Special Senses

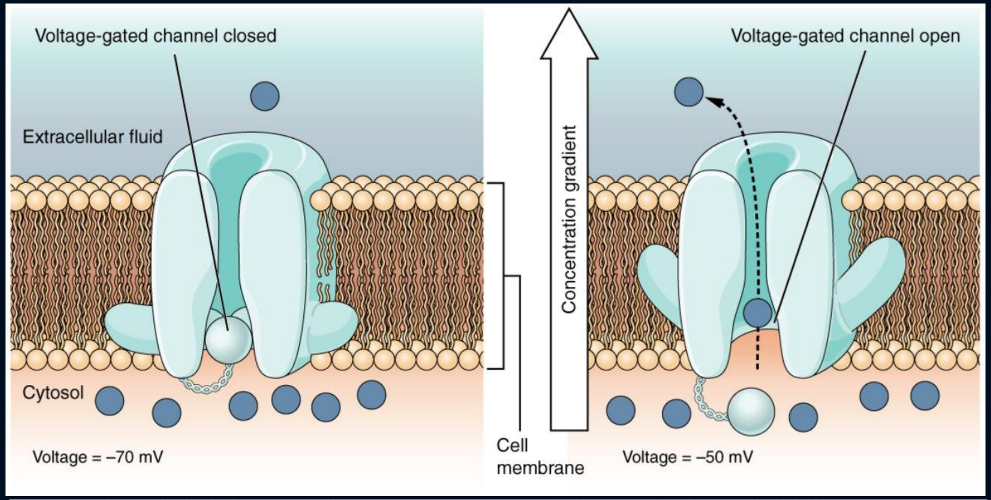
BIOL1025: ANATOMY / PHYSIOLOGY

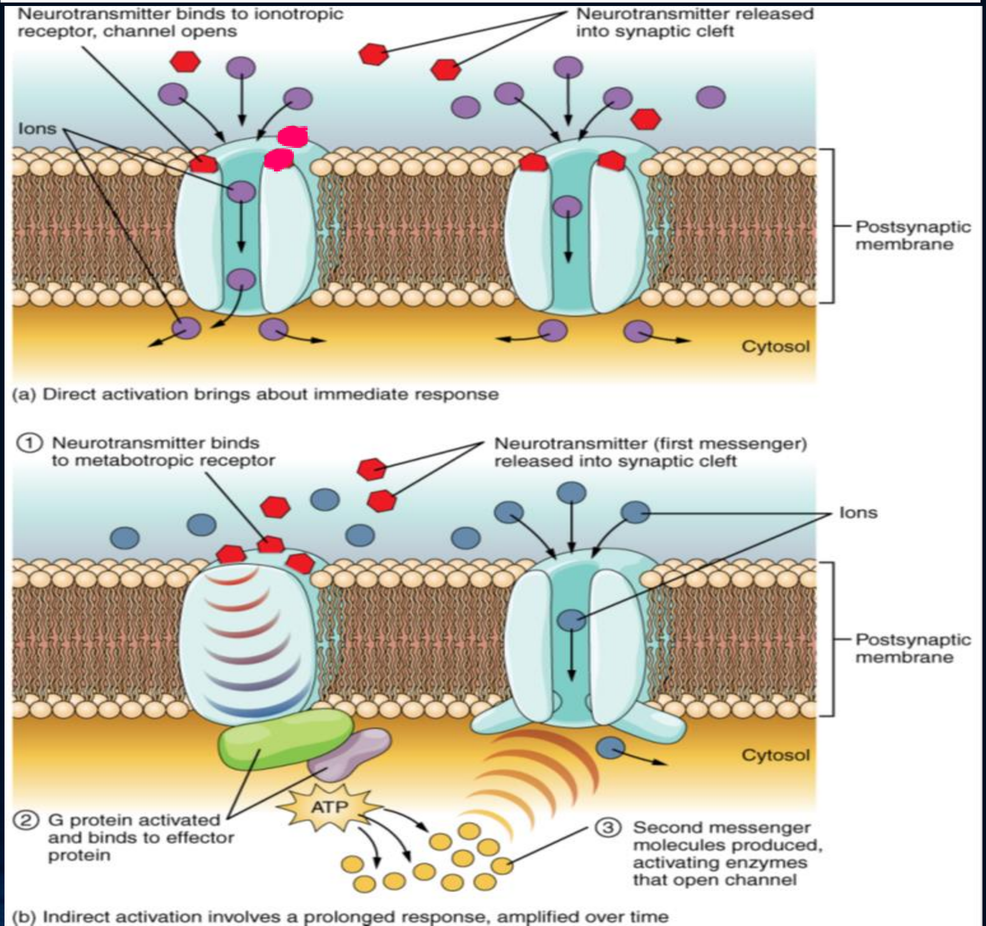
Outline

- Understand the anatomy and physiology of:
  - Olfaction
  - Vision
  - Hearing
  - Equilibirum

Types of receptors

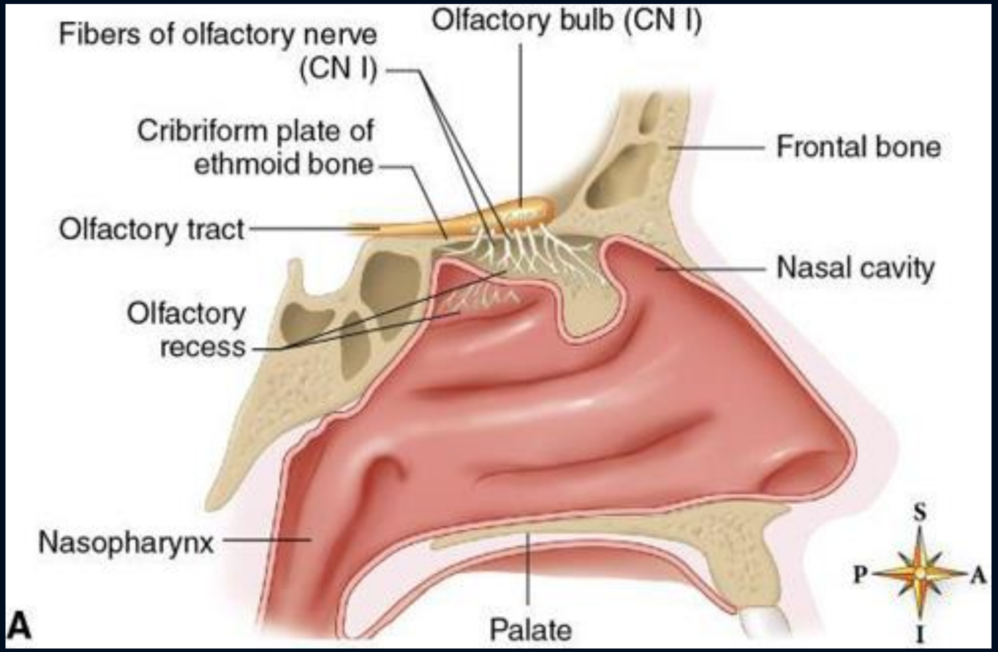
- Voltage-gated
  - Transmembrane proteins that open or close in response to changes in the cell's electrical membrane potential
  - Common with ion channels (Na, K, Ca) and cell signalling
  - Change in electrical potential changes shape of channel
- Ligand-gated
  - Ionotropic: ligand binds to receptor on ion channel, causing ion channel to change shape and open
  - Metabotropic: Ligand binds to receptor that is distinct from ion channel
    - Uses cellular machinery to open ion channel (ie GPCR)





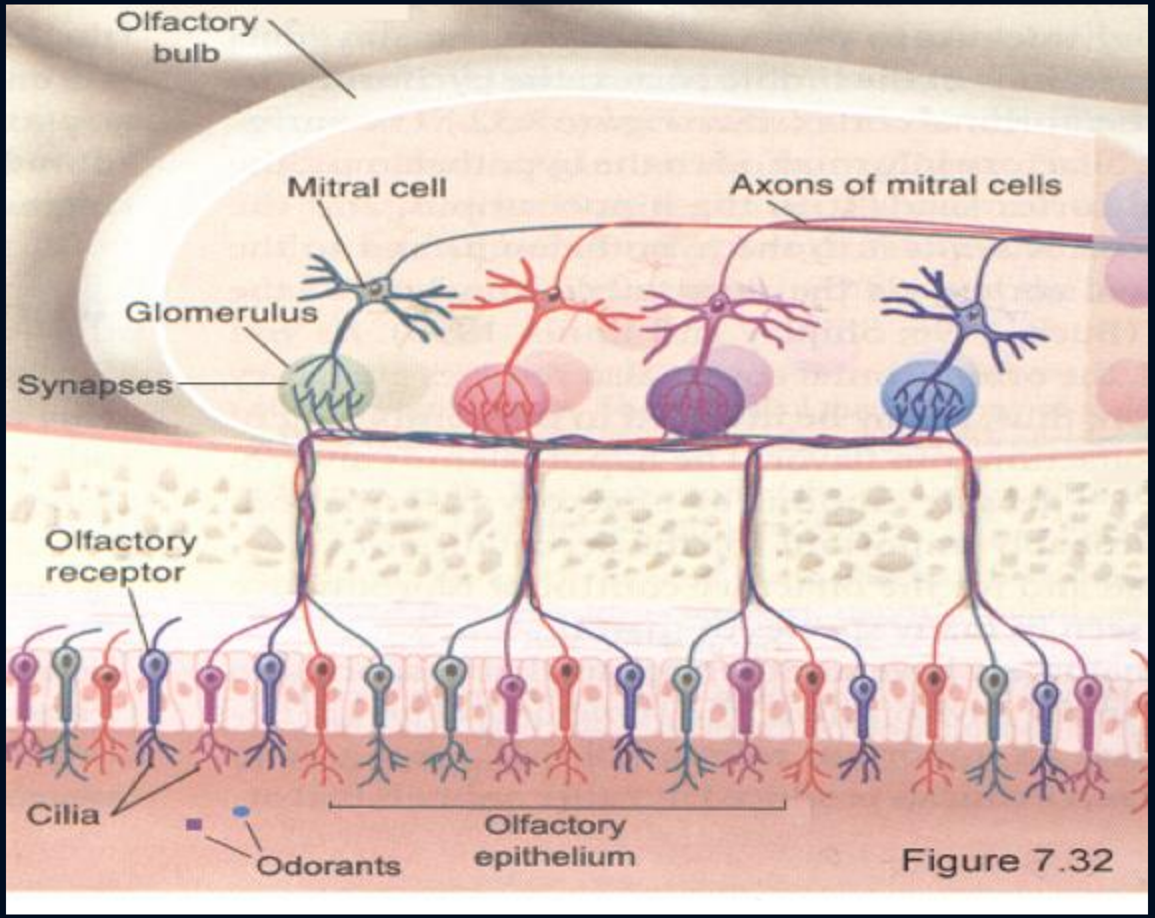
Olfaction

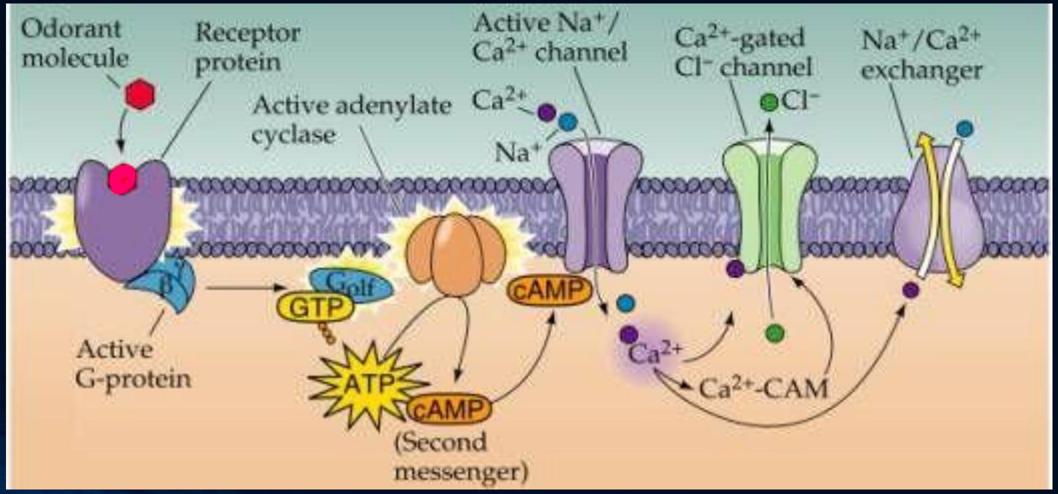
- Upper superior portion of nasal cavity
  - Poor location functionally
- Epithelial support cells, basal cells, olfactory sensory (receptor) neurons
  - Chemoreceptors
  - Replaced by basal cells on regular basis
- Cilia bind odorants – generate receptor potentials



Olfactory Sense – Chemoreceptors

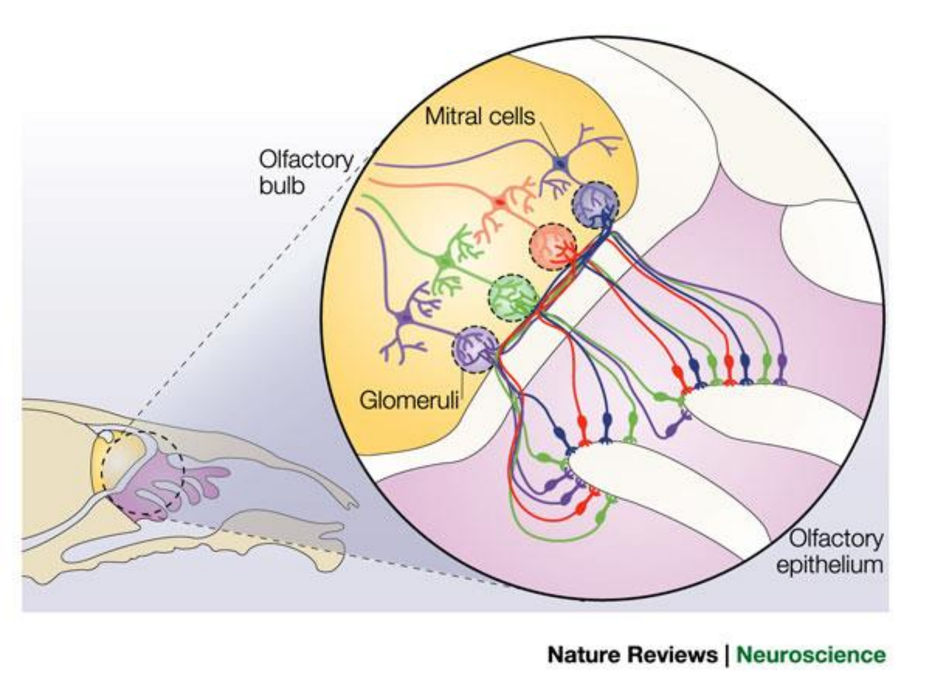
- Located in upper region of nasal cavity
- Olfactory receptor cells (bipolar cells) project through openings in the cribiform plate into olfactory epithelium
- Chemoreceptors are GPCRs that cause Na+ / Ca+2 channels to open to produce a receptor potential
- Sensory neurons connect with mitral cells in glomerulus region (olfactory bulb)
- Axons of mitral cells become CN I
- Receptors are rapidly adapting





Olfactory Sense

- At least 4 primary scents (similar to 5 or 6 primary tastes)
- Humans can distinguish between hundreds of scents based on combinations of primary scents and "sub-scents"
- CN I project to primary olfactory cortex in temporal lobe and to regions of the limbic system creating strong associations between scent, memories and emotion
  - Hippocampus
  - Amygdala



Odorants	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Odor character
					●										rancid, sour, goaty
		●				●									sweet, herbal, woody
	●			●	●		●			●	●				rancid, sour, sweaty
		●			●	●									violet, sweet, woody
	●			●	●		●	●		●	●	●			rancid, sour, repulsive
				●	●		●			●					sweet, orange, rose
	●			●	●		●	●		●		●		●	waxy, cheese, nut-like
				●	●		●			●		●			fresh, rose, oily floral

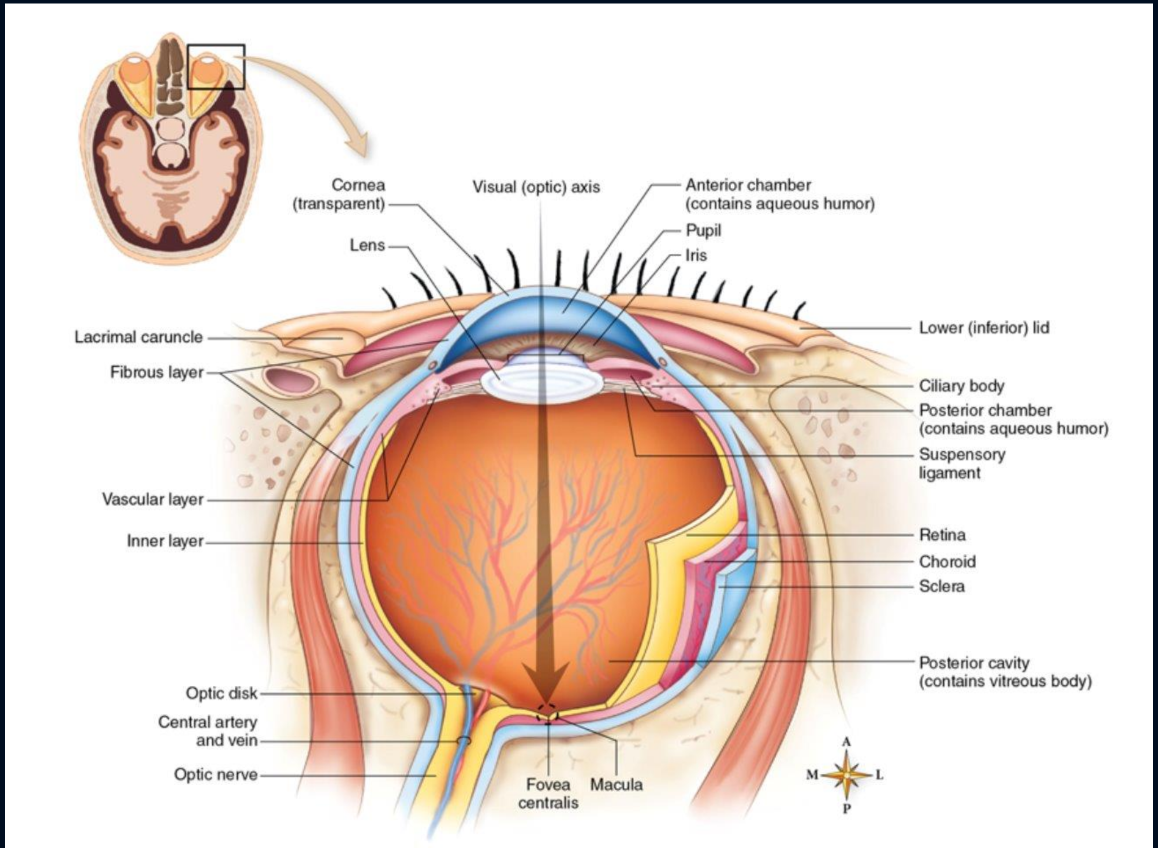
Odorant receptors

Vision

Anatomy of the eye

Layers of the eyeball

1. Fibrous layer
   - Sclera
   - Cornea
2. Vascular Layer
   - Choroid
   - Ciliary body
   - Iris
3. Inner Layer
   - Retina
   - Optic Nerve
   - Retinal blood vessels



Anatomy of the eye

Other Important Pieces!!

- Lens
- Ciliary muscle
- Anterior Chamber (aqueous humor)
- Posterior Chamber (vitreous body)

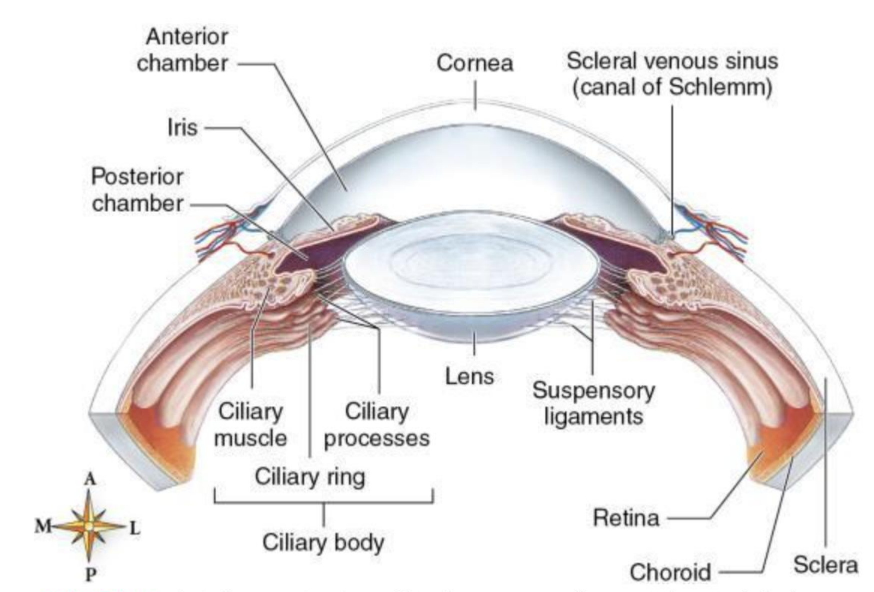
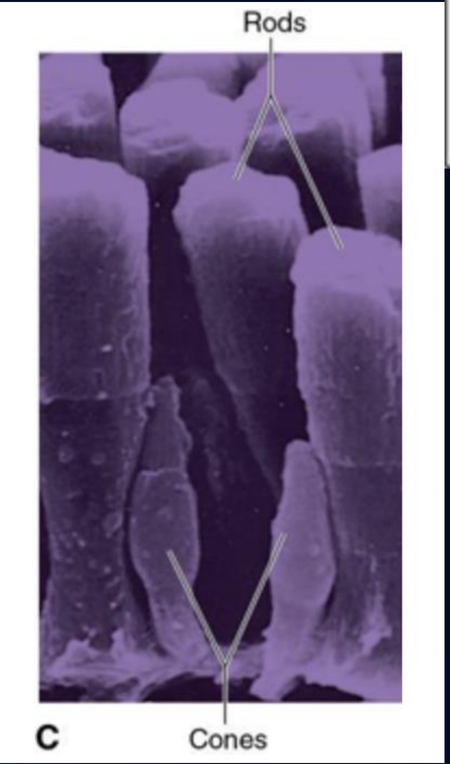
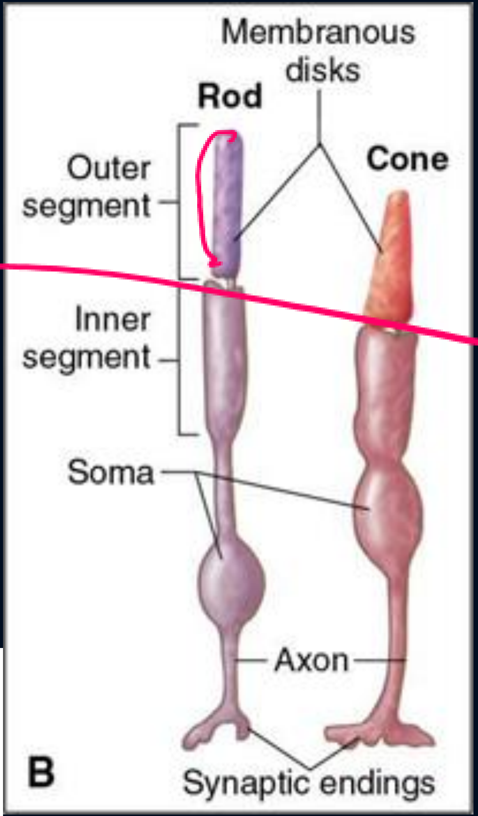


FIGURE 24-17 Anterior eye structures. Note the suspensory ligaments that attach the lens to the ciliary body.

Photoreceptors

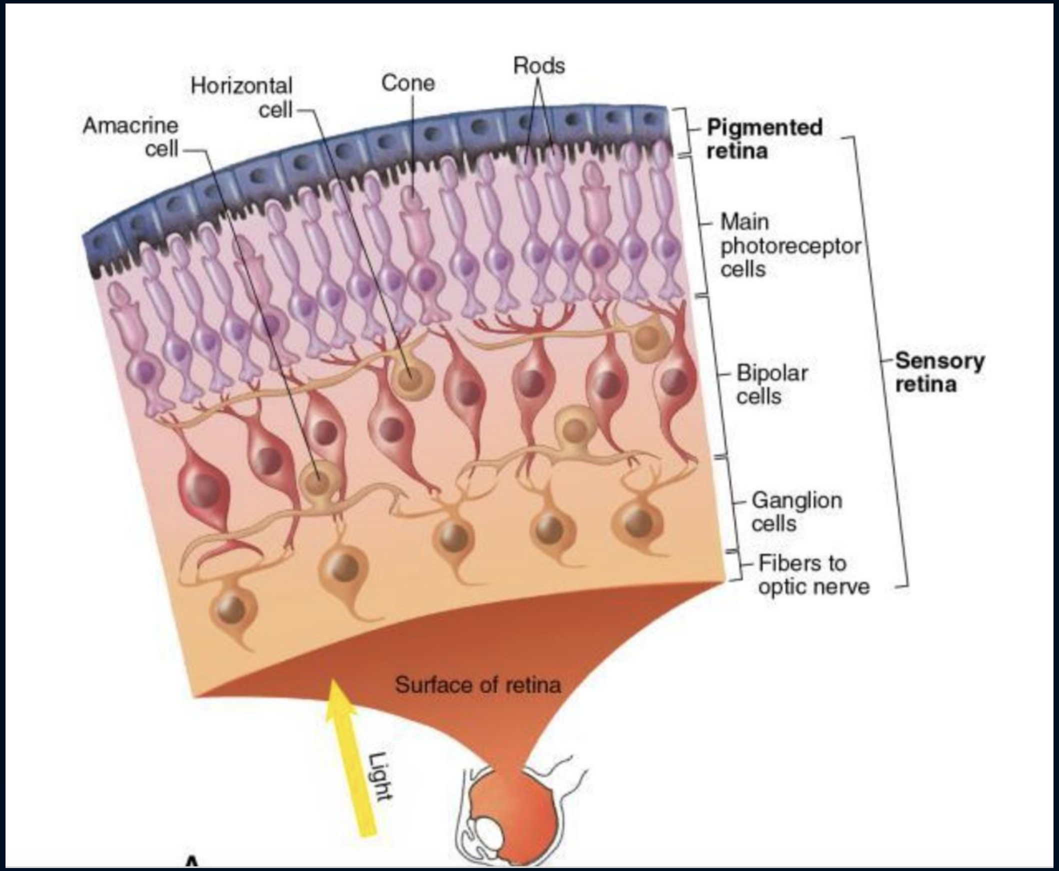
- Distal ends of dendrites of main photoreceptor neurons are named for their shape (rods and cones)
- Outer segments are continuously regenerated
  - Older sections slough off and are phagocytized by epithelial cells
- Differ in numbers, distribution and function
- 20:1 ratio (rods to cones)
  - Rods – light
  - Cones - colour
- Cones are located mostly in fovea centralis (in macula)
- Rods are absent from fovea centralis





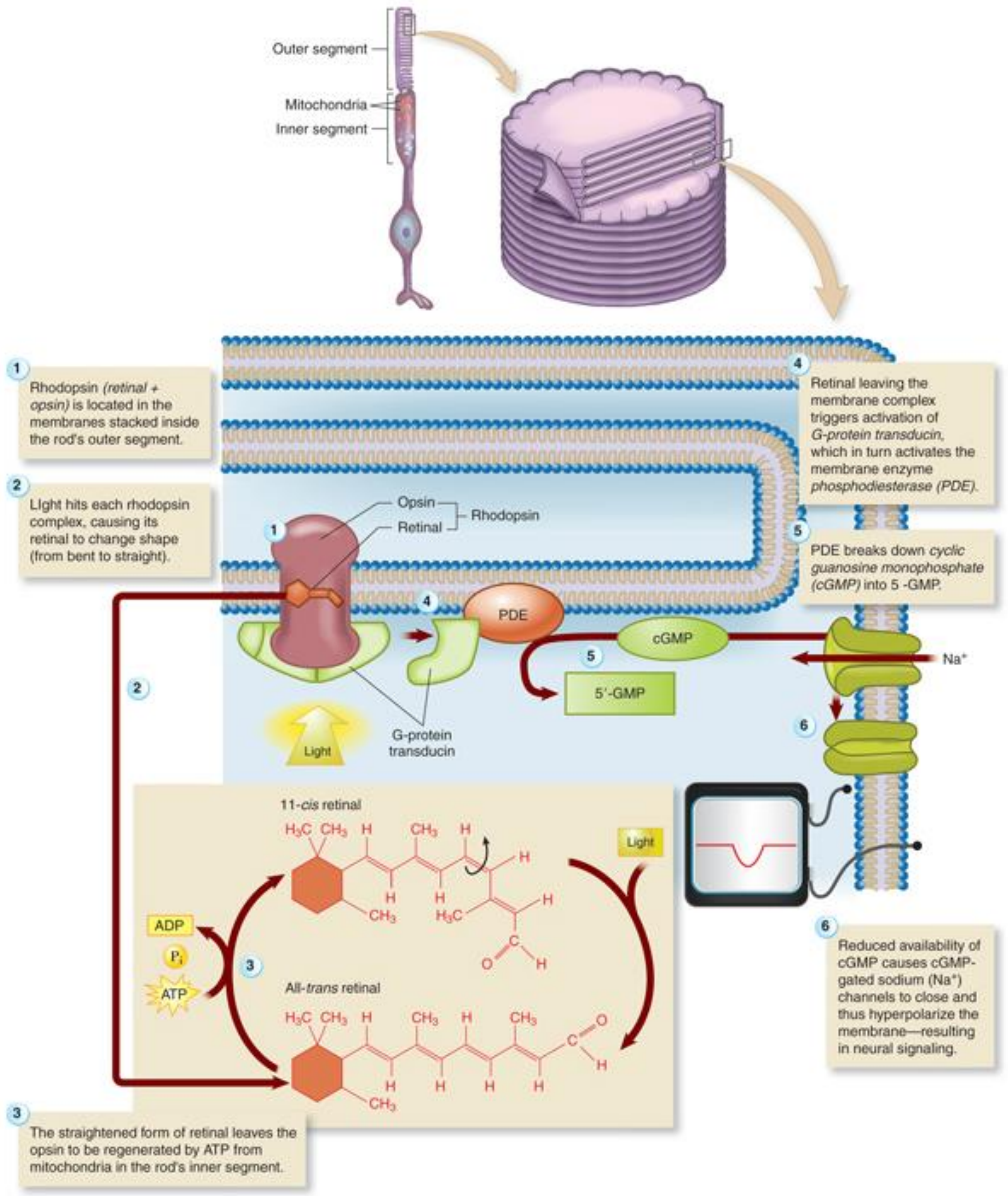
Vision - Photoreceptors

- Complex sense that features two types of photoreceptors (rods and cones) located in the retina (inner layer) of the eye
- Rods / cones synapse with bipolar cells (one cone or many rods) which connect indirectly with ganglion cells that make up CN II (optic nerve)
- When stimulated with light, rods hyperpolarize causing “on” bipolar cells to hyperpolarize (decreased release of glutamate onto bipolar cells)
- Bipolar cells synapse with amacrine cells which synapse with ganglion cells



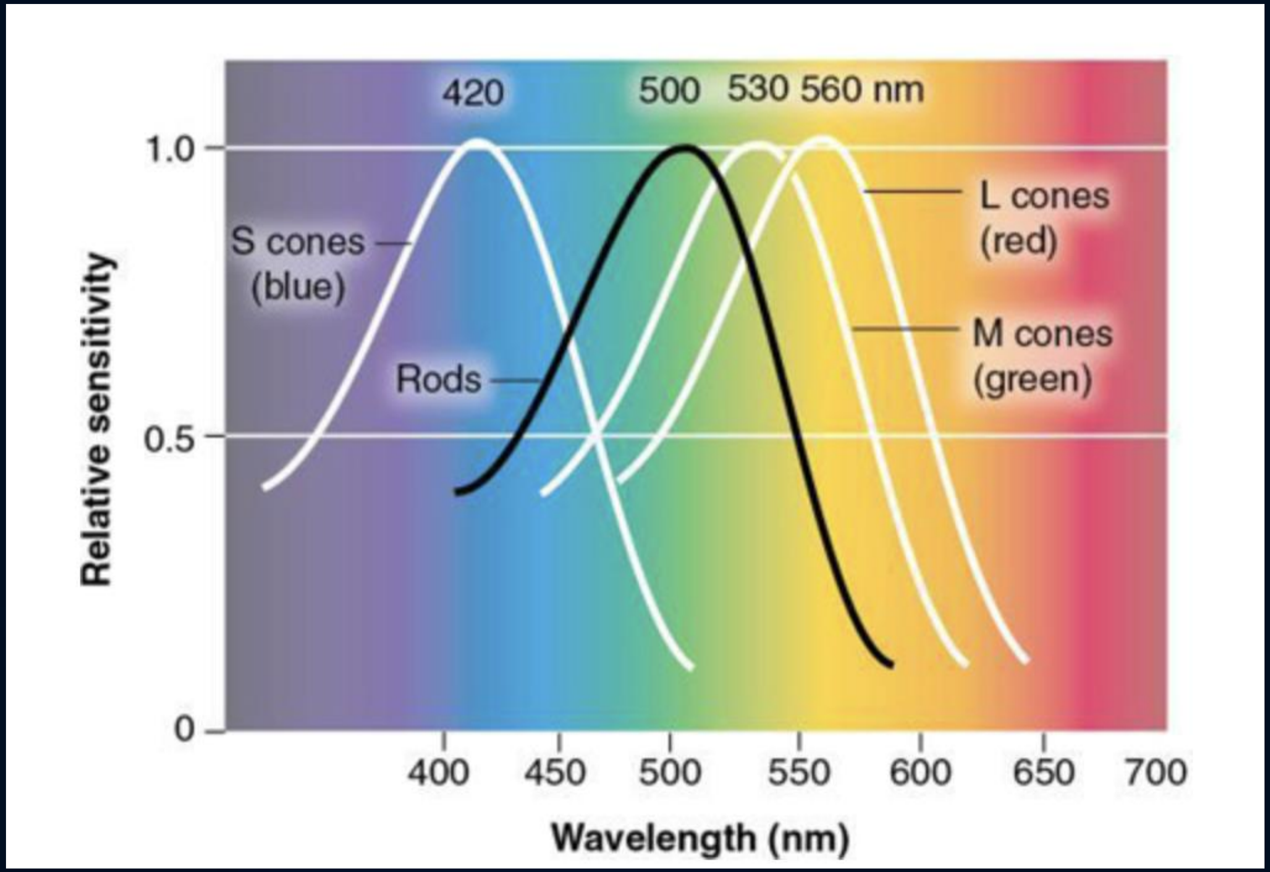
Rods – Transduction Mechanism

- Light strikes rods causing rhodopsin (opsin + cis-retinal) to change shape → cis-retinal transitions to trans-retinal
- Trans-retinal activates a G protein which in turn begins a cascade that reduces cGMP
- Decreased cGMP causes open Na+ channels to close which hyperpolarizes rod cell
- Rods release less of the NT glutamate onto bipolar cells
- ON bipolar cells release less inhibitory NT that in turn leads to depolarization of ganglion cells (loss of bipolar cell inhibition)



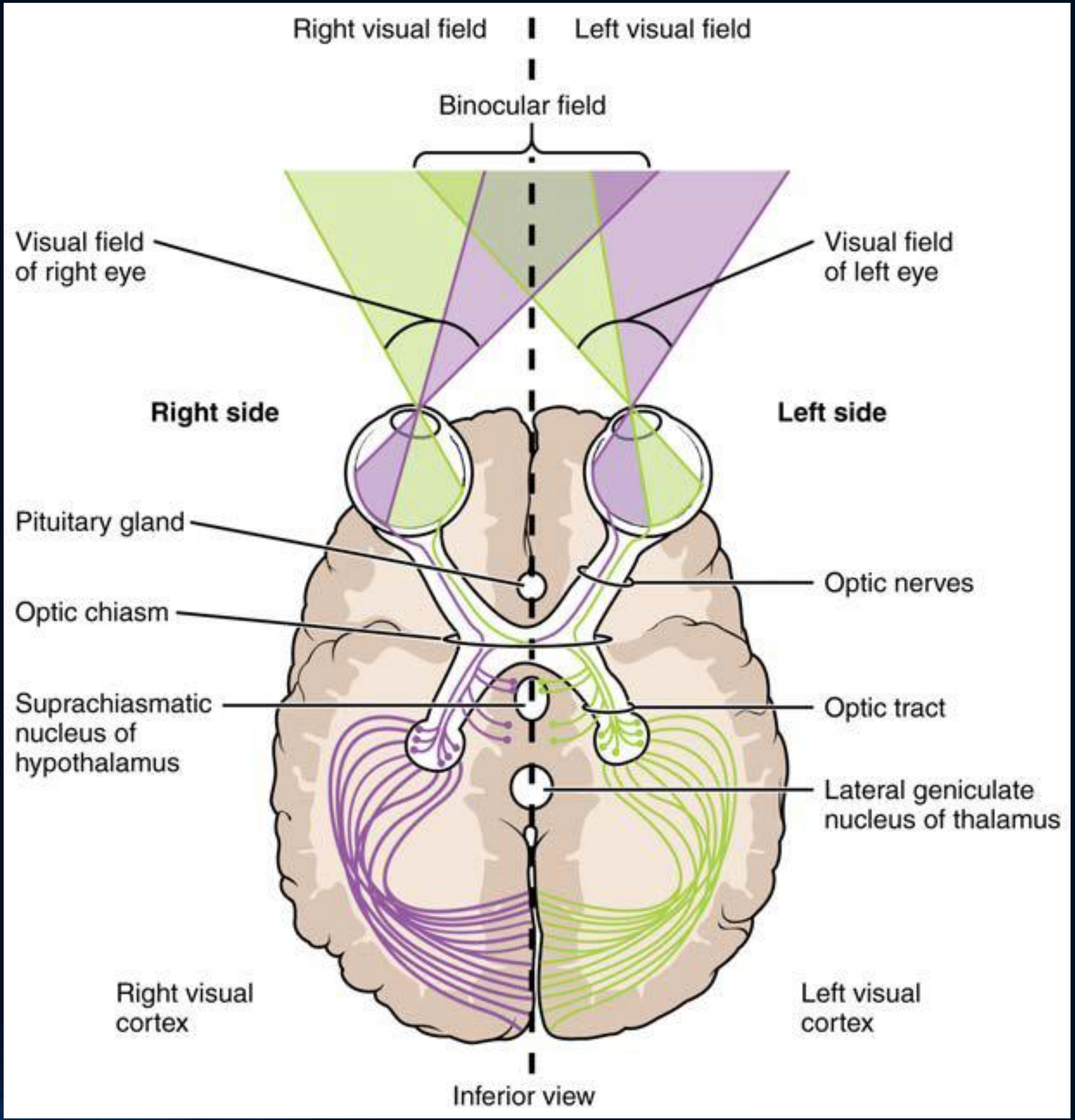
Cones

- 3 types of cones in retina
- Each contain its own version of rhodopsin, less sensitive to light (require bright light)
- Cones contribute more to sharpeness (1:1 with bipolar cells)
- Greatest concentration in the Fovea



Visual Pathway in CNS

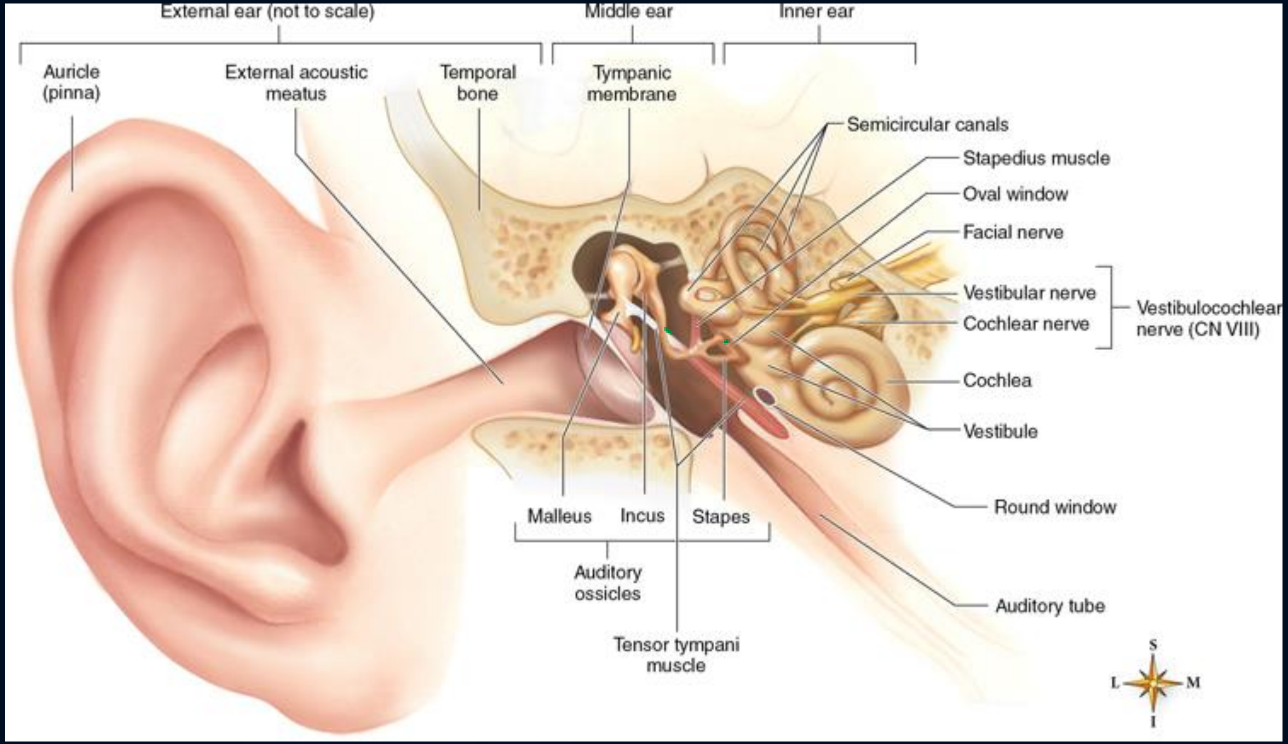
- Right visual field (medial right retina and lateral left retina (with some overlap in middle) is processed on left side of brain
- Thus some ganglion neurons (CN II) stay on the ipsilateral side while others cross over to the contralateral side at the optic chiasm
- Primary Pathway
  - visual neurons project to thalamus, then synapse with neurons that project to primary visual cortex
- Secondary Pathway
  - Visual neurons project to superior colliculi which connects with motor nuclei for CN III, IV and VI



Hearing and Equilibrium

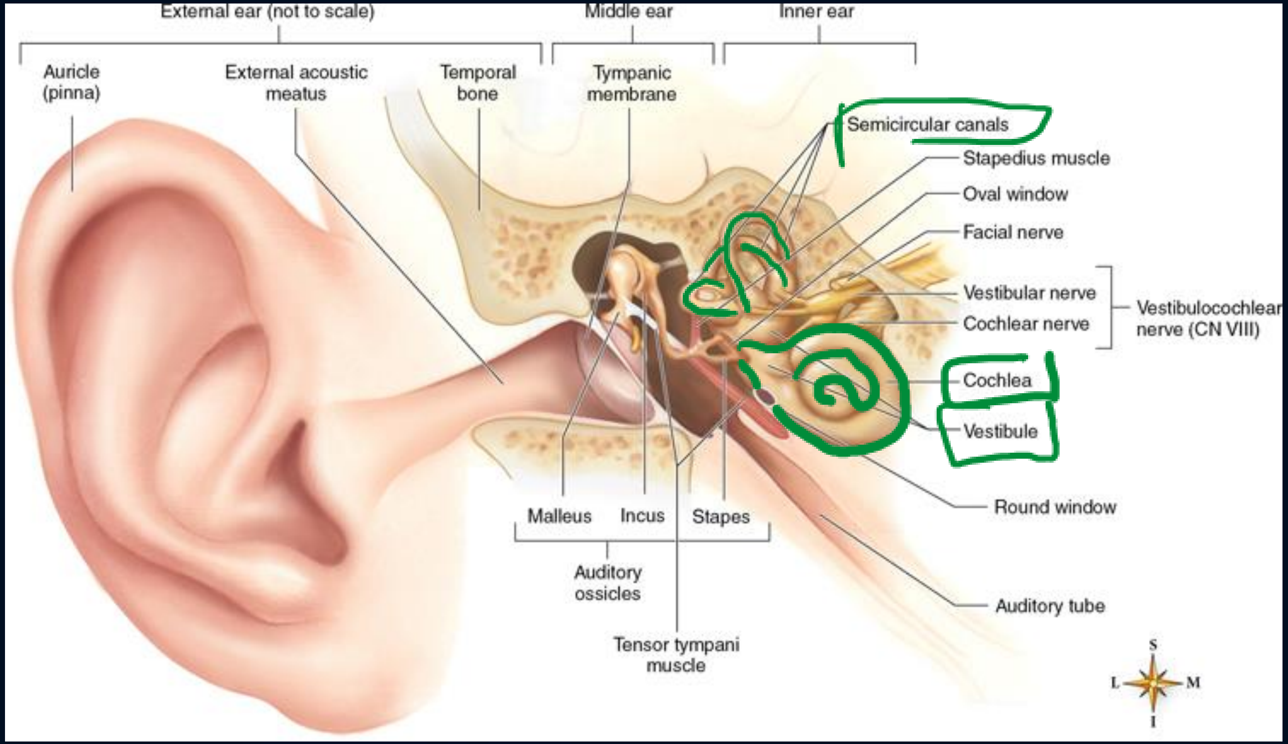
The Ear

- External ear: auricle and external acoustic meatus
  - Cerumen
- Middle ear: epithelial-lined cavity of hollowed out temporal bone
  - Auditory ossicles: malleus (hammer), incus (anvil), stapes (stirrup)
  - Attach tympanic membrane to oval window
  - Muscles and ligaments stabilize and dampen vibrations with loud sound
  - 4 openings: to external acoustic meatus, oval window, round window, auditory canal



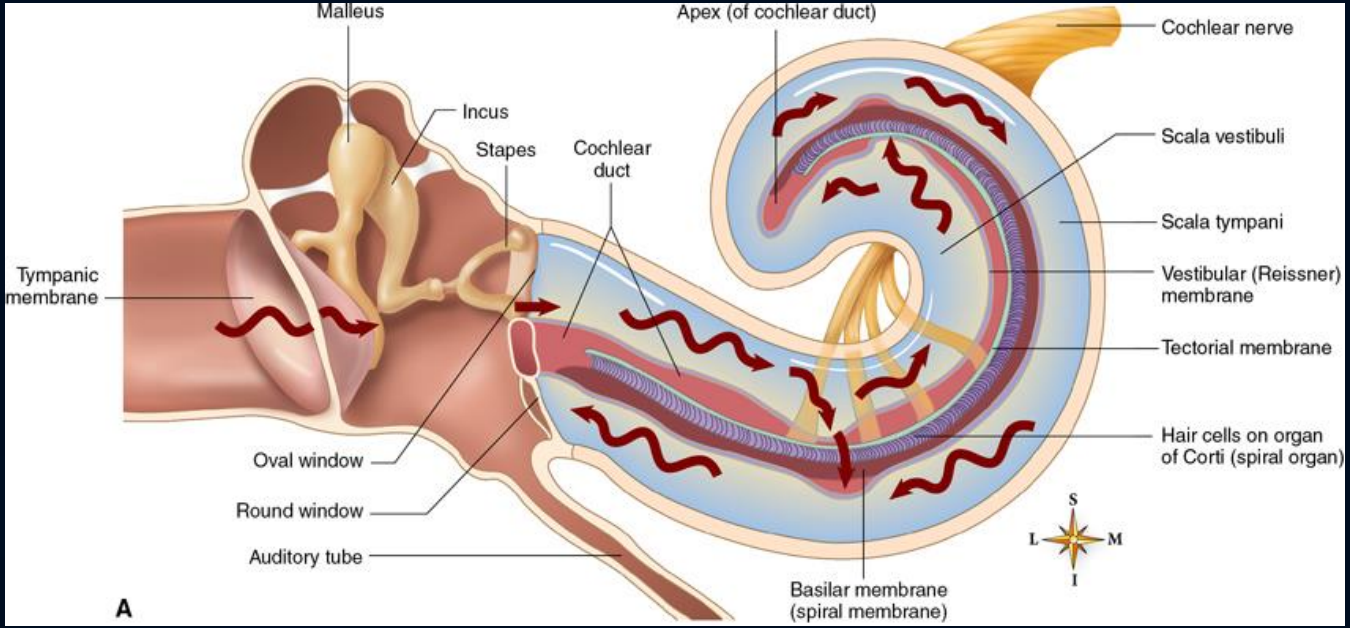
The Ear

- Inner Ear, or labyrinth
- Bony labyrinth
  - Vestibule, cochlea, semicircular canals
- Membranous labyrinth
  - Utricle and saccule, cochlear duct, semicircular ducts
- Endolymph – clear potassium-rich fluid in membranous labyrinth
- Perilymph – similar to CSF, space around membranous labyrinth



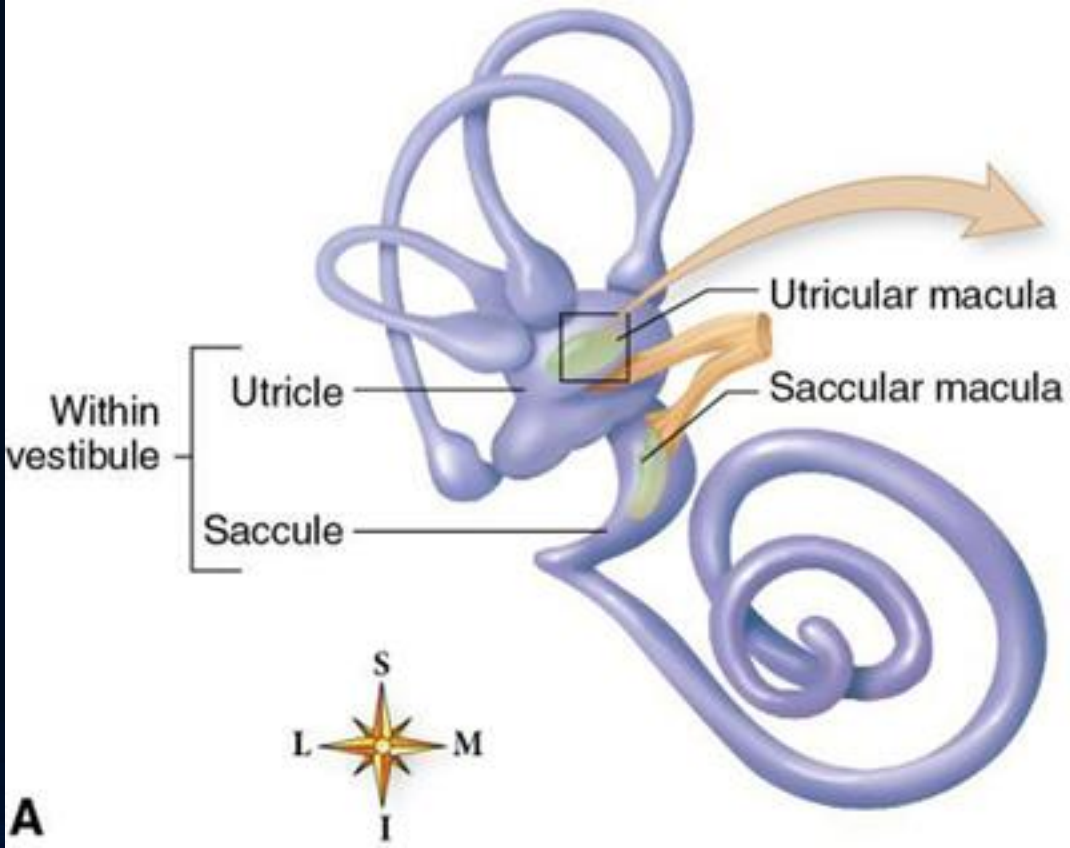
Hearing

- Humans hear between frequency (pitch) 20Hz and 20kHz (most sensitive between 1-4kHz
- Also volume measured in decibels (85dB or higher can cause damage)
- “cochlea” or snail
- Vibrations in middle ear stimulate oval window - perilymph of scala vestibuli of cochlea – transmitted through vestibular membrane to endolymph inside duct and to spiral organ and to basilar membrane – perilymph in scala tympani – round window



Equilibrium (or balance)

- Vestibule and semicircular canals
- Sense organs – utricle and saccule (static equilibrium)
  - Position of head relative to gravity, acceleration, deceleration
- Sense organs in semicircular ducts (dynamic equilibrium)
  - Balance when head or body is rotated or suddenly moved



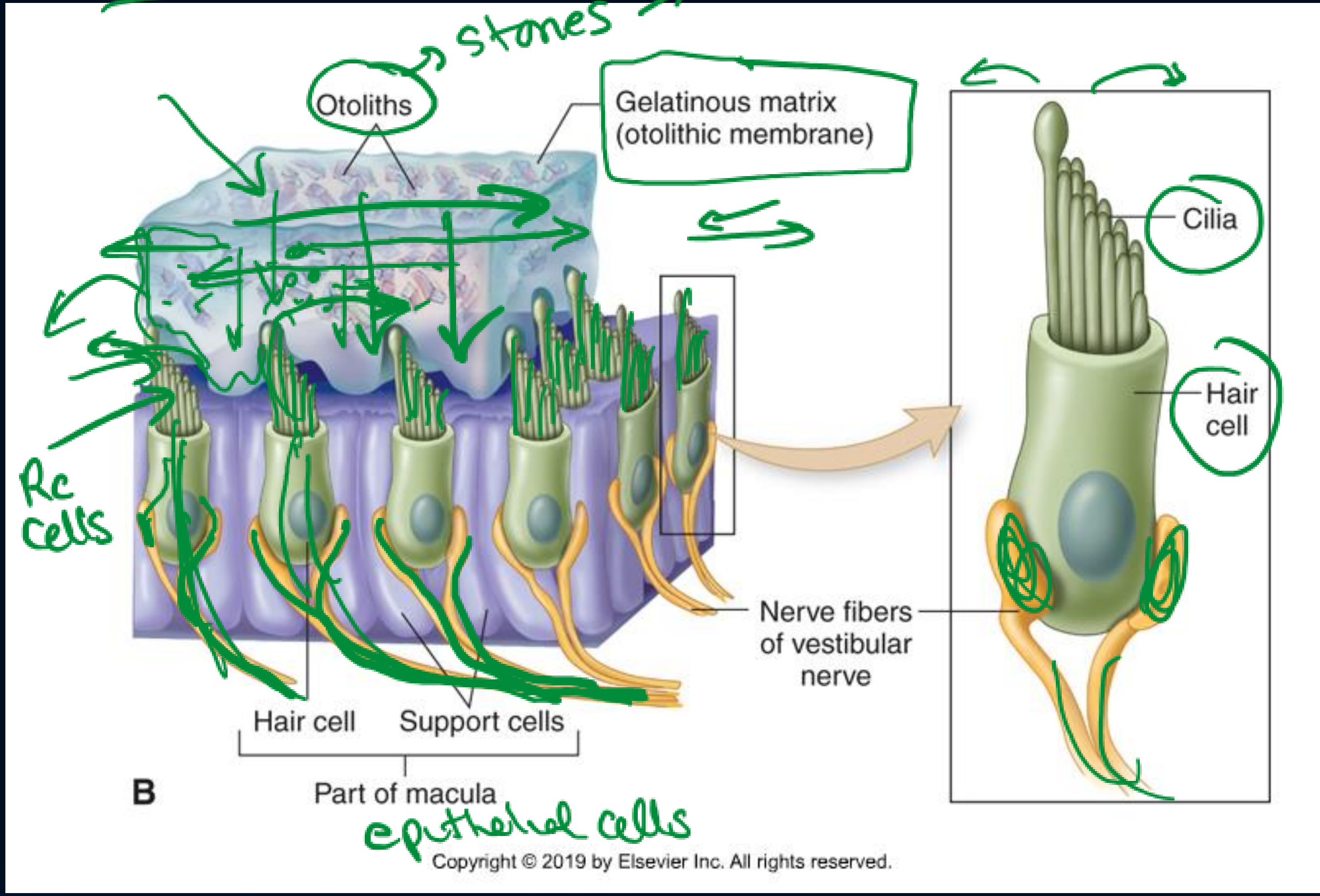
Vestibular Apparatus – acceleration

Meniere's Disease

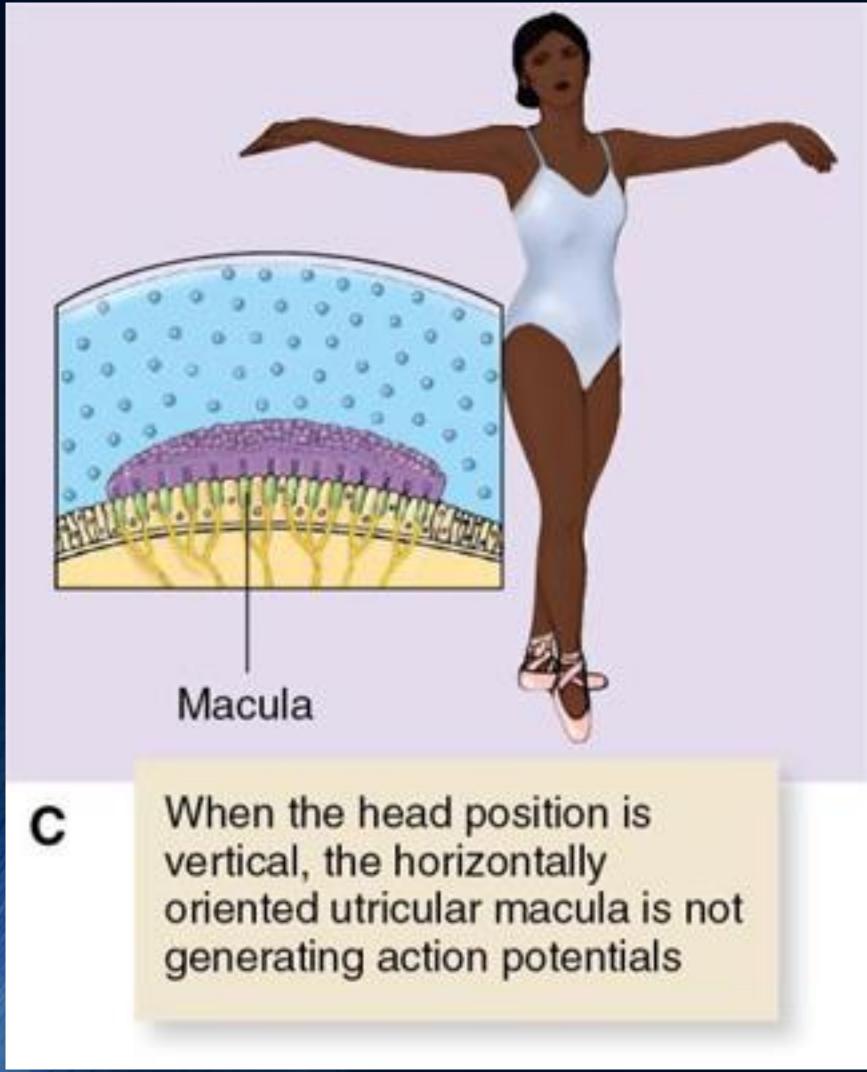
Stroke
menieres Disease
nerve problem
benign positional vert

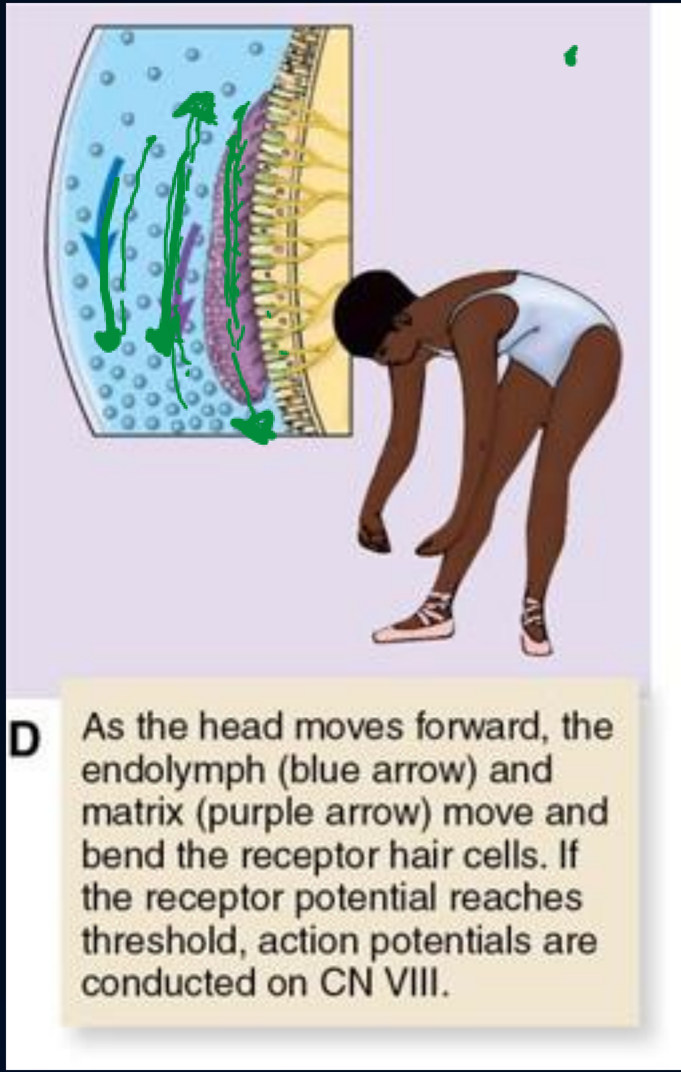
stones → calcium and things

- Composed of Otolith Organs and Semi-circular canals
- Otoliths organs – measure linear acceleration in vertical (saccule) and horizontal (utricle) planes
- Hair cells (receptors) project into endolymph (thick fluid) that contains $CaCO_3$ crystals (otoliths)
- Hair cells have large kinocilium and small sterocilia; as endolymph moves, stereocilia bend leading to receptor potentials
- Hair cells are oriented in many directions



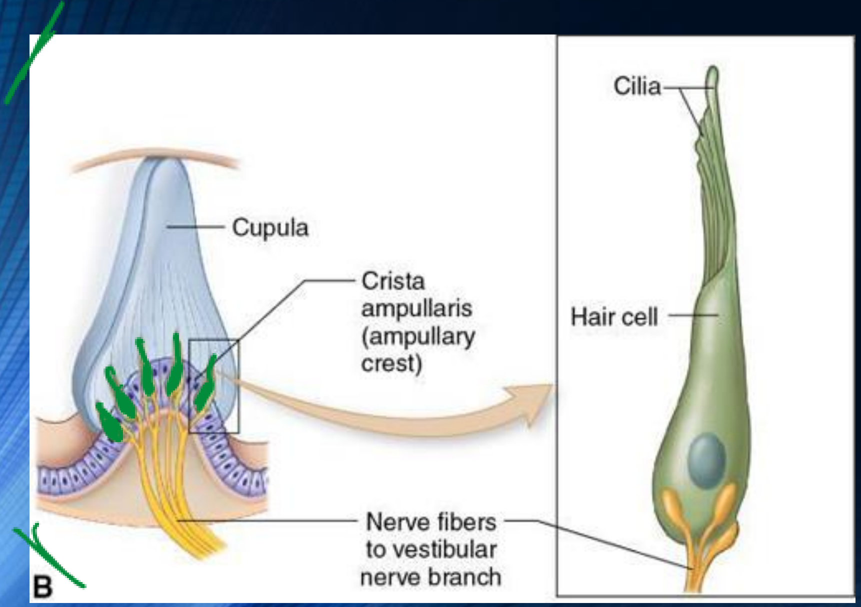
Dix-Hallpike.

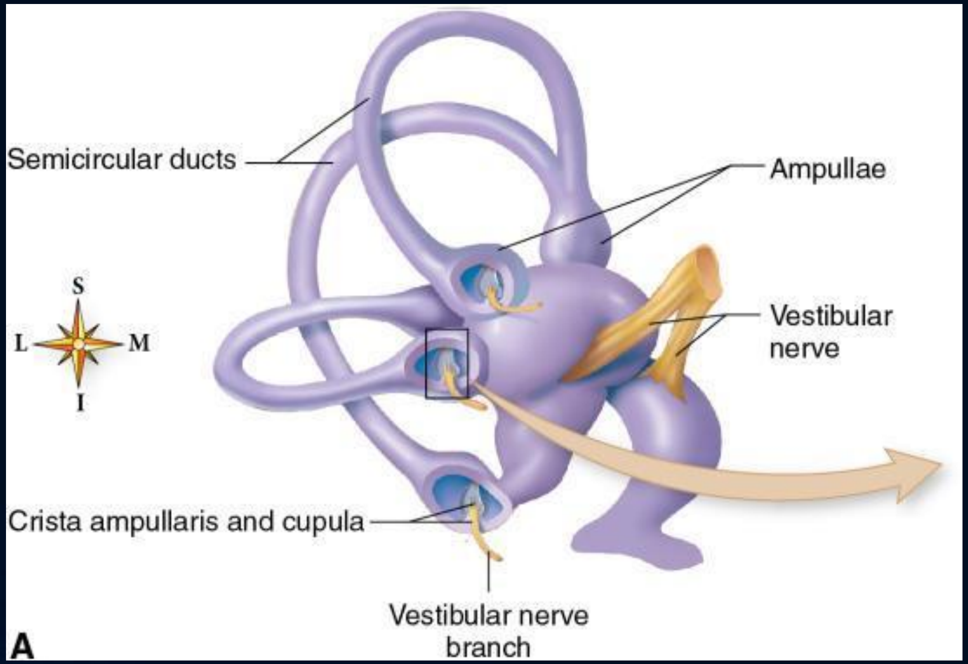

Macula
C
When the head position is vertical, the horizontally oriented utricular macula is not generating action potentials

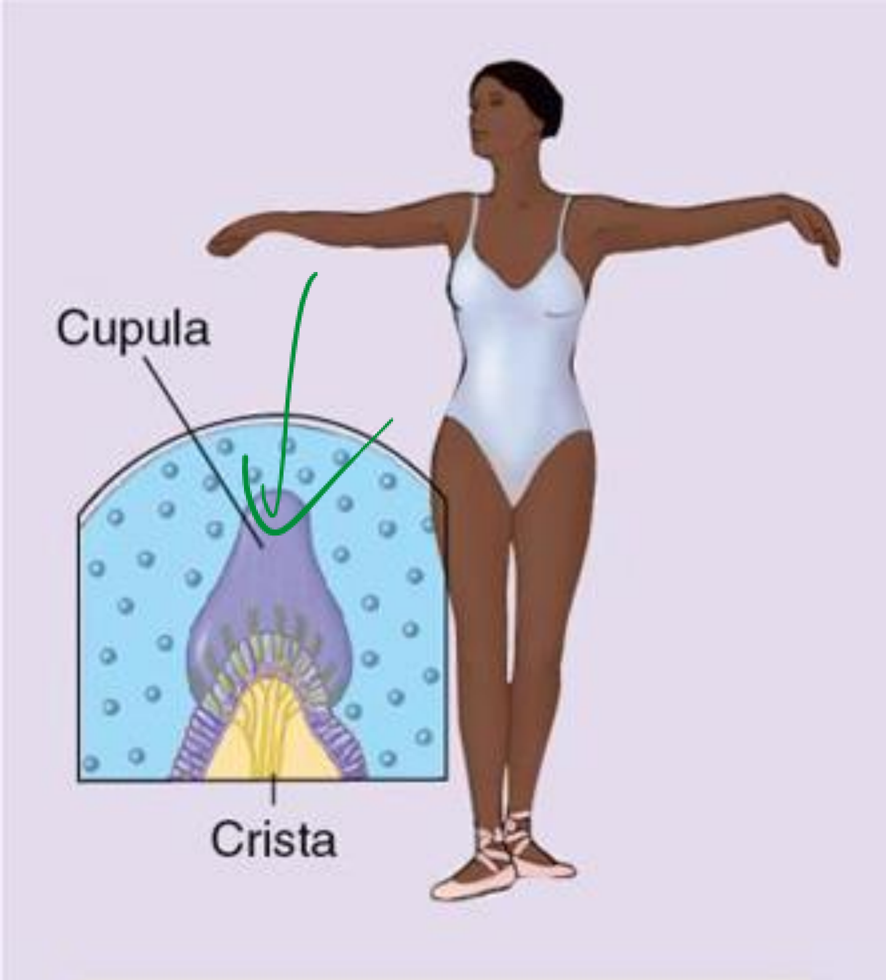

D
As the head moves forward, the endolymph (blue arrow) and matrix (purple arrow) move and bend the receptor hair cells. If the receptor potential reaches threshold, action potentials are conducted on CN VIII.

Dynamic Equilibrium

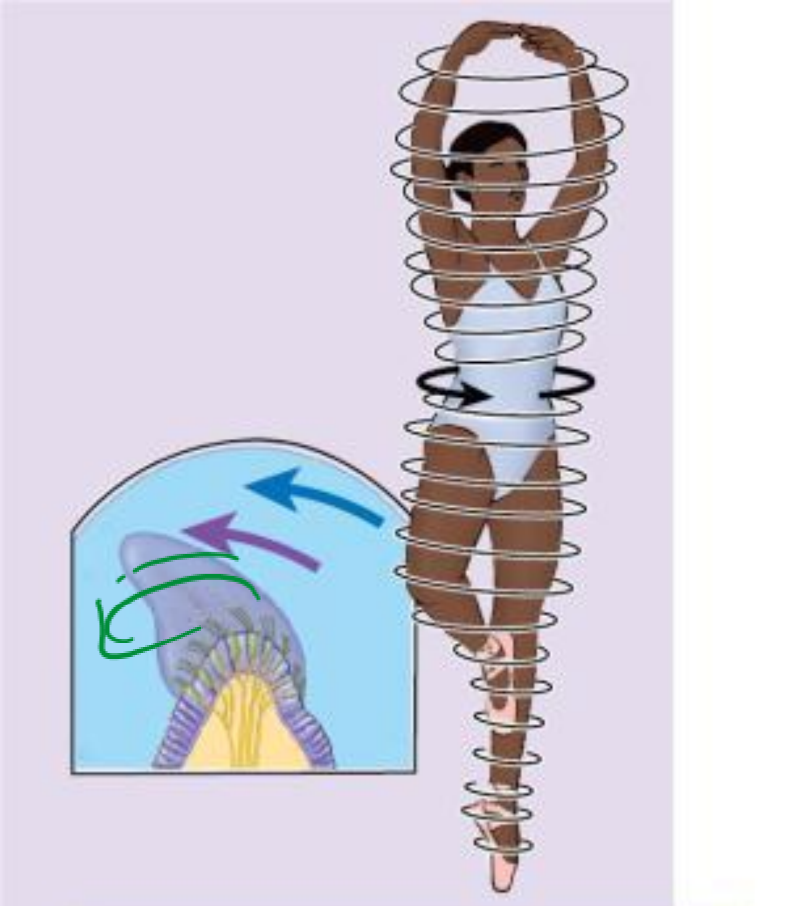
- Crista ampullaris – located in ampulla of each semicircular duct
  - Sensory epithelium (works similar to maculae)
- Hair cells located in capulla







C When the head position is not changing, the crista ampullaris is not generating any action potentials.

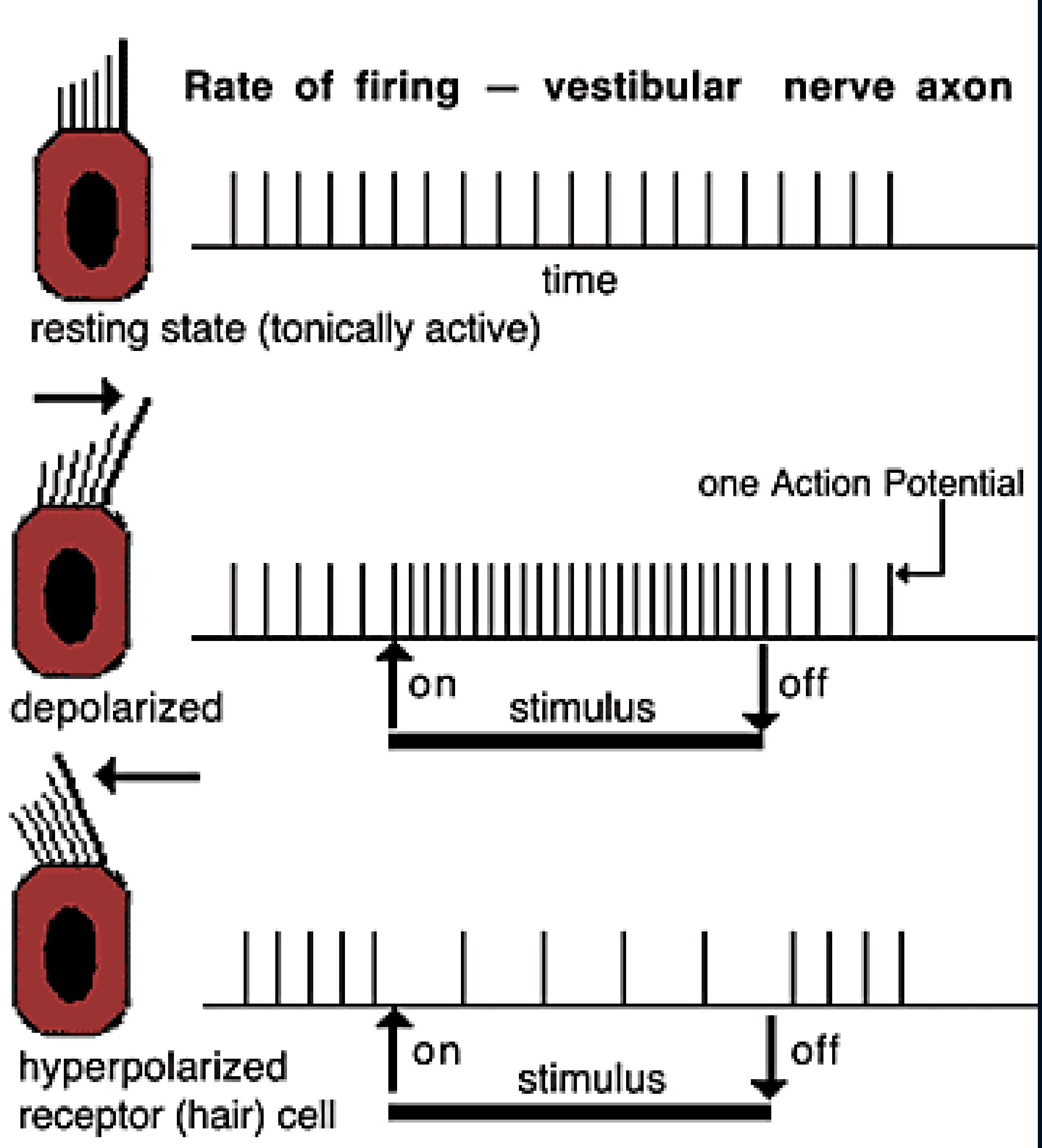


D As the head spins, the endolymph (blue arrow) and cupula (purple arrow) move in the opposite direction and bend the receptor hair cells. If the receptor potential reaches threshold, action potentials are conducted on CN VIII.

- Hair Cells fire at a set rate all the time
- When at rest or constant speed, stereocilia are upright
- When body accelerates in forward direction, endolymph lags behind causing hair cells in one orientation to depolarize (increase rate of APs in CN VIII while those in opposite orientation hyperpolarize (decrease rate of APs in CN VIII
- When body decelerates, the opposite occurs

- Combination of messages from hair cells in different orientations allow brain to sense acceleration in any direction

- How do we decide if we are accelerating?

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