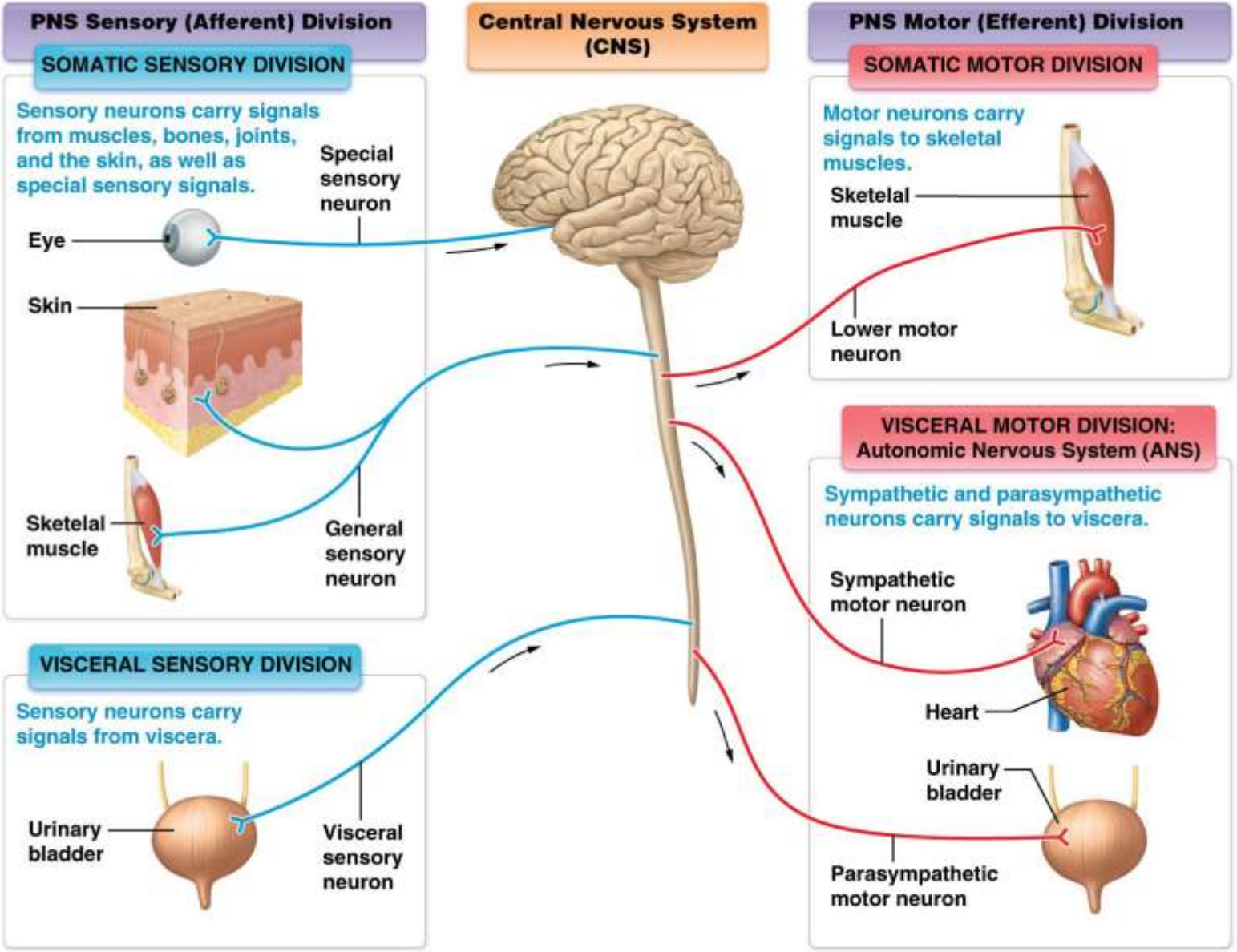
PNS – Sensory Division

Biology 260

M. Iyengar

Structural organization of the NS



Sensory Division

- Sensation = awareness of stimulus
- Perception = interpretation of stimulus in brain
    - REVIEW → where is the input received & processed?

- Classification
    1. Stimulus type
    2. Structure
        - Location of receptor
        - Receptor structure

Sensory Receptor based on Stimulus

1. **Mechanoreceptors:** Respond to mechanical force
   - **Tactile receptors**→ touch, pressure, and vibration
   - **Baroreceptors** → monitor pressure in walls of blood vessels (BP), digestive, reproductive & urinary tracts
   - **Proprioceptors** → in musculoskeletal system; detect *movement* and *position* of a joint or body part

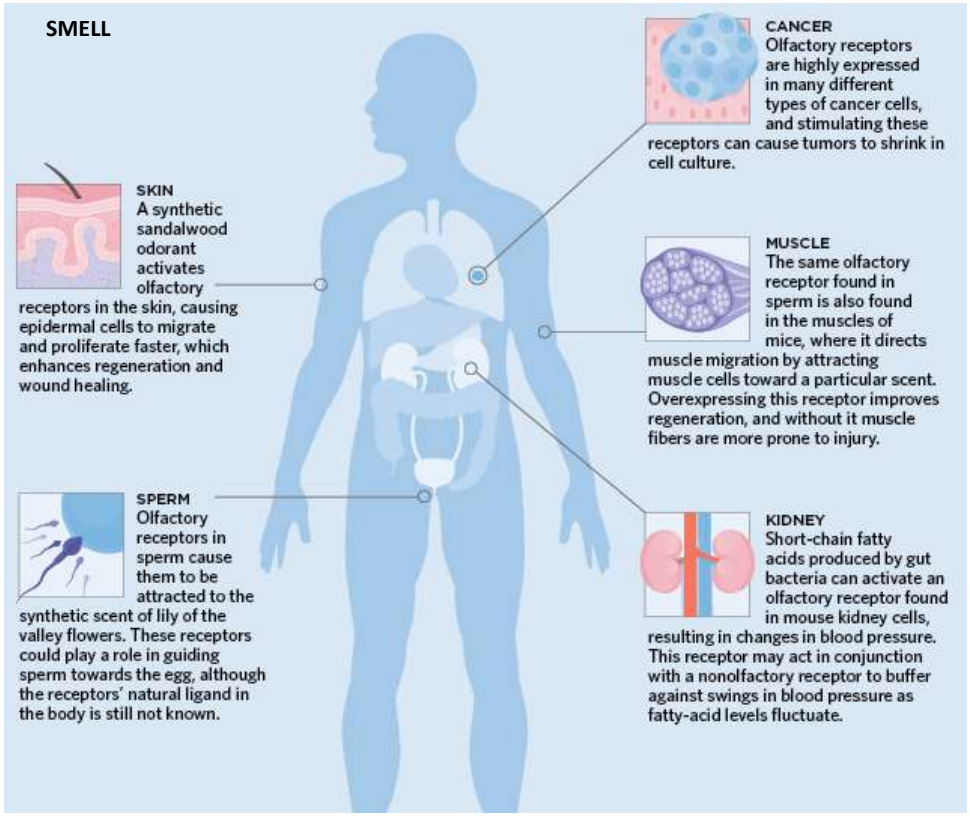
2. **Thermoreceptors:** Respond to temperature changes
   - Cold receptors (3-4x more common) & Warm receptors

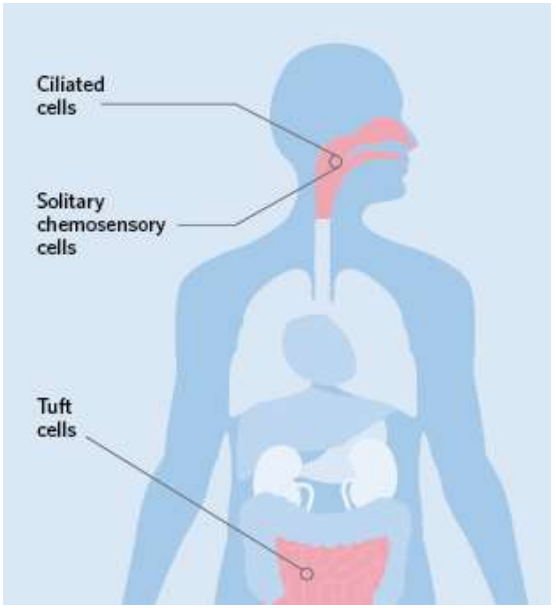
3. **Chemoreceptors:** Respond to chemical changes
   - smell, taste, changes in blood chemistry

4. **Nociceptors:** Respond to potentially damaging stimuli
   - Pain, *extreme* heat or cold, excessive pressure, inflammatory chemicals

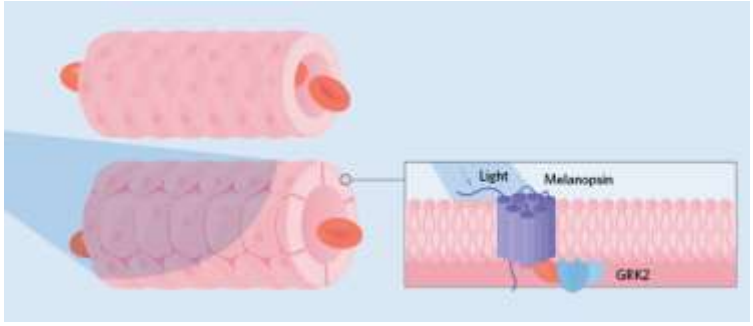
5. **Photoreceptors:** monitor changes in light

Odor, Taste, and Light Receptors in Unusual Locations





TASTE
Taste receptors have been found all over the body, including the testes, sperm, airway, and gut. They have many different functions, including detecting nutrients in food, regulating the immune response to bacteria and parasites, and influencing mouse fertility.



LIGHT
Melanopsin, a light-sensitive pigment not involved in vision, is expressed in many different blood vessels. When exposed to blue wavelengths of light, the melanopsin and G protein–coupled receptor kinase 2 (GRK2) mediate the relaxation of the vessels. The combination of light and a GRK2 inhibitor resulted in a 75 percent to 100 percent relaxation of blood vessels in vitro.

http://www.the-scientist.com/?articles.view/articleNo/46833/title/Odor--Taste--and-Light-Receptors-in-Unusual-Locations/

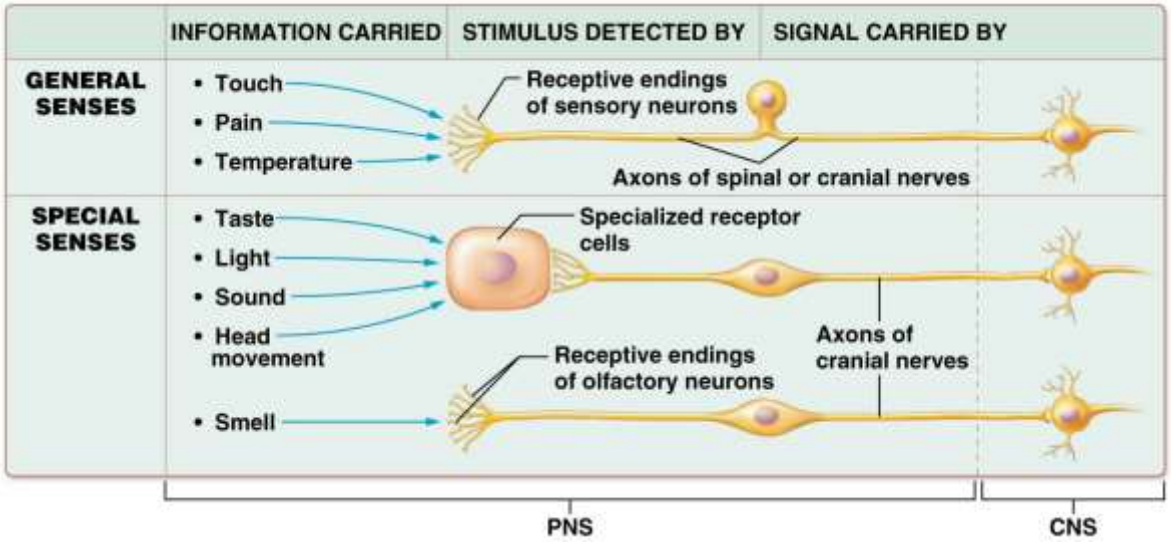
Sensory Receptors Locations

1. **Exteroceptors:** Sensitive to stimuli from outside the body, but near the body surface
   - Pressure, touch, temperature, and majority of special senses

2. **Interoceptors:** Stimuli from internal viscera (organs)
   - Changes in pH, chemical concentration, tissue stretching, temperature of digestive organs, lungs, bladder

Sensory Receptor Structure

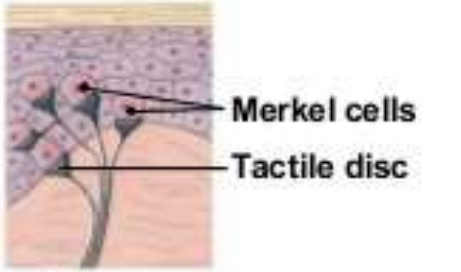
1. General senses → simple receptors
   – Found throughout body and monitor general sensory information
     • Include tactile sensations (touch, pressure, stretch, vibration), temperature, pain, and muscle sense
2. Special senses → complex receptors
   – Vision, hearing, equilibrium, smell, and taste



1. General Senses


a Free nerve endings


b Root hair plexus



c Tactile discs innervating Merkel cells

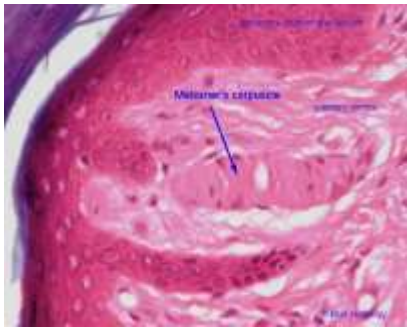
Free nerve endings:

- Dendritic endings without additional covering
  - Present in all tissues of the body
    - Nociceptors
    - Thermoreceptors
  - High number in Skin
    - Tactile (Merkel) discs
    - Hair follicle receptors

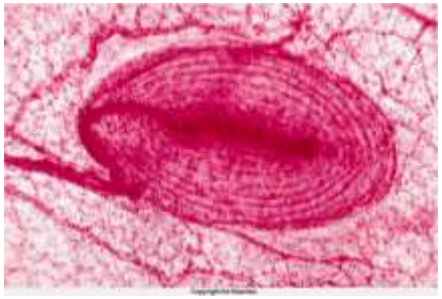
1. General Senses

Encapsulated nerve endings: CT wrapped around nerve endings.

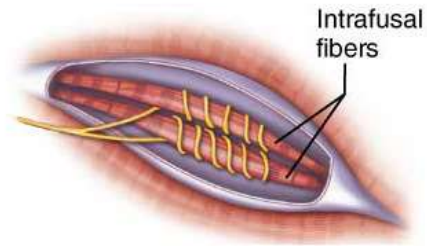
- Helps amplification/filtering of stimuli.



1. **Tactile (Meissner's) corpuscles:**
   - Schwann cells, surrounded by an egg-shape CT
   - sensitive & hairless areas (Palms, fingertips, hills, lips)



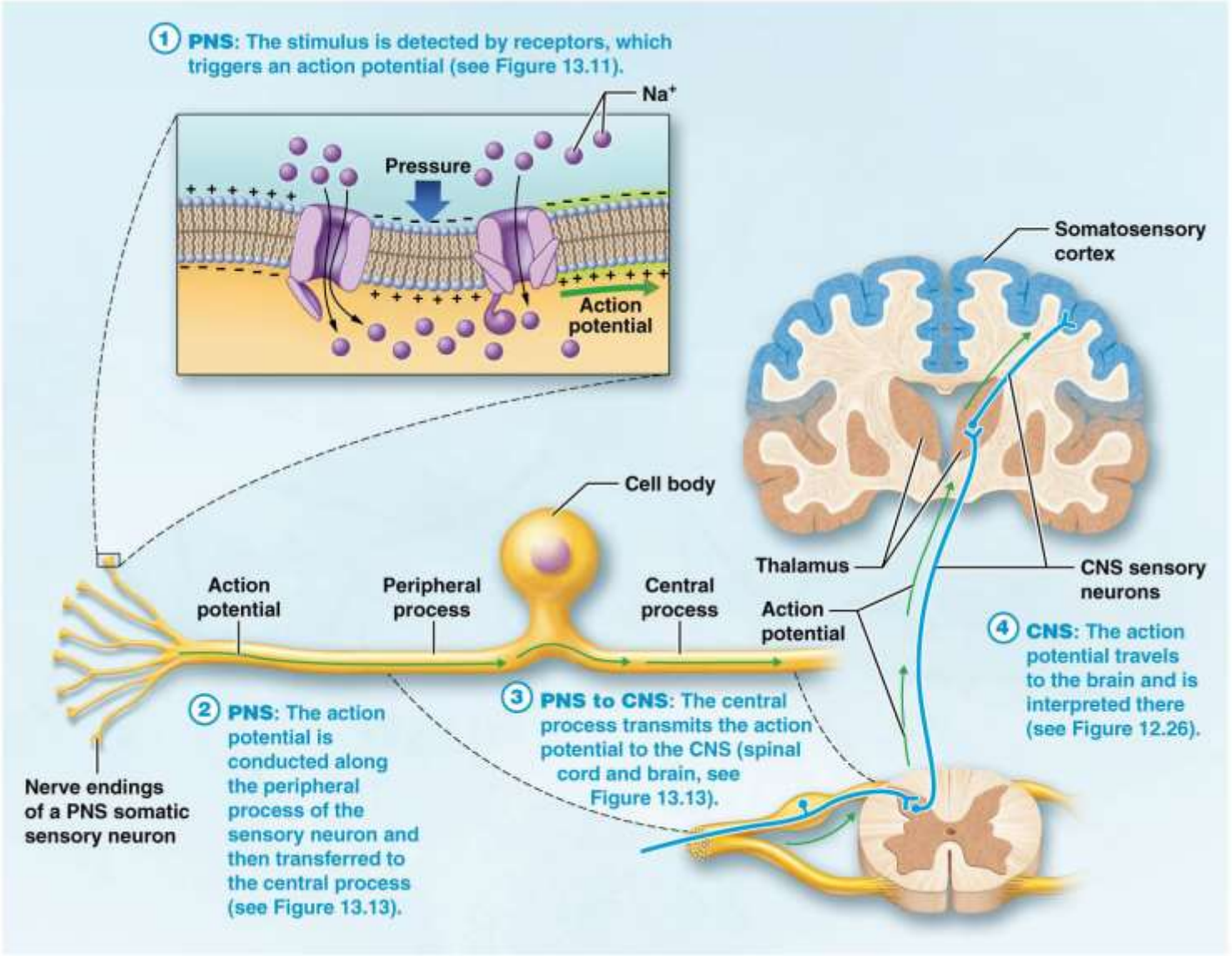
2. **Lamellar(Pacinian) corpuscles:**
   - Schwann cells surrounded by CT
   - Deep connective tissue of body
   - Sensitive to deep pressure



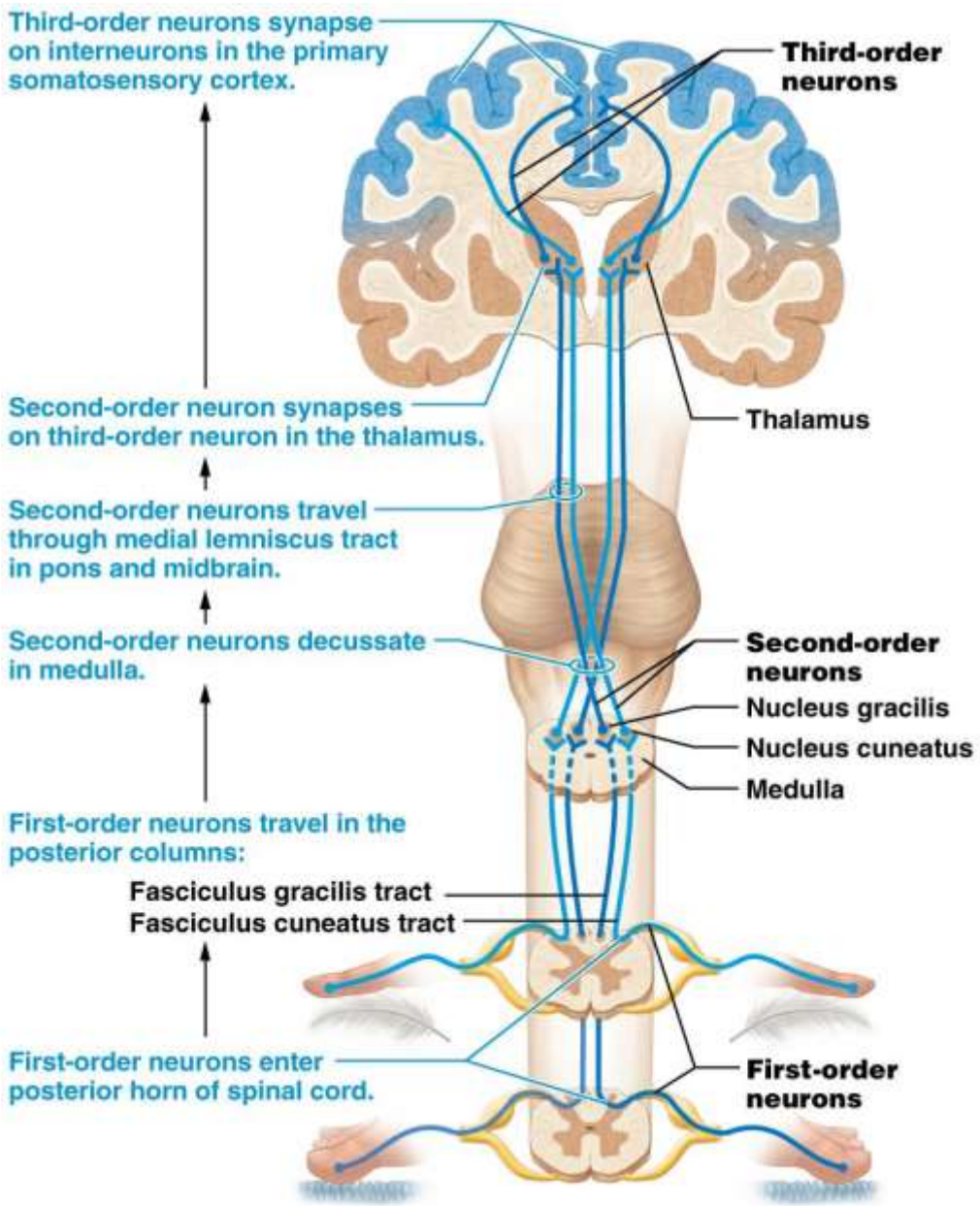
3. **Muscle spindles:**
   - Measure change of muscle length during contraction and relaxation
   - Embedded between clusters of skeletal muscle cells

The Big Picture

Detection and Interpretation of Somatic Sensation



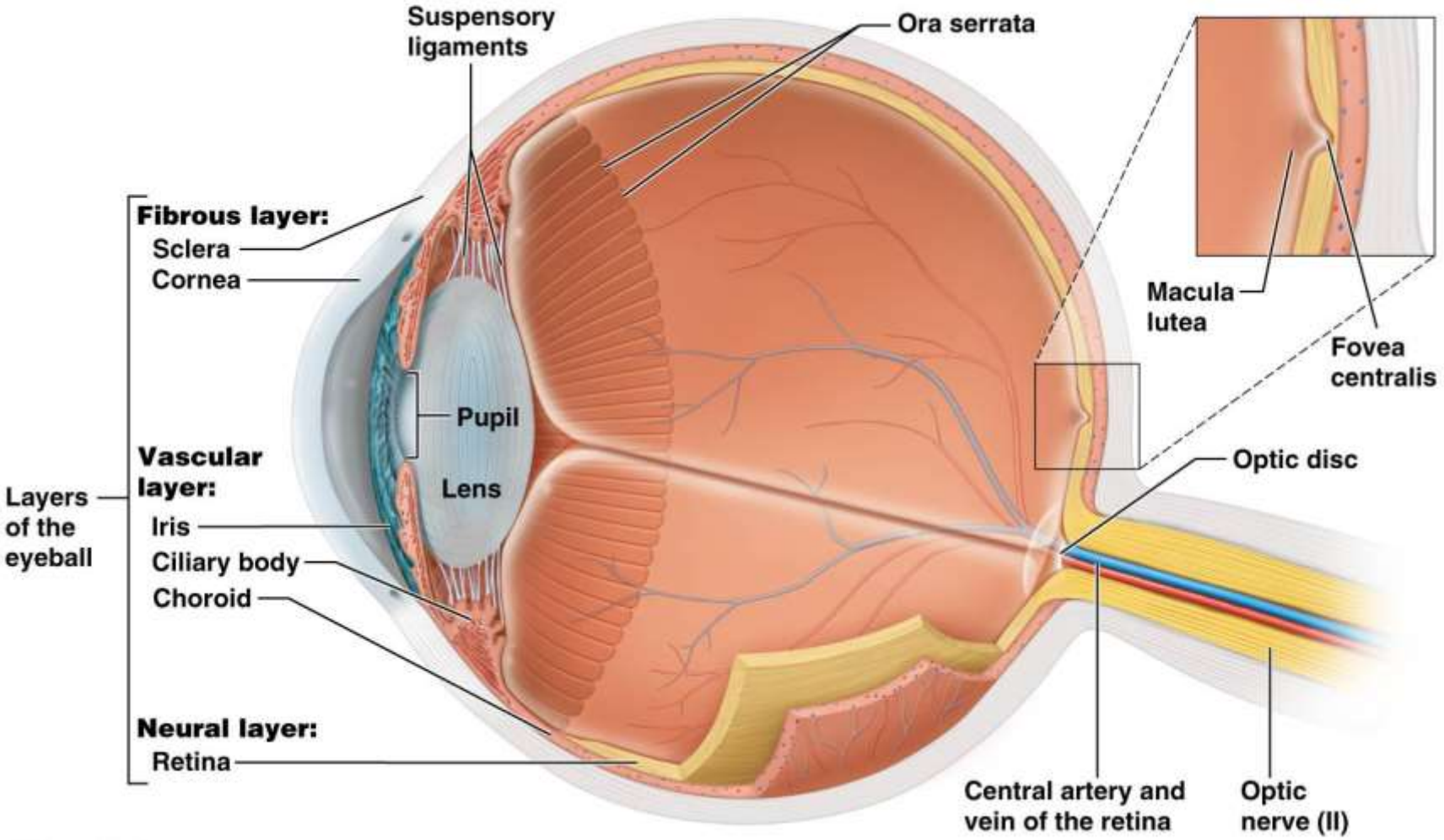
General Somatic Senses



2. Special Senses

- Special senses of body include:
  - **Eyeball** – hollow sphere; consists of an outer wall that surrounds several chambers and supports **lens** (focuses light as it enters eye)
  - **Ear** – anatomical structure associated with sense of **hearing**; only the inner ear is associated with **vestibular sense**, or equilibrium
  - **Taste buds** - small clusters of receptor cells and supporting cells scattered about tongue and other surfaces of oral cavity (involves chemoreceptors that are stimulated by various chemicals)
  - **Olfactory epithelium** - small region of specialized cells in superior nasal cavity; **chemoreceptors** that detect chemical substances perceived as odors

Anatomy of the Eyeball



Internal Chambers, Fluids and the Lens

Anterior segment: contains aqueous humor

- Blood from capillaries in ciliary processes create the aqueous humor

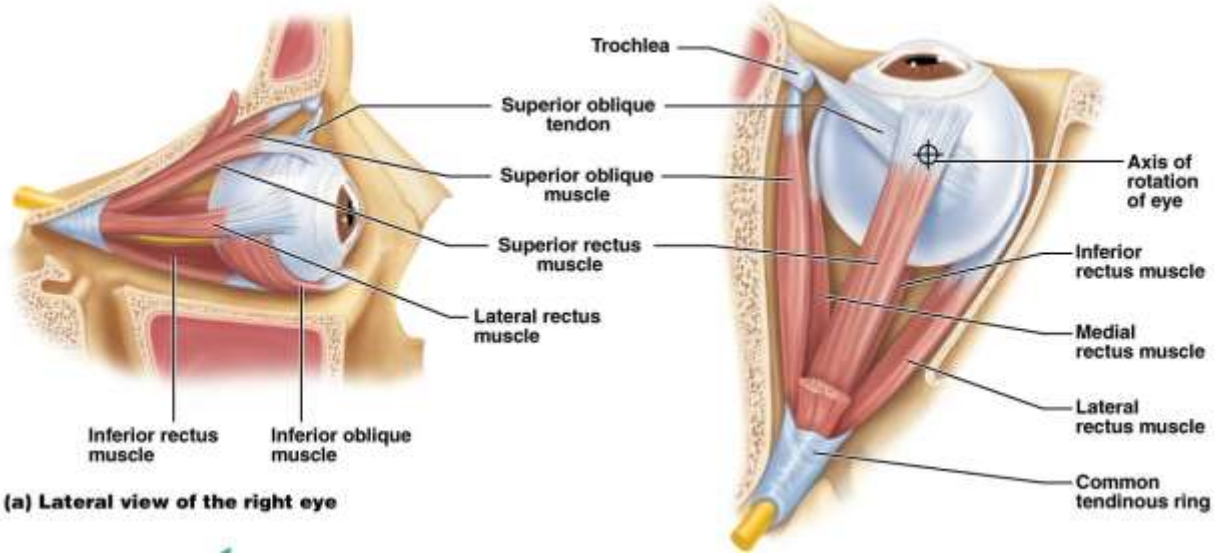
Posterior segment : contains vitreous humor

- Holds neural layer of retina firmly against the pigmented layer
- Contributes to intraocular pressure

Lens: a thick transparent, biconvex disc that changes shape to allow focusing of the light on the retina

Fibrous Tunic

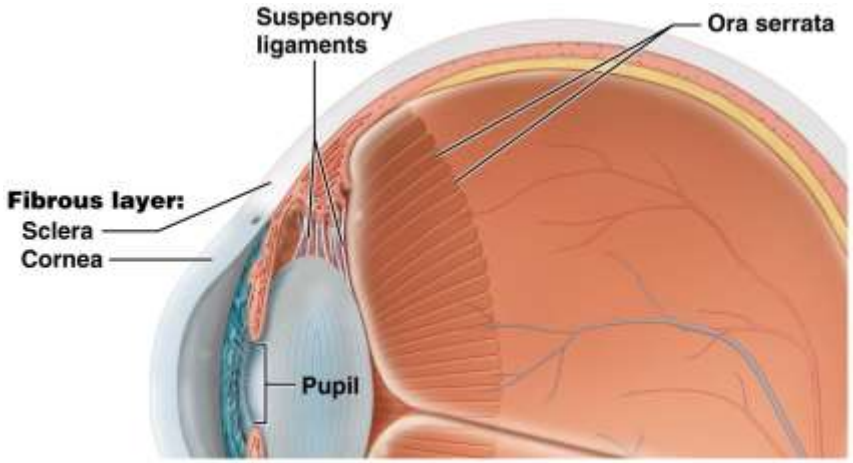
1. **Sclera**: Outer dense connective tissue.
   - Protects & shapes the eyeball
   - Anchors extrinsic muscles
     - **Lateral rectus** and **Medial rectus**
     - **Superior rectus** and **Inferior rectus**
     - **Superior oblique** and **Inferior oblique**
2. **Cornea:** transparent layer that allows for light to enter and bend
   - Avascular (oxygen from air, nutrients from aqueous humor)
   - Innervated with nerves, especially pain receptors

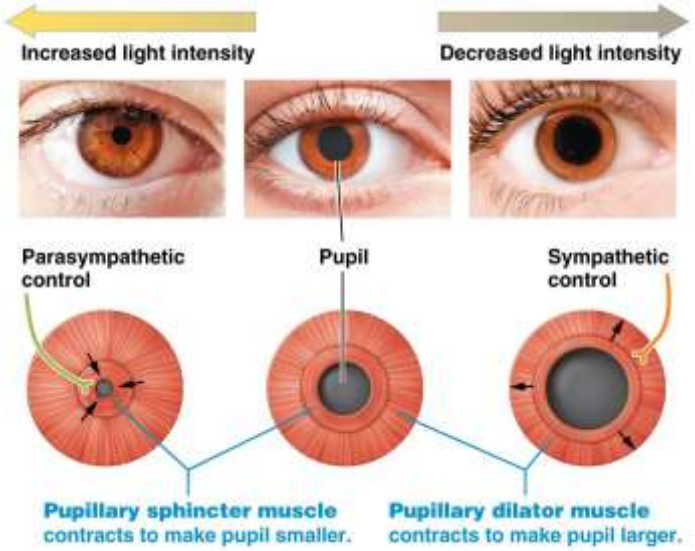


Vascular tunic

1. Choroid – Middle, vascularized and pigmented layer
   - Dark pigment due to melanin → traps light, prevent it from scattering
2. Iris – two smooth muscle layers continuous with the ciliary body
   - Circular: constriction of pupil (relax, digestion)
   - Radial: dilation of pupil (fight or flight response)

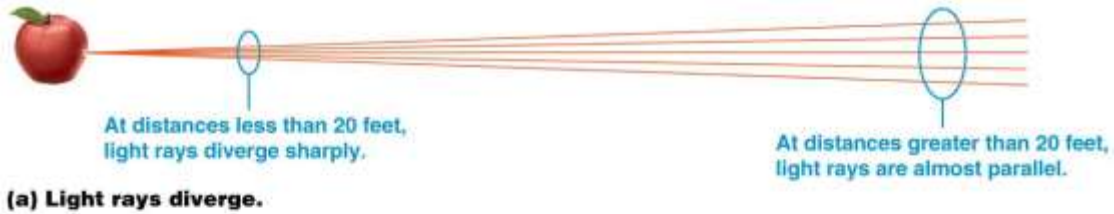
- **Pupil** - central opening that regulates amount of light entering the eye



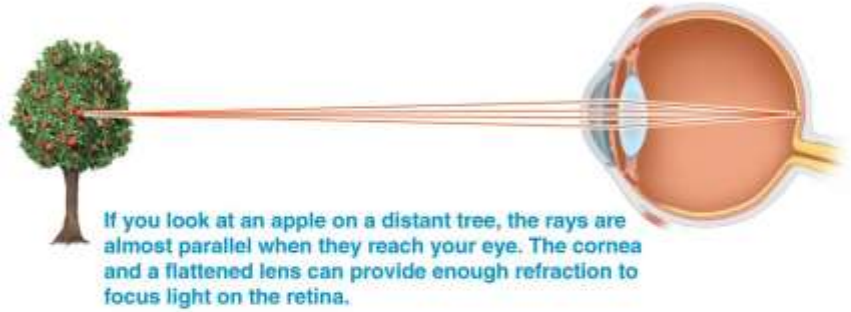


Vascular tunic

3. Ciliary body- Smooth muscles that anchor the lens by suspensory ligaments
   - » Adjusts the lens shape with the help of suspensory ligaments

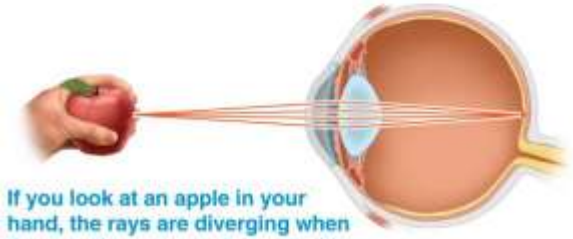


(a) Light rays diverge.



(b) The lens flattens for distant vision.

- tightening of suspensory ligaments → extends lens → see objects in distance



(c) The lens "rounds up" for near vision.

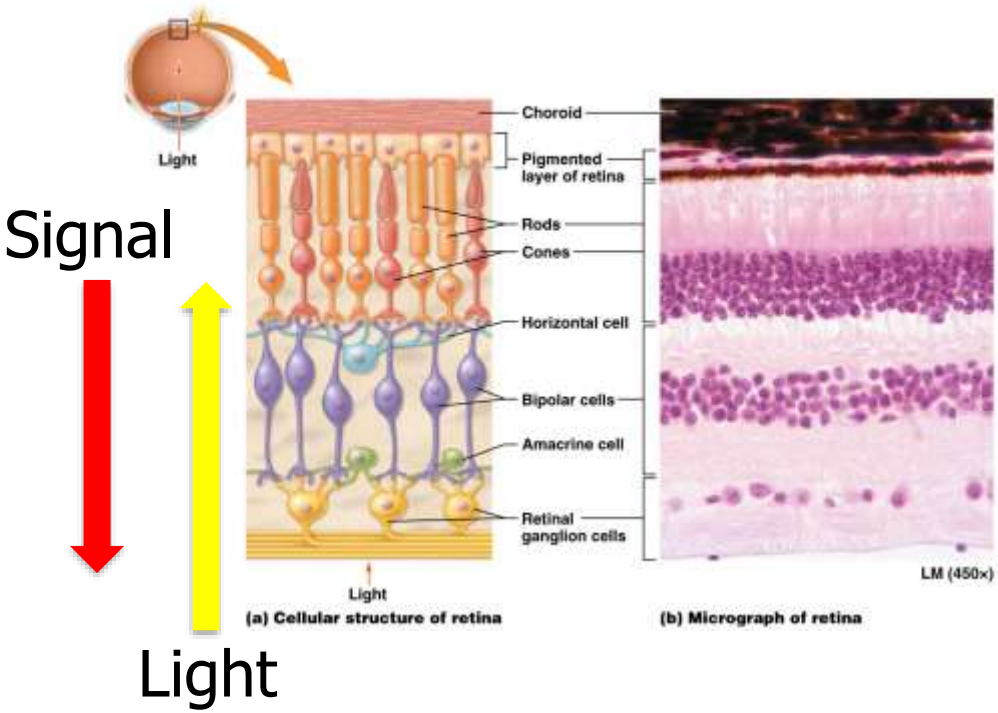
- slacken suspensory ligament → rounded appearance of lens → see objects up close

Sensory Tunic - Retina

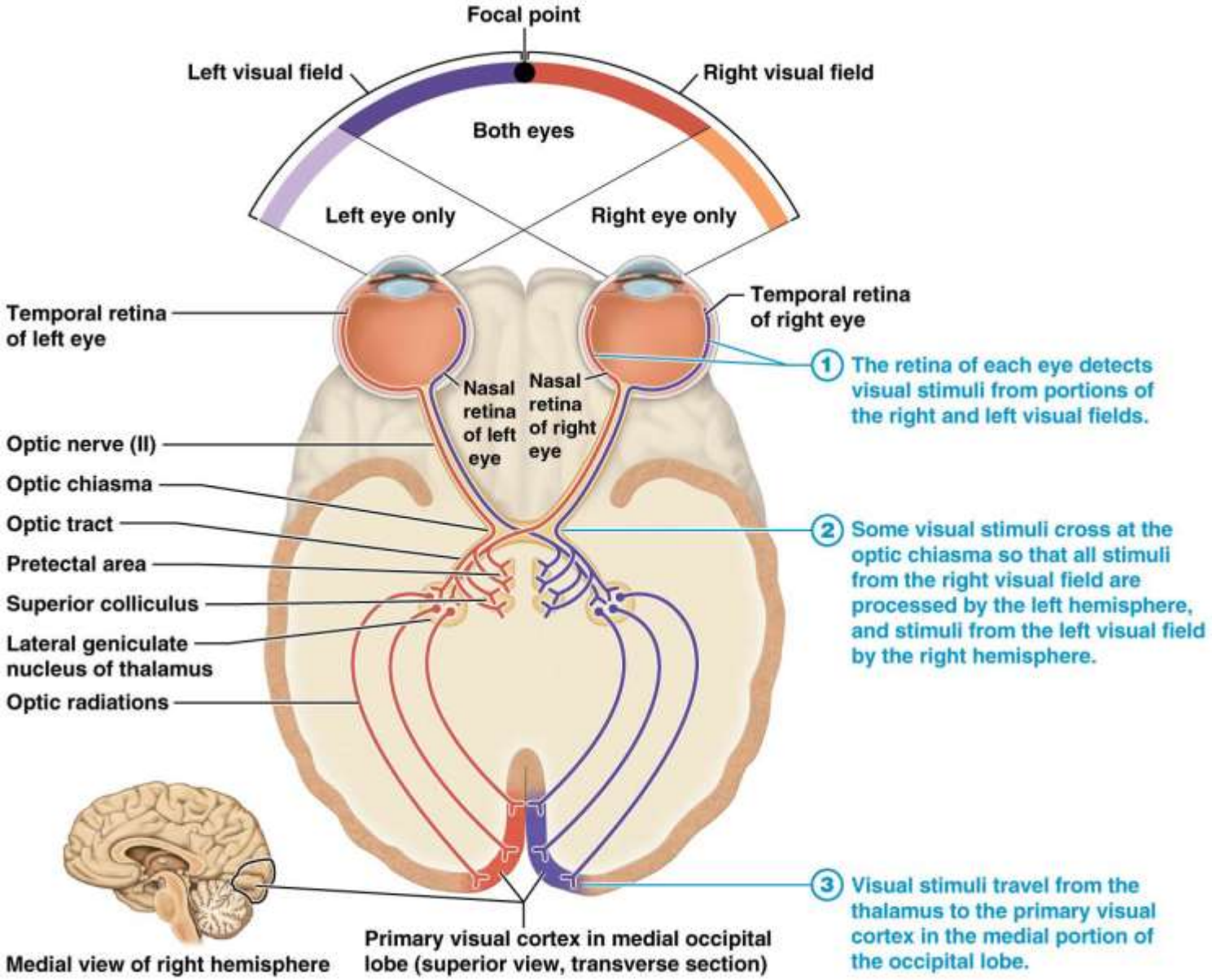
- **Photoreceptors**
  1. **Cones** = work best in bright light, high quality colored visions (blue, red, green light sensitivity)
  2. **Rods** = more sensitive to light, vision in the dim light

- **Bipolar cells**: transmit signals from cones and rods to Ganglion cells

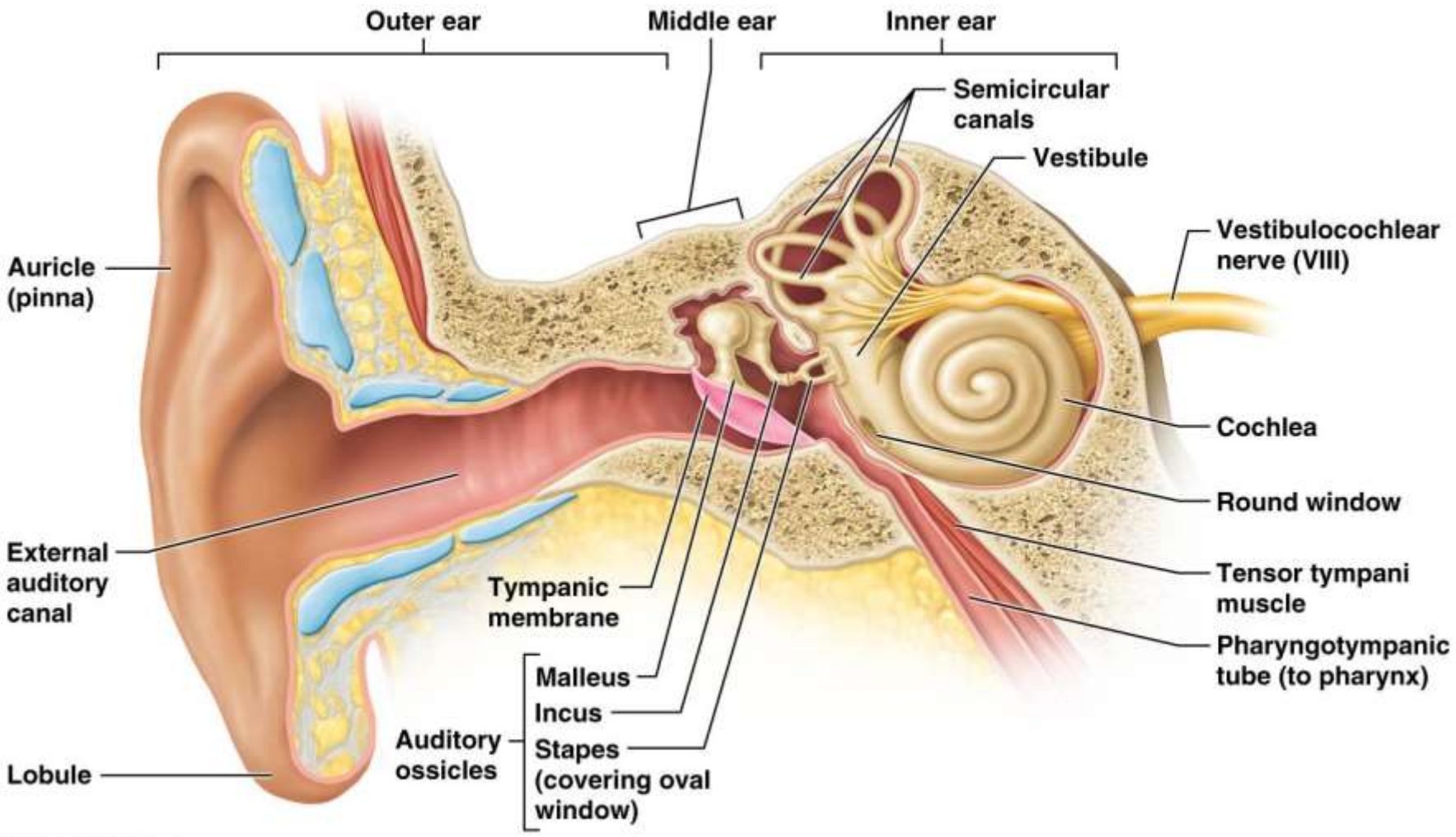
- **Ganglion cells**: most internal; face vitreous humor, axons join together to form optic nerve. Collect signals from bipolar cells



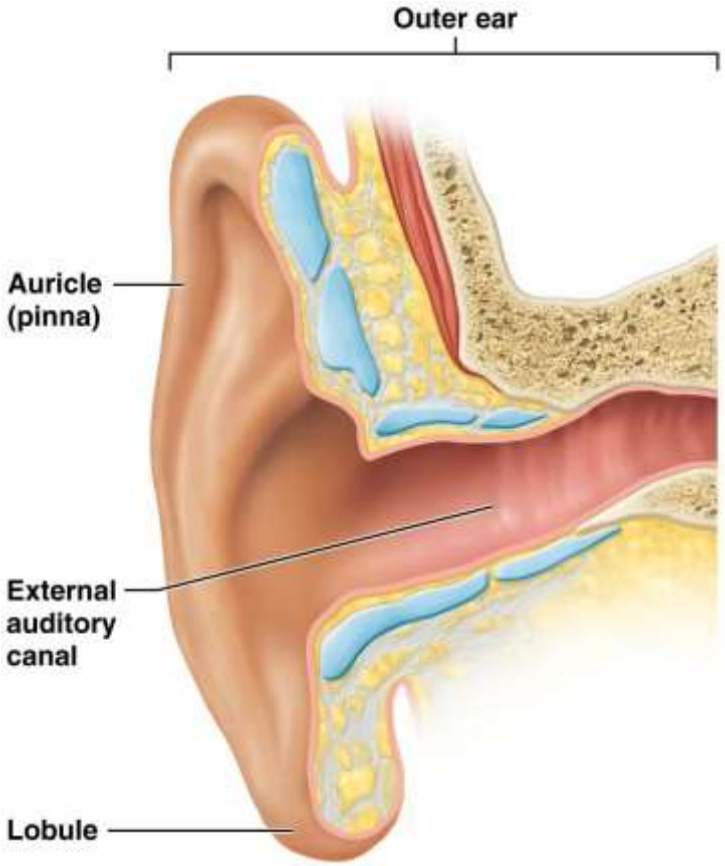
The Visual Pathway



Anatomy of the Ear



Anatomy of the Ear



Outer ear

- Auricle (Pinna): functions to funnel sound waves into auditory canal
- External acoustic meatus (auditory canal): Transmits sound waves to eardrum
- Tympanic membrane (eardrum):
  - Separates outer from middle ear
  - Shaped like a flattened cone
  - Transmits air vibrations to auditory ossicles

Anatomy of the Ear

Middle Ear

- Ossicles:
  - Transmit sound from external ear to internal ear.
  - Composed of smallest bones in the body
    - Malleus (hammer) - attaches to the eardrum
    - Incus (anvil) - between the malleus and stapes
    - Stapes (stirrup) - vibrates against the oval window

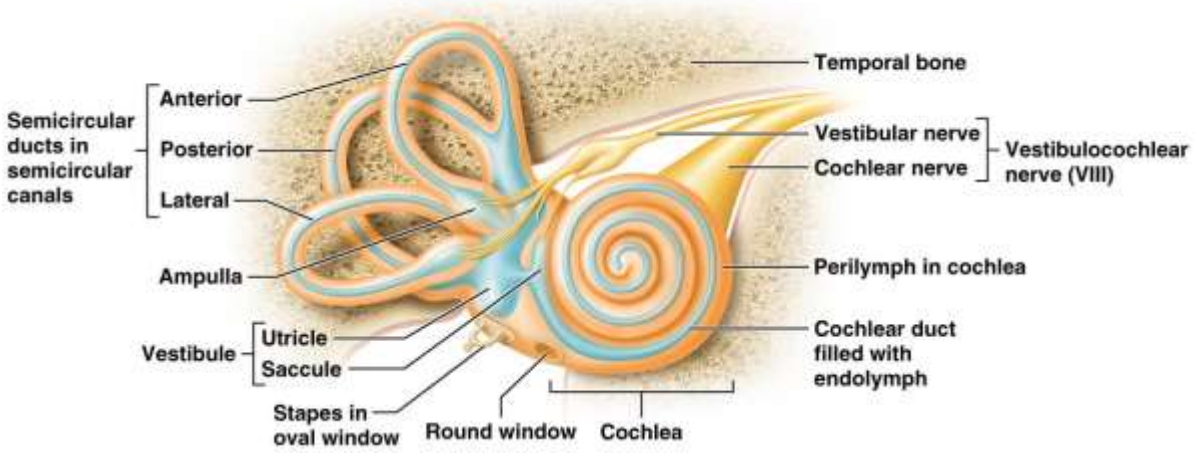
- Round window: Dissipates left-over energy in cochlea

- Auditory (Pharyngotympanic) tube: Equalizes air pressure in the middle ear with external air pressure

Anatomy of the Ear

Inner Ear

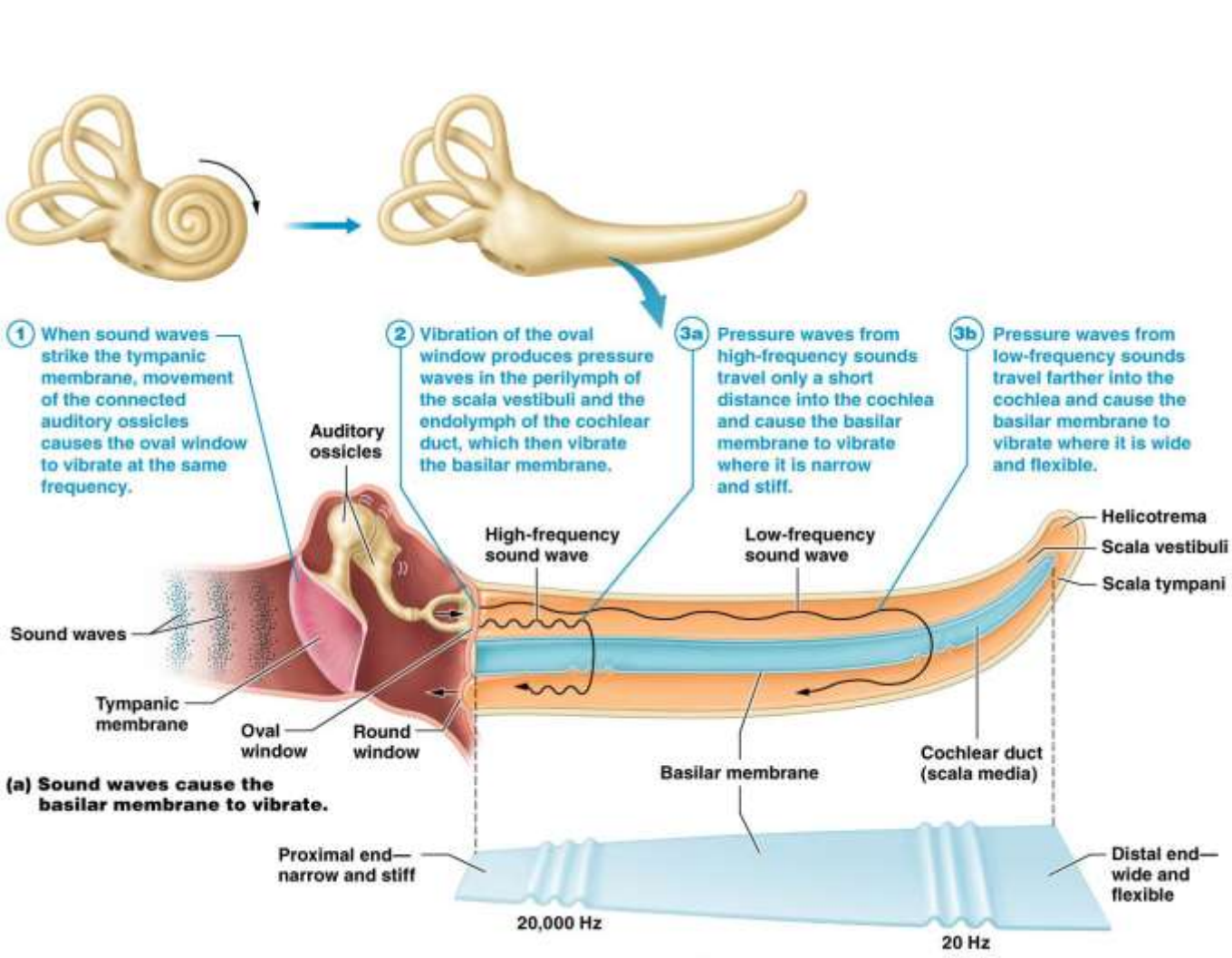
- Found in the temporal bone behind the eye socket
  - Vestibule - Central egg-shaped cavity
    - Respond to changes in the position of the head with respect to gravity
  - Semicircular canals
    - Lined with membranous ducts
      - Contains equilibrium receptors that respond to angular (rotational) movements of the head.

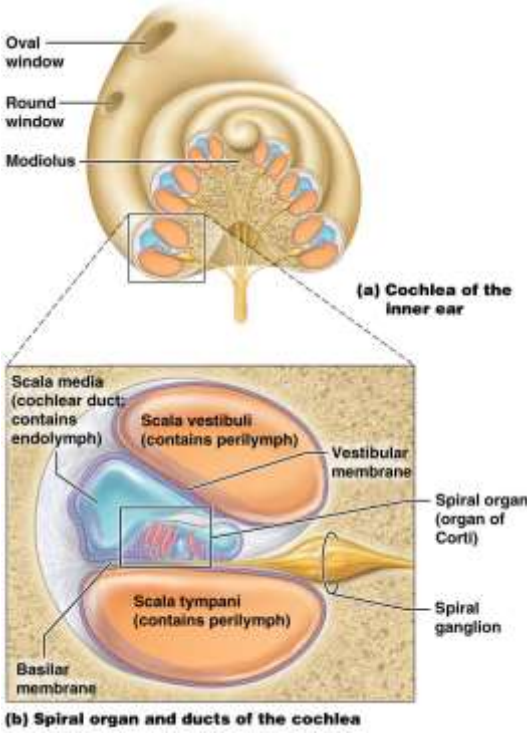


Anatomy of the Ear

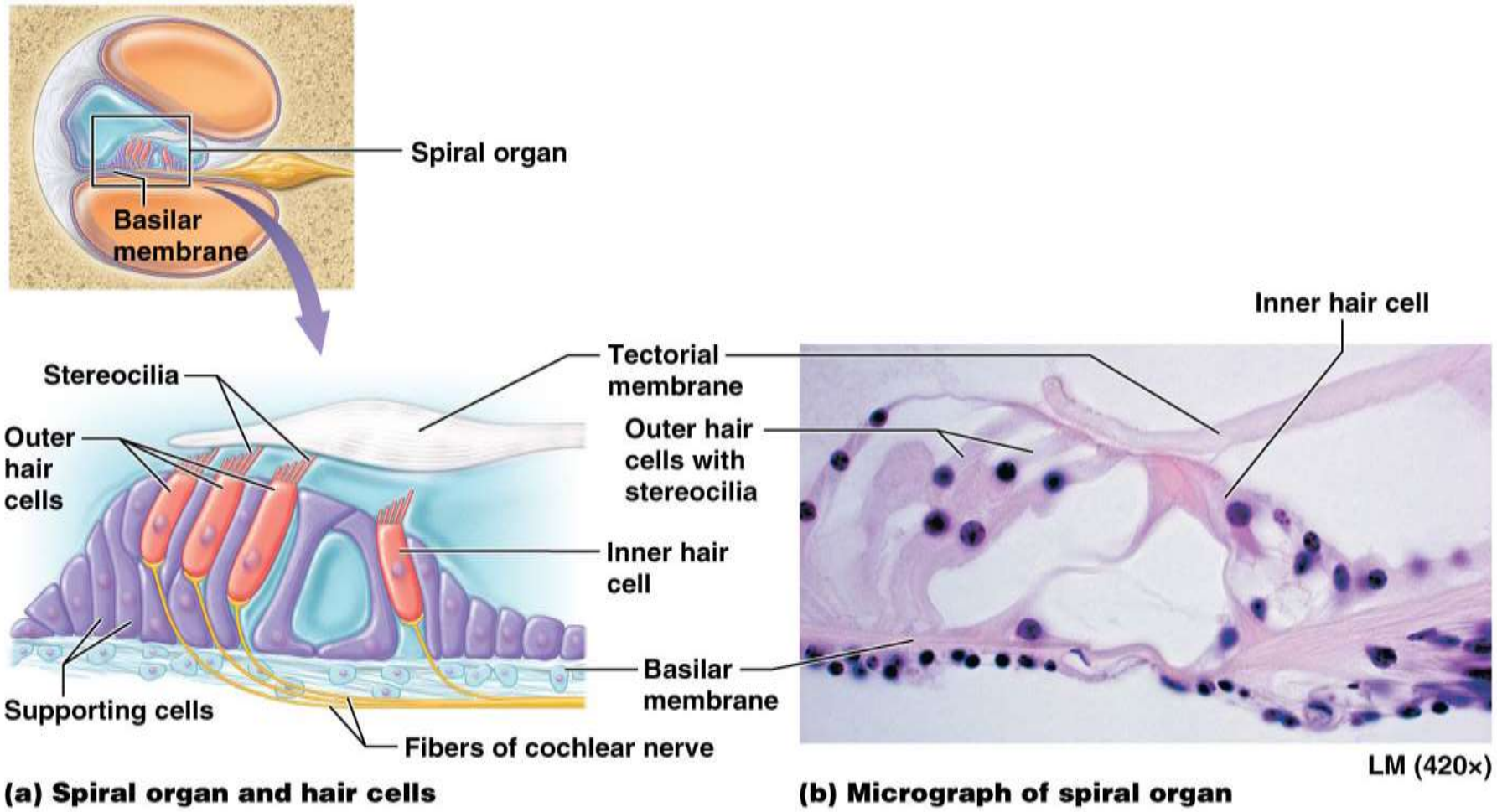
Inner Ear

- Found in the temporal bone behind the eye socket
  - Cochlea – Spiral, conical, bony chamber
  - Three fluid filled chambers
    1. Scala vestibuli: Starts from oval window, contains perilymph
    2. Scala tympani: Merge onto round window, contains perilymph
    3. Scala media (cochlear duct): contains endolymph
       - Contain cochlear hair cells that converts sound waves to nerve impulses
       - The cochlear branch of nerve VIII runs from spiral organ to brain

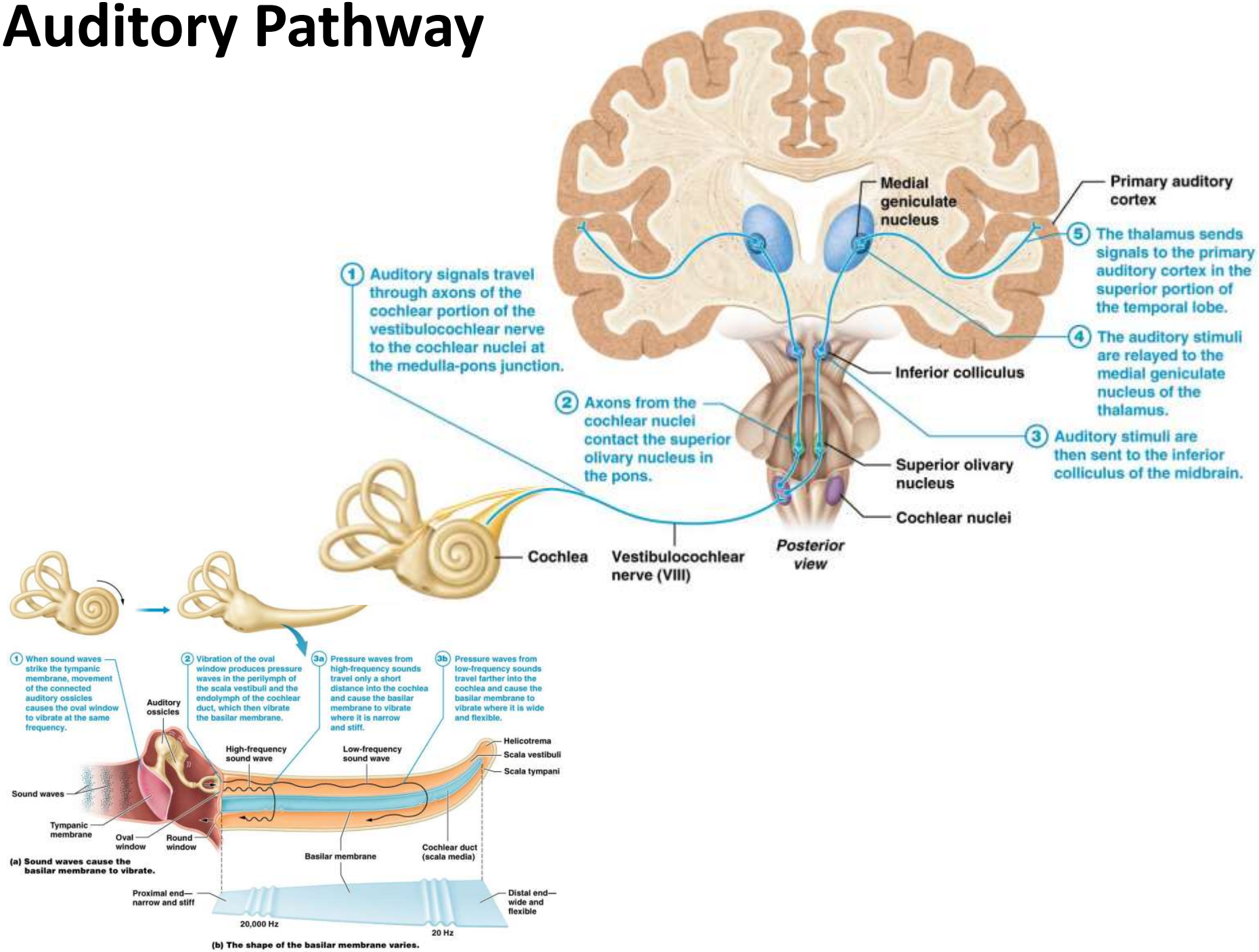

1 When sound waves strike the tympanic membrane, movement of the connected auditory ossicles causes the oval window to vibrate at the same frequency.
2 Vibration of the oval window produces pressure waves in the perilymph of the scala vestibuli and the endolymph of the cochlear duct, which then vibrate the basilar membrane.
3a Pressure waves from high-frequency sounds travel only a short distance into the cochlea and cause the basilar membrane to vibrate where it is narrow and stiff.
3b Pressure waves from low-frequency sounds travel farther into the cochlea and cause the basilar membrane to vibrate where it is wide and flexible.
Auditory ossicles
High-frequency sound wave
Low-frequency sound wave
Helicotrema
Scala vestibuli
Scala tympani
Sound waves
Tympanic membrane
Oval window
Round window
Basilar membrane
Cochlear duct (scala media)
Proximal end— narrow and stiff
Distal end— wide and flexible
20,000 Hz
20 Hz
(a) Sound waves cause the basilar membrane to vibrate.
(b) The shape of the basilar membrane varies.


Oval window
Round window
Modiolus
(a) Cochlea of the inner ear
Scala media (cochlear duct; contains endolymph)
Scala vestibuli (contains perilymph)
Vestibular membrane
Spiral organ (organ of Corti)
Scala tympani (contains perilymph)
Spiral ganglion
Basilar membrane
(b) Spiral organ and ducts of the cochlea

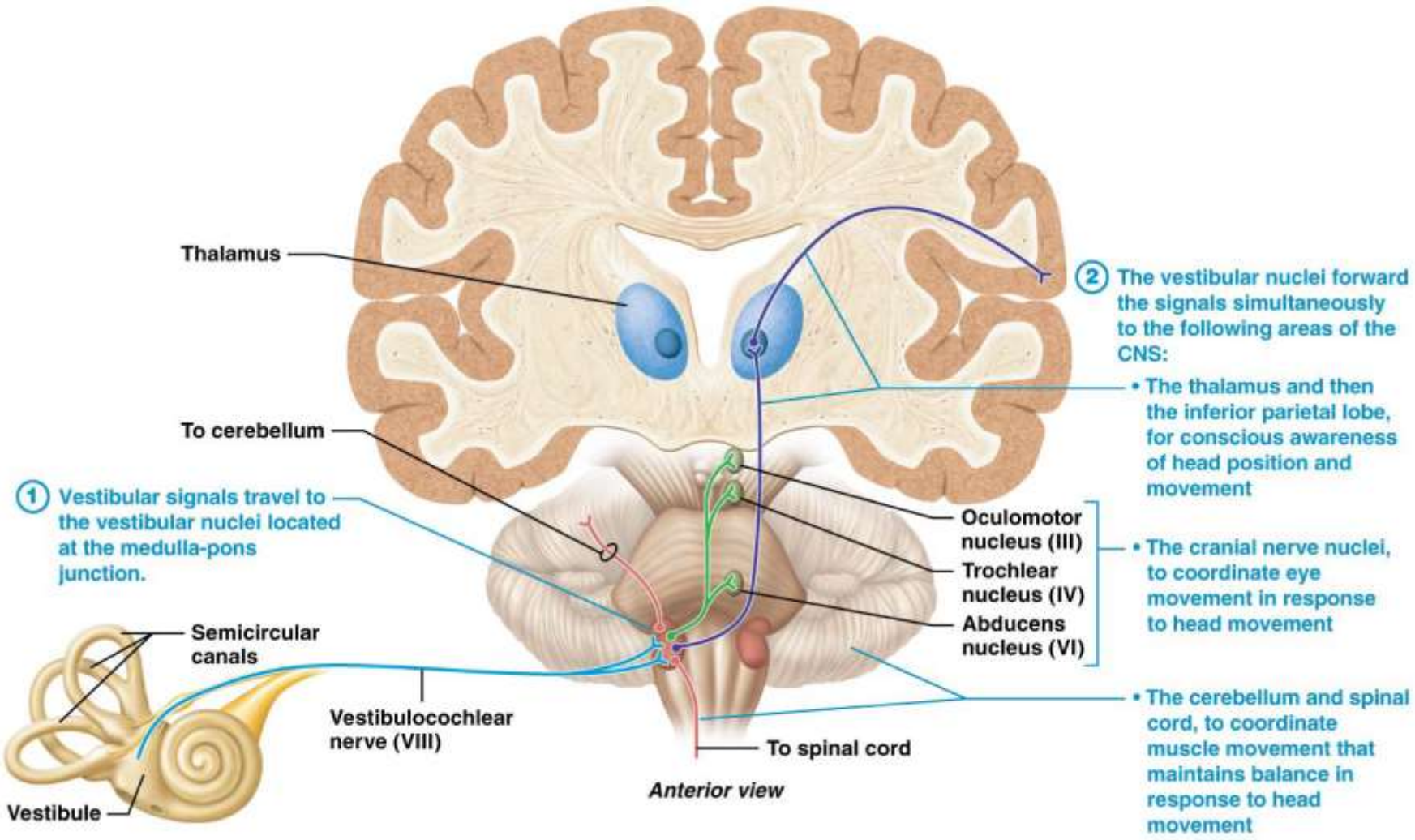
Anatomy of the cochlea.



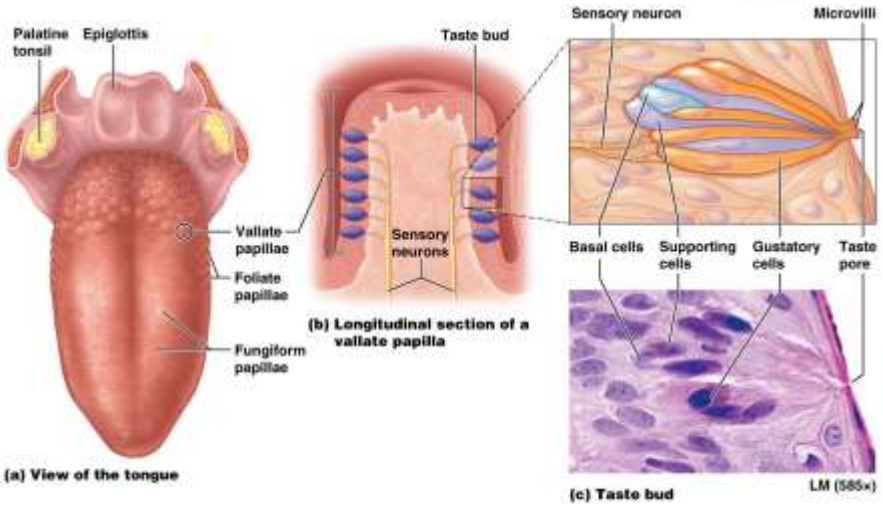
Auditory Pathway

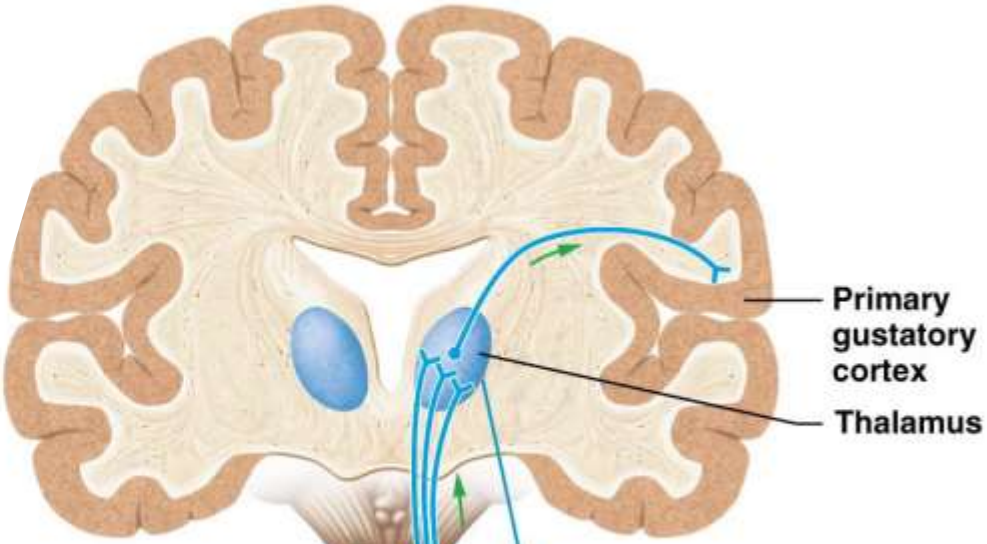


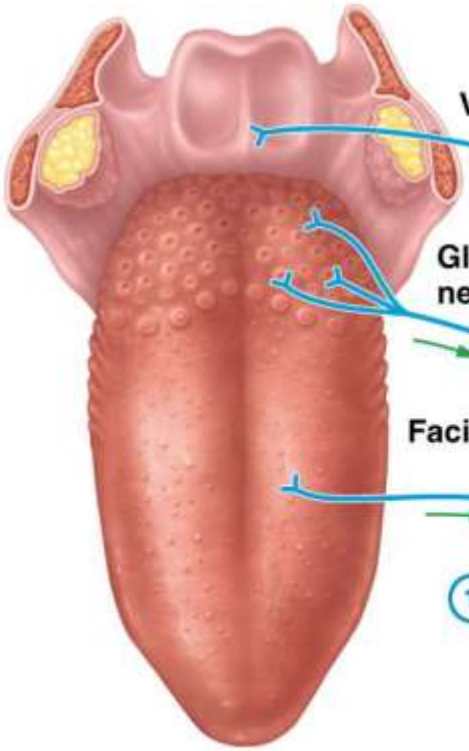
Vestibular Sensation Pathway



Anatomy and Pathway of Gustation







Vagus nerve (X)

Glossopharyngeal nerve (IX)

Facial nerve (VII)

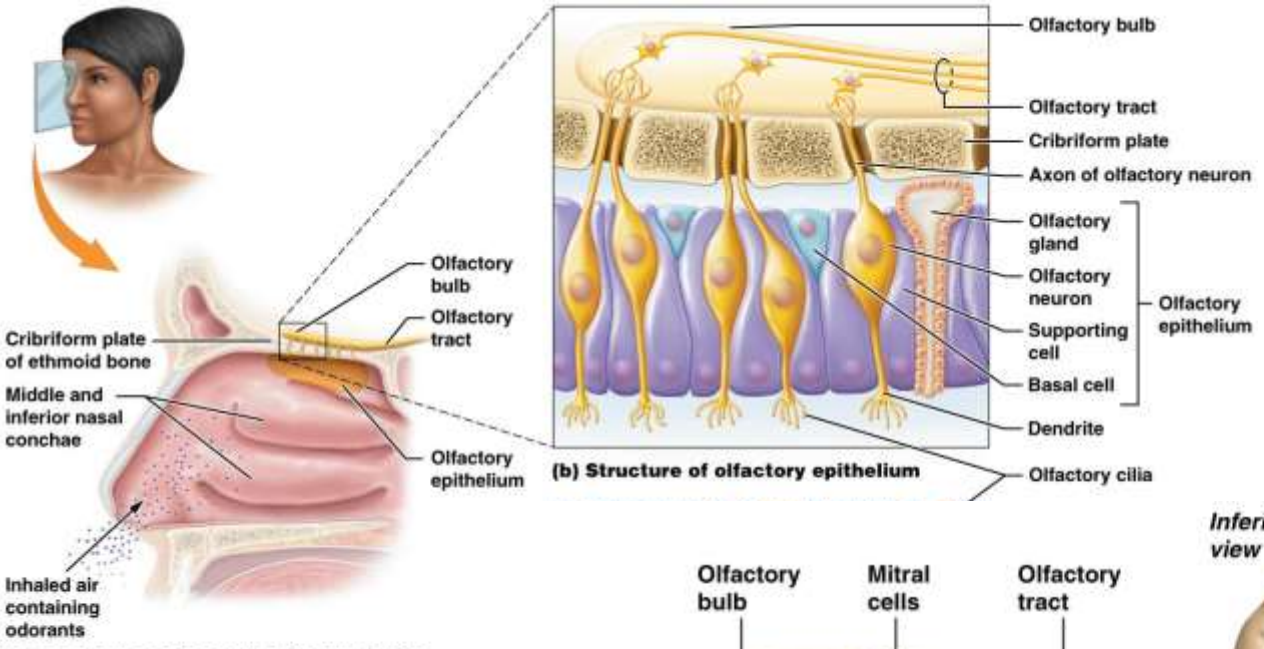
Solitary nucleus in medulla

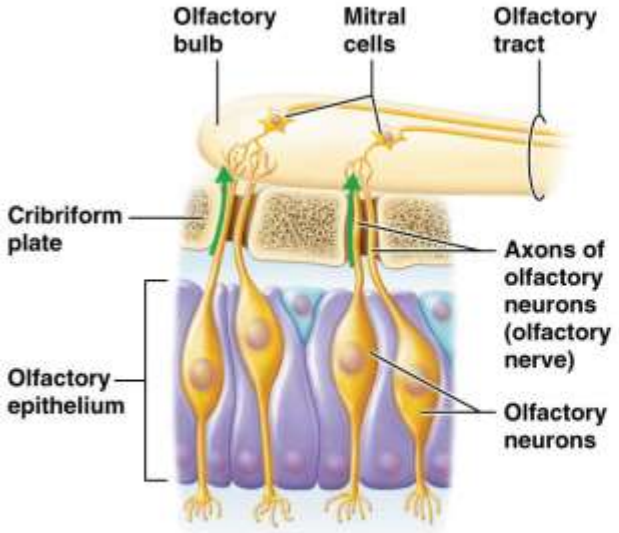
3 Axons from the solitary nucleus synapse on neurons in the thalamus, which then send the taste signals to the primary gustatory cortex in the parietal lobe.

2 Axons of these three nerves terminate in the solitary nucleus in the medulla oblongata by synapsing on central sensory neurons.

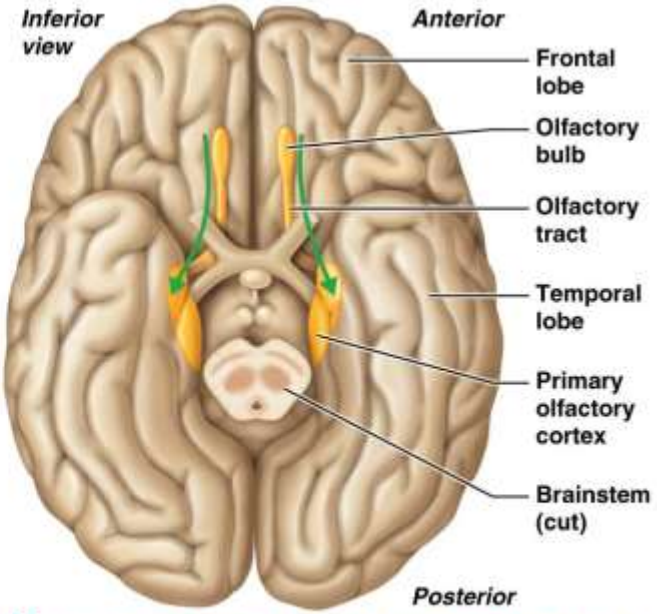
1 Axons of the facial, glossopharyngeal, and vagus nerves carry taste stimuli from the tongue into the CNS.

Anatomy and Pathway of Olfaction





(1) The axons of olfactory neurons (making up the olfactory nerve) carry olfactory stimuli to the olfactory bulb in the CNS.



(2) An olfactory stimulus travels from the olfactory bulb to the primary olfactory cortex in the temporal lobe.