THE BRAIN

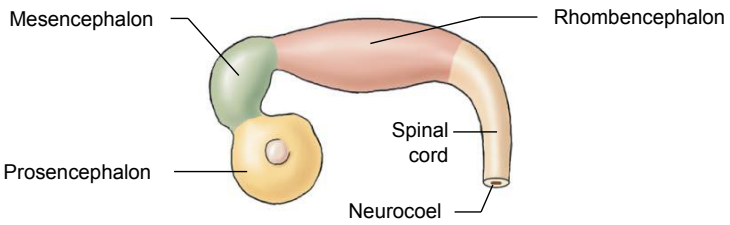
Functional anatomy of brain and cranial nerves

- characteristics of typical brain
  - weight = 3lbs
  - volume = 1.2L

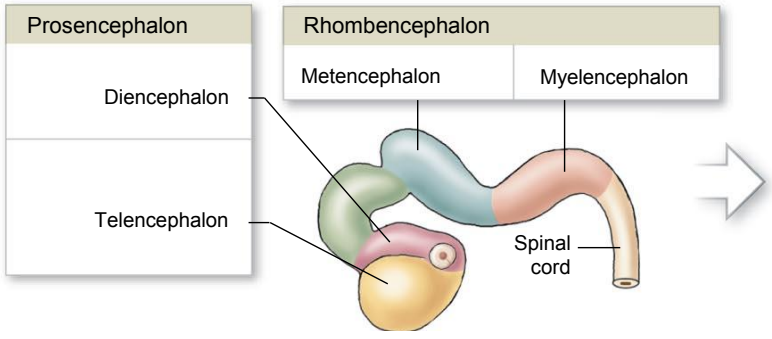
DEVELOPMENT

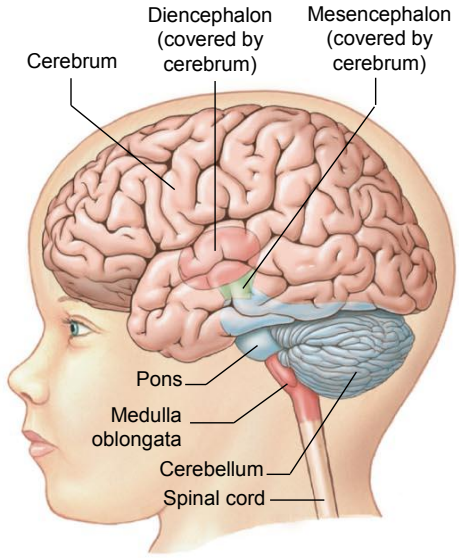
- neural tube is derived from the ectoderm
  - in middle of neural tube is the neurocoel which is fluid-filled
- 3 separate regions at 3-4week stage
  - mesencephalon (midbrain), prosencephalon (forebrain), rhombencephalon (hindbrain) – these are the 3 primary brain regions in early development
  - this is because the neurocoel is getting closed off at different points, forming these distinct regions
  - pressure build-up occurs in different regions because neurocoel still fluid-filled; causes swelling, and triggers cell division in these regions – neurospecialized cells
- 5-week stage
  - 3 primary brain regions shift positions relative to each other
  - green region = mesencephalon and stays relatively the same, does not develop into separate regions like the other primary brain regions
  - secondary brain regions formed from the primary brain regions
    - prosencephalon: splits into diencephalon (thalamus) and telencephalon (cerebrum)
    - mesencephalon: midbrain still
    - rhombencephalon: metencephalon (develops into cerebellum, pons), myelencephalon (develops into medulla oblongata – continuous with the spinal cord)
  - increasing complexity the further you get toward the cranial end

A lateral view of the brain of an embryo after 4 weeks of development showing the neural tube



A lateral view of the brain of a 5-week-old embryo

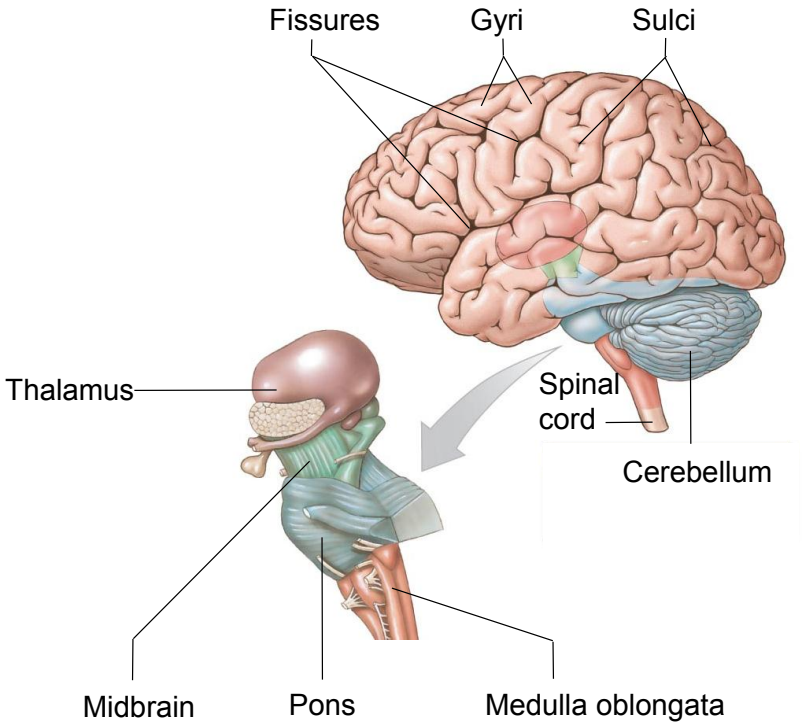




Brain development in a child, showing the cerebrum covering other portions of the brain

MAJOR BRAIN REGIONS

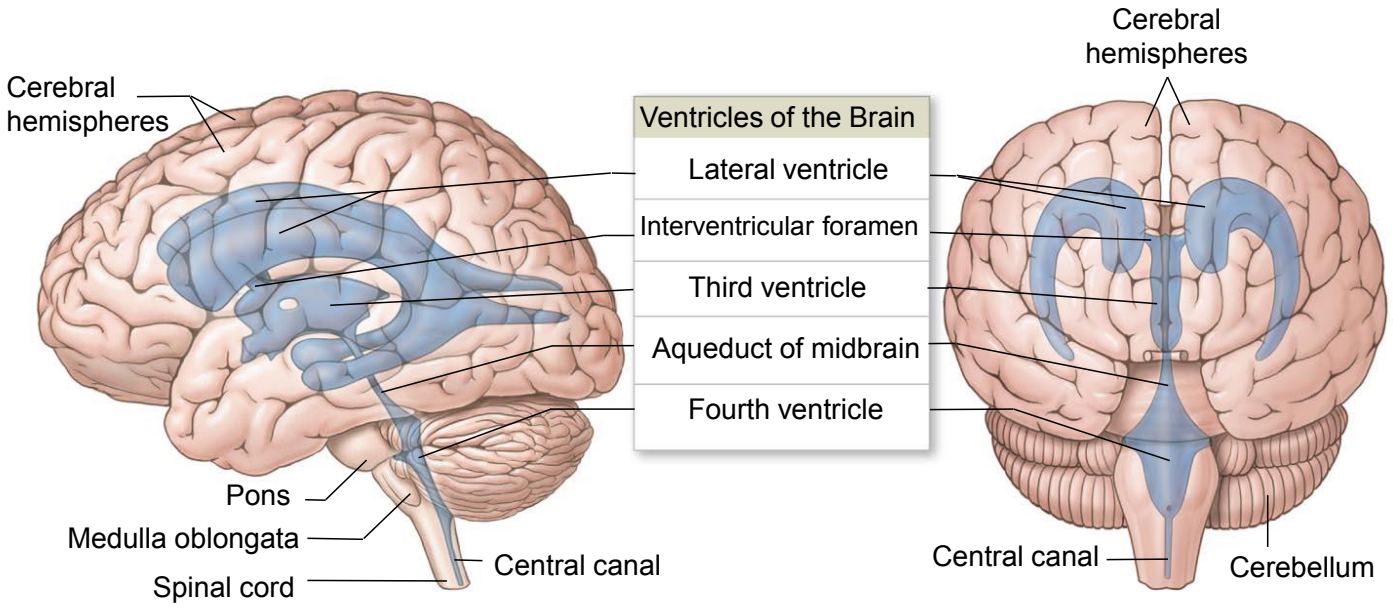
- brainstem
  - medulla, pons, midbrain
  - pons – bridge; a relay station that projects information from medulla to rest of brain and vice versa
    - also connection between brainstem and the cerebellum
    - connects cerebellum with rest of the brain
  - midbrain – deals with auditory and visual input
    - any reflexes associated with these sensory functions is controlled by the midbrain
    - also projects a lot of information further up into the CNS
  - cerebellum NOT part of brainstem; connected to it by the pons
- thalamus
  - receives sensory information sends visual + auditory to midbrain
  - also projects up to the primary visual, primary auditory cortices
  - it is the most complicated sensory processing station
  - the link between the cortex and the entire rest of the body
- fissures = deep grooves that subdivide hemispheres
  - pattern remains fairly constant between individuals; gyri + sulci are variable
- gyri = folds and increase in SA
- sulci = separates the gyri with a slight depression
  - certain sulci ALWAYS present



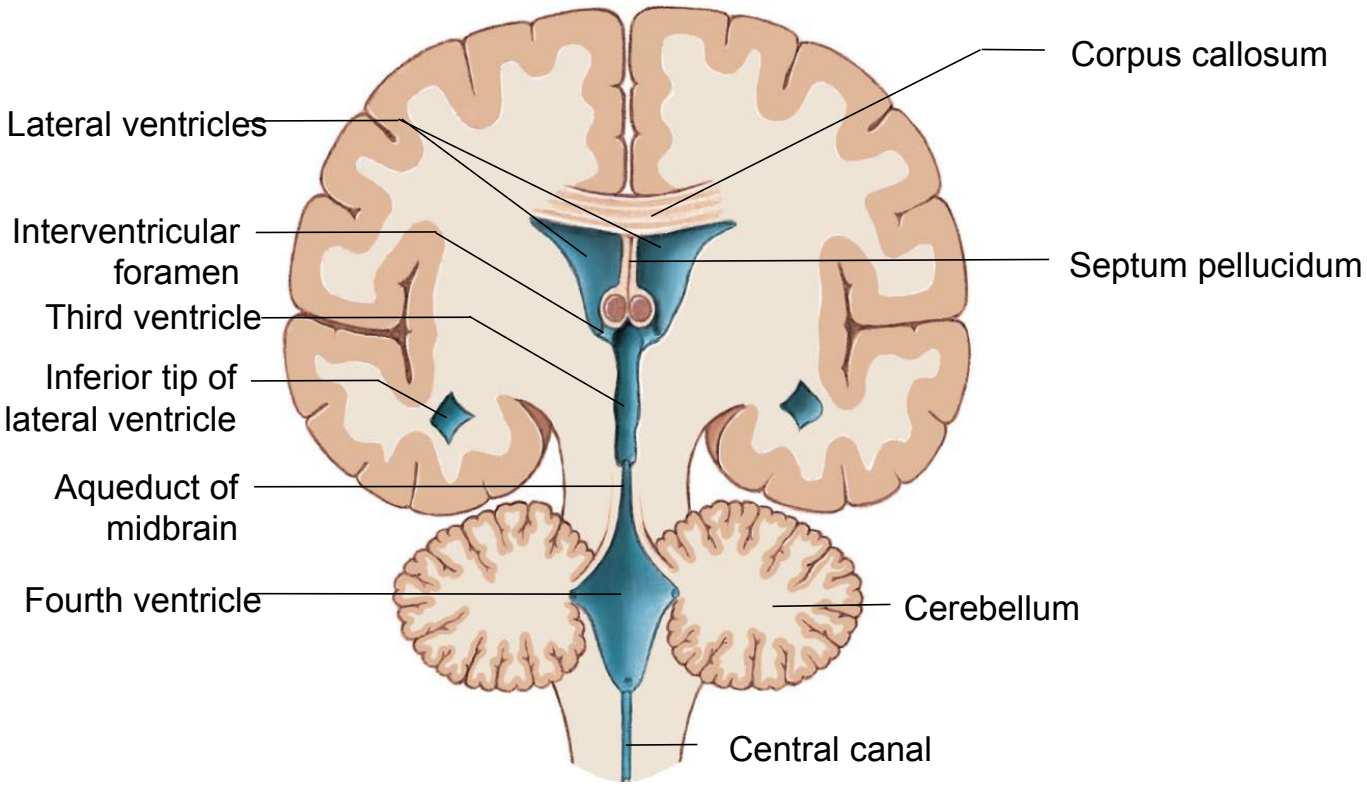
Ventricles

- so what happens to this neurocoel region?
- Ventricles circulate CSF
- All ventricles are continuous! Occlusions disappear
- Lateral ventricles
  - Connected to third venctricle via intraventricular foramen (cnnxn)
- Third ventricle
  - Drains through aqueduct duct in midbrain; connects to 4th ventricle
- Fourth ventricle

- Extends down to medulla, thins out, becomes central canal of the spinal cord



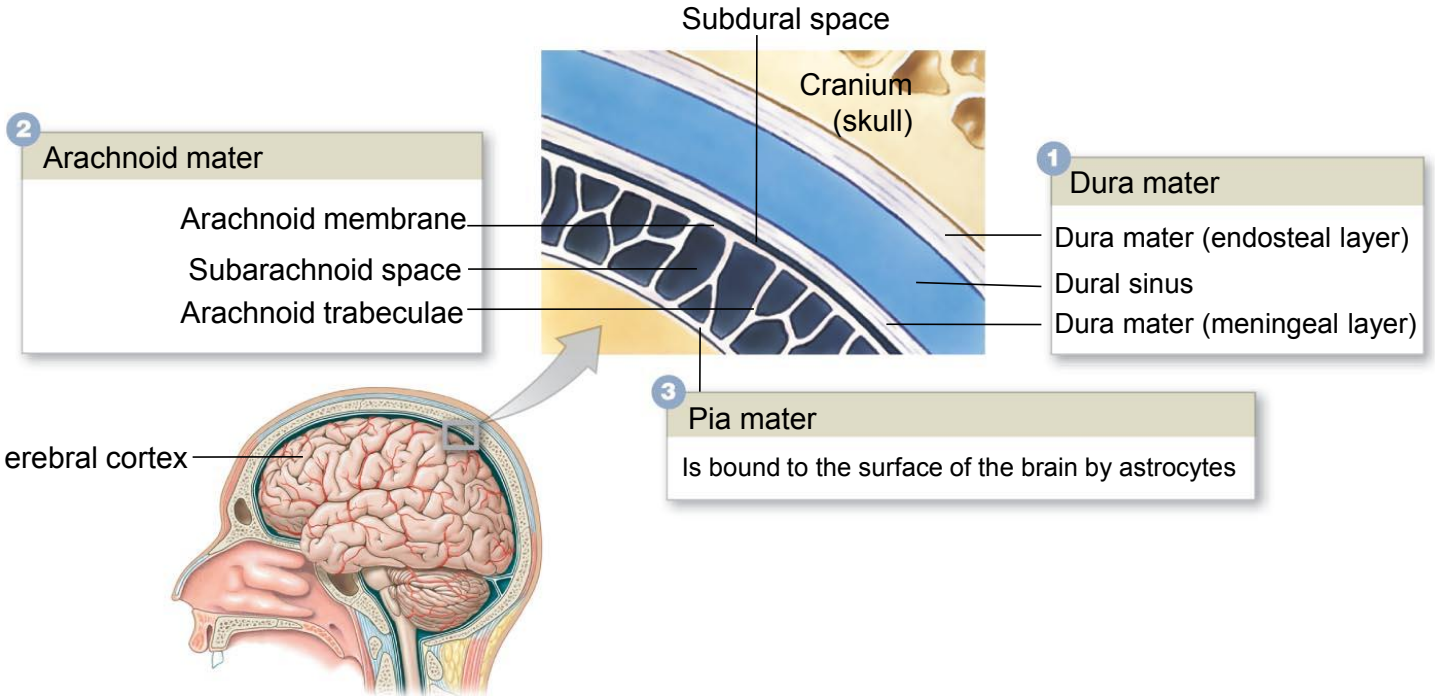
Ventricular system, lateral view **Ventricular system, anterior view**



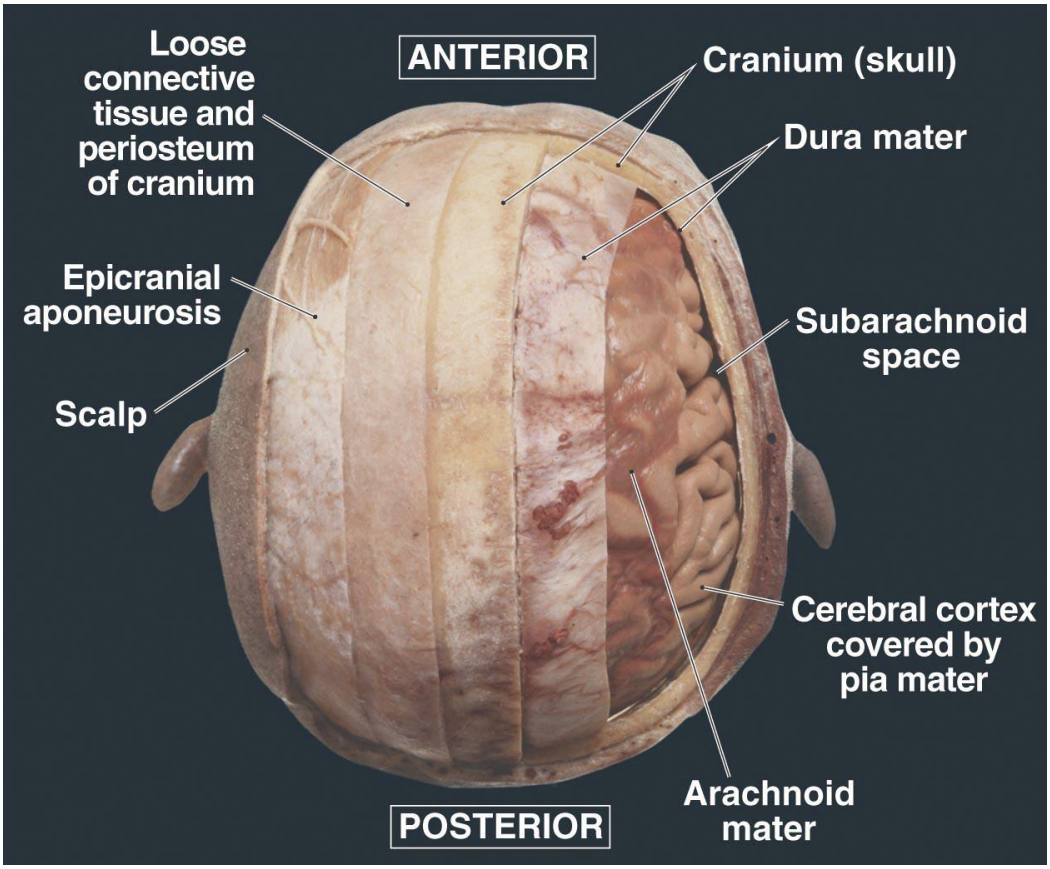
- septum pellucidum
  - dividing wall between 2 lateral ventricles
- corpus callosum

- allows for interhemispheric communication
- massive bundle of fibres that connects 2 hemispheres
- has 250 million axons
- only evolved with placental mammals
- agenesis corpus callosum (ACC)
  - either no cc or only a partial one (50/250million)
  - range of symptoms is widespread
  - associated with developmental delay
  - can also be asymptomatic – only ever find out post-mortem
  - cnnxn between ACC and autism spectrum – correlation has been found
  - split brain patients – lost corpus callosum
    - put something in left side of visual space, individual can process the image and know what it is, but could never vocalize what it was because connection has been lost

Three layers of cranial meninges

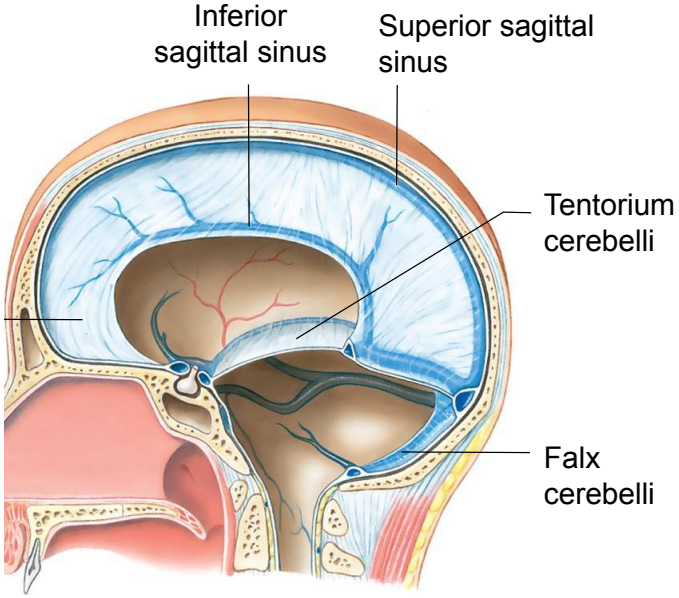


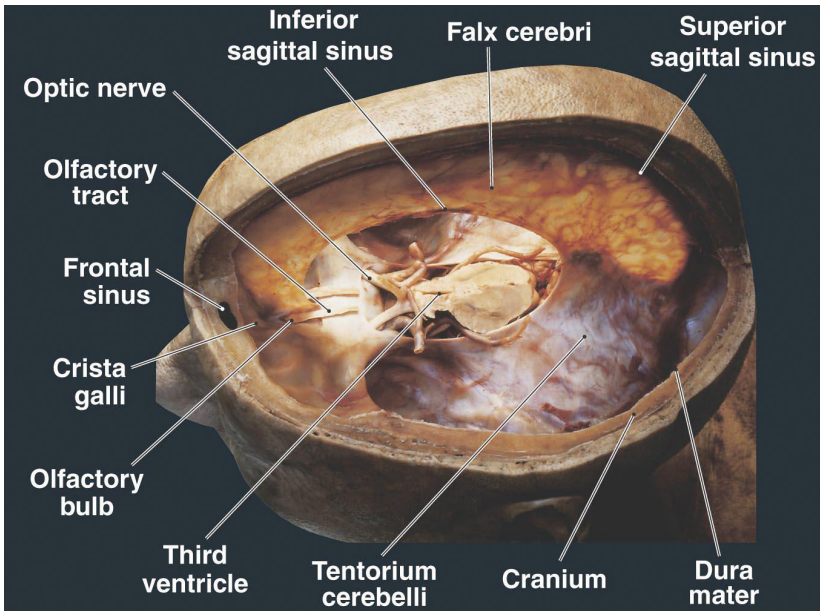
- brain is protected and supported by the cranial meninges and CSF
- dura mater
  - tough outer-covering
  - 1 layer in spinal cord, but in brain there are layers associated with it
    - endosteal layer – fused to bones of the cranium
    - dural sinus – fluid-filled, vessels
    - meningeal layer – similar to that of the spinal cord dura mater
- arachnoid mater
  - arachnoid membrane, subarachnoid space, and then arachnoid trabeculae within the subarachnoid space
- pia mater
  - bound to the surface via astrocytes



Dural sinuses & dural folds

- folds = reflections
- dip into cranial cavity and return
- provide additional stabilization and support to brain
- falx cerebri
    - physically separates the 2 hemispheres – attached to outer dural layer
    - inferior attachment to crista galli (anteriorly) and internal occipital crest (posteriorly)
    - superior and inferior sagittal sinuses lie within
- falx cerebelli
    - cerebellum separated into its own 2 hemispheres

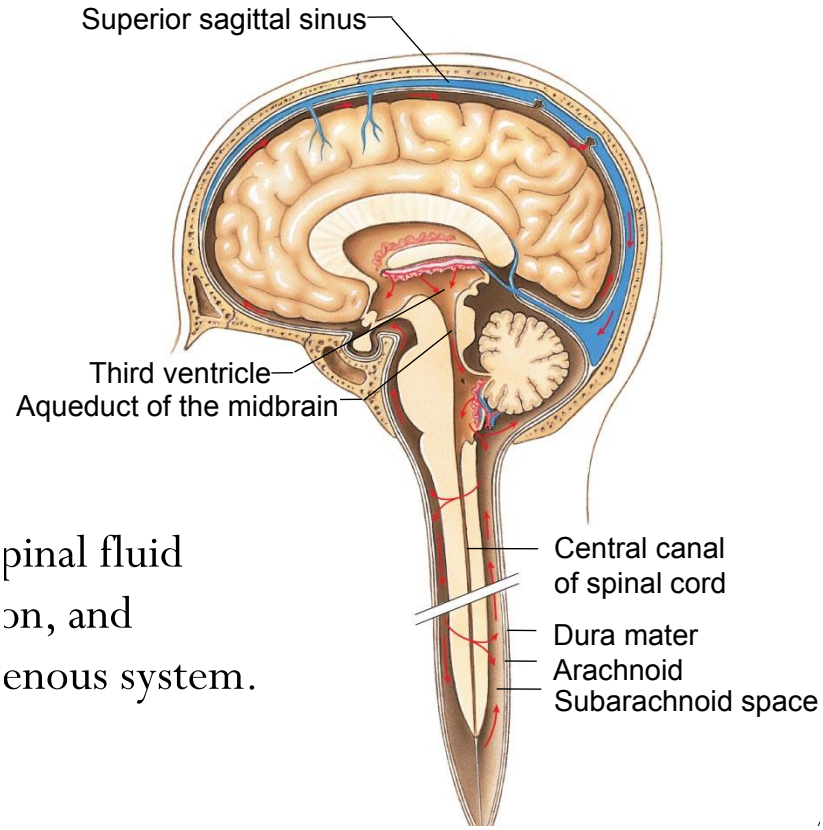




- tentorium = covering
- falx = sieve
    - shape
- these membranes are very sharp
    - shaking baby syndrome
        - damage caused by the falx and the tentorium because these membranes are so tough
        - can slice through the brain when you shake a baby

Cranial meninges and CSF

- the sites of CSF production, circulation, and absorption into venous system



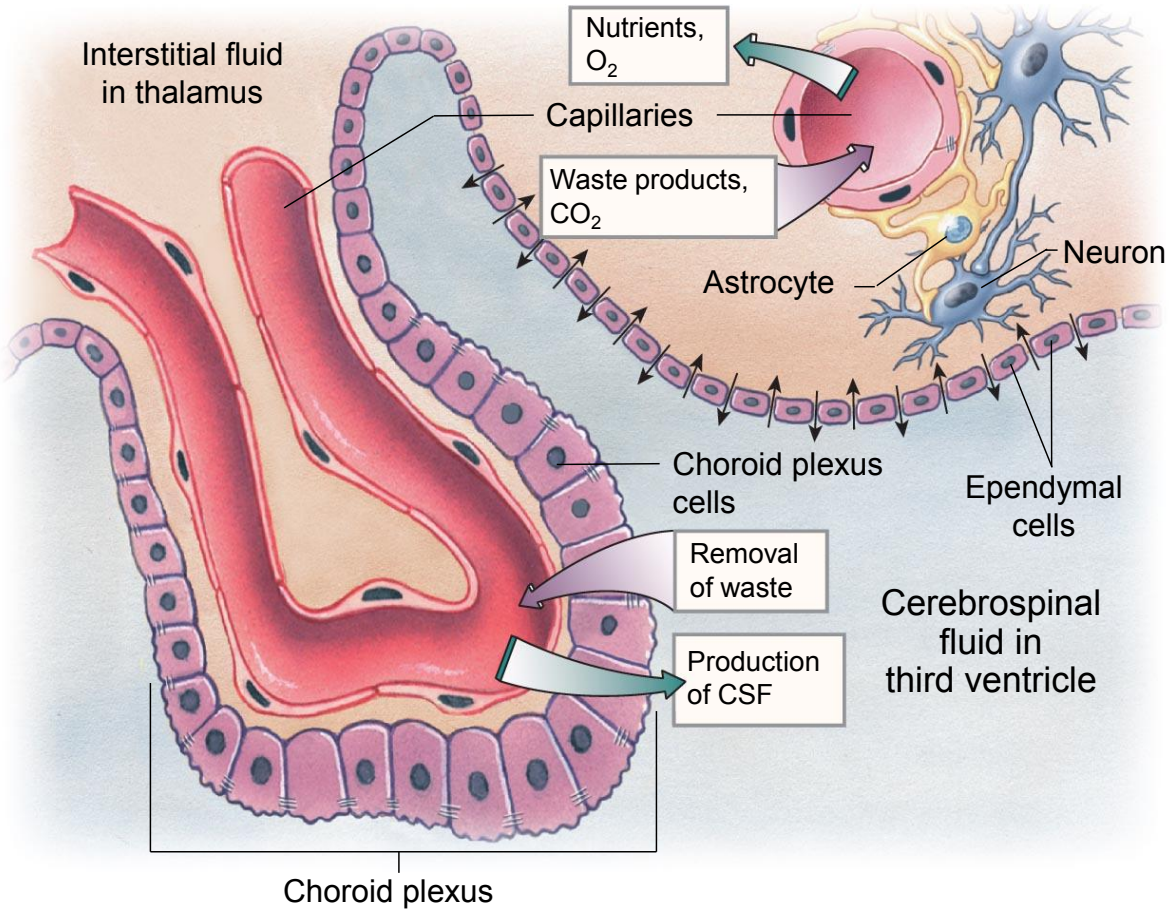
pinal fluid
ɔn, and
enous system.

- also in subarachnoid space
- CSF does not only stay in the ventricles

- Escapes out through ventricular system and into subarachnoid space, will move its way around arachnoid membrane
    - This is why it covers brain and spinal cord

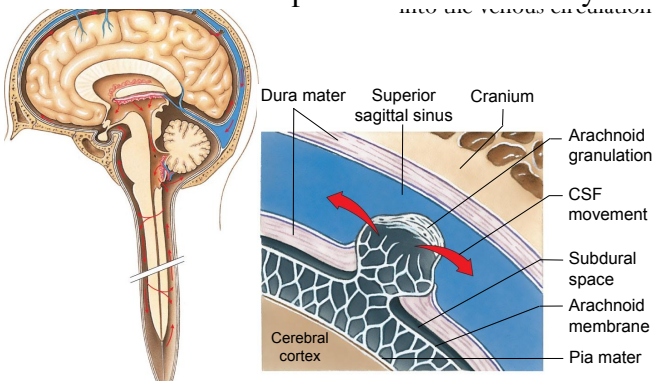
The choroid plexus

- ependymal cells help circulate CSF, may also help produce it
- actual CSF produced by choroid plexus in every ventricle region
- each ventricle has these choroid plexi which dips into the ventricle
    - within this region are a bunch of capillaries, CSF is fluid from capillaries forced out from vessel
- within any given time, amount of CSF circulating 250mL
- choroid plexus produces 500mL of CSF
- CSF lost to venous system



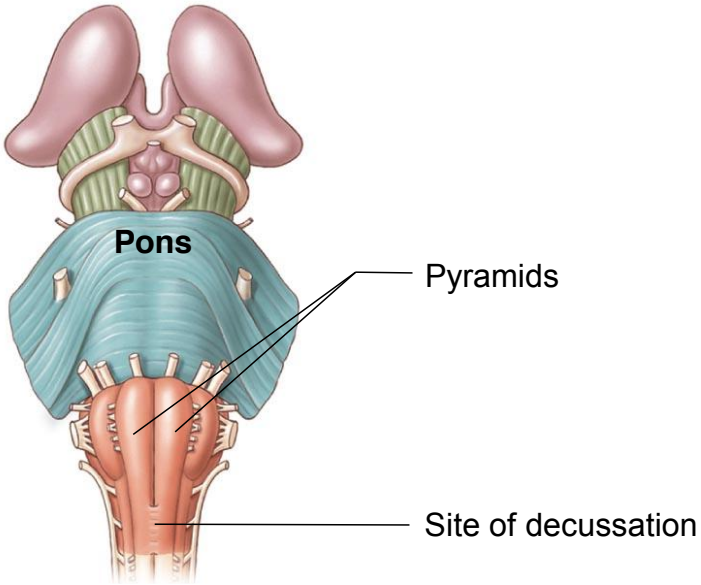
Arachnoid granulation

- site at which CSF is absorbed into venous circulation
- finger-like projections pop through dural membrane (granulation), contact sinus, allows CSF to exit out subarachnoid space and into venous system



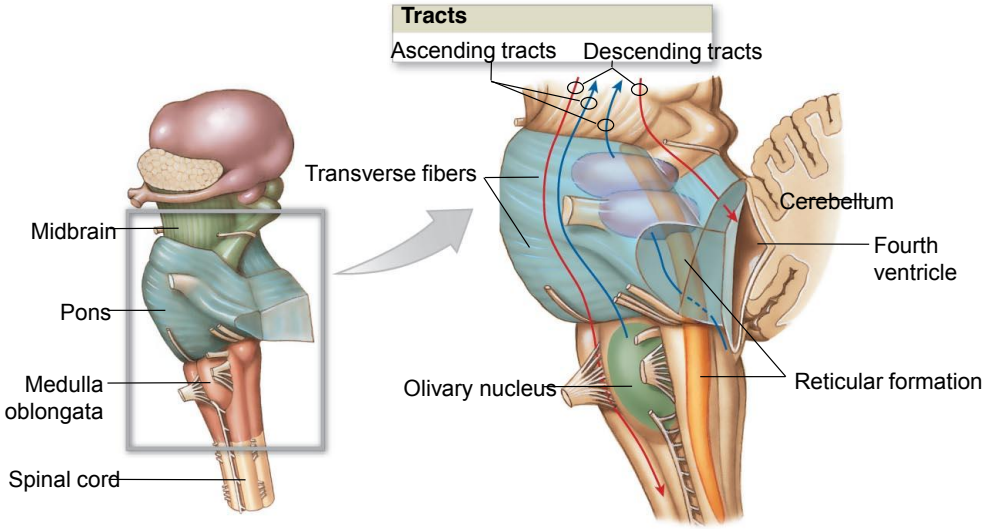
- movement of CSF is one-way due to pressure gradient

Medulla oblongata and pons

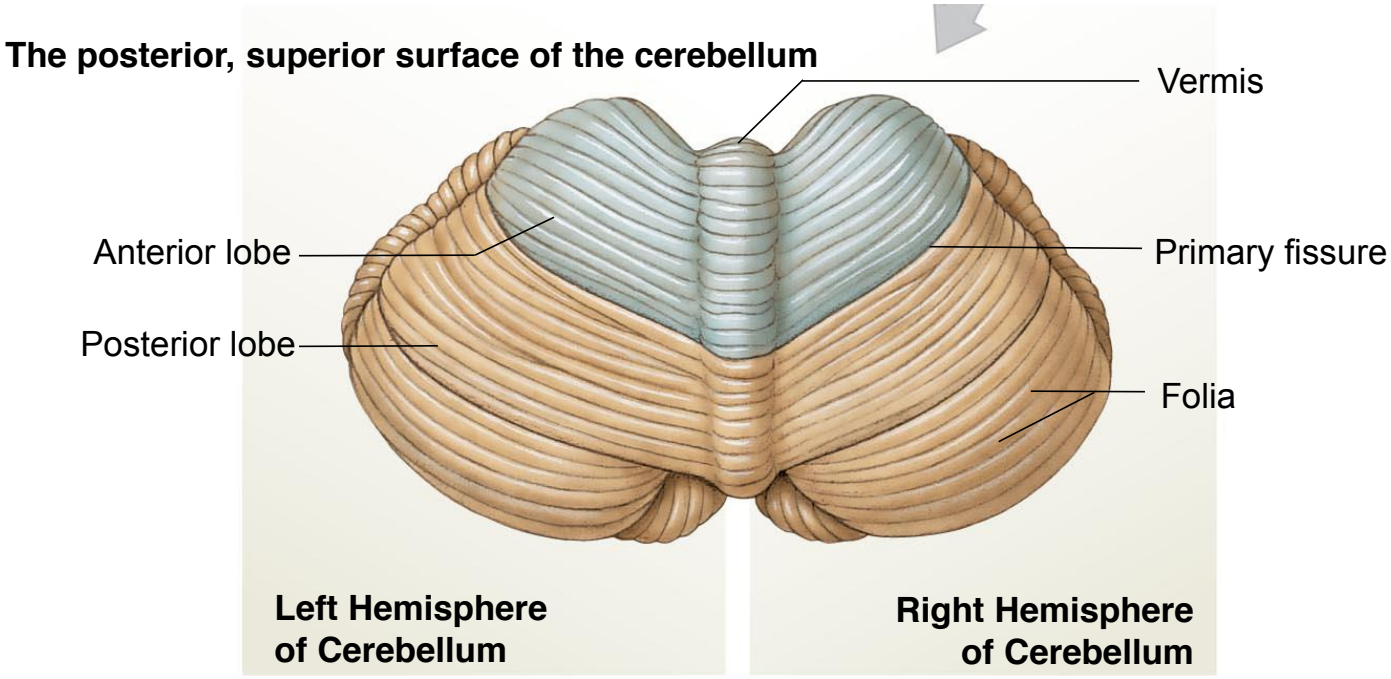


The anterior surface of the medulla oblongata

- contains cardiovascular control centre (CCC) – autonomic function
- major anatomical features
    - olive
        - prominent bulge along anterolateral surface
        - relay station into cerebellum
        - lateral surface
    - pyramids
        - contain descending/motor tracts from cerebral cortex
            - some fibres cross over to other side of spinal cord (decussation)
        - anterior surface
        - look for these when trying to distinguish medulla from spinal cord, because the medulla starts where this is a bulge = pyramids
- pons
    - metencephalon
    - means ‘bridge’
    - really serves as a bridge to the cerebellum
    - without pons, cerebellum has very little connection with cerebrum, medulla, midbrain, diencephalon, and spinal cord
    - whole series of fibres
    - will probably be given the word ‘bridge’ in an MC question

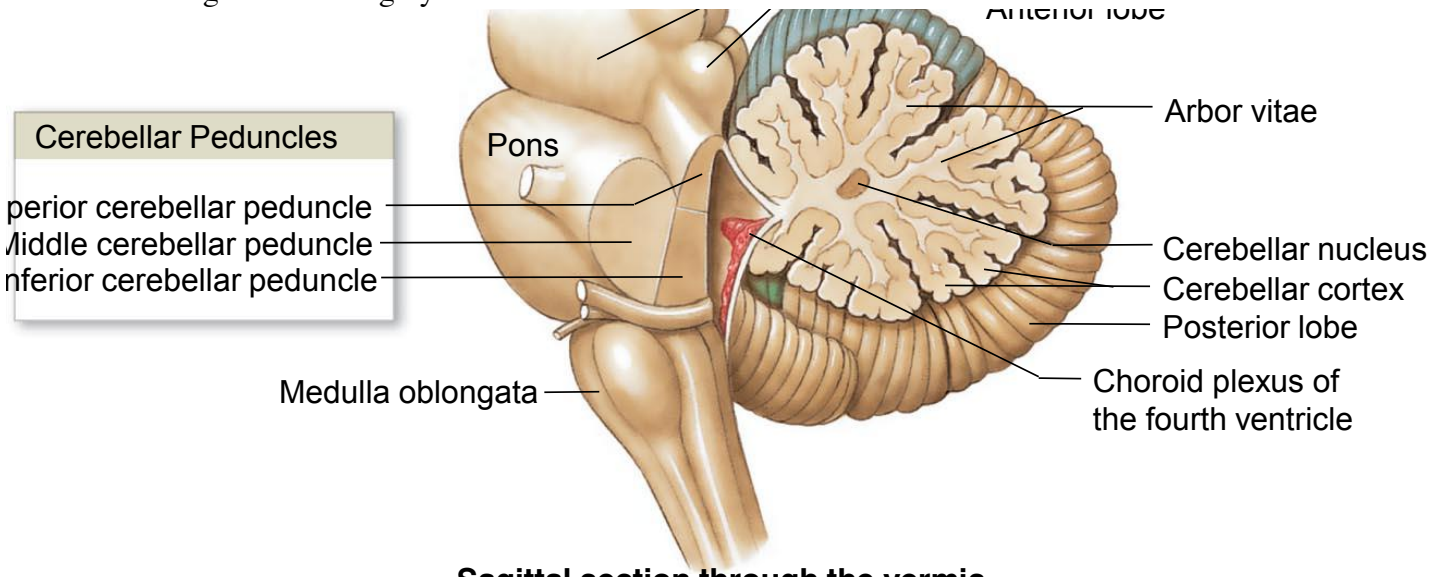


Structural features of the cerebellum



- processes an enormous amount of information
    - proprioceptive sensation – limb position, muscles, etc
    - has to deal with incoming visual and auditory information
- 2 key functions
    - postural control
        - proprioception
        - constantly monitoring body position, readjusting muscle tension all the time
    - fine tuning
        - a series of other nuclei within the brain (basal ganglia, motor cortex) will be given motor commands to muscles
        - in order for this to work effectively and for generation of smooth movements, cerebellum must monitor these commands
        - knows what pre-existing muscle tension is in muscles you command to move
        - must compare descending motor commands with what it already knows from proprioceptive input, and must combine to generate smooth movement
        - cerebellar lesions – particular movements can't be executed smoothly

- two hemispheres, and in the middle is the vermis (means worm)
    - vermis is a cellular mass most involve in maintaining balance
- fissures
- folia
    - means fold
    - gyri to cerebrum
    - thinner than gyri, greater degree of regularity to them
- same organization of grey and white matter as cerebral cortex



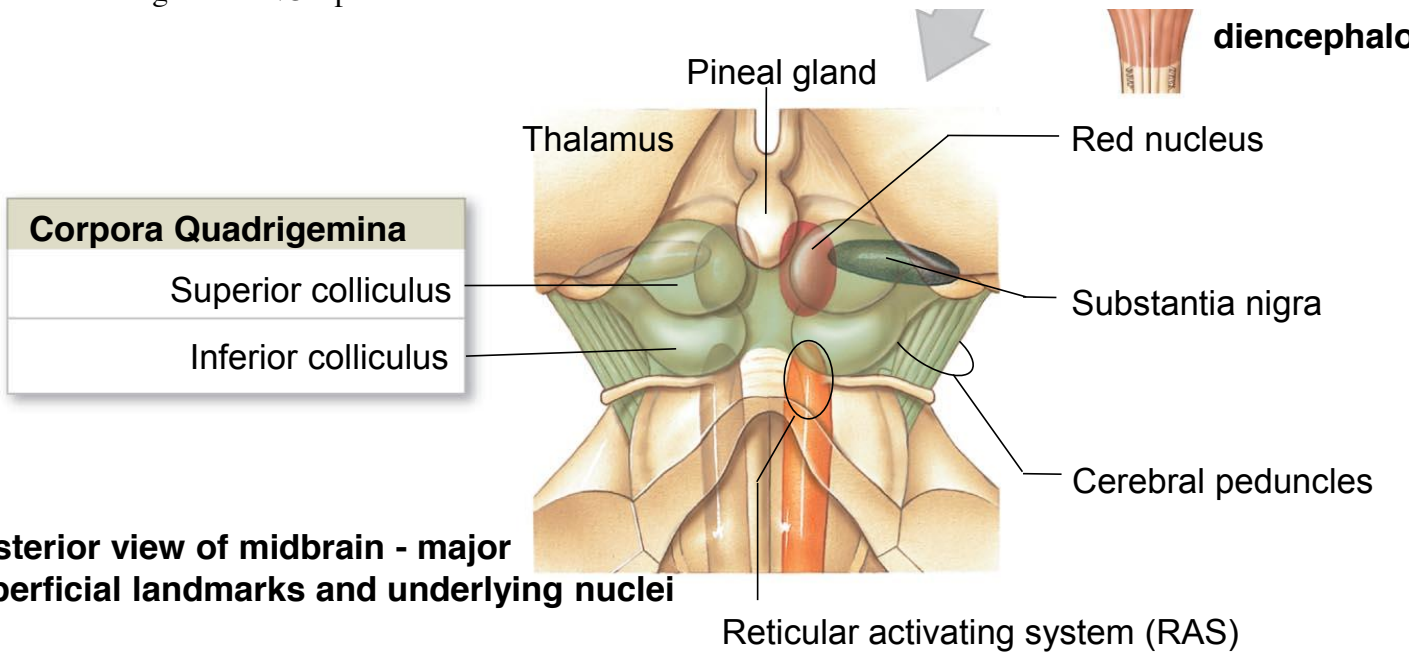
Sagittal section through the vermis

- white matter is arbor vitae (tree of life)
- around arbor vitae is cortical brain matter
- Purkinje cells of cerebral cortex – sensory information comes in directly to these cells and then to the cerebellum, any motor command that comes down must stop at pons first and is then transmitted to these cells
- Peduncle
    - Means tract
    - 3 peduncles
        - superior – connects to midbrain and up into cerebrum
        - middle - connects pons to cerebellum
        - inferior – cerebellum down to medulla and spinal cord

THE MIDBRAIN

- final part of brainstem
- most complex and integrative portions of the brainstem
- can direct complex motor patterns at subconscious level
    - corpora quadrigemina
        - superior colliculus – important aspect of visual system
            - first place visual information is relayed to from thalamus
            - responsible for visual reflex movement (turning of head or neck in response to visual stimulus)
        - inferior colliculus
            - does same thing but does this for the auditory system
            -
- influences activity level of entire nervous system
    - in particular, the substantia nigra

        - ultimately one of the main inputs to the striatum which is a region that generates movement
        - part of basal ganglia
        - subconscious control of movement – will talk more when discussing basal ganglia
        - red nucleus plays similar role
    - RAS
        - Loose grouping of nuclei
            - Directs attention to what information you are going to pay attention to when a bunch is coming in at once – cocktail party phenomenon
        - Damage to RAS often results in loss of consciousness
- Pineal gland is NOT part of midbrain – will come to later

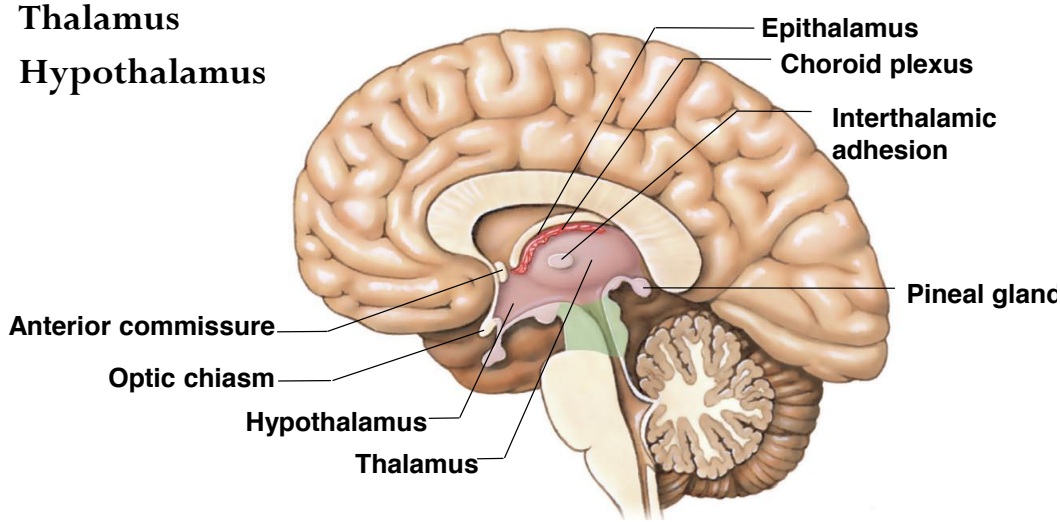


osterior view of midbrain - major uperficial landmarks and underlying nuclei

THE DIENCEPHALON

Diencephalon components

- **Epithalamus**
- **Thalamus**
- **Hypothalamus**



Sagittal section

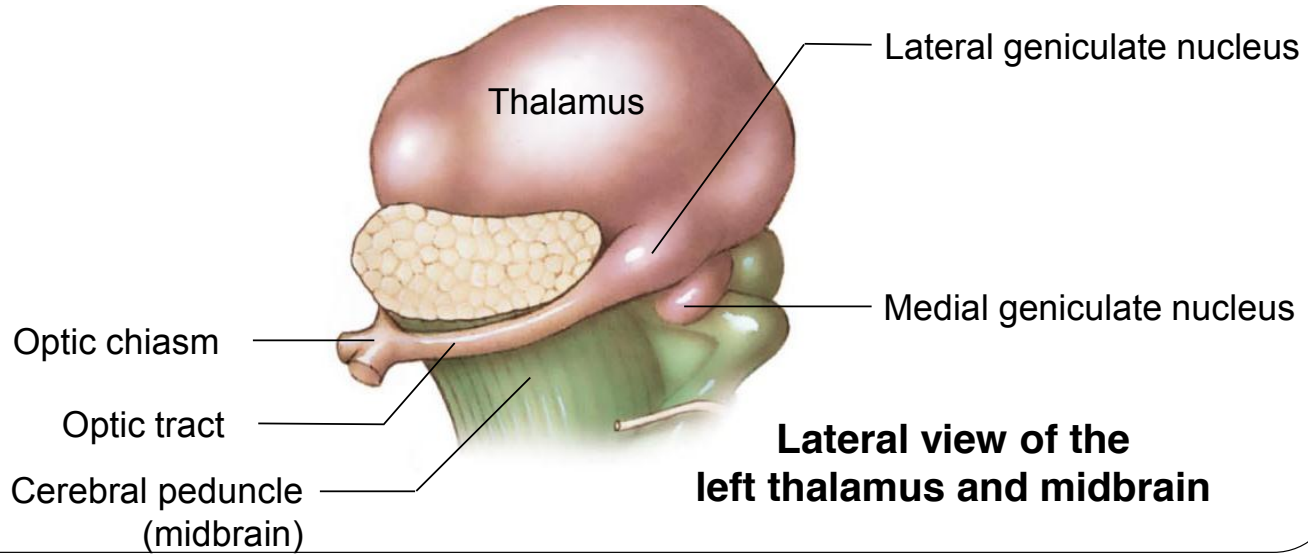
Epithalamus

- links to the limbic system
    - without epithalamus, limbic system lacks connection to a lot of other brain areas
    - pineal gland part of epithalamus

- habenula
    - regulators food and water intake
    - sits just above pineal gland
- choroid plexus a part of epithalamus

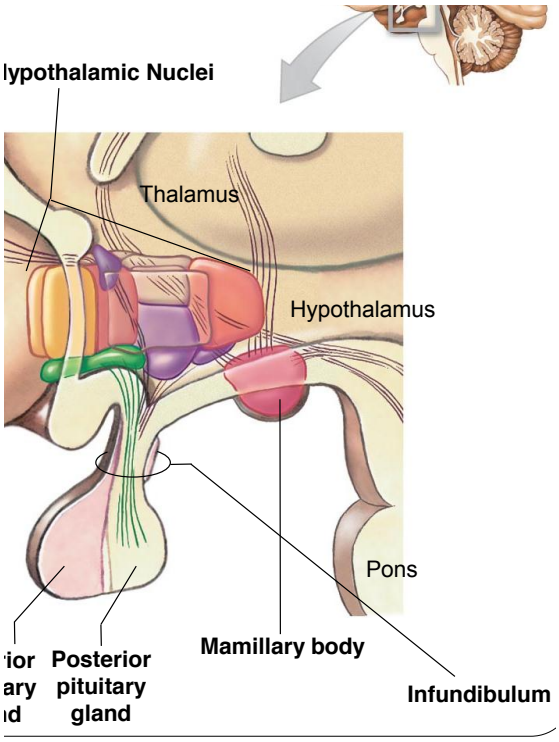
Thalamus

- interthalamic adhesion
    - connects thalamic hemispheres
    - no neural fibres cross
- Lateral geniculate nucleus (LGN)
    - Receives visual information over optic nerve and relays signals to midbrain and occipital lobe
    - Axon travels from retina and synapses onto a cell in the LGN
    - Neighbouring retinal ganglion cells will synapse on neighbouring cells on LGN – this is called retinotopic projection
    - This tells us the spatial arrangement of what we see in our actual retina is maintained in the LGN
    - Needed to maintain a map of visual space
- Medial geniculate nucleus (MGN)
    - Relays auditory information form inner ear receptors to appropriate cerebral cortex area
- Major and final sensory relay station for info destined for cerebrum
- Rest of sensory information has to run through the thalamus
    - Thalamus organized into tiny sets of nuclei which transfer specific info to specific regions of the cerebrum
    - Cuts out a lot of the sensory information that we are not aware of – filtering



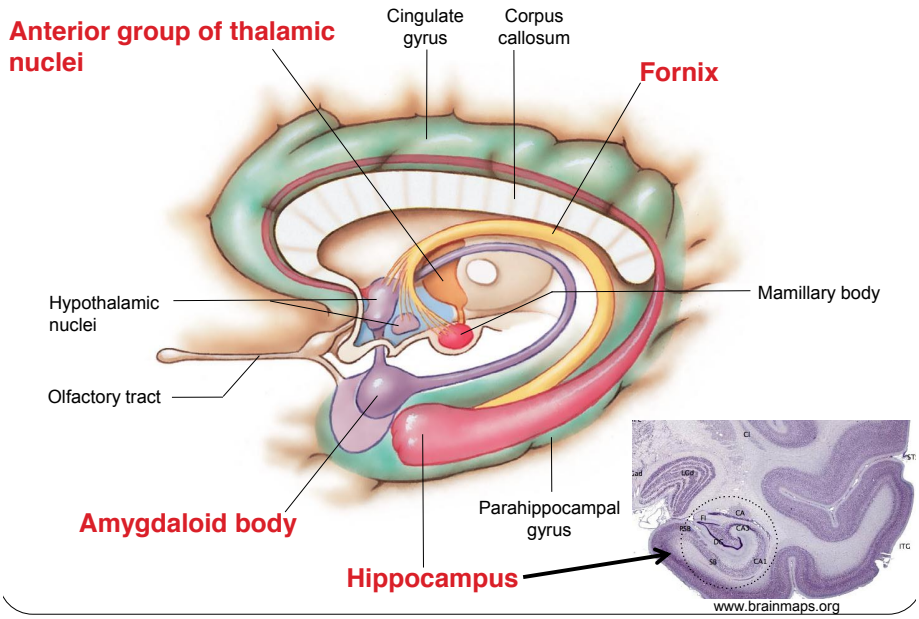
Hypothalamus

- around hypothalamus, BBB is not there
- extremely sensitive to changes in CSF, interstitial fluid
- major control centre
- samples what is in CSF, interstitial fluid, blood, and changes accordingly
- a lot of what the medulla is responsible for the instructions come down from hypothalamus
- pituitary gland – master gland
    - regulated entirely by hypothalamus
    - a whole bunch of nuclei regulate which hormones the pituitary is going to release



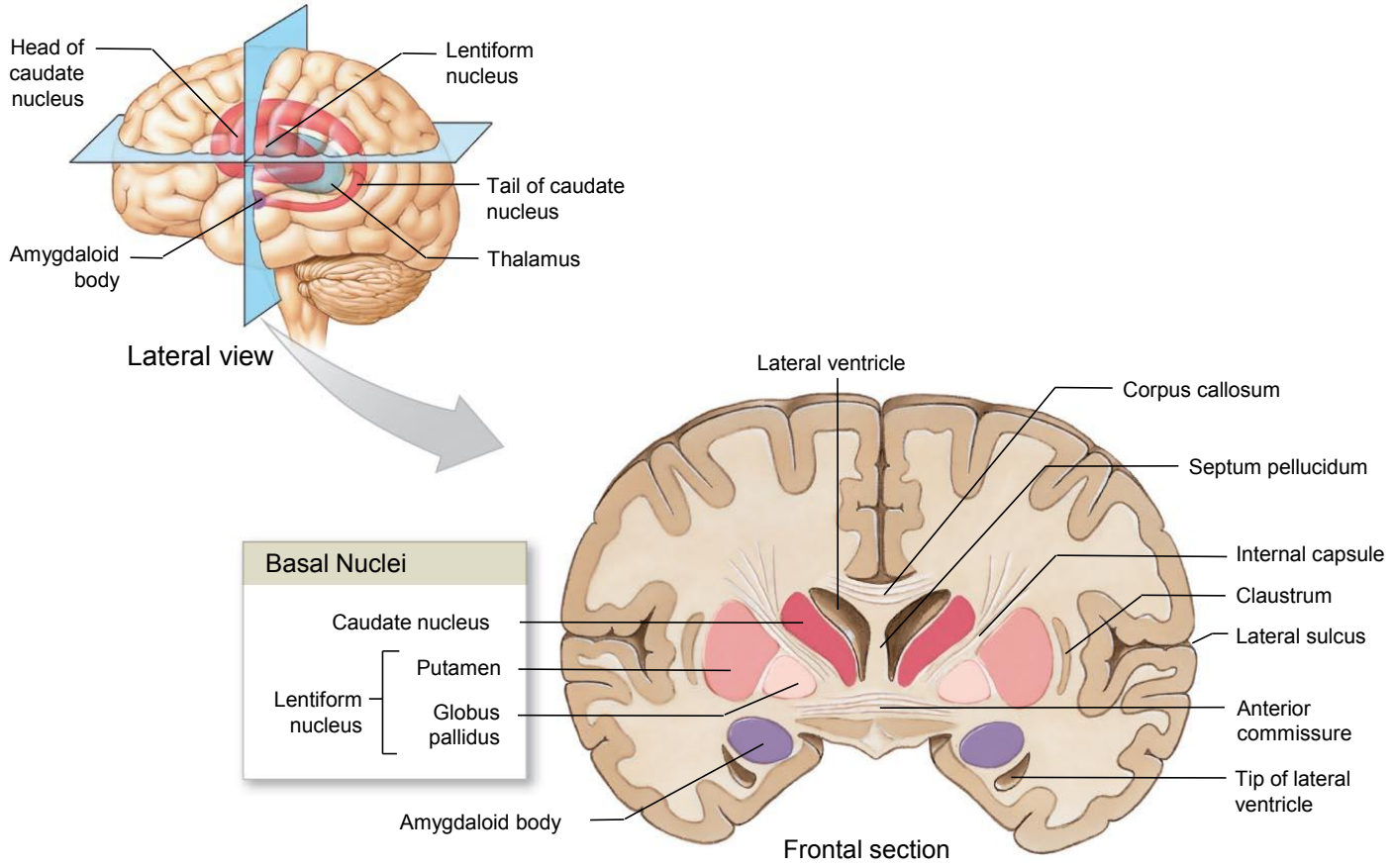
Limbic system

- superior end of diencephalon
- the borders of the diencephalon & telencephalon due to its loose grouping of nuclei
- group of structures on the edge of both diencephalon and telencephalon which are functionally related
- not a tight, anatomical grouping – all about a functional grouping
- the 'emotional centre of the brain'
- debate about functionality of limbic system
- cingulate and parahippocampal gyrus
    - edges of the cortex (cortex has 6 layers)
- hippocampus (telencephalonic component)
    - is part of the cortex (telencephalon)
    - elaboration of the inner surface
    - function is learning and memory
    - see neural stem cells active here
    - Alzheimer's – hippocampal abnormalities
- Diencephalic components
    - Amygdala, mammillary body, fornix
    - Fornix
        - Connects hippocampus with hypothalamus
    - Amygdala
        - Emotional memory



Basal nuclei of the cerebrum

- aka basal ganglia
    - masses of gray matter within each hemisphere deep to lateral ventricle floor
- provides subconscious control of skeletal muscle and help coordinate learned movement patterns, but does NOT initiate movement
    - provide general pattern and rhythm of movement
- comprised of caudate nucleus, lentiform nucleus
- substantia niagra
    - also part of basal ganglia
    - striatum = caudate nucleus and putamen
    - corpus striatum = striatum + globus pallidus
    - thus, basal ganglia = corpus striatus and striatum + the substantia niagra
- substantia niagra is the major input into the striatum
    - split into 2 different parts
        - SN pars compacta
            - Connects to the striatum
            - Main thing: dopaminergic neurons here
        - SN pars reticulate
            - Takes signals coming back from other basal ganglia nuclei and takes it to other brain regions
- Parkinson's disease marked by degeneration of substantia niagra (80% degeneration before becoming symptomatic)
    - Key symptom: resting tremor
    - Dyskinesia
        - L-dopa does not have desired effect anymore
        - Jerky, uncontrollable, writhing movements



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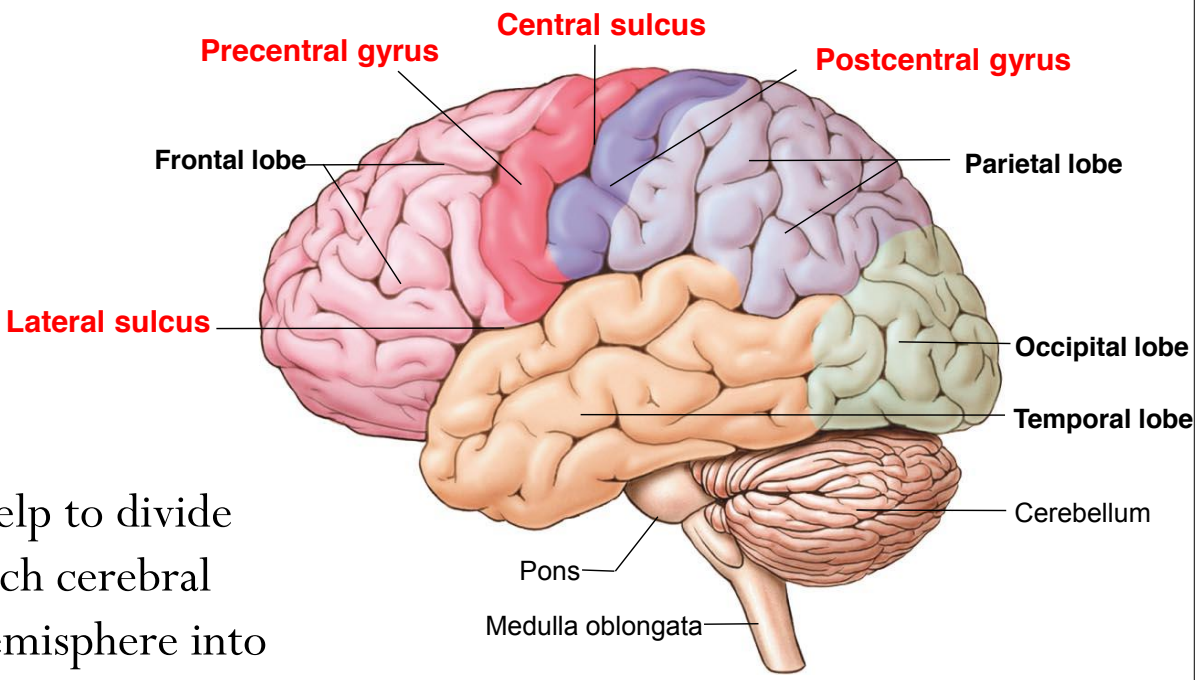
THE CEREBRUM

Superficial landmarks

- gyri help to divide each hemisphere into lobes

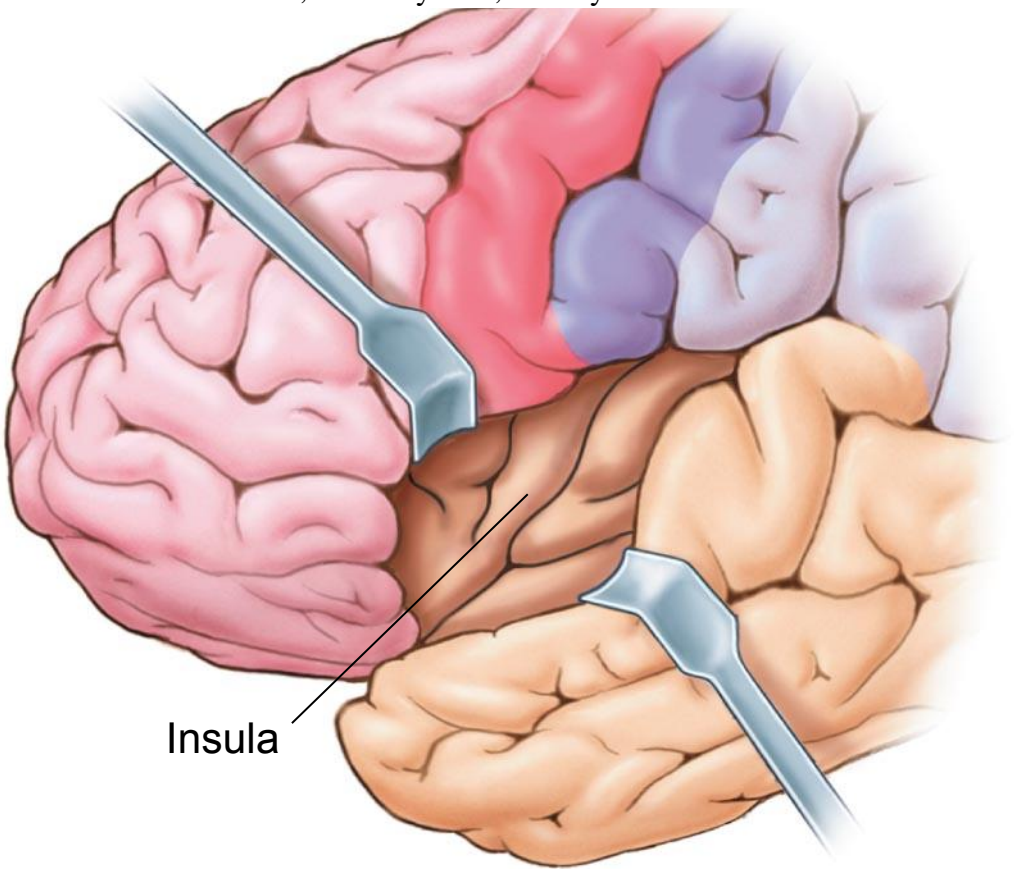


Lobes of the cerebral cortex in the left cerebral hemisphere - lateral view

Help to divide each cerebral hemisphere into lobes

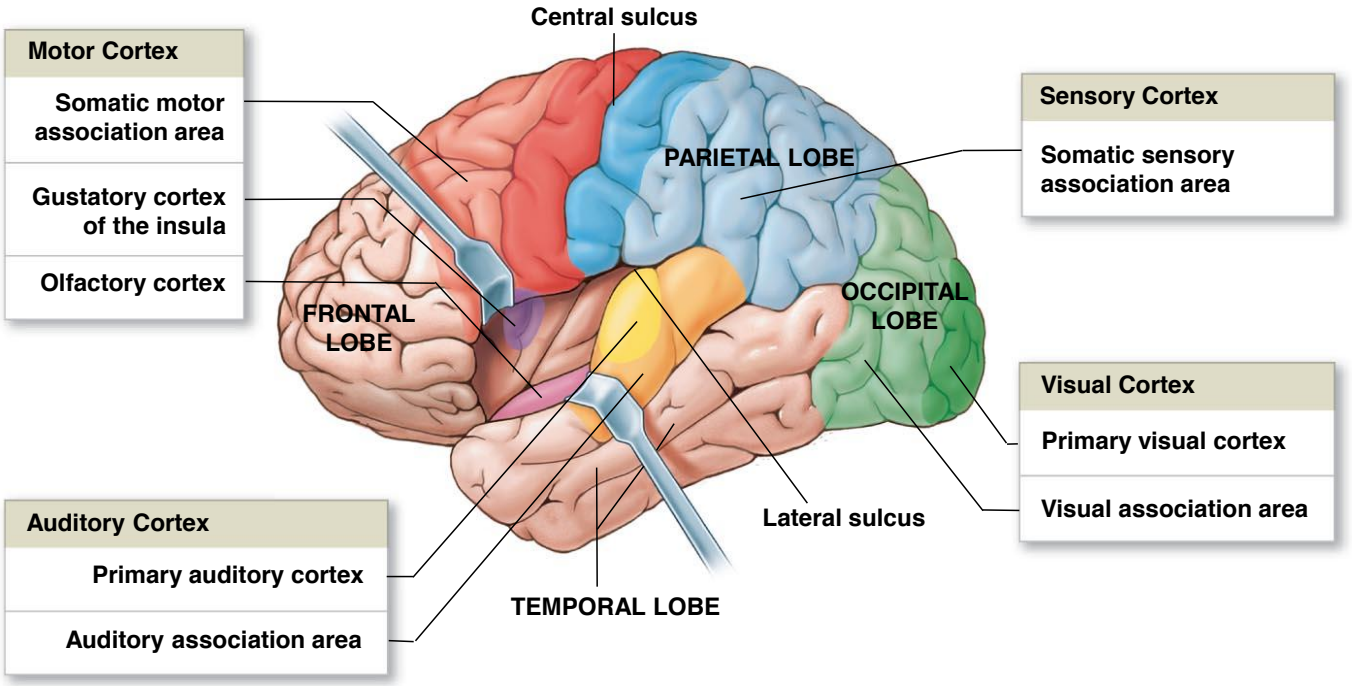
- *Sylvian fissues*

    - parieto-occipital sulcus
- insular cortex
    - exposed by retraction of the superficial cerebral cortex along lateral sulcus
    - some people say this should be considered the 5th lobe of the brain
    - 2% of SA of brain, yet, received input from a remarkable array of regions!
        - Thalamus, limbic system, sensory association areas



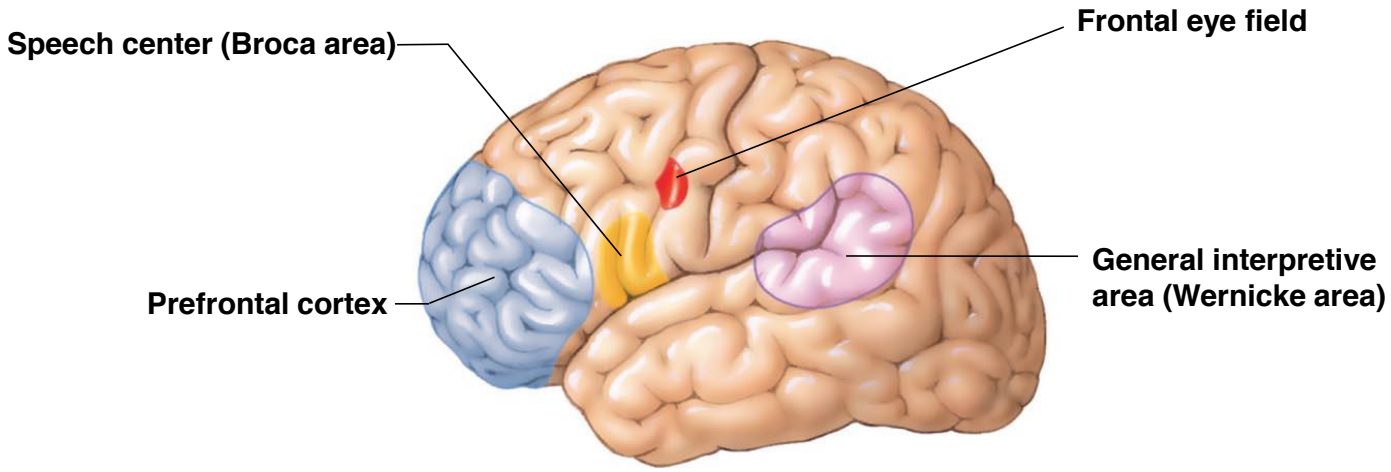
Cerebral hemisphere function

- each hemisphere receives sensory information from and sends motor information to the opposite side of the body
    - has no known functional significance
- hemispheres may look identical but may have different functions
- mapping of specific functions to specific areas is imprecise
    - boundaries indistinct, overlap
    - some functions may be found in multiple regions
- all primary areas have an association areas adjacent
    - e.g. primary visual cortex has a visual association area (this is where visual recognition comes from)
- when you get a traumatic brain injury, nature of injury can be indicative of where the damage is without an MRI or CT scan



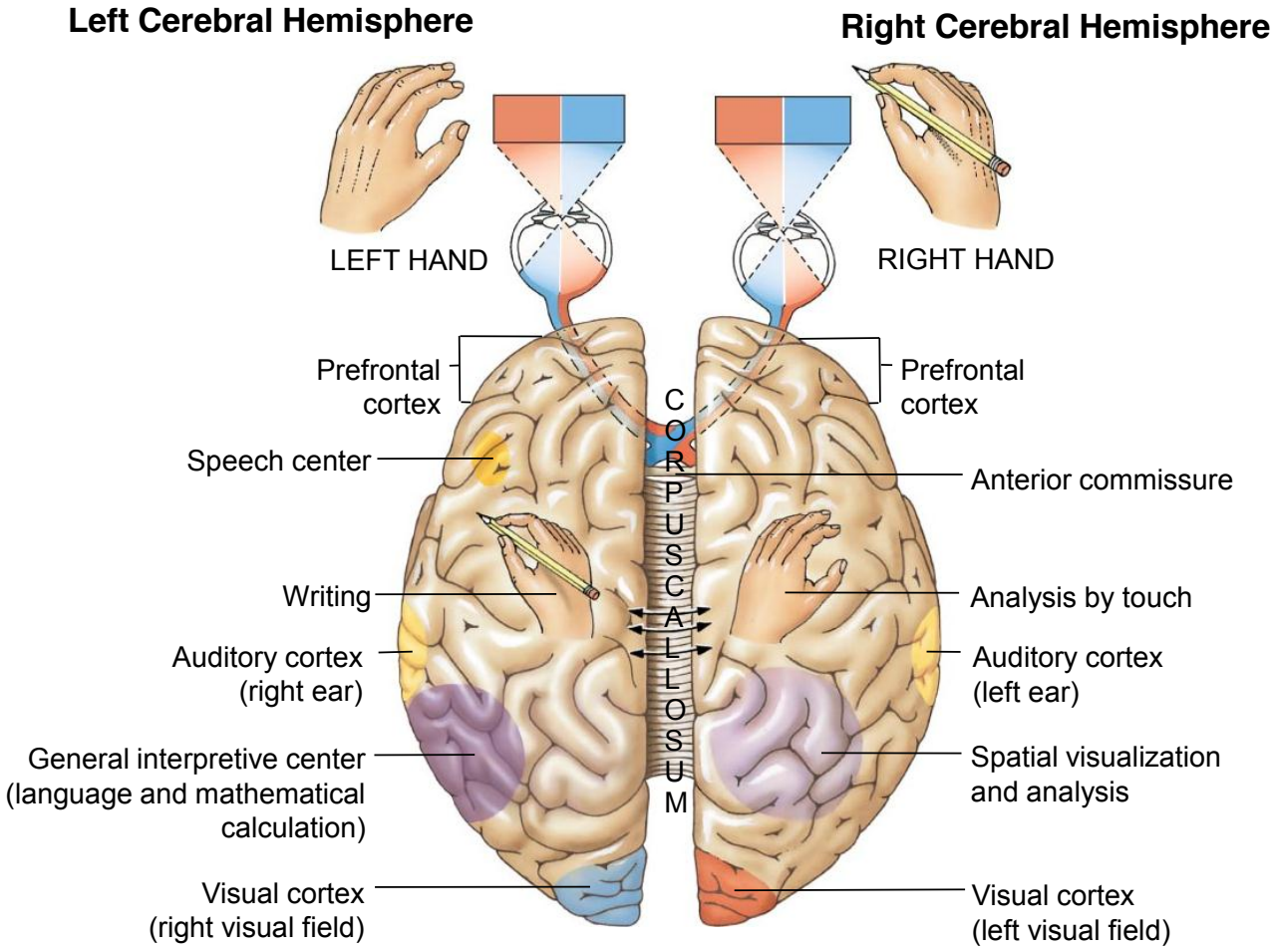
Integrative centres

- concerned with performance of complex processes such as speech, writing, math, spatial relationships
- restricted to either right or left hemisphere
- higher, complicated functions
    - e.g. many areas of the brain involved in speech production
- Wernicke's area
    - Extensive sensory association inputs
    - Appears to take sensory input and merges it with complex visual and auditory memory so that you can understand and produce speech
    - Damage: Wernicke's aphasia – individual can generate speech no problem, grammatically correct, syntax, but the words that they are actually saying make no sense in how they are put together
        - Real words but wrong order
        - Cannot understand spoken or written language
    - Damage does not apply to music processing – if you play them a song and ask them to learn it and repeat it, they can actually do it
        - Processing of music must be in a different area!
- Broca's area
    - Generate patterns required for forming speech
    - Damage: cannot form and speech or recognize language at all
- Prefrontal cortex
    - Slightly mysterious
    - Understanding consequences of actions
- Frontal eye field
    - Allows us to read
- Focus on Wernicke's and Broca's area
    - Lateralized



Left-side vs. right-side brain

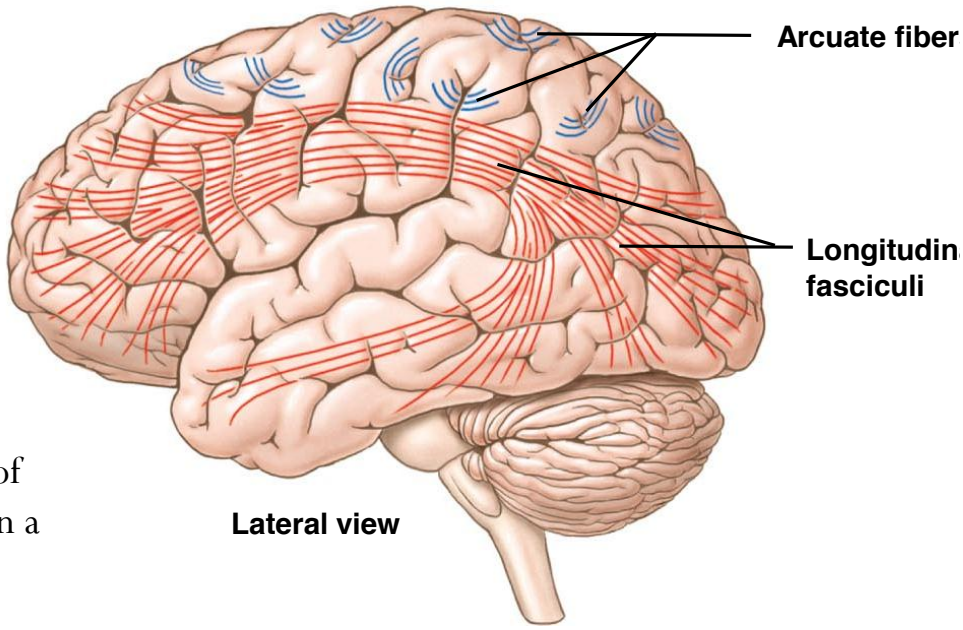
- left side associated with language skills (reading, writing, arithmetic)
- right side associated with sensory processing, emotional states, sense of self
- prof doesn't agree with this



White matter in the brain

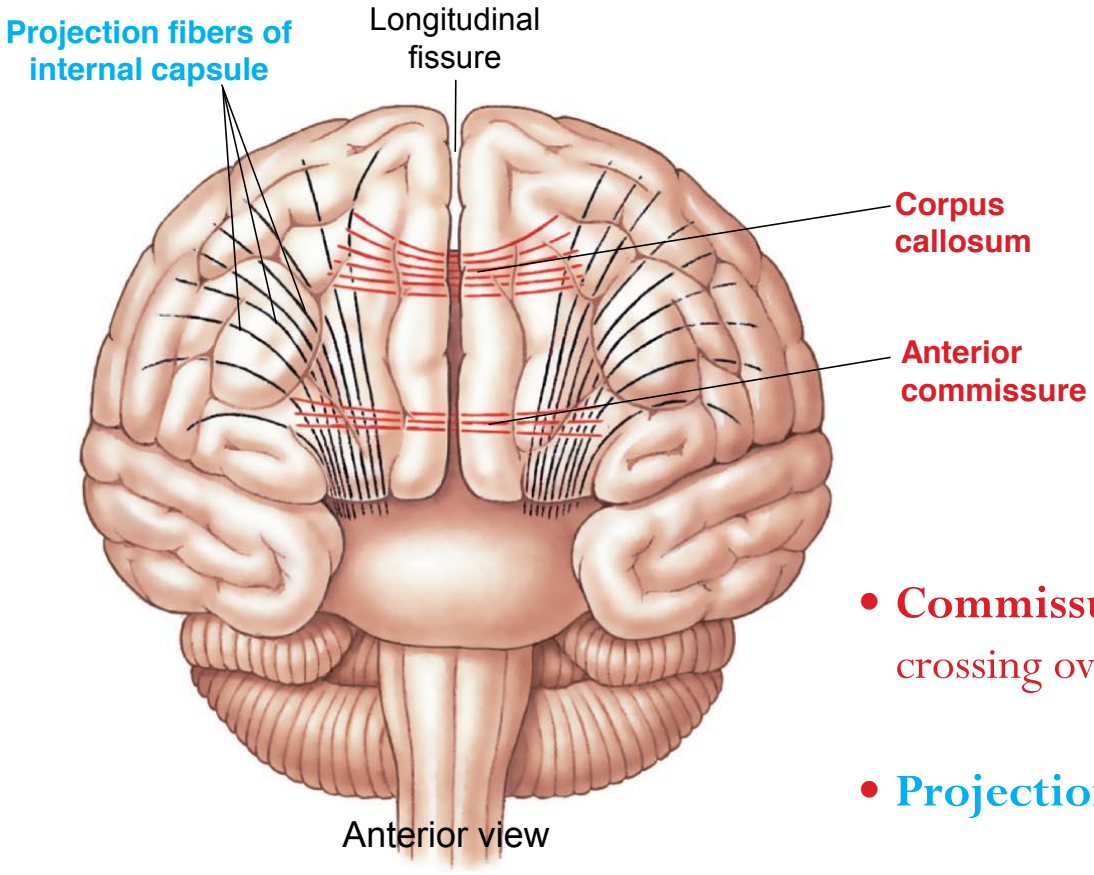
- extensive communication between regions
- functional groups of white matter in the inner cerebrum
- connect each gyrus with each neighbouring gyrus, and distant areas of the brain
- arcuate fibres: connect gyrus to fyrus
- longitudinal fasciculi/association fibres: connect entire lobes with each other

- Functional groups of white matter in inner cerebrum



- **Association fibers**
  - Interconnect areas of neural cortex within a hemisphere

- commissural fibres interconnect the cerebral hemispheres and projection fibres, which link cerebral cortex to rest of brain
- anterior commissure – pain reception, olfactory system decussates through here
  - people used to think that the thickness of this had influence on sexuality
- corpus callosum – communication between hemispheres



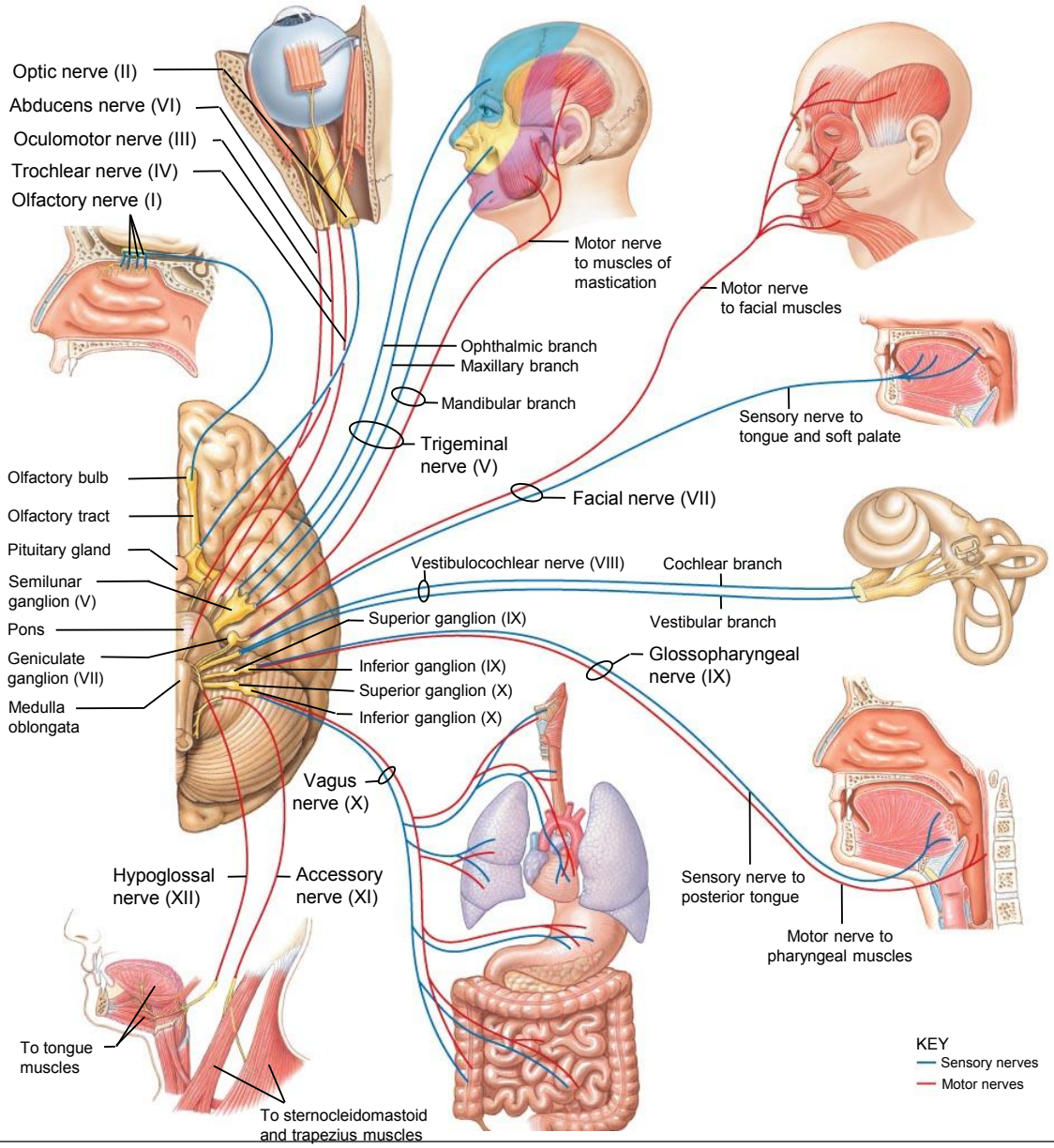
- **Commissural** (*commissura*, crossing over) **fibers**
- **Projection fibers**

Electroencephalograms (EEG)

- neural function relies upon electrical signaling
- a lot going on even in a resting brain, generates an electric field
- can detect using EEG
- brain activity always recorded in waves
- rhythmicity like in the heart
- alpha waves – normal, healthy adult, sitting down, shut their eyes
    - will disappear and change by doing either:
        - falling asleep → get large amplitude, low frequency delta waves
            - delta waves in coma patients and signify brain damage in awake patients
        - if you suddenly start to focus on something sharply → beta waves
- theta waves
    - see these in process of falling asleep, though very transient
    - see them in:
        - young children while awake
        - really frustrated adults
    - symptom of brain damage if you are not frustrated and you have these theta waves
- abnormal brain activity and EEG
    - electrical activity in each hemisphere in generally synchronized by thalamus
        - asynchrony may indicate localized damage or cerebral abnormalities
        - seizures
            - temporary cerebral activity disorder accompanied by
                - abnormal movements
                - unusual sensations
                - inappropriate behaviours
                - some combination of above symptoms
            - can start in one area and spread across cortical surface
        - epilepsies
            - clinical conditions characterized by seizures
            - also known as seizure disorders

Cranial nerves

- 12 pairs
- only 2 of them are from the telencephalon (CEREBRUM)
    - optic nerve (CN 2)
    - olfactory nerve (CN 1)
- remaining 10 originate from the brainstem (this is where nuclei/cell bodies of nerves are located)
- 5 deal with visual system
- trigeminal nerve
    - frozen by dentists so you don't feel pain
- vagus nerve
    - the only nerve that doesn't deal with sensory/motor information
    - this deals with visceral innervation
- MUST KNOW THE CRANIAL NERVES:
    - Do not worry about foramen, branch, sensory ganglion, innervation
    - All we need to know is what are their names and numbers, as well as if they are either sensory, motor, mixed



SOMATIC SENSORY PATHWAYS

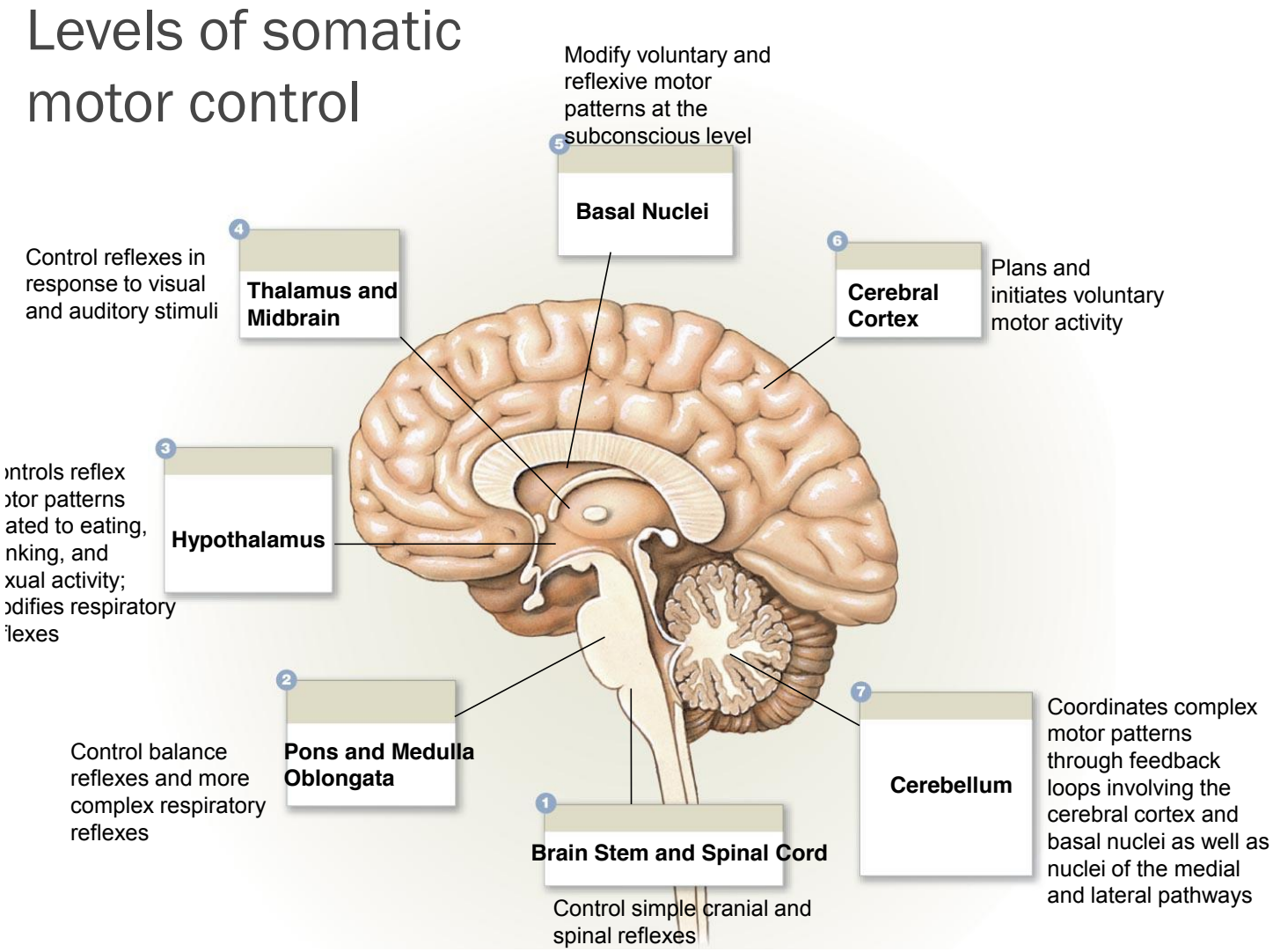
- sensory info in, motor response out
- posterior column pathway
    - all about really fine touch and proprioception
    - axon comes in through dorsal root and ascent up the spinal cord, stay on ipsilateral side until they reach the medulla where decussation occurs
    - 3-order neuron pathway
        - ipsilateral in spinal cord, which then synapse with 2nd-order neuron in medulla and decussates, goes up through midbrain, synapses with 3rd-order neuron in the thalamus
- spinocerabellar pathway
    - all about Golgi tendon organs, muscle spindles, joint capsules
    - contains crossing contralateral axons and ipsilateral axons
    - 2nd-order neuron on level of the spine, message crosses sides and travels up
    - no 3rd-order neuron
    - CROSSING OVER OCCURS IN SPINAL CORD

SOMATIC MOTOR PATHWAYS

- always involve at least 2 motor neurons

    - upper motor neuron
        - cell body in a CNS processing centre (midbrain and above)
    - lower motor neuron
        - cell body in a nucleus of brain stem or spinal cord
    - upper motor neuron synapses on lower, which then innervates single motor unit of skeletal muscle
- corticospinal pathway
    - starts in cortex, ends in spine
    - all starts with motor cortex, axon tracts make their way down, travel through diencephalon, reach midbrain
    - corticobulbar tract: breaks off at level of midbrain and medulla, because you need upper motor neuron control of those cranial nerves
    - rest of the tract travels down and reaches the medulla and travel through the pyramids of the medulla
    - decussatoin occurs
        - 85%
        - 15% travels ipsilateral until it crosses over in the SPINAL SEGMENT

Levels of somatic motor control



Somatic motor control → movement

- preparing for movement
    - once a decision to move has been made, information is relayed
        - frontal lobes make this decision → motor association areas contacted → contact basal nuclei and cerebellum to regulate the muscle rigidity, form, etc. and cerebellum deals with proprioceptive information wrt position of muscles
        - motor association areas → primary motor cortex → lower motor neurons → muscle contraction
        - basal nuclei continue to maintain aspects of muscle tone, cerebellum has to continually compare all proprioceptive information at each time point to connect back up to primary motor cortex cells to modulate level of activity
        - THESE ALL WORK IN PARALLEL AND FEED BACK ON EACH OTHER