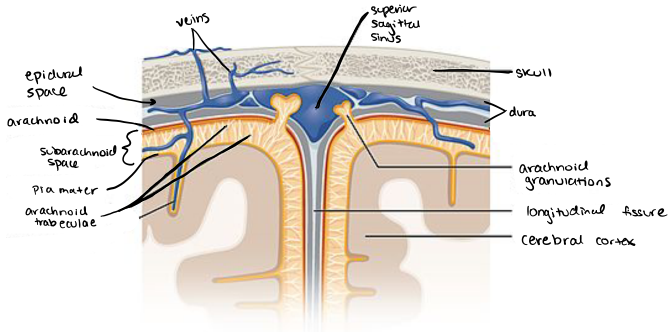
Ventricles + Cerebrospinal Fluid

Ventricles

- brain sewer system → metabolites of all cells in the brain circulate through blood and are pushed into ventricular system
- functions like lymphatic system, but no white blood cells (leucocytes)
- lined w/ ependyma (epithelial lining) that may contain stem cells



Path of CSF

- produced by choroid plexus in the ventricles (made up of capillaries + ependyma)
- travels through ventricles to 4th ventricle
- exits 4th ventricle via medial + lateral apertures which lead to cisterns (part of subarachnoid space)
- exits subarachnoid space into the sinuses via arachnoid granulations

Subarachnoid Space

- subarachnoid space is below arachnoid and above pia mater
- contains pressurized CSF
  - volume of ventricles + subarachnoid space ~150mL
  - 600mL of CSF produced daily
- normally a very thin space (mm) except in cisterns (lumbar + cisterna magna)

→ lumbar cistern (L2 - S5) + cisterna magna are the site of spinal taps to monitor for blood and metabolites in CSF

Arachnoid Granulations - protrusions of arachnoid into the sinuses, which then drain into jugular vein

Hydrocephalus - increased pressure in the ventricular system

Symptoms in Babies → get enlarged head b/c bones have not fused

Symptoms in Adults → skull can't expand, so severe brain compression

- Hydrocephalus occurs due to blockage of ventricular paths + blockage of subarachnoid granulations
  - tumors (ex. tumor of pineal gland blocks cerebral aqueduct | cerebellum tumor block lateral apertures)
  - cysts (ex. blockage of foramen of monro)
  - infections → pus can block foramens

2 types of Hydrocephalus

1. Non-communicating Hydrocephalus → blockage of ventricle to subarachnoid connection
2. Communicating Hydrocephalus → blockage of subarachnoid space to sinus connection (arachnoid granulations)

Original Hydrocephalus Diagnosis

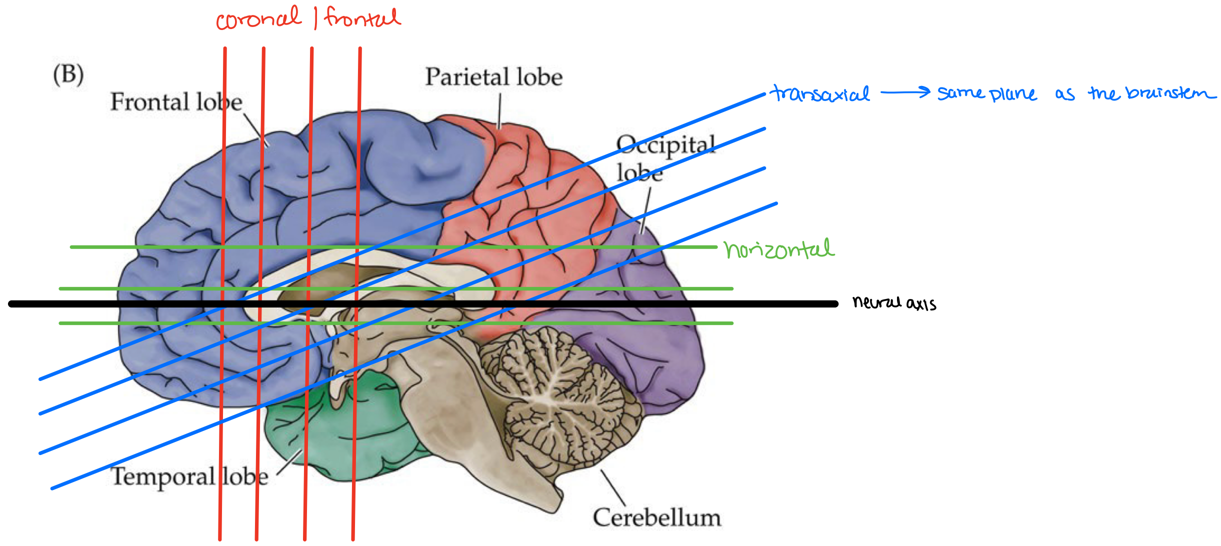
- dye injected into lateral ventricle
- Spinal tap taken in lumbar cistern

· no dye in lumbar tap ⟶ non-communicating (severe ventricle dilation)

· dye in lumbar tap ⟶ communicating hydrocephalus

⟶ now an MRI can be used to make this distinction

Brain Slices | Planes



transverse axis ⟶ cuts across $\overbrace{\text{neural axis}}^{\text{neural axis changes in forebrain | brainstem}}$

· in forebrain coronal slices are transverse slices

· in brainstem transaxial slices are transverse slices

archistriatum - amygdala

paleostriatum - globus pallidus

Basil Ganglia / Deep Cerebral Nuclei

Collections of nuclei

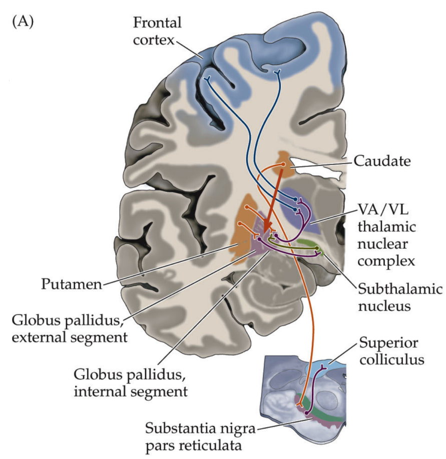
- Corpus Striatum — caudate, putamen, stripes from internal capsule
- Neostriatum — caudate, putamen, nucleus accumbens ⟶ Striatum
- lenticular nuclei — globus pallidus + putamen (near genu of internal capsule)
- limbic striatum — amygdala + accumbens

basil ganglia inputs ⟶ main target of inputs is the striatum

1. cerebral cortex — almost all cerebrum projects to basil ganglia except primary auditory / visual cortex
2. brainstem — substantia nigra pars compacta + raphe nuclei
3. Thalamus — midline + intralaminar thalamic nuclei (not VA/VL of motor thalamus)

Striatal outputs

- putamen + caudate projects to globus pallidus
- globus pallidus projects to motor control areas
  - internal globus pallidus ⟶ VA/VL thalamic nuclei
  - external globus pallidus ⟶ subthalamic nucleus
  - ⟶ subthalamic nucleus projects back to internal globus pallidus
- all neostriatal / globus pallidus projections are inhibitory (GABA)



Direct Projections to Motor Cortex

caudate + putamen $\xrightarrow{\ominus}$ internal globus pallidus $\xrightarrow{\ominus}$ VA/VL thalamus $\xrightarrow{\oplus}$ Frontal Cortex

- activation of direct projection means activation of caudate + putamen, which results in increased motor cortex activation
- dopamine excites neostriatum via D1 receptors ⟶ loss of activation by direct projection system by dopamine produces hypokinesia

Auditory + Vestibular System

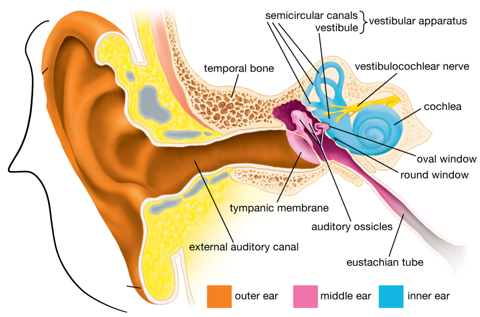
The auditory + vestibular system detect vibrations

- cochlea ⟶ detects vibrations in the air (sound) ⟶ 20-20,000Hz is human audible sound
- semicircular canals + vestibule ⟶ detects head vibrations (0-10 Hz)
    - detects dynamic movements (angular/linear acceleration) and static tilt

External Ear Anatomy

- pinna — concentrates sound, direction filter
- tympanic membrane
- external auditory meatus — large hole that goes to middle ear

pinna



Middle Ear Anatomy

- middle ear is an air filled chamber
- eustachian tube connects middle ear to pharynx
- bones : tympanic membrane ⟶ malleus ⟶ incus ⟶ stapes ⟶ oval window
- muscles : tensor tympani (CN5) and stapedius (CN7) dampen vibration. Hyperacusis w/ CN5 or 7 lesion
- windows of the inner ear :
    - oval window
    - round window ⟶ allows for pressure release when sound pushes oval window in, round window allows movement of fluid by stretching

Inner Ear Anatomy

Bony Labyrinth - spaces in the bones filled w/ non-viscous perilymph fluid (ex. vestibule, semicircular canals, cochlea)

Membranous Labyrinth — sacs inside the bony labyrinth. They are filled with viscous endolymph and contain receptor cells

- ex. utricle, saccule, semicircular ducts, cochlear duct

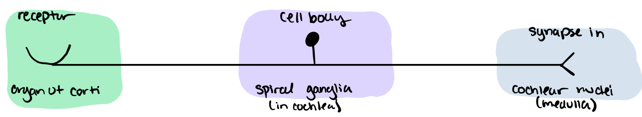
Bony Labyrinth	Sac	Function	
Vestibule	utricle	linear acceleration horizontal plane	static tilt
	saccule	linear acceleration verticle plane	
Semicircular Canal	semicircular ducts		
	ampulla	angular acceleration	
Cochlea	cochlear duct	hearing	

Auditory Hair Cells

- hairs are stereocilia ⟶ mechanically gated channels that depolarize
- make synaptic contact w/ primary afferent fibers
- detect vibration of membranes in the organ of corti

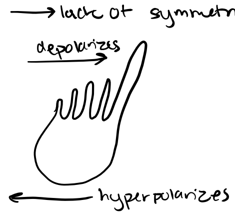
Auditory Primary Afferents

- action potentials encode amplitude of sound as frequency of firing



Vestibular Hair Cells

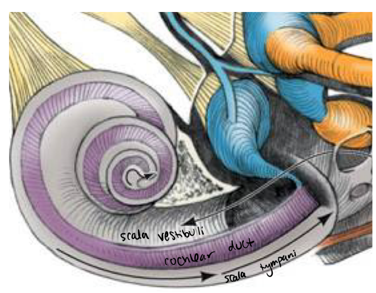
- exist in ampullary crest and macula of utricle + saccule
- have kinocillia ⟶ lack of symmetry allows it to detect direction of movement due to directionality of sensation



Vestibular Primary Afferents

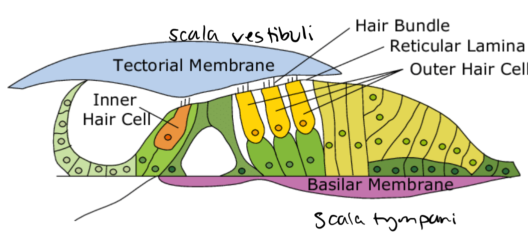
- cell bodies located in scarpa's ganglia in vestibule
- synapse in ipsilateral vestibular nuclei
  - ampullary crest ⟶ to medial / superior vestibular nuclei which detects head rotation (angular acceleration)
  - macula of utricle + saccule ⟶ to lateral vestibular nucleus which detects tilt + linear acceleration

The Cochlea



- the cochlea is a spiral chamber in the petrous temporal bone
- cochlear duct is the membranous labyrinth inside the cochlea
- sound vibrates stapes which hits oval window which moves perilymph through scala vestibuli then around to scala tympani to round window
- cochlear duct is filled w/ endolymph + organ of corti sensory receptor

Organ of Corti



- hair cells embedded in basilar membrane
- hair cells contact the tectorial membrane, which stays still, but functions to amplify movement in endolymph
- vibration moves basilar membrane causing depolarization when hair cells

press against tectorial membrane

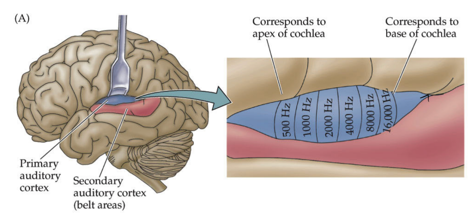
- helicotrema — part of cochlear apex where scala tympani + scala vestibuli meet

Tonotopic Receptive Fields

- hair cells encode amplitude of vibration (max rate 100 hz)
- Place Theory – location of hair cells in organ of corti determines sound frequency
    - basilar membrane is tuned to different frequencies → very tight near oval window, but more flexible towards apex
    - cochlea contains tonotopic receptive field → high pitch @ base of cochlea (↑ hz) and low pitch at apex (20hz)

Cochlear Implants – takes advantage of place theory, but must have hair cells for it to work. It activates specific hair cells along the cochlea

Primary Auditory Cortex (Broadmann's Area 41)



- tonotopic organization maintained in cortex
- pitch is kept separate until primary auditory cortex

Deafness – loss or reduction of hearing

① Conduction deafness – damage/blockage in external/middle ear

ex. congestion, too much ear wax

② Sensorineural Deafness – damage to cochlea / organ of corti

- can occur in total hearing loss or just high or low or notch hearing (specific frequency hearing loss)

③ Acoustic Neuropathy — damage to auditory part of CN8

ipsilateral damage, ipsilateral loss

④ Central Deafness – damage to cochlear nuclei

Auditory Pathways

- Primary afferents synapse in cochlear nuclei in medulla
- from cochlear nuclei (1), multiple paths to reach the inferior colliculus (2)
    1. bilateral projection directly to inferior colliculus via lateral lemniscus
    2. Bilateral projection to superior olivary nucleus (1.5) which ipsilaterally projects to superior colliculus
    3. bilateral projection to nucleus of lateral lemniscus (1.5) and then to inferior colliculus

    → cell bodies of neurons that synapse in inferior colliculus are located in superior olivary nucleus, nucleus of lateral lemniscus, cochlear nuclei
- from inferior colliculus, ipsilateral projections to medial geniculate nucleus (thalamus) (3) via branchium of the inferior colliculus
- MGN projects to primary auditory cortex (4) via auditory radiations (in superior temporal gyrus)
- left/right cortex recieves sound input from both ears

Auditory Cortical Areas

① Primary Auditory Cortex (Area 41) – tone, intensity, localization

② Auditory Association Cortex (Area 42, 22) – memory regarding differentiating between speech, music, noise

③ Speech Sensation Cortex (22, 39, 40) – wernike's area impacts comprehension of language

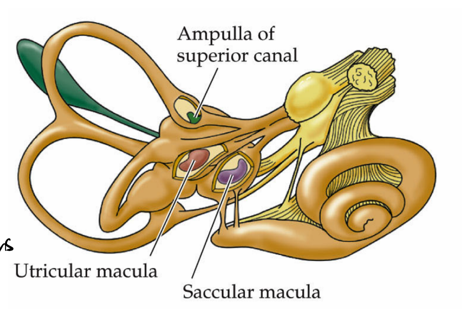
Unilateral Lesions

- Ipsilateral Deafness ⟶ damage to labyrinth
- No Deafness ⟶ damage to superior olivary nucleus, lateral lemniscus nucleus, left inferior colliculus, medial geniculate, auditory radiations, auditory cortex

Auditory Problems still arise even if there isn't deafness. Ipsilateral lesions result in difficulty w/

- sound localization
- detection of complex sounds

Vestibular System Receptor Organs



① Ampulla ⟶ ampullary crests (crista ampullaris)

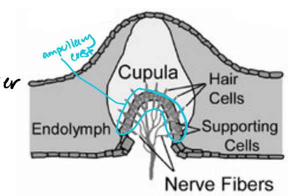
② Utricle ⟶ macula

③ Saccule ⟶ macula

⟶ all contain vestibular hair cells that only depolarize in particular orientations

Ampulla

- ampulla is a dilation of semicircular ducts. There are 3 semicircular ducts (horizontal, sagittal, coronal)
- inside ampulla is the ampullary crest ⟶ hair cells all have same orientation
- cupula is a gelatinous mass that the hair cells are inside of that acts as a mechanical amplifier
- head rotation makes the endolymph flow in direction opposite of head direction
- endolymph then moves cupula/hair cells.



- ipsilateral rotatation depolarizes contralateral hyperpolarizes ⟶ move head left, left ampula is depolarized

Vestibular Postural Control

1. head is tilted, which activates hair cells in the macula
2. primary afferent activated (cell body in scarpa's ganglia)
3. synapse in lateral vestibular nucleus (dieter's cells)
4. travel via lateral vestibulospinal tract
5. activate LMNs to increase ipsilateral extensor tone

Abnormal Nystagmus

- head still but eyes still move
- vestibular lesion can produce contralateral beating nystagmus

Vestibuloocular reflex – produces eye movements that counter head movements to allow gaze to remain fixed

ex. move head left, left ampulla activates, eyes move right

① ampulla is activated

② primary afferent synapses in medial + superior vestibular nuclei → ascending afferent

③ secondary fibers cross in rostral medulla and travel via MLF to abducens nucleus

abducens nucleus ⟶ LMNs to lateral rectus

abducens nucleus ⟶ interneurons ⟶ cross ⟶ project to occulomotor nucleus

Ex. turn head right, activates ampulla on right side which synapses on right vestibular nucleus

⟶ left abducens is activated, so left lateral rectus activated, which moves eye to the left (laterally)

⟶ left abducens activated, so excitatory interneurons cross and synapse in right oculomotor nucleus, which activates LMNs that make right eye adduct (towards midline) and move left

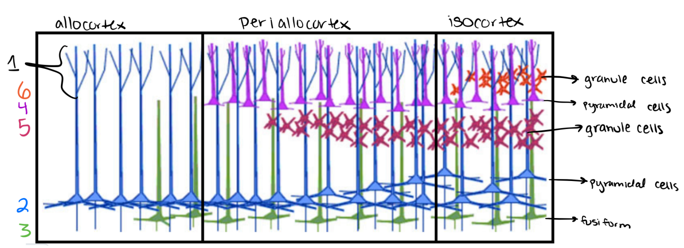
Cerebral Cortex Anatomy

Composed of:

- Grey Matter: between 2-6 layers of cortex
- Two types of white matter
  - ① interhemispheric – connections between hemispheres (ex. corpus callosum, anterior commissure)
  - ② intrahemispheric – connections within hemispheres (corona radiata, capsules)

Types of Cortex: all types have a molecular layer composed of just axons + dendrites

- Allocortex (Archicortex) – contains 2-3 layers ⟶ ex. hippocampus, induseum griseum
- Periallocortex (paleocortex) – 4-5 layers (ex. posterior cingulate cortex, piriform cortex, perihippocampal cortex)
- Isocortex (neocortex) – 6 layers (most of the cortex)



Layer 6: fusiform layer

Layer 3,5: pyrimidal layers

Layer 2,4: granule cell layers

Broadmann's Areas – based on anatomy of cortical layers such as density/structure

- Primary Somatosensory Cortex ⟶ Area 1,2,3
- Primary Motor Cortex ⟶ Area 4
- Primary Visual Cortex ⟶ Area 17
- Primary Auditory Cortex ⟶ Auditory Sensation 41,42

Association Cortex

- Premotor Cortex:

  Location: anterior to primary motor cortex

  Function: motor planning / coordinating multi limb movements

Damage: lose connection between visual memory and movement. Can't plan motor responses, but no impact on volitional control of movement → issues coordinating limbs

- Dorsal Parietal Association Cortex (Somatosensory Association Cortex)
  - Location: superior parietal lobule
  - Function:
  - Damage: astereognosis — inability to distinguish specific objects by touch
    - asomatognosia — part of your body doesn't feel like yours. No touch localization
- Occipital and Temporal Association cortex
  - Damage results in:
    - simultanagnosia — can't recognize an object if part is obscured
    - prospagnosia — can't recognize faces
- Language Areas
  - Location: Inferior frontal + superior temporal gyrus
  - Function: Wernike's area — understanding speech   Broca's Area — speech production
  - Damage: Broca's Aphasia/Expressive aphasia — comprehension in tact but can't produce sentences
    - Wernike's Aphasia/Receptive aphasia — can produce language, but can't understand language
- Lateral Parietal Association Cortex
  - Function — attention
  - Location — supramarginal/angular gyrus
  - Damage: neglect of contralateral universe (strongest when non-dominant hemisphere is damaged)
- Prefrontal Cortex/Anterior Cingulate Cortex
  - Function: conception of self, executive function, prediction of outcomes, emotions/affect, and suppression of urges
  - Damage: when given a frontal lobotomy through hole or supraorbital notch, no more delusions or inability to suppress urges. Personalities can recover, but lose connection to previous sense of self

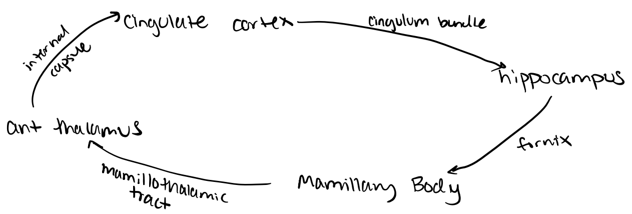
Limbic Lobe + Limbic System

- Limbic Lobe was initially defined by Broca 1879
  - Ring of cortex at medial part of brain consisting of 4 parts
    - cingulate cortex
    - hippocampus (parahippocampal gyrus)
    - piriform cortex (the amygdaloid cortex)
    - orbitofrontal gyrus

Cranial Nerve I/Rhinencephalon

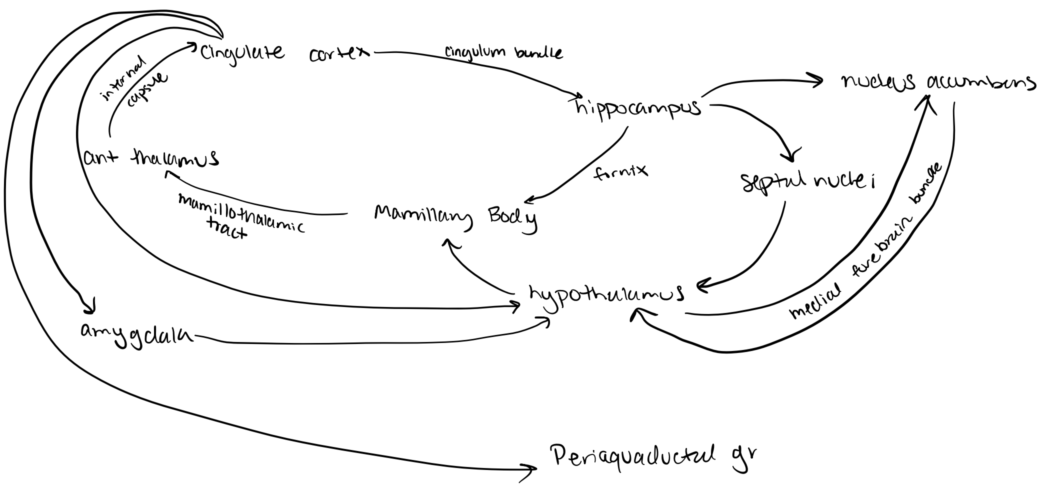
- cranial nerve I goes through cribiform plate and the synapses in olfactory bulb and travels via olfactory tract to amygdala + piriform cortex (rhinencephalon)
- olfactory tract crosses via anterior commissure

Papez Circuit – identified structures involved in emotion



- Papez showed that damage to any of these areas impacted emotion

Modern Limbic System



Function of Limbic System

- Emotion – damage alters emotional behavior → frontal lobotomy loss of affect
- Short term memory – the case of HM (damage to medial temporal lobe)
- Reward and Motivation
- Feeding, Fighting, Fleeing, Reproduction
- hypothalamus is the output area of limbic system

Feeding Disorders as a result of damage to hypothalamus/septal nuclei/nucleus accumbens

- damage medial hypothalamus → hyperphagia (eat too much)
- damage lateral hypothalamus → aphagia (won't eat at all)

Fighting and Fleeing

- if forebrain removed w/ hypothalamus → calm
- if hypothalamus is left intact when forebrain removed → animal loves very angry
- phobias/anxiety result from overactivity of hypothalamus

Reproductive Behaviors

- anterior hypothalamus is sex center of brain
    - Lesions reduce sex drive
    - stimulation → hypersexuality
- controls sex hormones → area that differs between males + females } sexual dimorphism

-vestibular nuclei (what each does)

- medial + superior → to

arteries → midbrain post cerebral artery

medulla anterior spinal