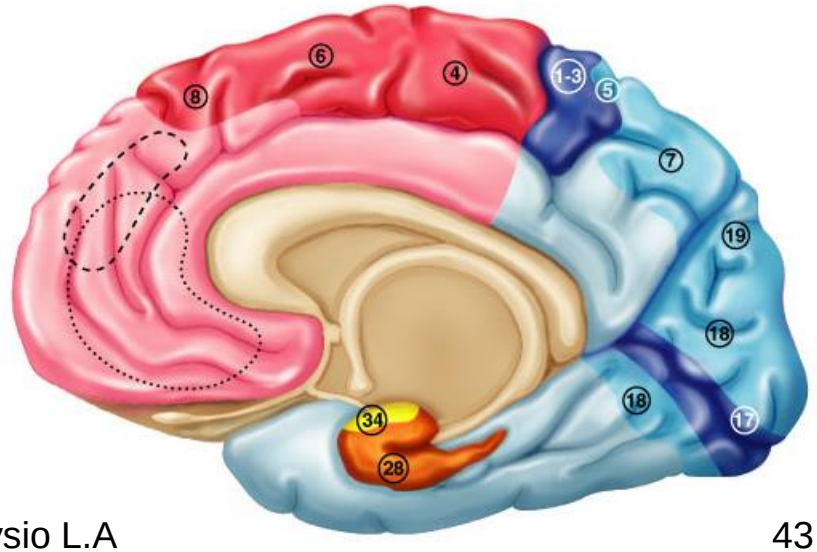


(a)

Motor areas – continued

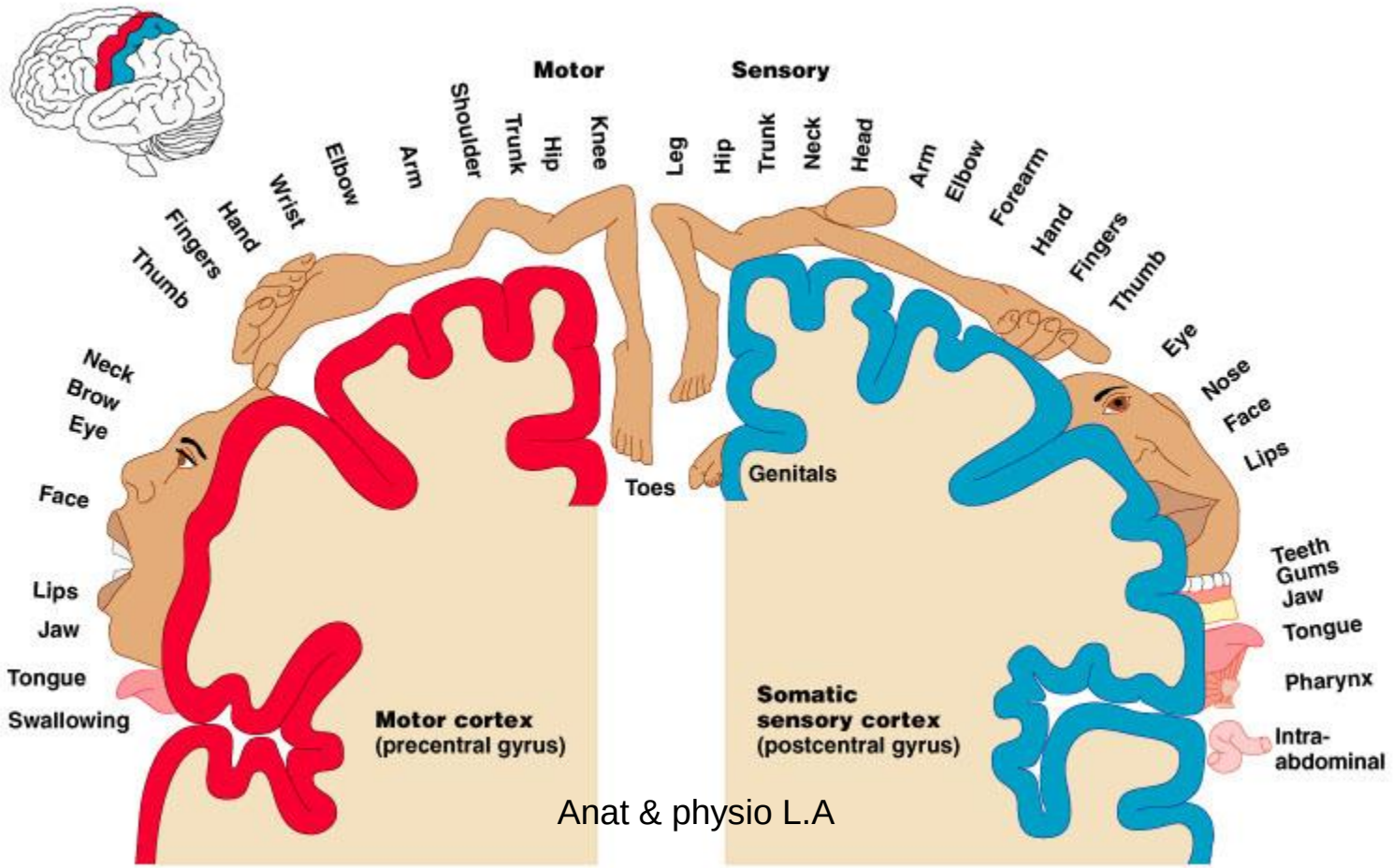
- Premotor cortex (6): complex movements asociated with highly processed sensory info; also planning of movements
- Frontal eye fields (inferior 8): voluntary movements of eyes





Homunculus

- Body map: human body spatially represented
  - Where on cortex; upside down



Association Areas

Remember…

- Three kinds of functional areas (cerebrum)
  1. ***Motor*** areas: movement
  2. ***Sensory*** areas: perception
  3. ***Association*** areas: everything else

Association Areas

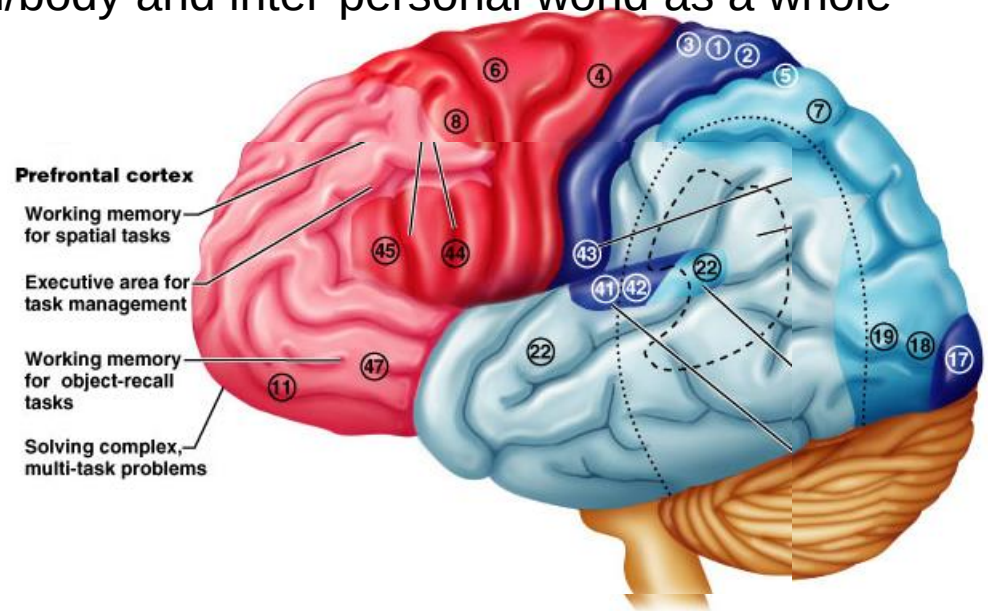
- Is to be renamed ***"higher-order processing" areas***

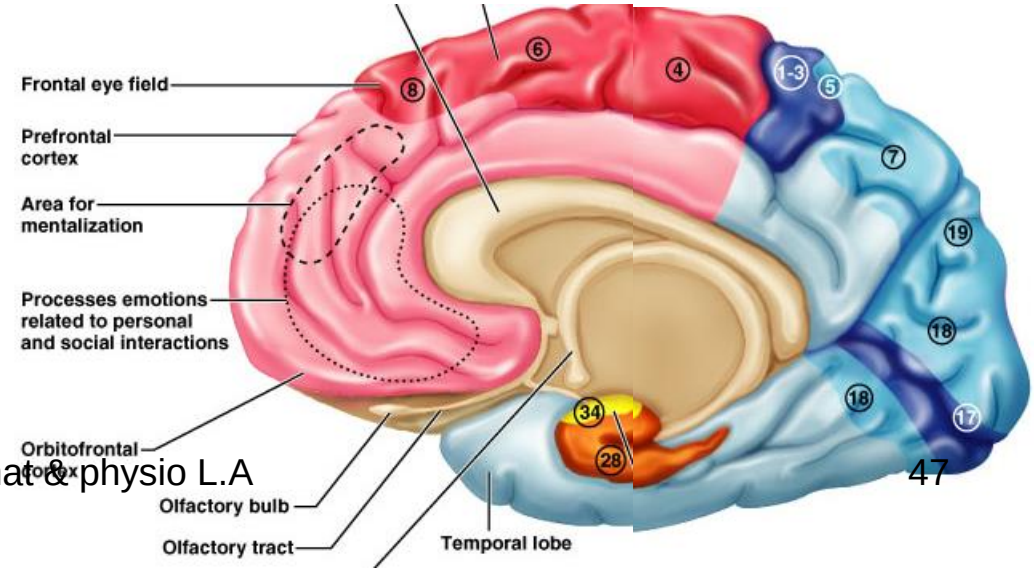
Prefrontal cortex: cognition

This area is remodeled during adolescence until the age of 25 and is very important for well-being; it coordinates the brain/body and inter-personal world as a whole

Intellect
Abstract ideas
Judgment
Personality
Impulse control
Persistence
Complex
Reasoning
Long-term
planning

Social skills
Appreciating
humor
Conscience
Mood
Mental
flexibility
Empathy

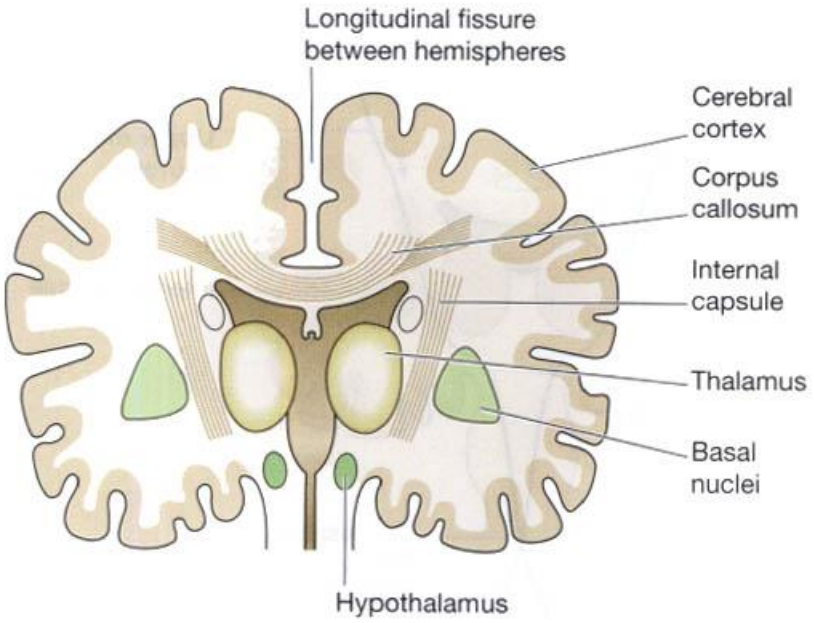


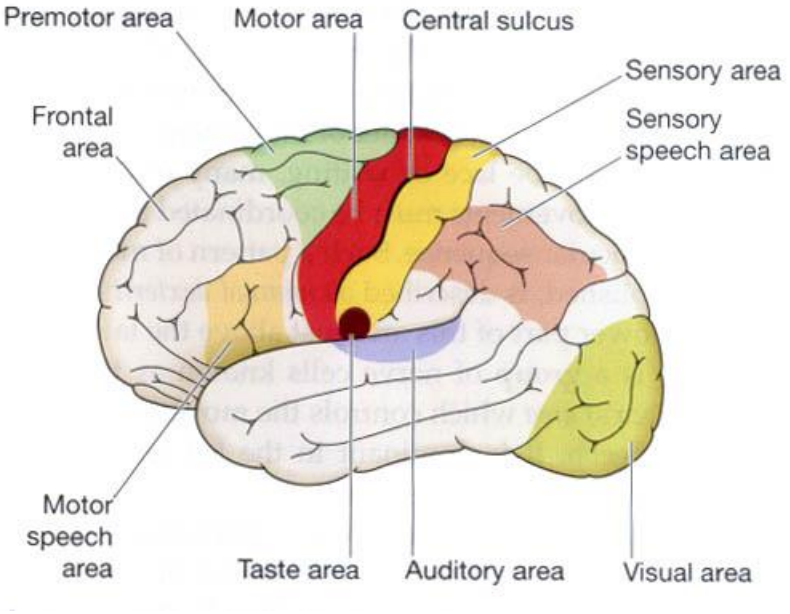


Executive functioning

e.g. multiple step problem solving requiring temporary storage of info (working memory)

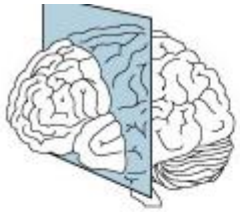
Functional areas of the cerebrum

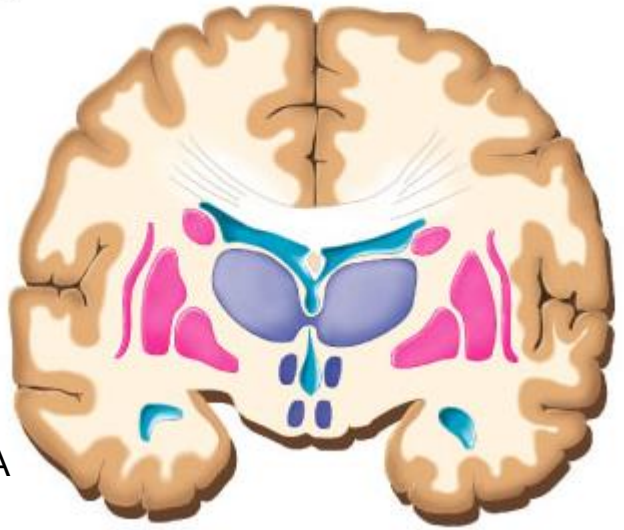




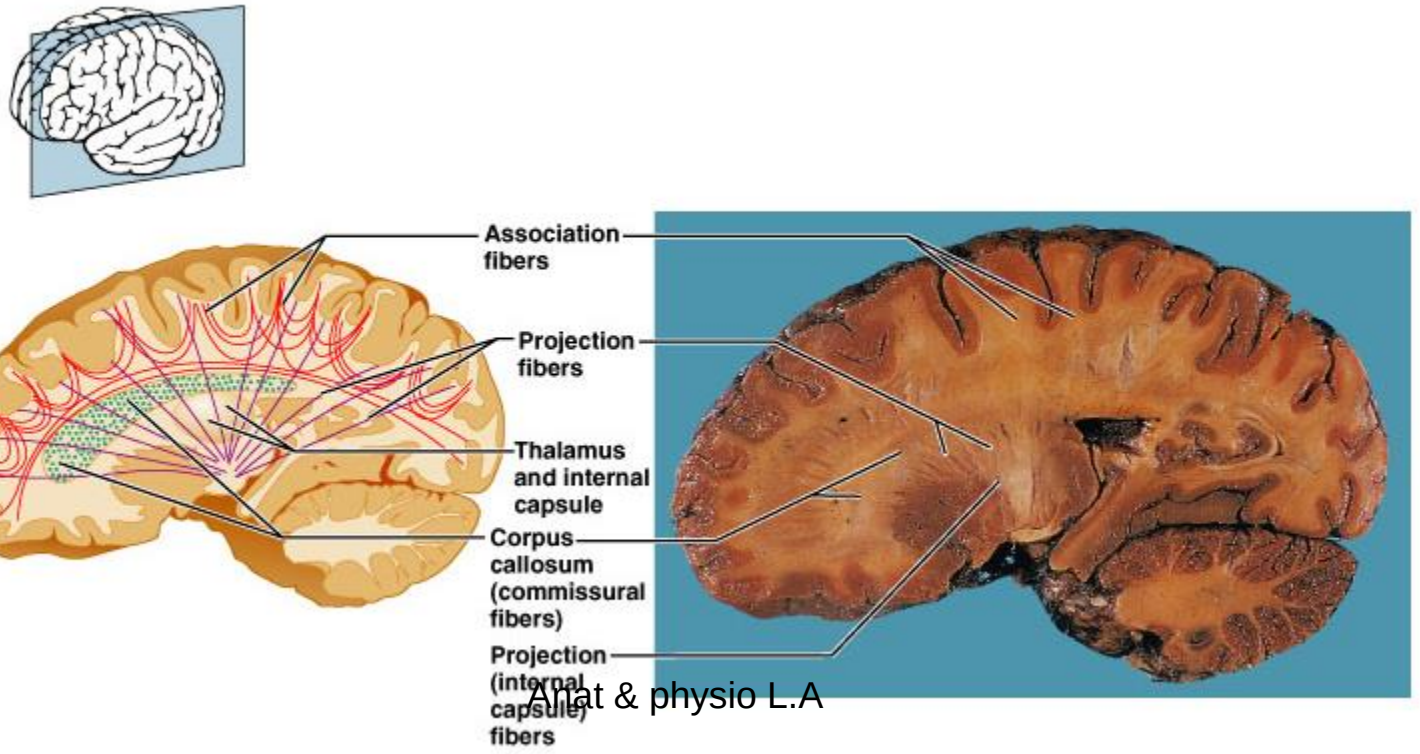
Cerebral white matter

- Extensive communication
  - Areas of cortex with each other
  - Areas of cortex with brain stem and spinal cord
- Via (mostly) myelinated axon fibers bundled into tracts
  - Commissures
  - Association fibers
  - Projection fibers

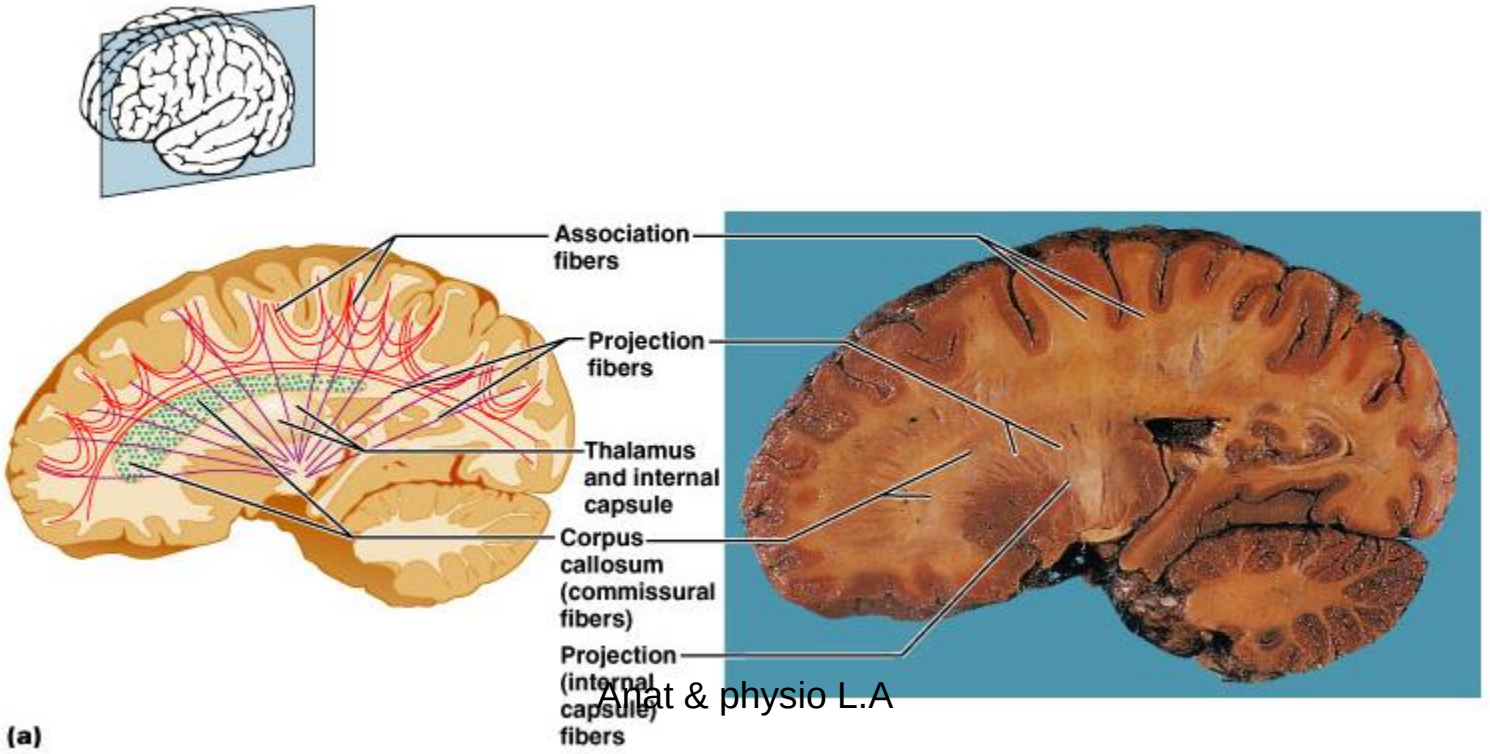




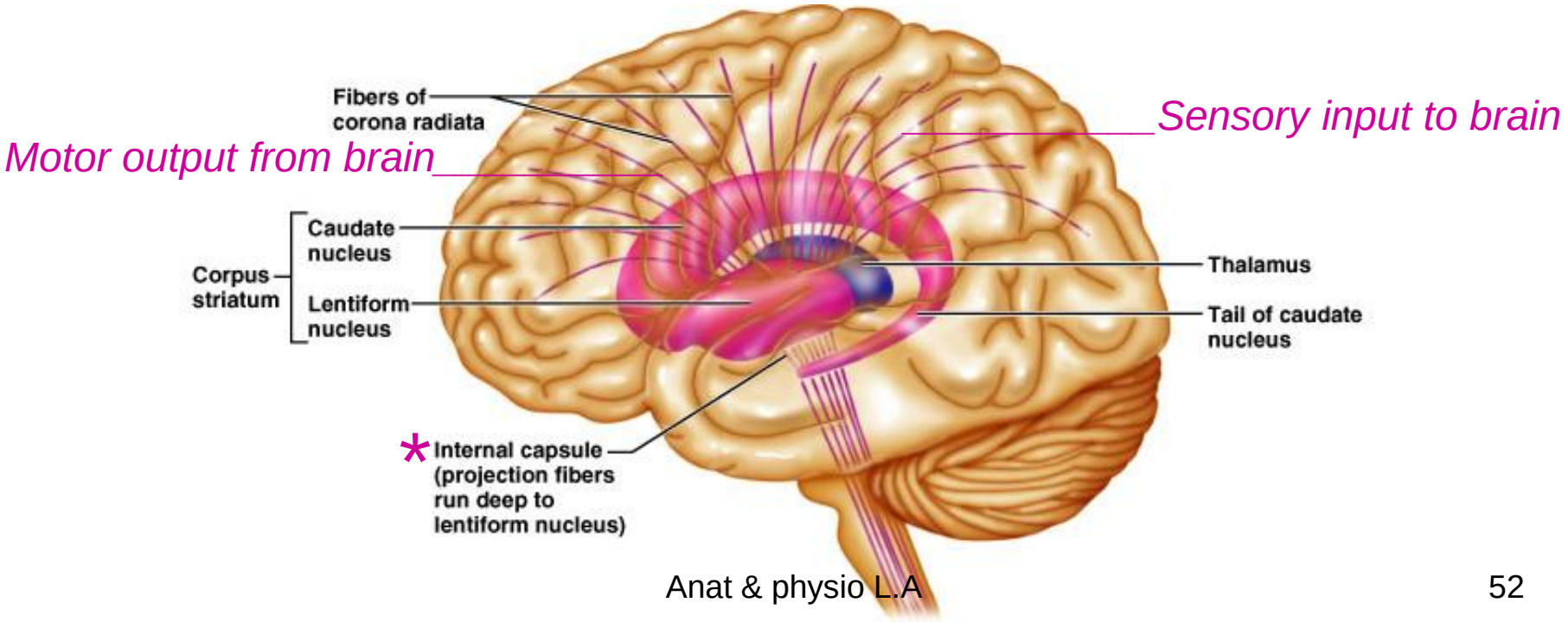
- **Commissures**: interconnect right and left hemispheres so can act as a whole
  - ***Corpus callosum*** is largest
- **Association fibers**: connect different parts of the *same* hemisphere; can be long or short



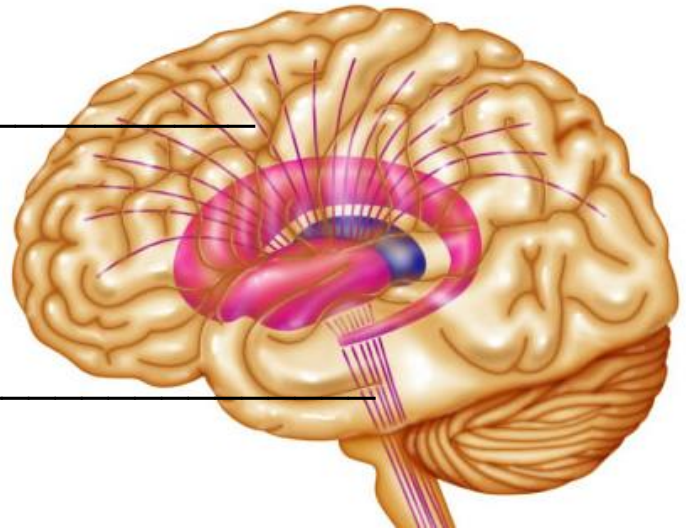
- **Projection fibers**: run *vertically*
  - Cerebral cortex running down (with motor instructions)
  - Or ascend to cerebral cortex from below (sensory info to cortex)

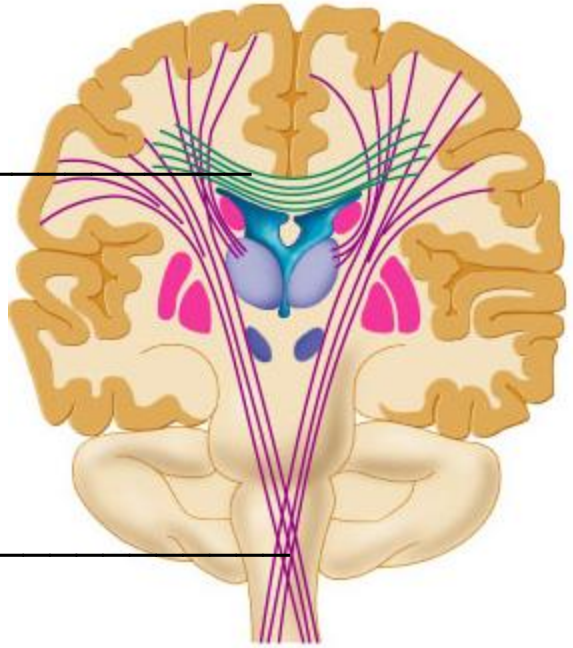


- ***Corona radiata***: spray of projection fibers
  - From precentral (motor) gyrus
  - Combines with sensory fibers traveling to sensory cortex
  - Form a band of fibers called ***internal capsule****



- Projection fibers
  - Corona radiata: fanning out of the fibers
  - Internal capsule: bundled, pass down
- Commisure
  - Corpus callosum: connects right and left hemispheres
- Decussation: crossing of pyramidal tracts

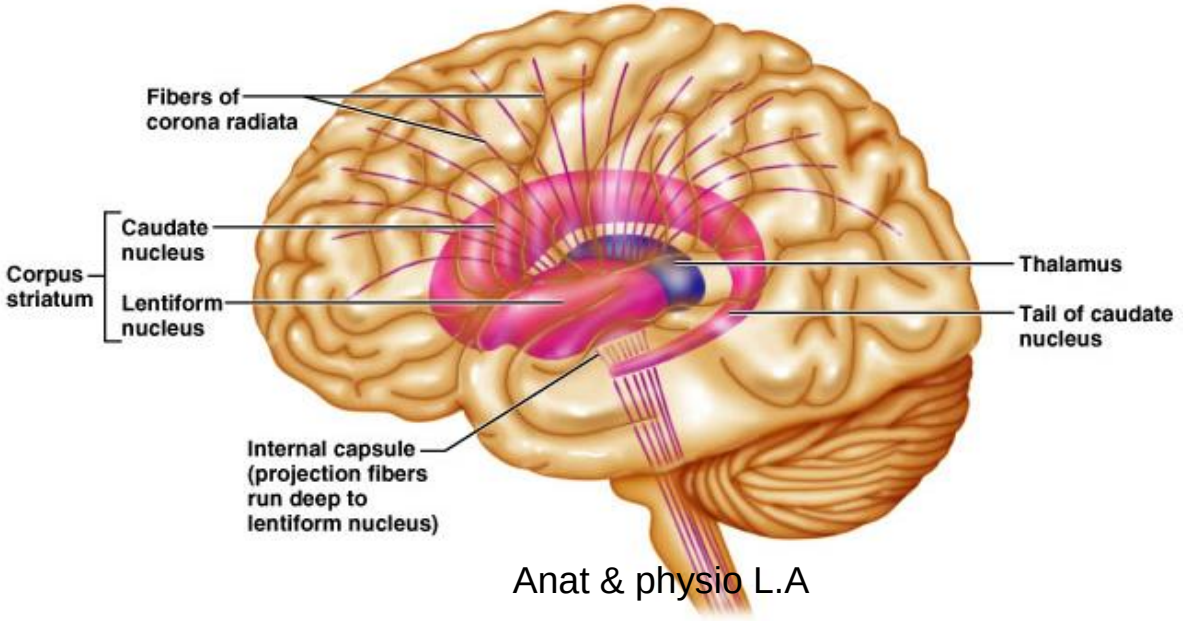




- Cerebral hemisphere gray
  - Cortex – already reviewed
  - Basal forebrain nuclei: near hypothalamus - related to arousal, learning, memory and motor control
  - "Islands" of gray: ***nuclei*** (clusters of neuron cell bodies)

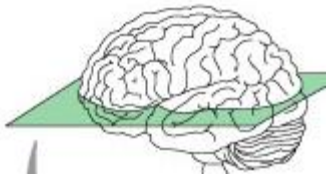
Important group is ***basal ganglia***

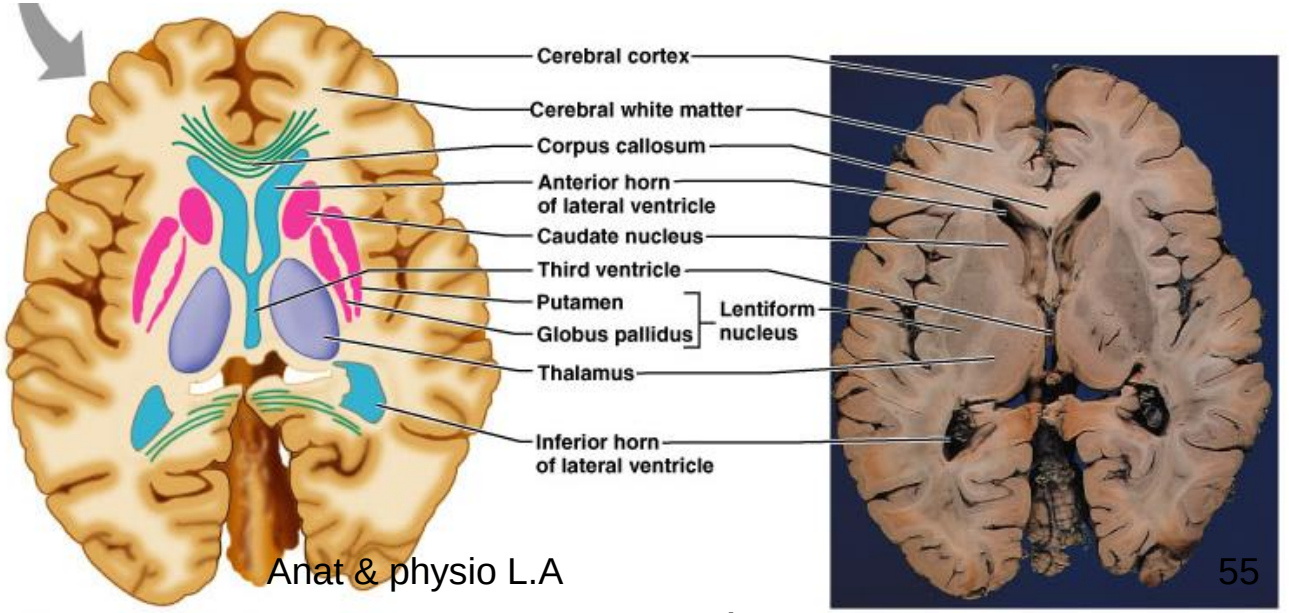
(here "ganglia" *doesn't* refer to PNS cell bodies)



Basal ganglia

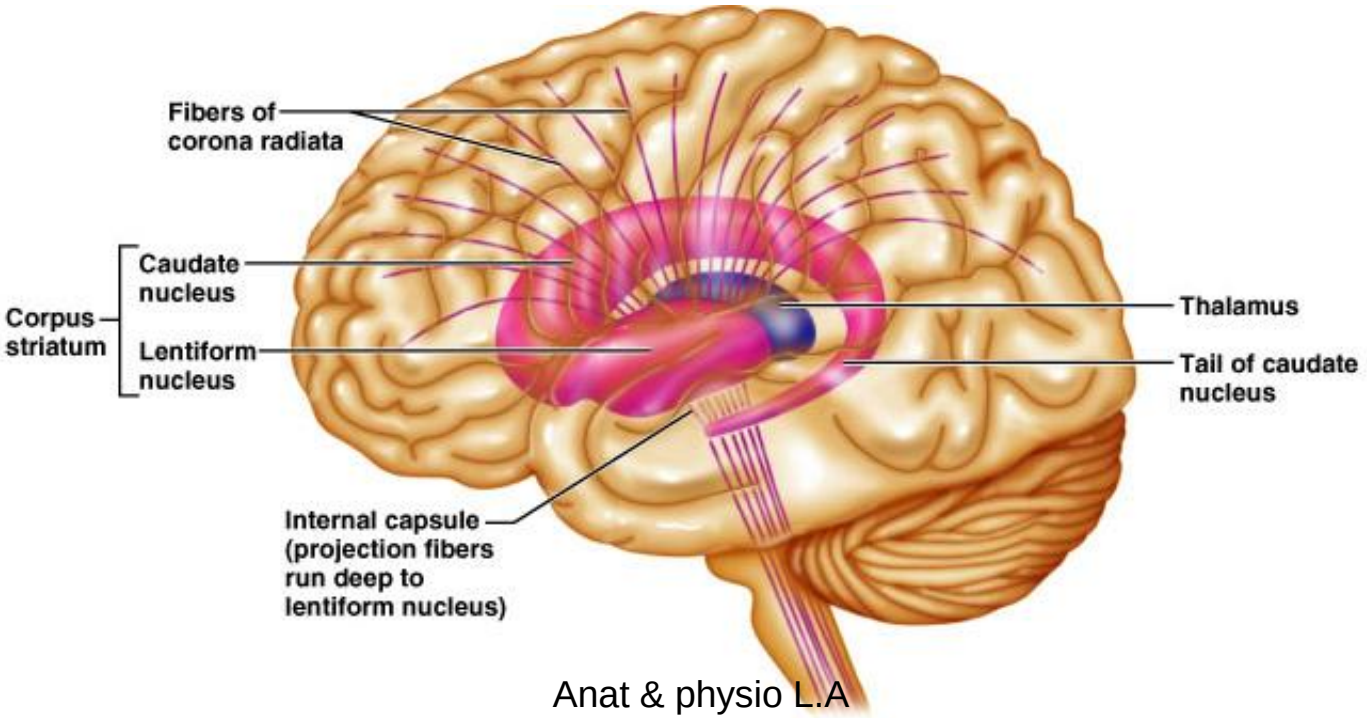
- Subcortical ***motor*** nuclei
- Part of “extrapyramidal system”
- Cooperate with cerebral cortex in controlling movements
- Most important ones: ***caudate nucleus***, ***lentiform nucleus*** composed of ***putamen*** and ***globus pallidus***





Transverse section

- Internal capsule passes between diencephalon and basal ganglia to give them a striped appearance
  - Caudate and lentiform sometimes called ***corpus striatum*** because of this



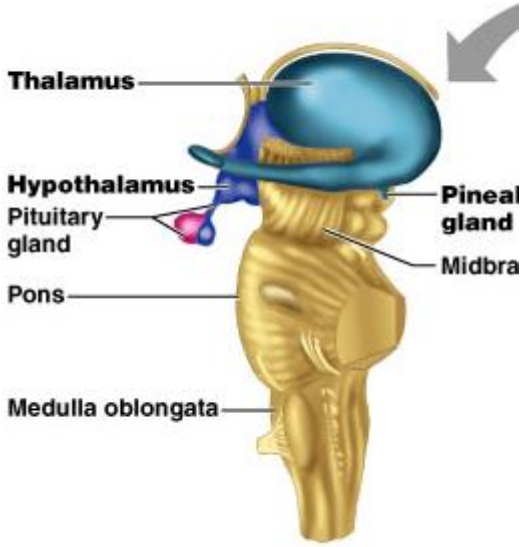
Basal ganglia

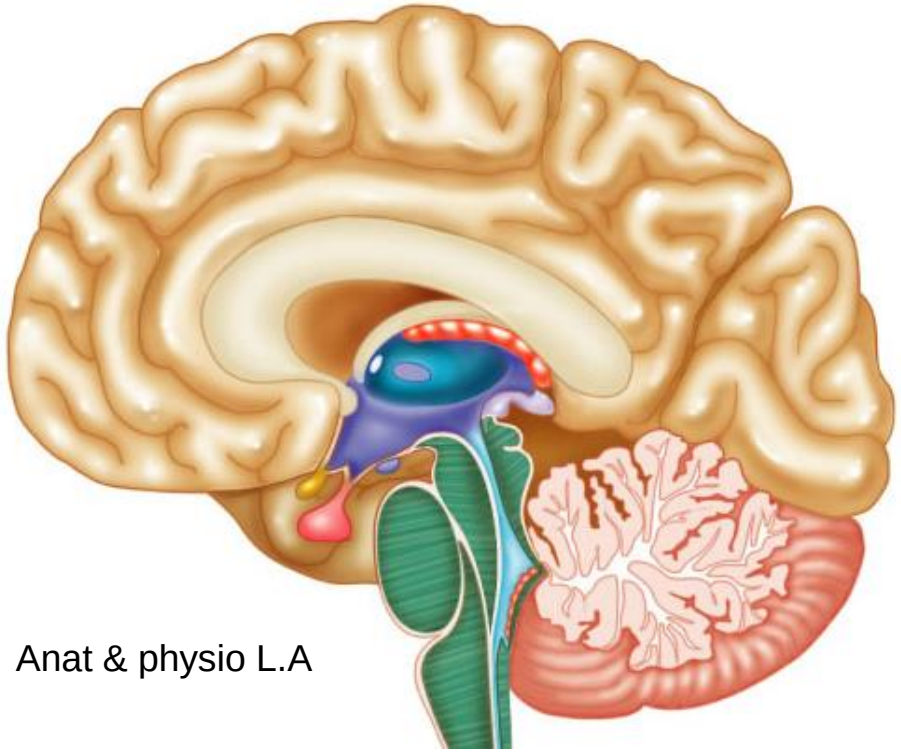
- Cooperate with cerebral cortex in controlling movements
- Communicate with cerebral cortex, receive input from cortical areas, send most of output back to motor cortex through thalamus
- Involved with stopping/starting & intensity of movements
- “Dyskinesias” – “bad movements”
  - Parkinson’s disease: loss of inhibition from substantia nigra of midbrain – everything slows down
  - Huntington disease: overstimulation (“choreoathetosis”) – degeneration of corpus striatum which inhibits; eventual degeneration of cerebral cortex)
  - Extrapyramidal drug side effects: “tardive dyskinesia”
    - Can be irreversible; haloperidol, thorazine and similar drugs

Diencephalon (part of forebrain)

Contains dozens of nuclei of gray matter

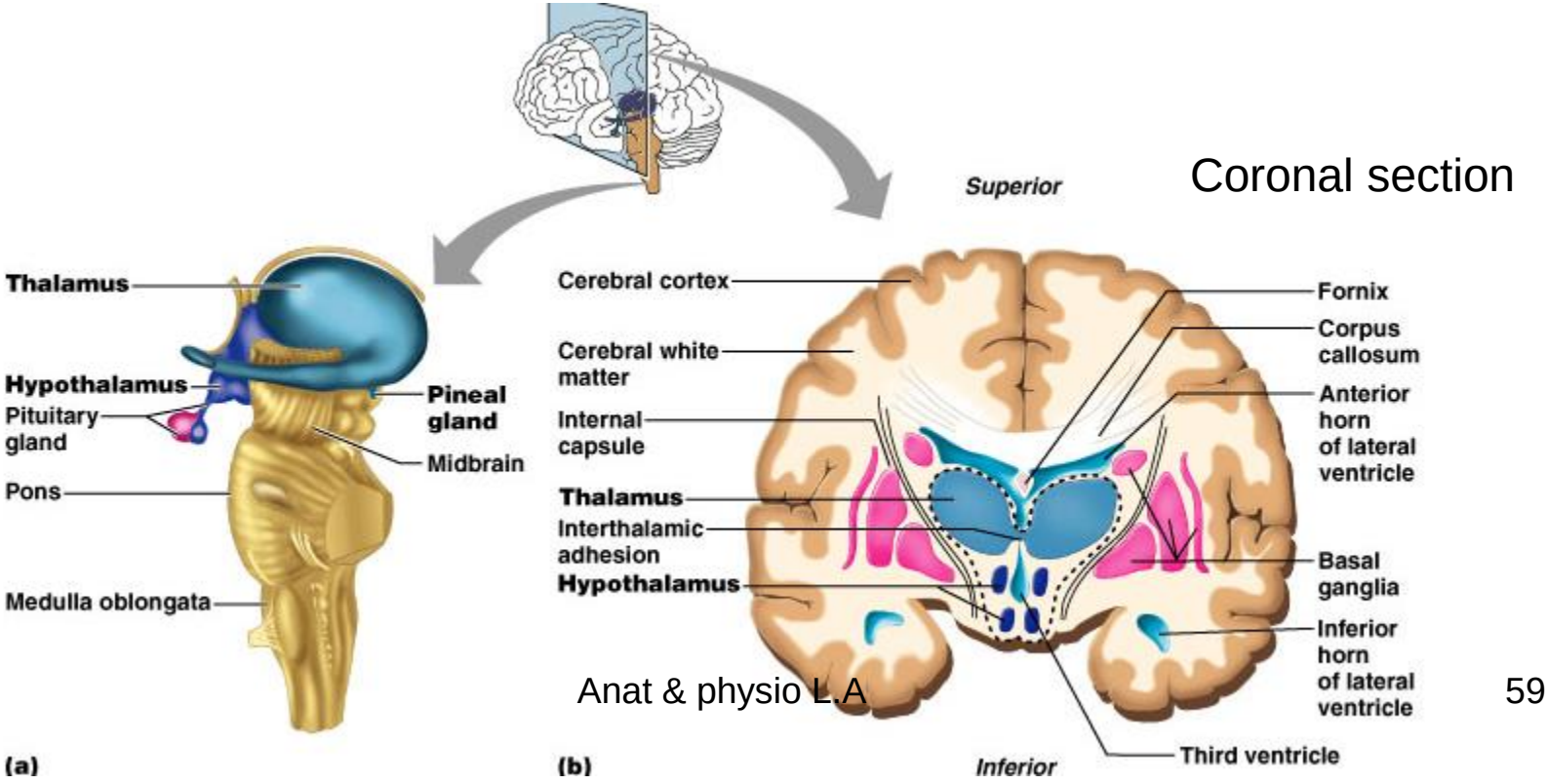
- Thalamus
- Hypothalamus
- Epithalamus (mainly pineal)





Thalamus (egg shaped)

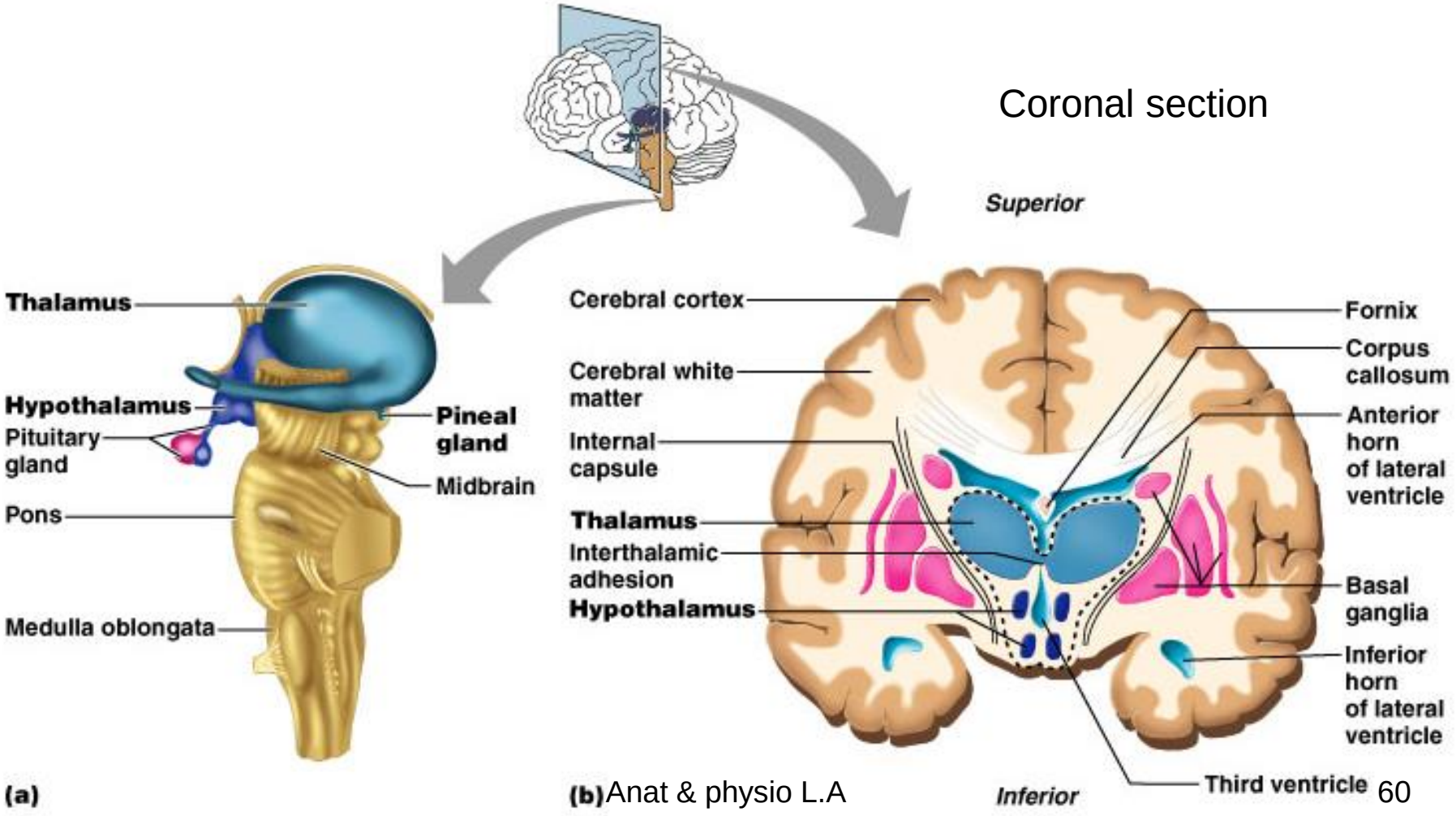
- Two large lobes of gray matter (over a dozen nuclei)
- Laterally enclose the 3rd ventricle
- Gateway to cerebral cortex: ***every part of brain that communicates with cerebral cortex relays signals through a nucleus in the thalamus*** (e.g. certain nucleus for info from retina, another from ears, etc.)
- Processing (editing) occurs also in thalamus



Hypothalamus

Forms inferolateral walls of 3rd ventricle

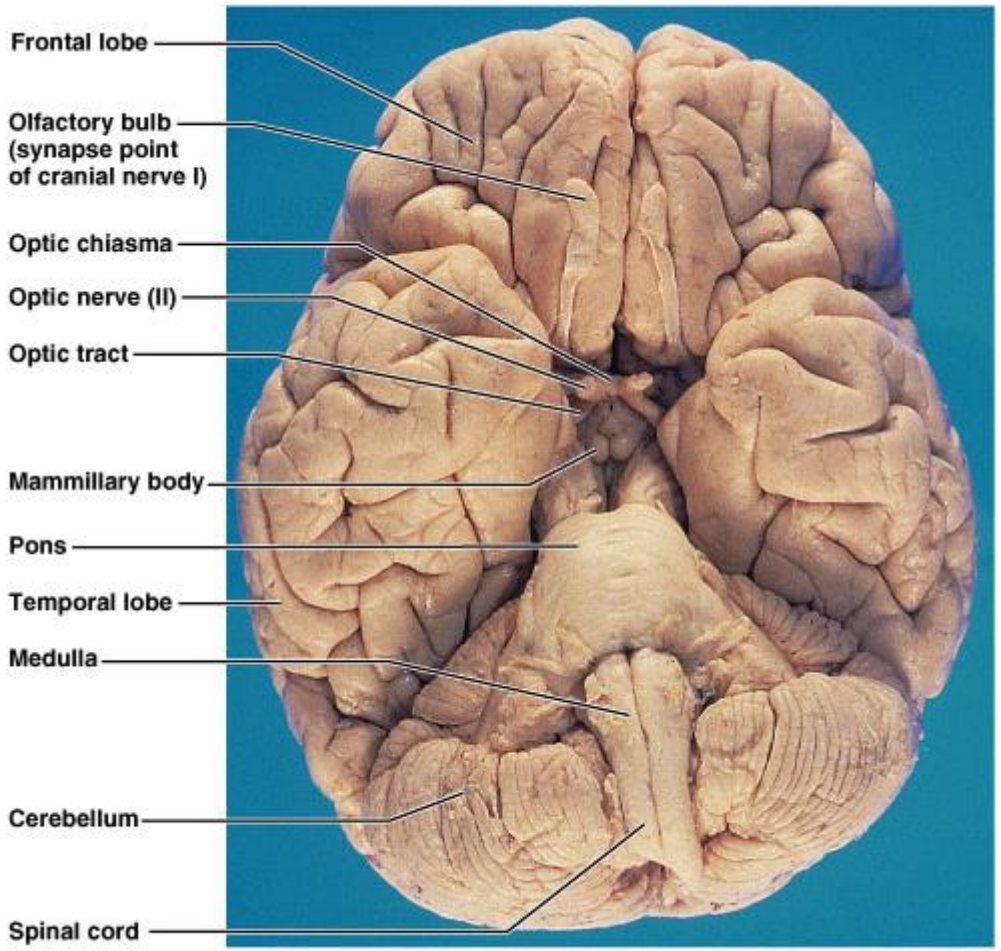
Many named nuclei



Diencephalon – surface anatomy

Hypothalamus is between optic chiasma to and including mamillary bodies

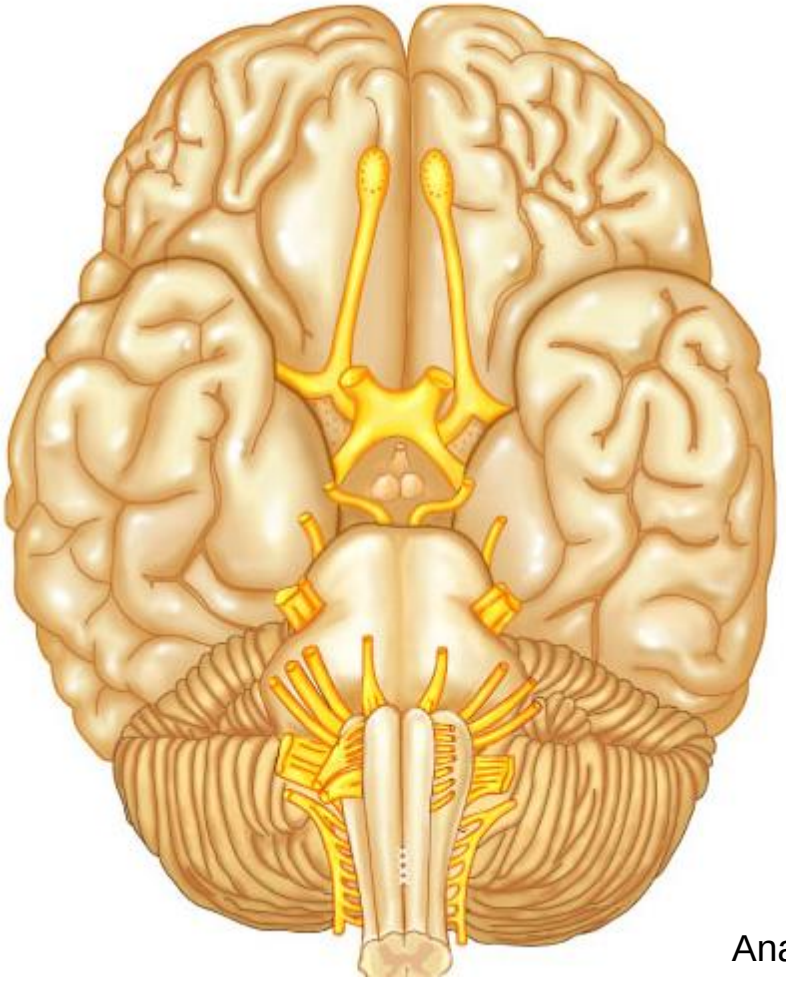
- Olfactory bulbs
- Olfactory tracts
- Optic nerves
- Optic chiasma (partial cross over)
- Optic tracts
- Mammillary bodies

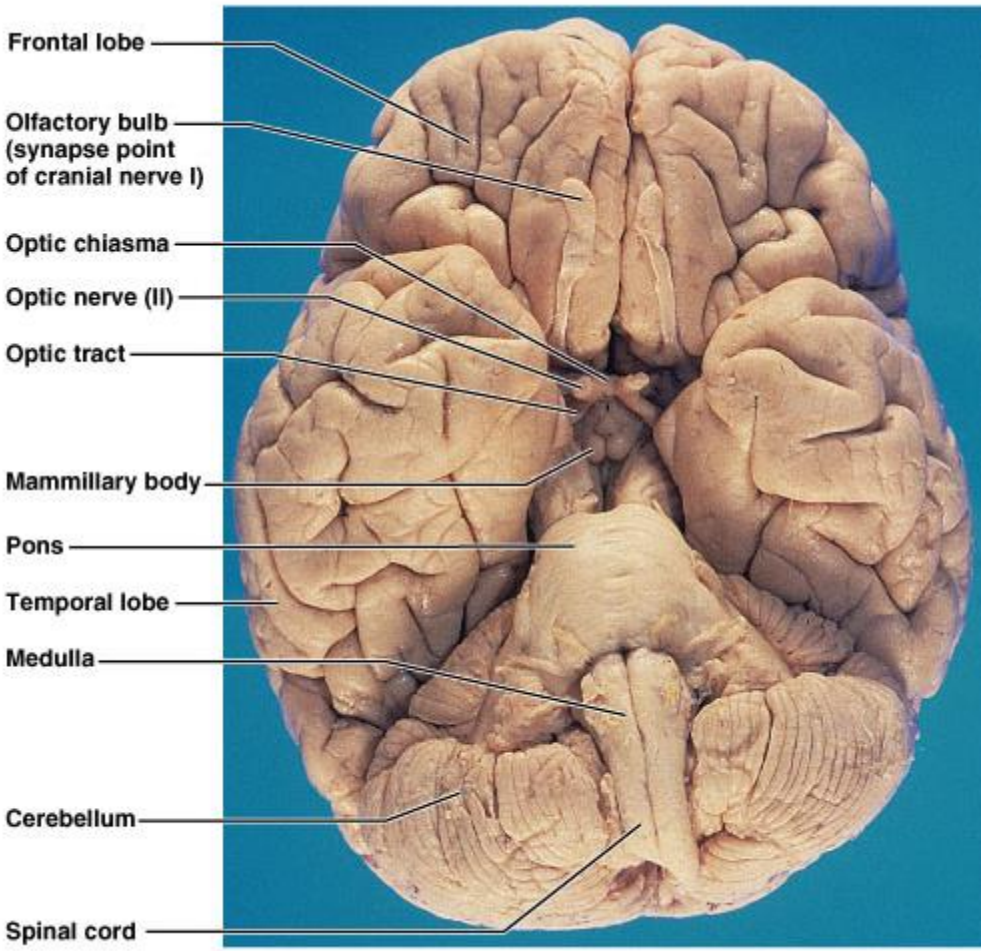


(looking at brain from below)

Diencephalon – surface anatomy

Hypothalamus is between optic chiasma to and including mamillary bodies





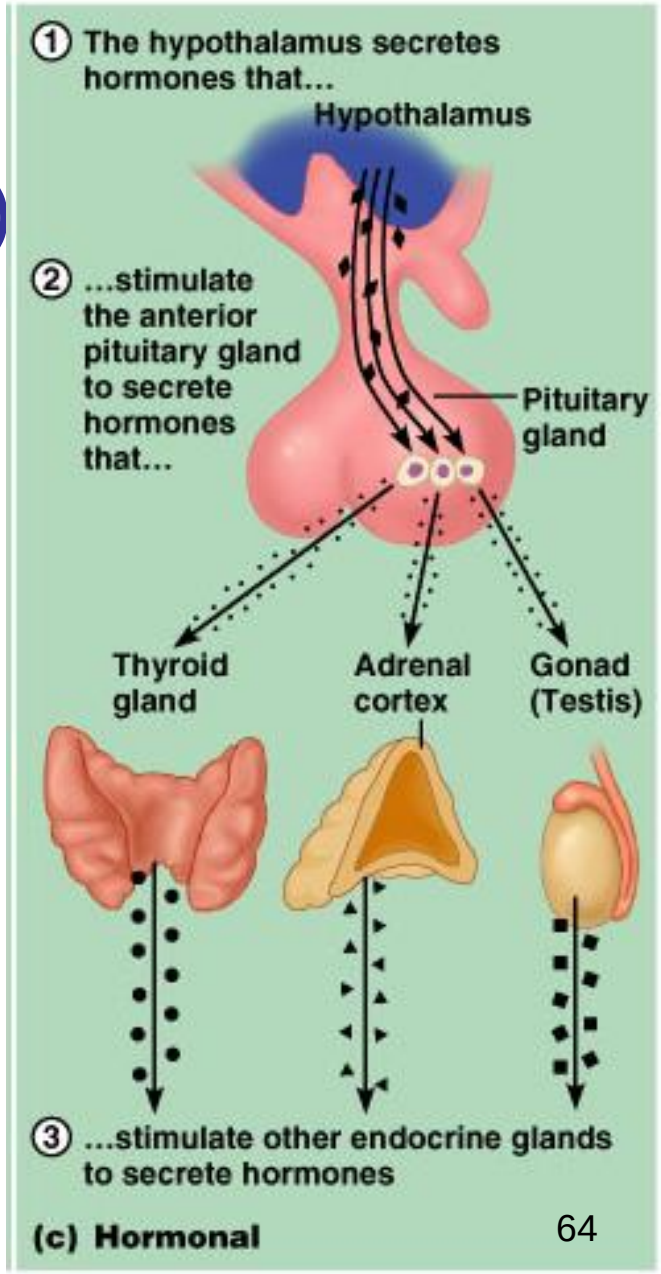
Hypothalamus

- “Below thalamus”
- Main visceral control center
  - Autonomic nervous system (peripheral motor neurons controlling smooth and cardiac muscle and gland secretions): heart rate, blood pressure, gastrointestinal tract, sweat and salivary glands, etc.
  - Emotional responses (pleasure, rage, sex drive, fear)
  - Body temp, hunger, thirst sensations
  - Some behaviors
  - Regulation of sleep-wake centers: circadian rhythm (receives info on light/dark cycles from optic nerve)
  - Control of endocrine system through pituitary gland
  - Involved, with other sites, in formation of memory

Hypothalamus

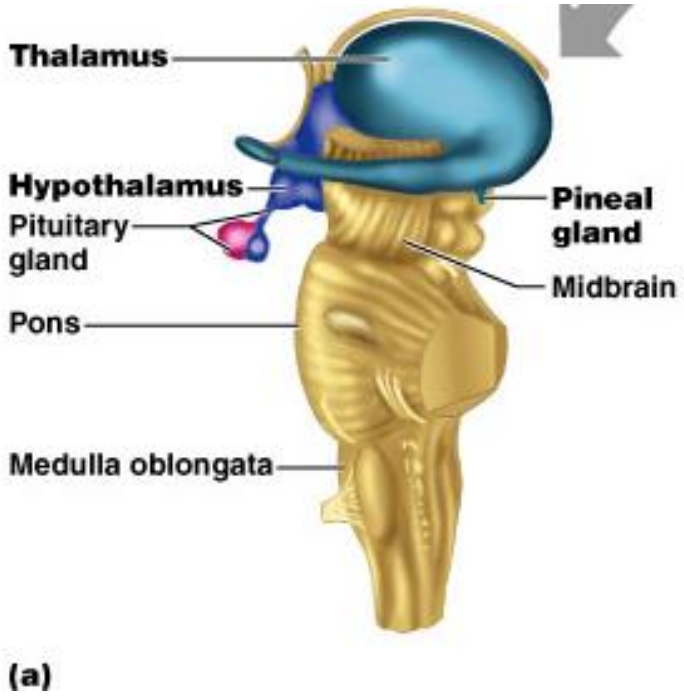
(one example of its functioning)

Control of endocrine system through pituitary gland

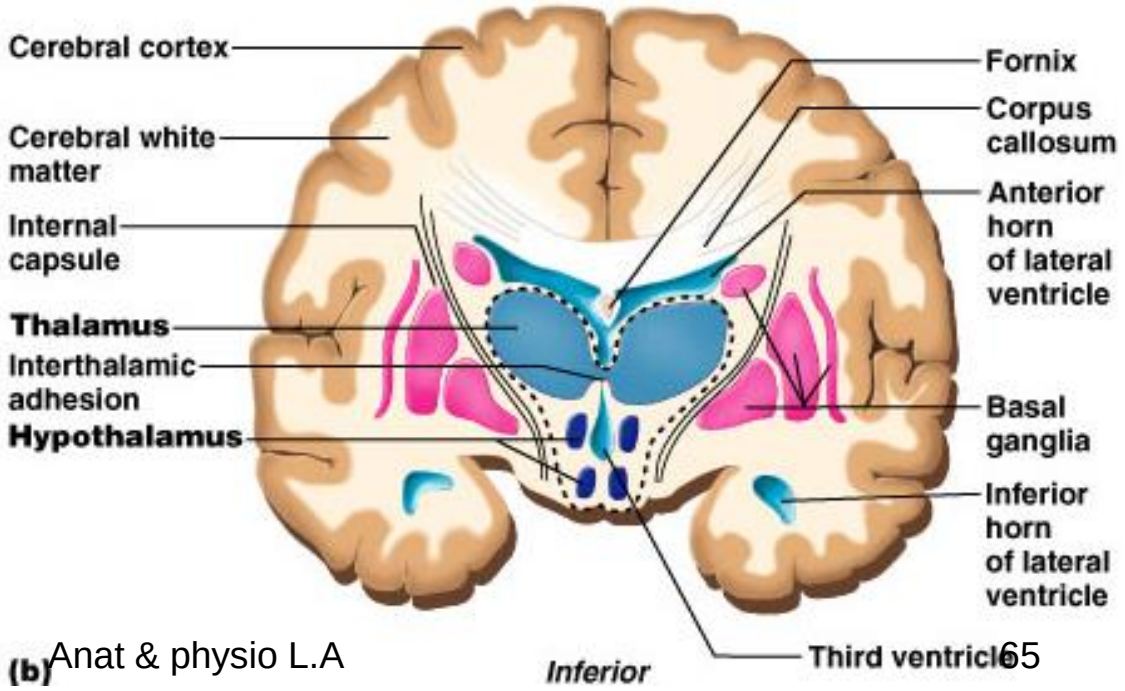


Epithalamus

- Third and most dorsal part of diencephalon
- Part of roof of 3rd ventricle
- Pineal gland or body (unpaired): produces melatonin signaling nighttime sleep
- Also a tiny group of nuclei



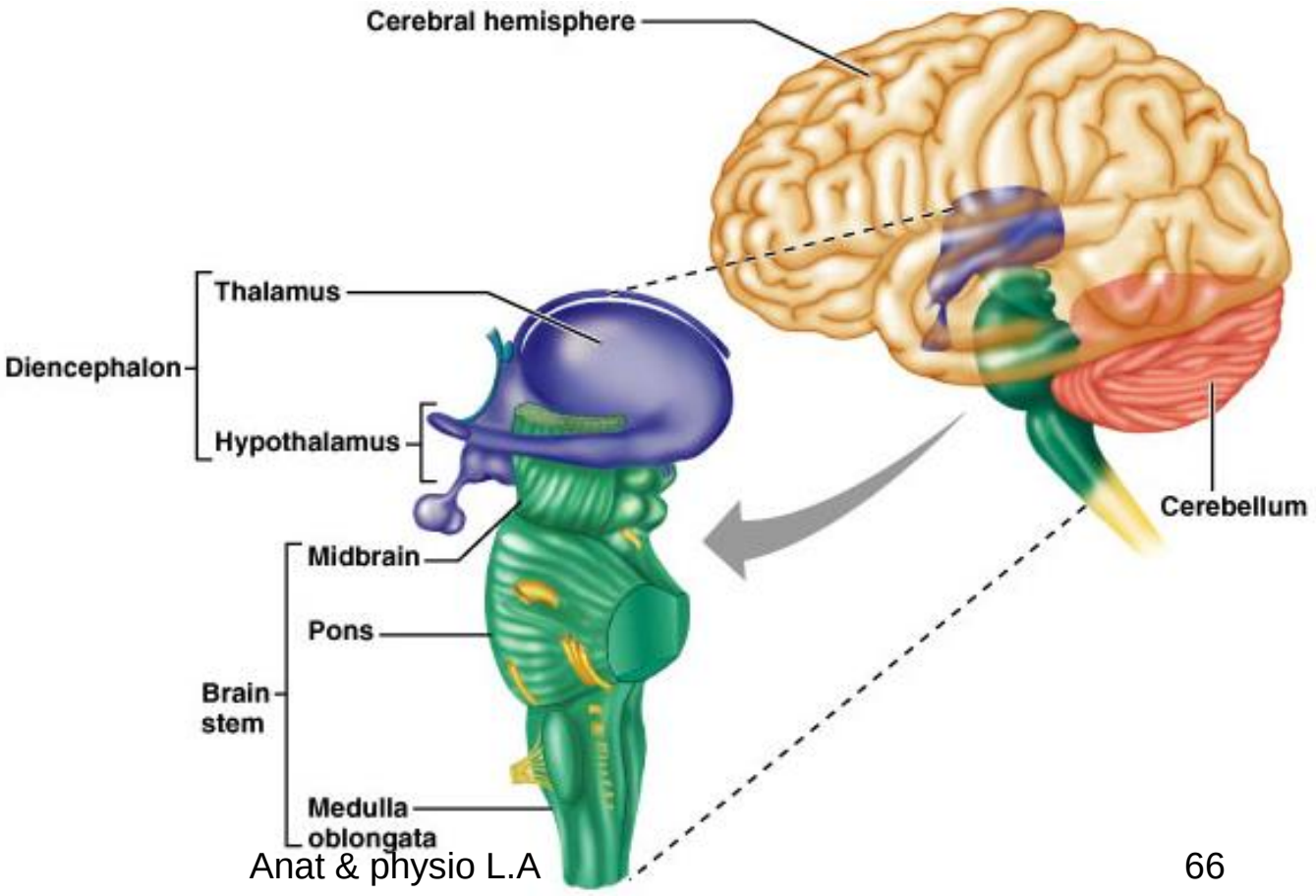
Coronal section



Brain Stem

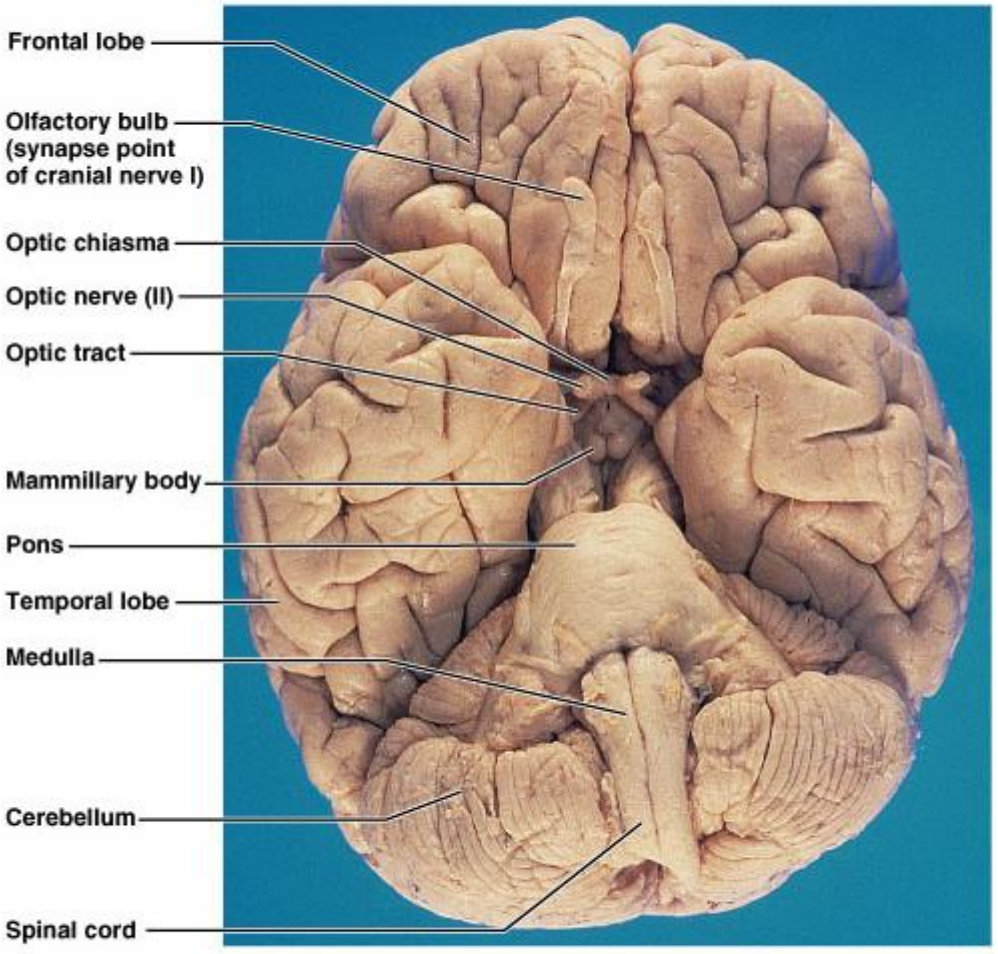
Rigidly programmed automatic behavior necessary for survival
Passageway for fiber tracts running between cerebrum and spinal cord
Heavily involved with innervation of face and head (10 of the12 cranial nerves attach to it)

- Midbrain
- Pons
- Medulla oblongata

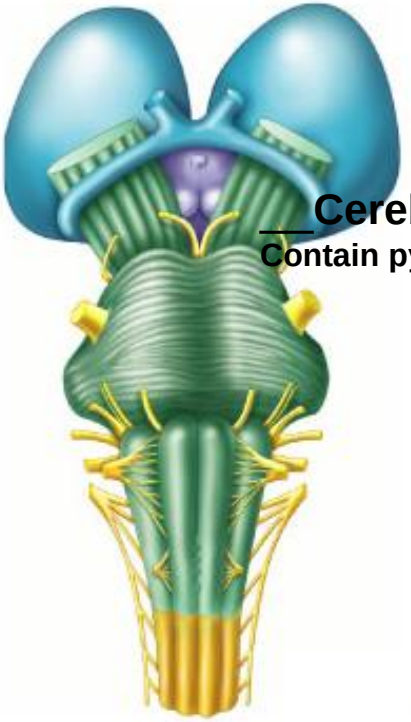


Brain stem

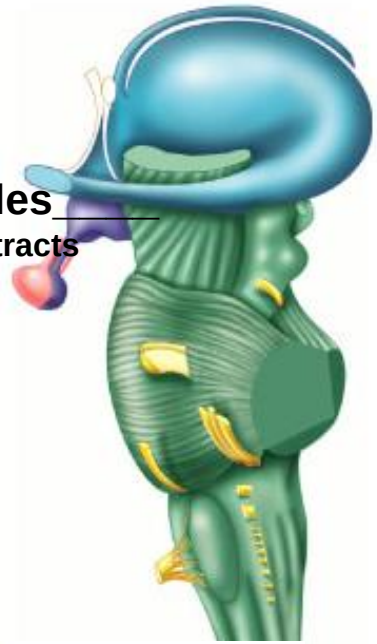
- Midbrain
- Pons
- Medulla oblongata



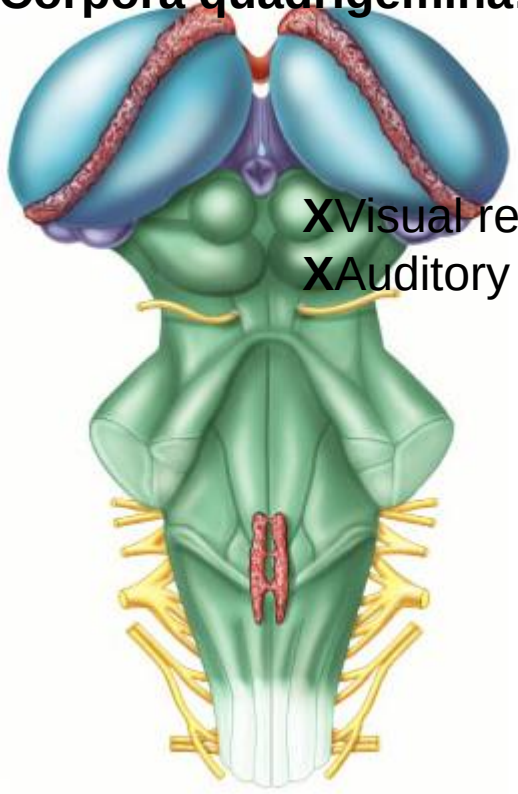
Midbrain



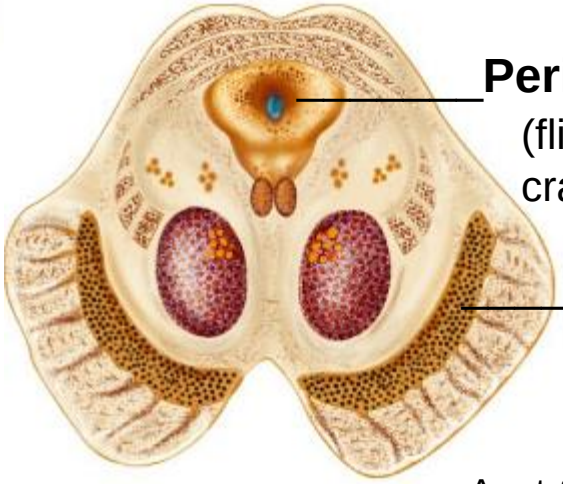
Cerebral peduncles
Contain pyramidal motor tracts



Corpora quadrigemina:



XVisual reflexes
XAuditory reflexes

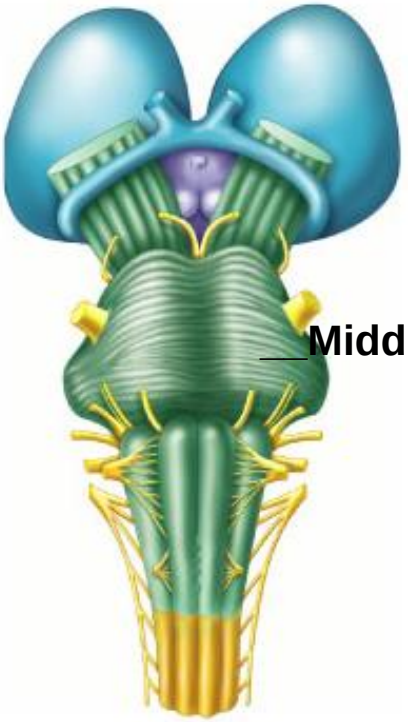


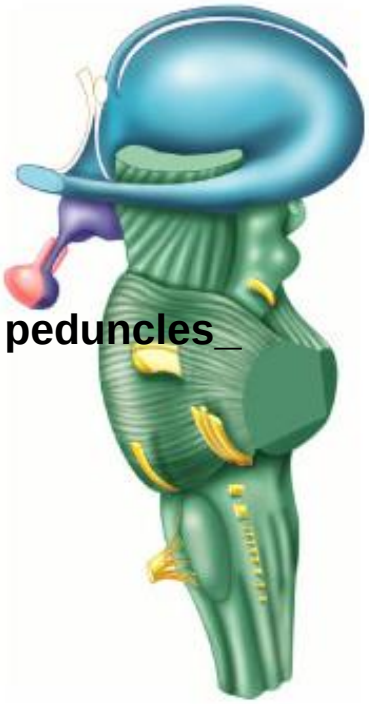
Periaqueductal gray
(flight/flight; nausea with visceral pain; some cranial nerve nuclei)

Substantia nigra
(degeneration causes Parkingson's disease)

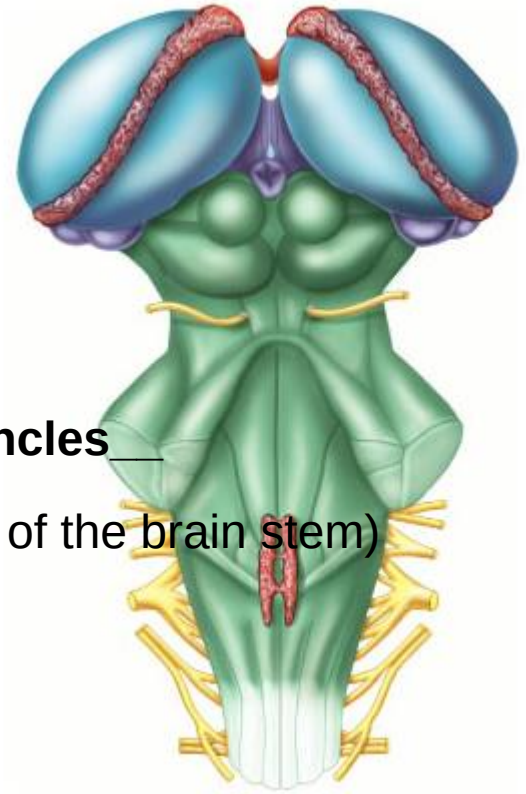
Pons

Also contains several CN and other nuclei





__Middle cerebellar peduncles_



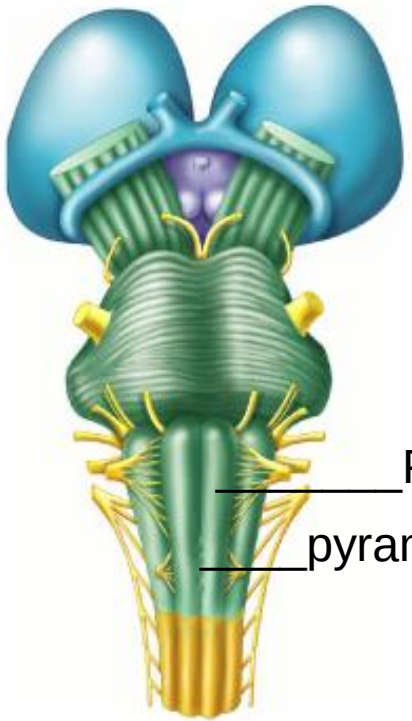
3 cerebellar peduncles__

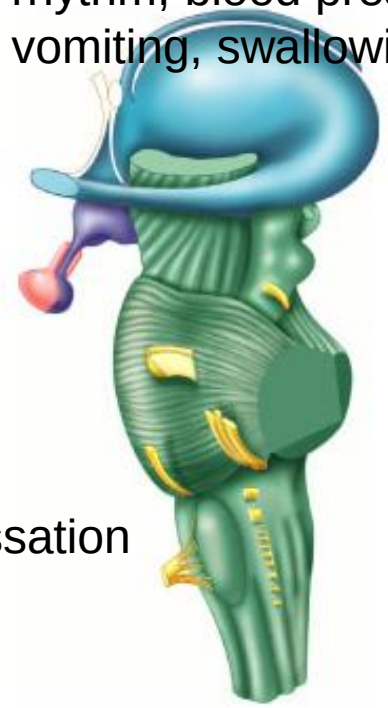
(one to each of the three parts of the brain stem)

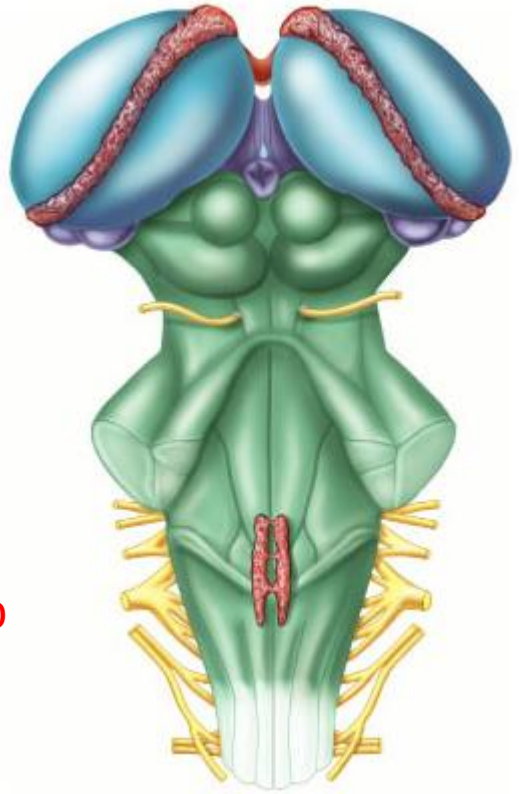
Dorsal view

Medulla oblongata

Relays sensory info to cerebral cortex and cerebellum
Contains many CN and other nuclei
Autonomic centers controlling heart rate, respiratory rhythm, blood pressure; involuntary centers of vomiting, swallowing, etc.







Dorsal view

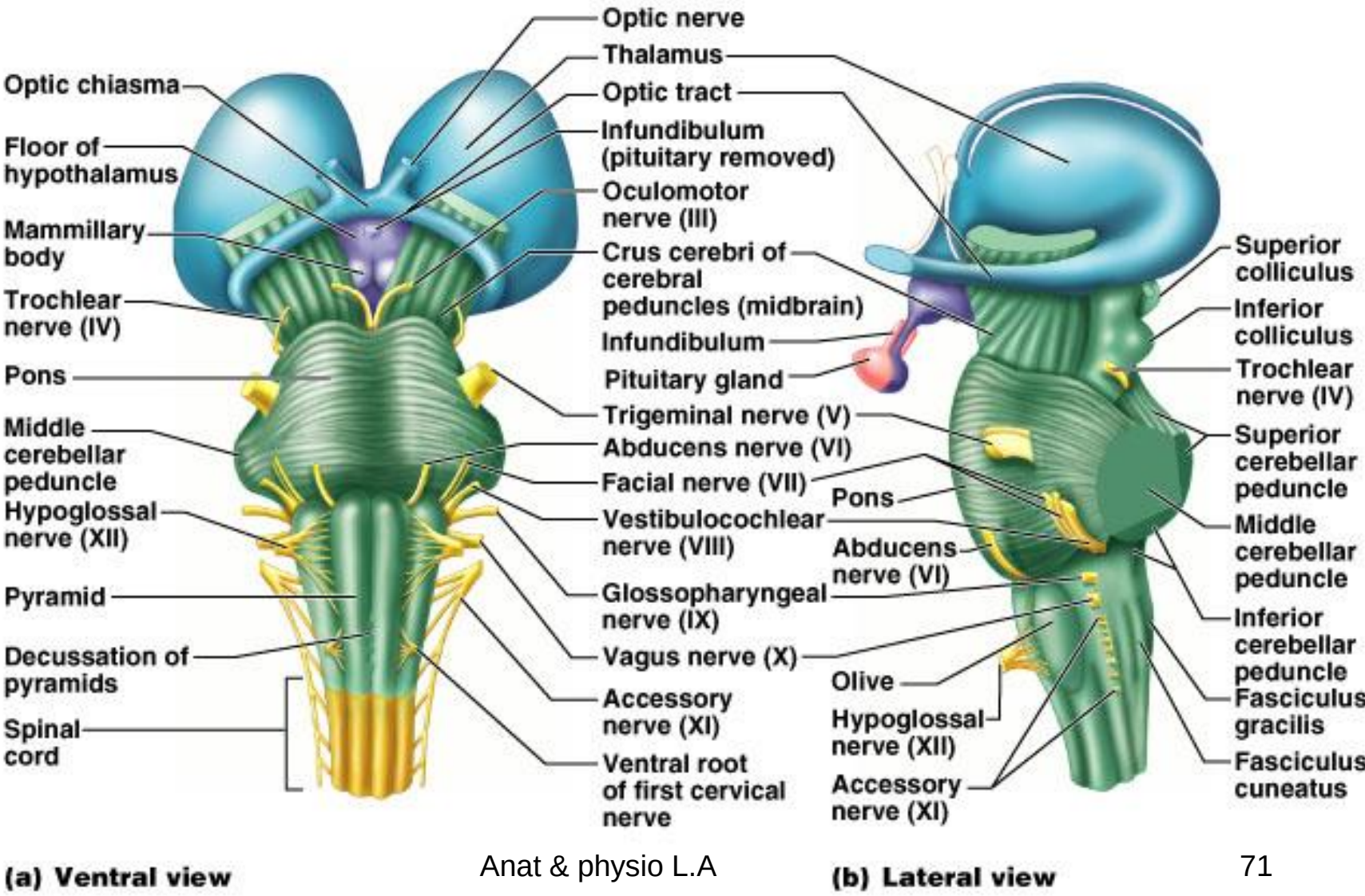
_____Pyramids

____pyramidal decussation

"Pyramidal"=corticospinal tracts; these are motor tracts which cross over in the decussation. They are named pyramids because they supposedly look like them, and also they originate from "pyramidal" neurons in the motor cortex. The tracts have the name of origin 1st, therefore "corticospinal" tells you they go from the cortex ("cortico-") to the spinal cord ("-spinal")

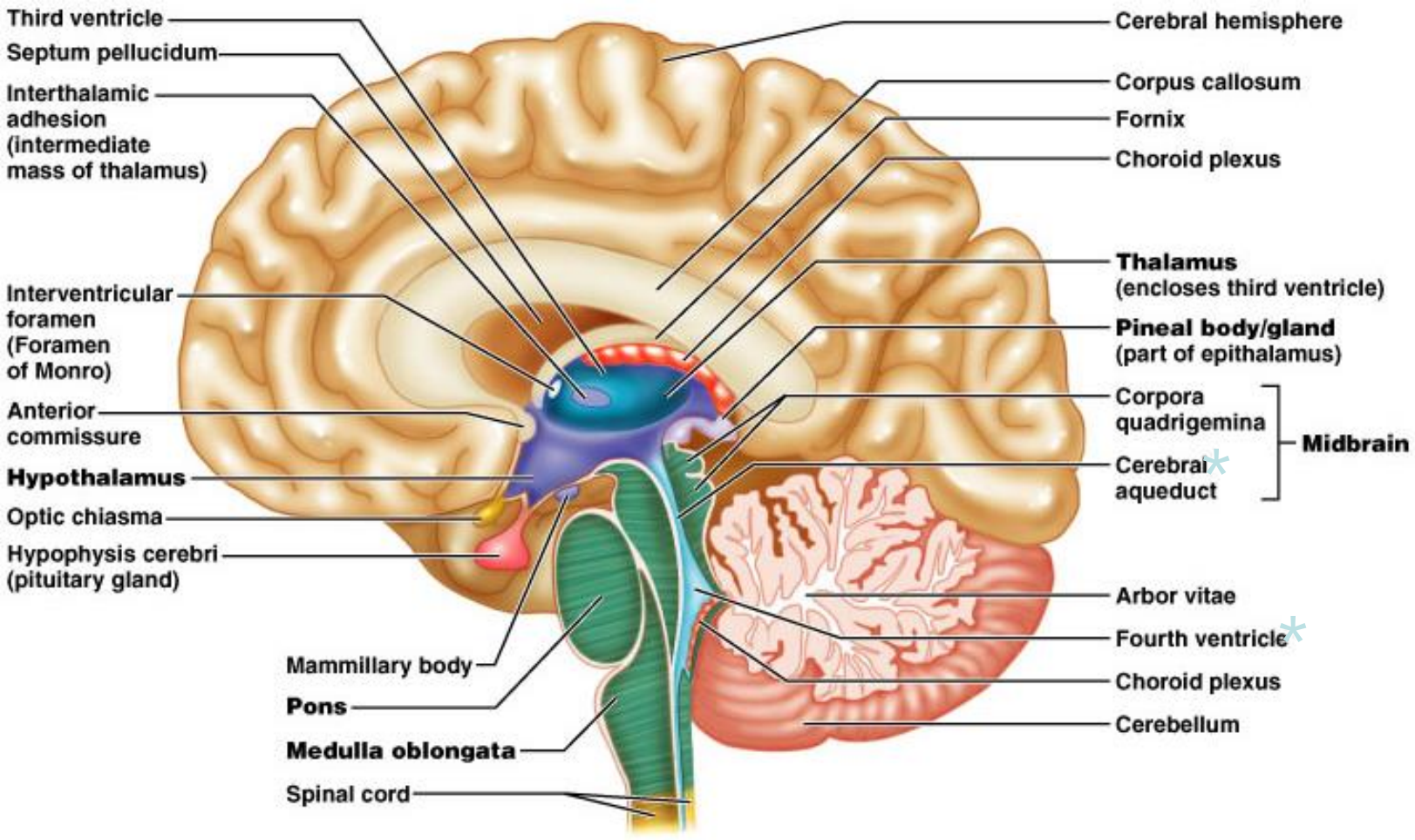
see later slides

With all the labels….



Brain Stem in mid-sagittal plane

Note cerebral aqueduct and fourth ventricle*

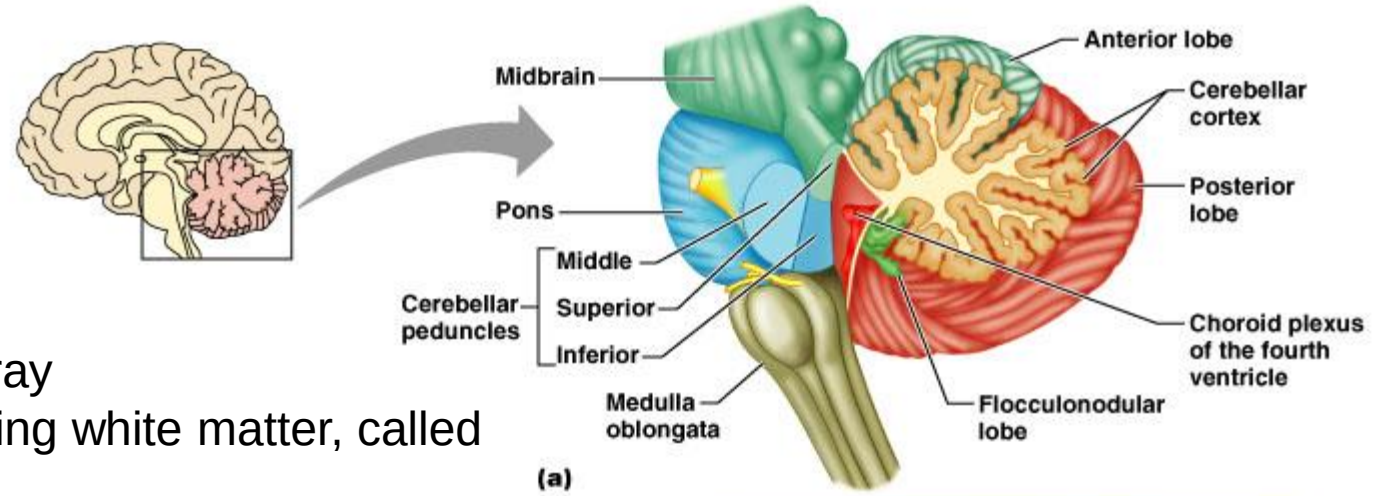


Cerebellum

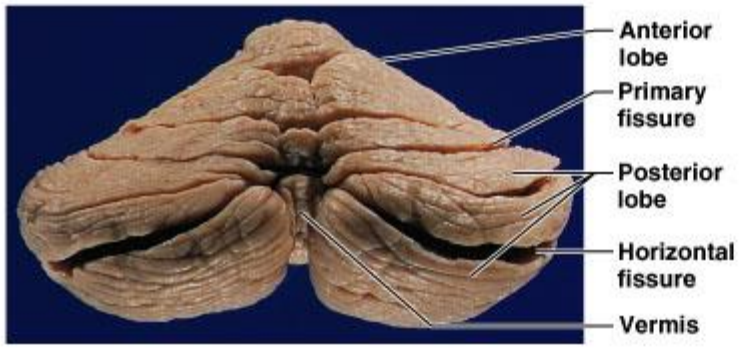
Two major hemispheres: three lobes each
- Anterior
- Posterior
- Floculonodular

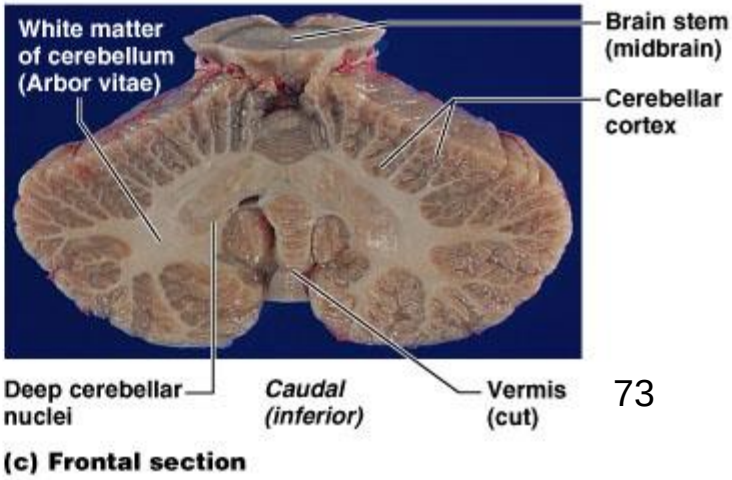
Vermis: midline lobe connecting hemispheres

Separated from brain stem by 4th ventricle



Outer cortex of gray
- Inner branching white matter, called "arbor vitae"





Functions of cerebellum

- Smooths, coordinates & fine tunes bodily movements
- Helps maintain body posture
- Helps maintain equilibrium
- How?
  - Gets info from cerebrum re: movements being planned
  - Gets info from inner ear re: equilibrium
  - Gets info from proprioceptors (sensory receptors informing where the parts of the body actually are)
  - Using feedback, adjustments are made
- Also some role in cognition

- Damage: ataxia, incoordination, wide-based gait, overshooting, proprioception problems

Functional brain systems
(as opposed to anatomical ones)

Networks of distant neurons that function together

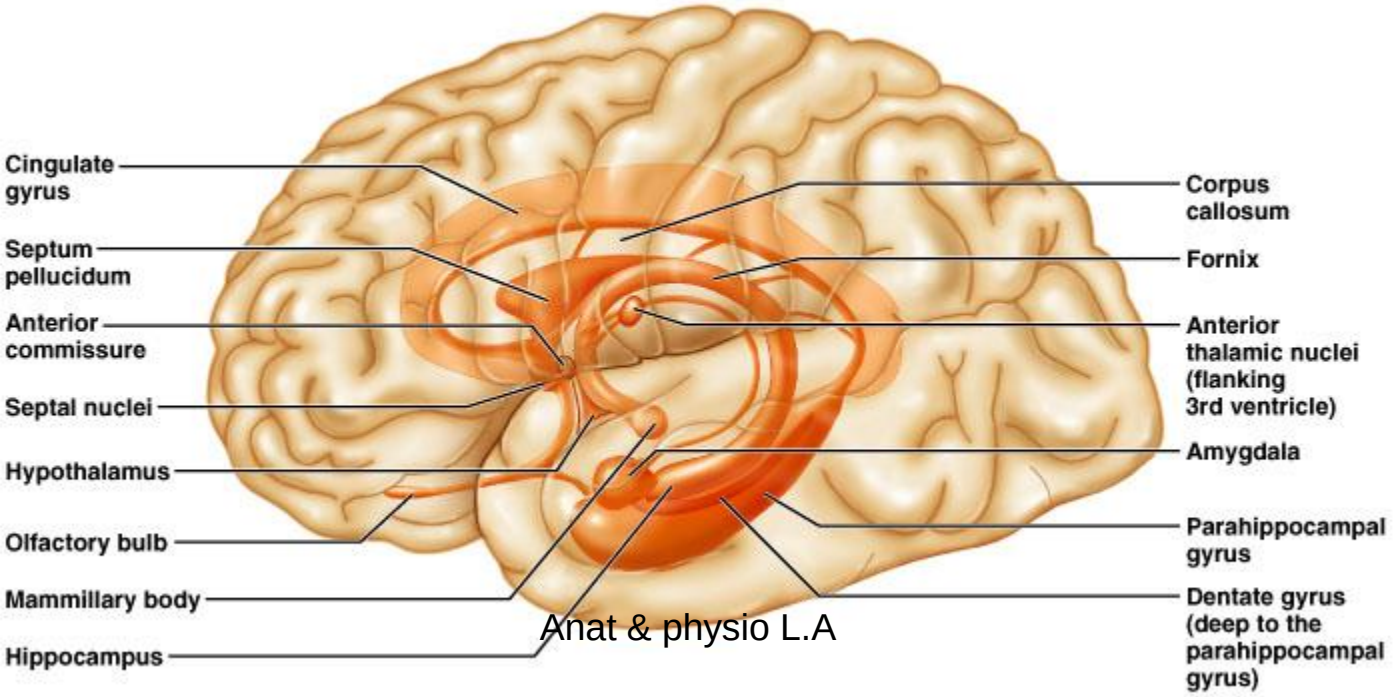
Limbic system

Reticular formation

Limbic system

(not a discrete structure - includes many brain areas)

- Most important parts:
  - Hipocampus
  - Amygdala
  - Cingulate gyrus
  - Orbitofrontal cortex (not labeled; is behind eyes - part of the prefrontal cortex but connects closely)



Limbic system continued

- Called the “emotional” brain
- Is essential for flexible, stable, adaptive functioning
- Links different areas so integration can occur
  - Integration: separate things are brought together as a whole
  - Processes emotions and allocates attentional resources
- Necessary for emotional balance, adaptation to environmental demands (including fearful situations, etc.), for creating meaningful connections with others (e.g. ability to interpret facial expressions and respond appropriately), and more…

Reticular formation

Runs through central core of medulla, pons and midbrain

- Reticular activating system (RAS): keeps the cerebral cortex alert and conscious
- Some motor control