

SPECIAL SENSES

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Sensory Receptors

- Receptor potential
 - The potential that develops when an adequate stimulus acts on a receptor
 - Impulses travel over sensory pathways to the brain and spinal cord
- Adaptation
 - Receptor potential decreases over time in response to a continuous stimulus, which leads to decreased intensity of sensation

Sensory Receptors

- Sensory receptors allow the body to respond to stimuli caused by changes in our internal or external environment
- Receptor response
 - General function: responds to stimuli by converting them to nerve impulses
 - Different types of receptors respond to different stimuli

Sensory Receptors

- Distributions of receptors
 - Receptors for **special senses** of smell, taste, vision, hearing, and equilibrium are grouped into localized areas or complex organs
 - **General sense** organs of somatic senses are microscopic receptors widely distributed throughout the body in the skin, mucosa, connective tissue, muscles, tendons, joints, and viscera

Types of Senses

- **General senses**
 - receptors over large part of body
 - **somatic** provide info. about body and environment
 - **visceral** provide info. about internal organs, pain, pressure
 - touch, pressure, pain, temp., and itch
- **Special senses**
smell, taste, sight, hearing, and balance

Classification of Receptors

- Classification by location
 - **Exteroceptors**
 - On or near body surface
 - Often called *cutaneous receptors* (e.g., pressure, touch, pain, temperature)
 - **Visceroceptors (interoceptors)**
 - Located internally, often within body organs, or viscera
 - Provide body with information about internal environment (e.g., pressure, stretch, chemical changes, hunger, thirst)
 - **Proprioceptors**: special type of visceroreceptor
 - Location limited to skeletal muscle, joint capsules, and tendons
 - Provide information on body movement, orientation in space, and muscle stretch

Classification of Receptors

- Classification by stimulus detected
 - **Mechanoreceptors**: activated when “deformed”
 - **Chemoreceptors**: activated by amount or changing concentration of certain chemicals (e.g., taste and smell)
 - **Thermoreceptors**: activated by changes in temperature
 - **Nociceptors**: activated by intense stimuli that may damage tissue; sensation produced in pain
 - **Photoreceptors**: found only in the eye; respond to light stimuli
 - **Osmoreceptors**: concentrated in the hypothalamus; activated by changes in concentration of electrolytes (osmolarity) in extracellular fluids

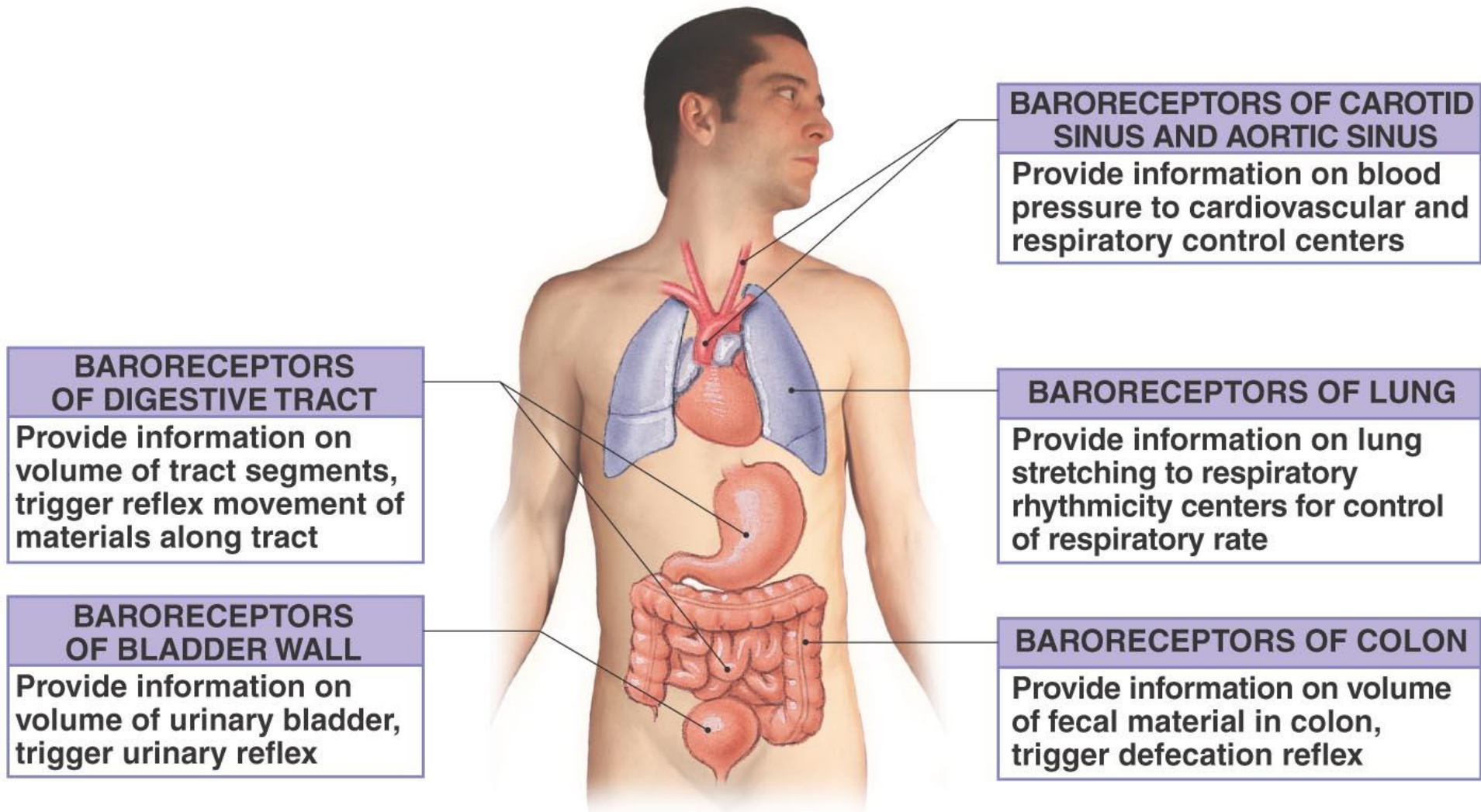


Fig 18.4 **Baroreceptors and the Regulation of Autonomic Functions**

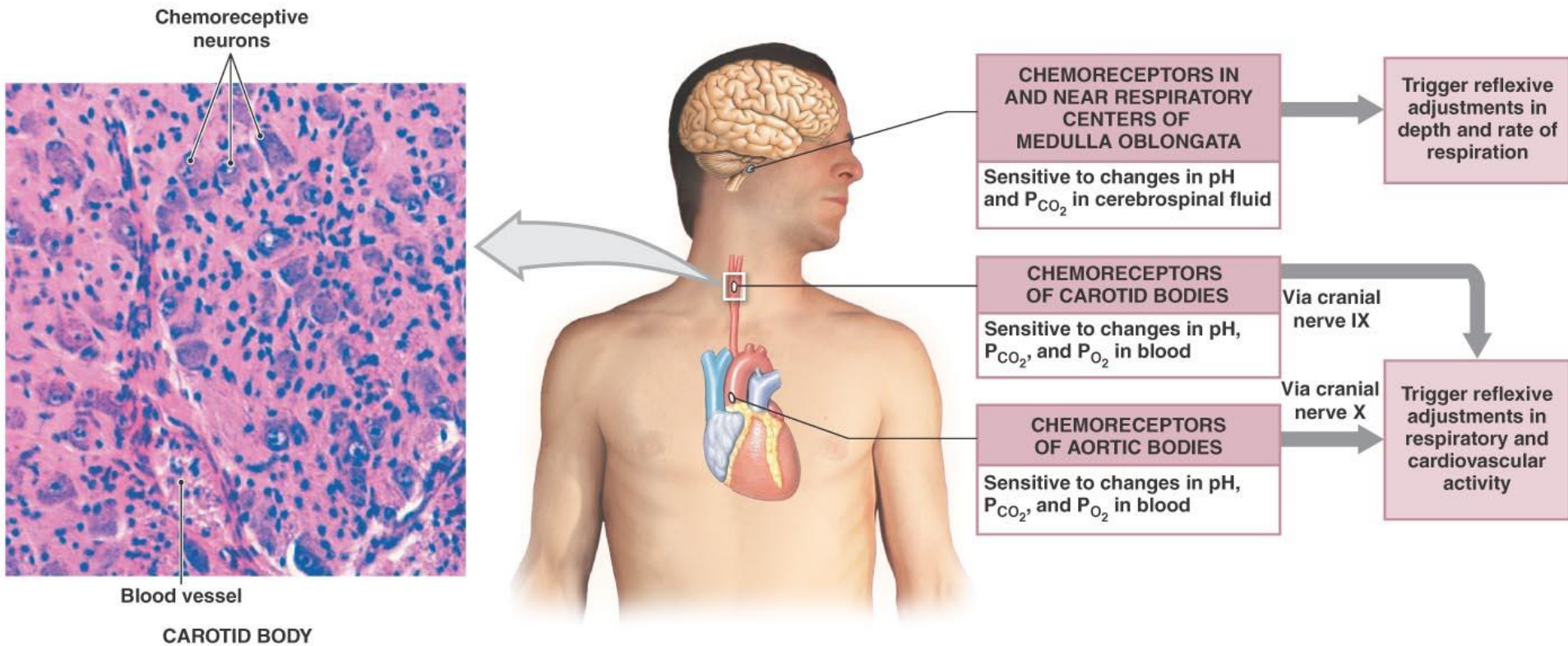
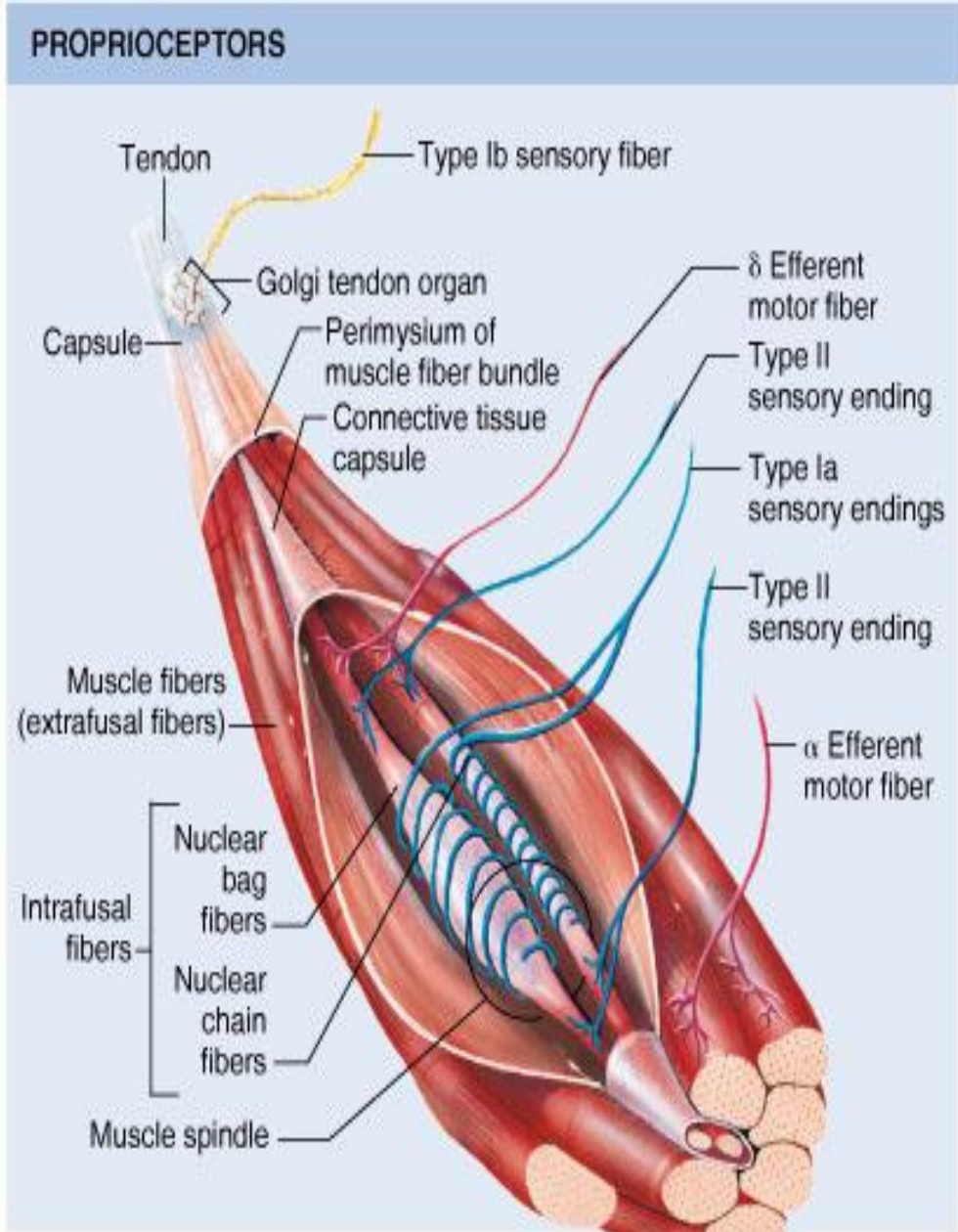
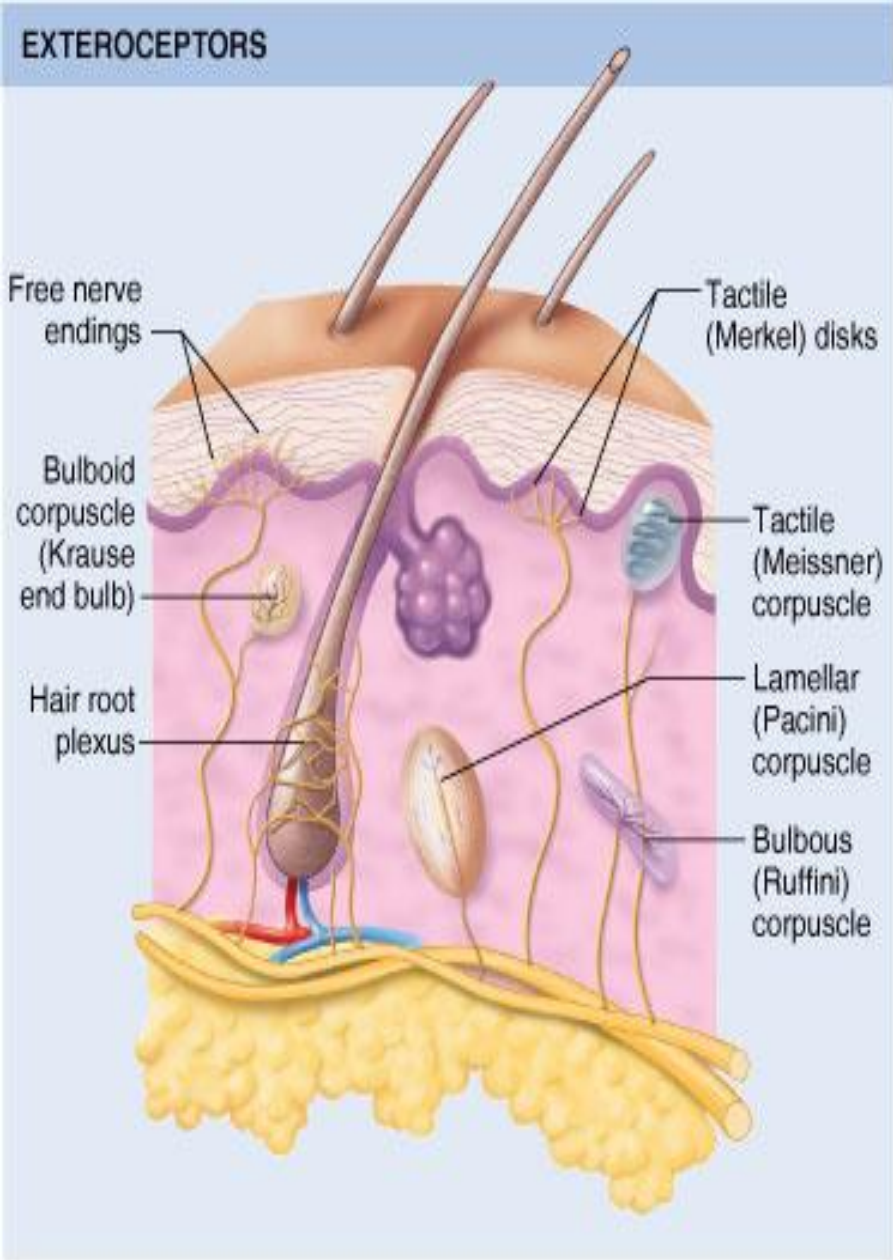


Figure 18.5

Chemoreceptors

Classification of Receptors

- Classification by structure: divides sensory receptors into those with free nerve endings or encapsulated nerve endings
 - Free nerve endings
 - Most widely distributed sensory receptor
 - Include both exteroceptors and visceroreceptors
 - Called *nociceptors*; primary receptors for pain
 - Primary receptors for heat and cold
 - Pain sensations
 - Acute fibers mediate sharp, intense, localized pain
 - Chronic fibers mediate less intense but more persistent dull or aching pain



A
Fig. 15-5. Somatic sensory receptors.

B

Types of Touch Receptors

- **Merkel's disk:**
detect light touch and pressure
- **Hair follicle receptors:**
detect light touch
- **Meissner corpuscle:**
 - deep in epidermis
 - localizing tactile sensations

- **Ruffini corpuscle:**
 - deep tactile receptors
 - detects continuous pressure in skin

- **Pacinian corpuscle:**
 - deepest receptors
 - associated with tendons and joints
 - detect deep pressure, vibration, position

Free nerve endings
(respond to painful
stimuli, temperature,
itch, or movement)

Merkel's disks
(detect light touch and
superficial pressure)

Hair follicle receptor
(detects light touch)

Hair

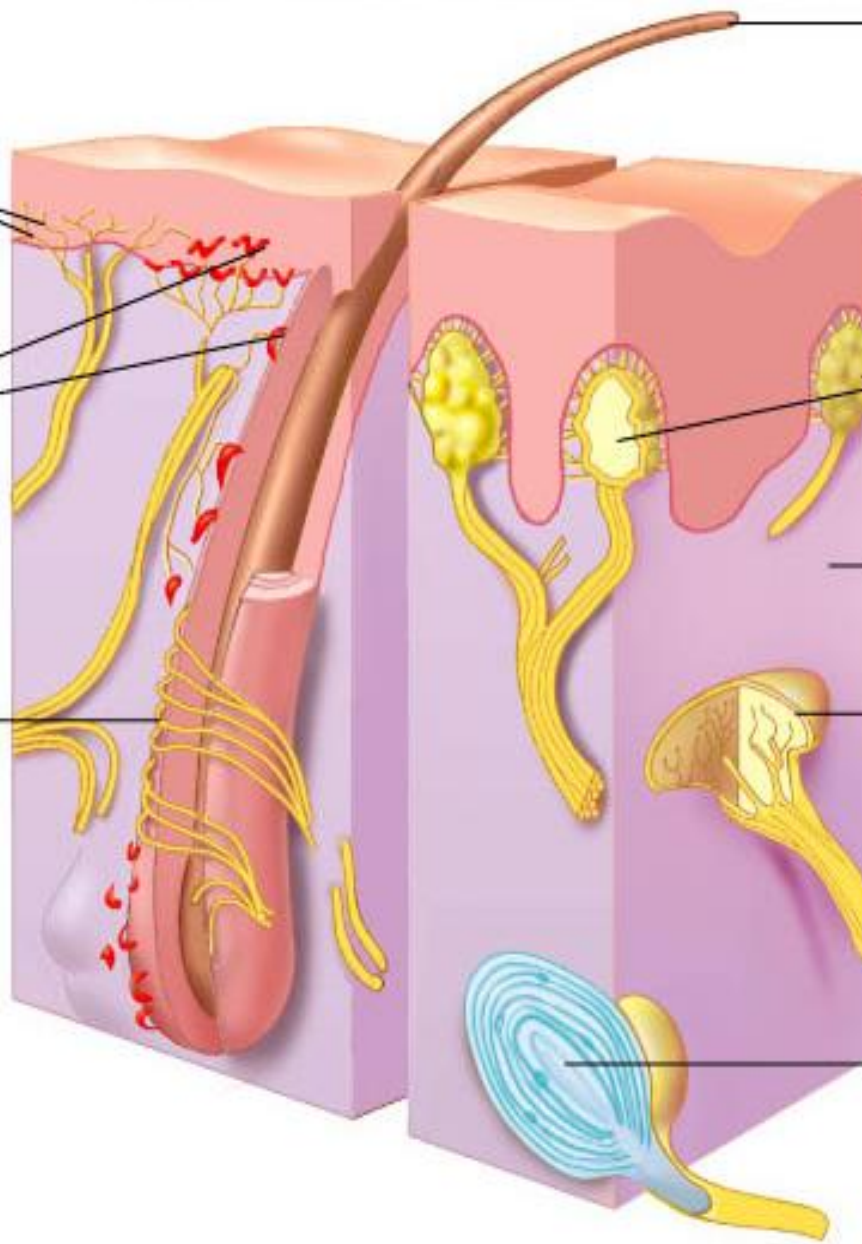
Epidermis

Meissner's corpuscles
(involved in fine, discriminative touch)

Dermis

Ruffini's end organ
(detects continuous touch or pressure)

Pacinian corpuscle
(detects deep pressure, vibration,
and position)



Pain

- **What is it?**
unpleasant perceptual and emotional
experience

Types of Pain

- **Localized:**
 - sharp, pricking, cutting pain
 - rapid action potential

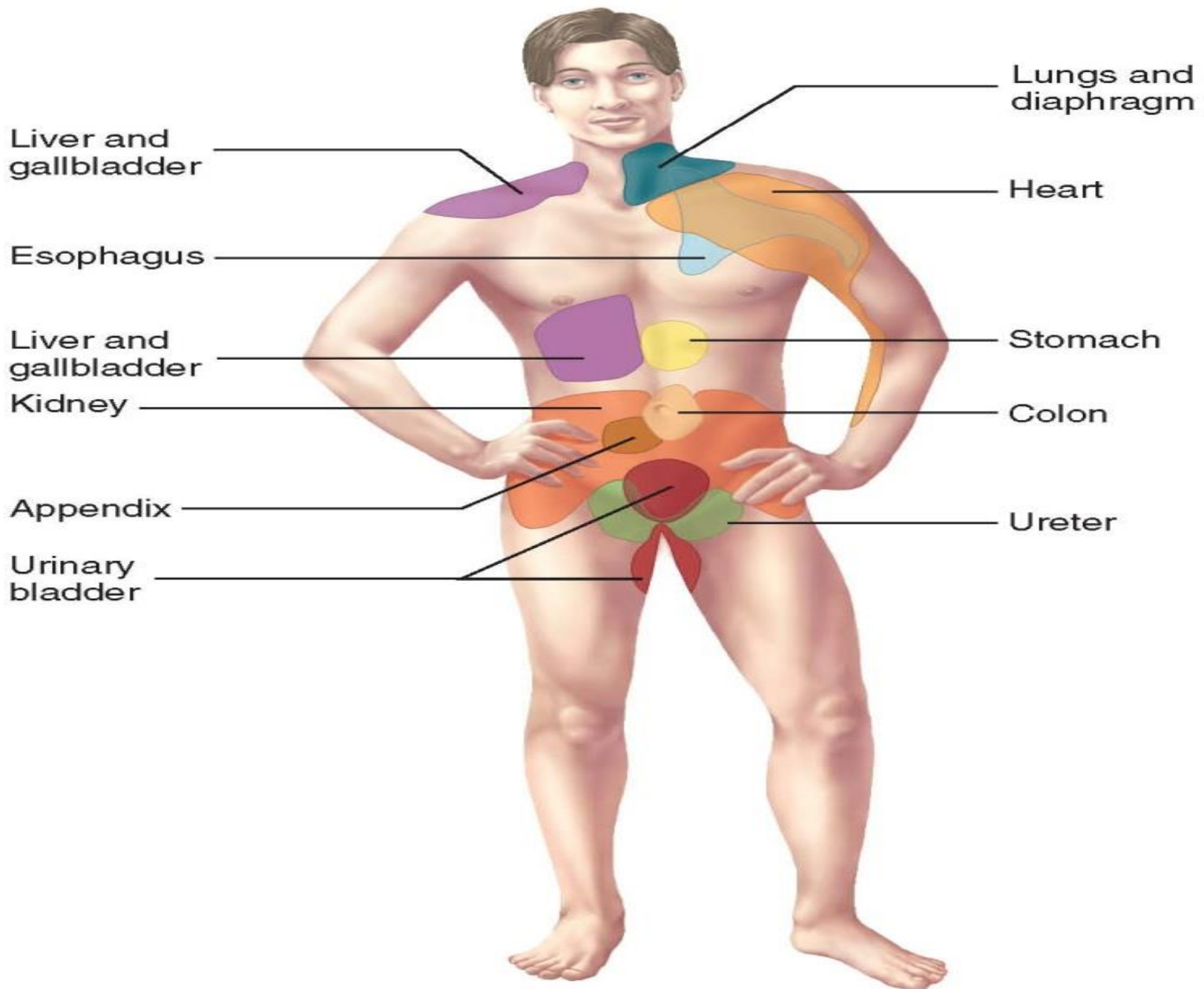
- **Diffuse:**
 - burning, aching pain
 - slower action potentials

Pain Control

- **Local anesthesia:**
 - action potentials suppressed from pain receptors in local areas
 - chemicals are injected near sensory nerve
- **General anesthesia:**
 - loss of consciousness
 - chemicals affect reticular formation

Referred Pain

- **What is it?**
 - originates in a region that is not source of pain stimulus
 - felt when internal organs are damaged or inflamed
 - sensory neurons from superficial area and neurons of source pain converge onto same ascending neurons of spinal cord



Liver and
gallbladder

Esophagus

Liver and
gallbladder

Kidney

Appendix

Urinary
bladder

Lungs and
diaphragm

Heart

Stomach

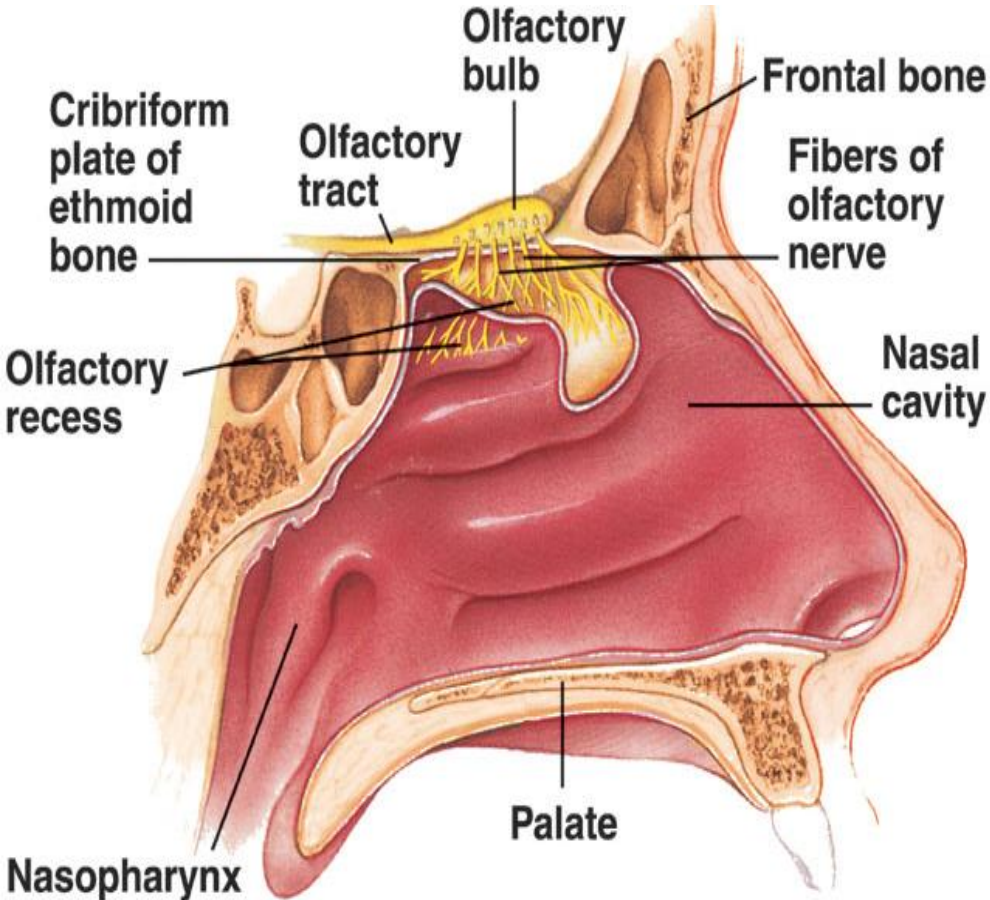
Colon

Ureter

Olfaction

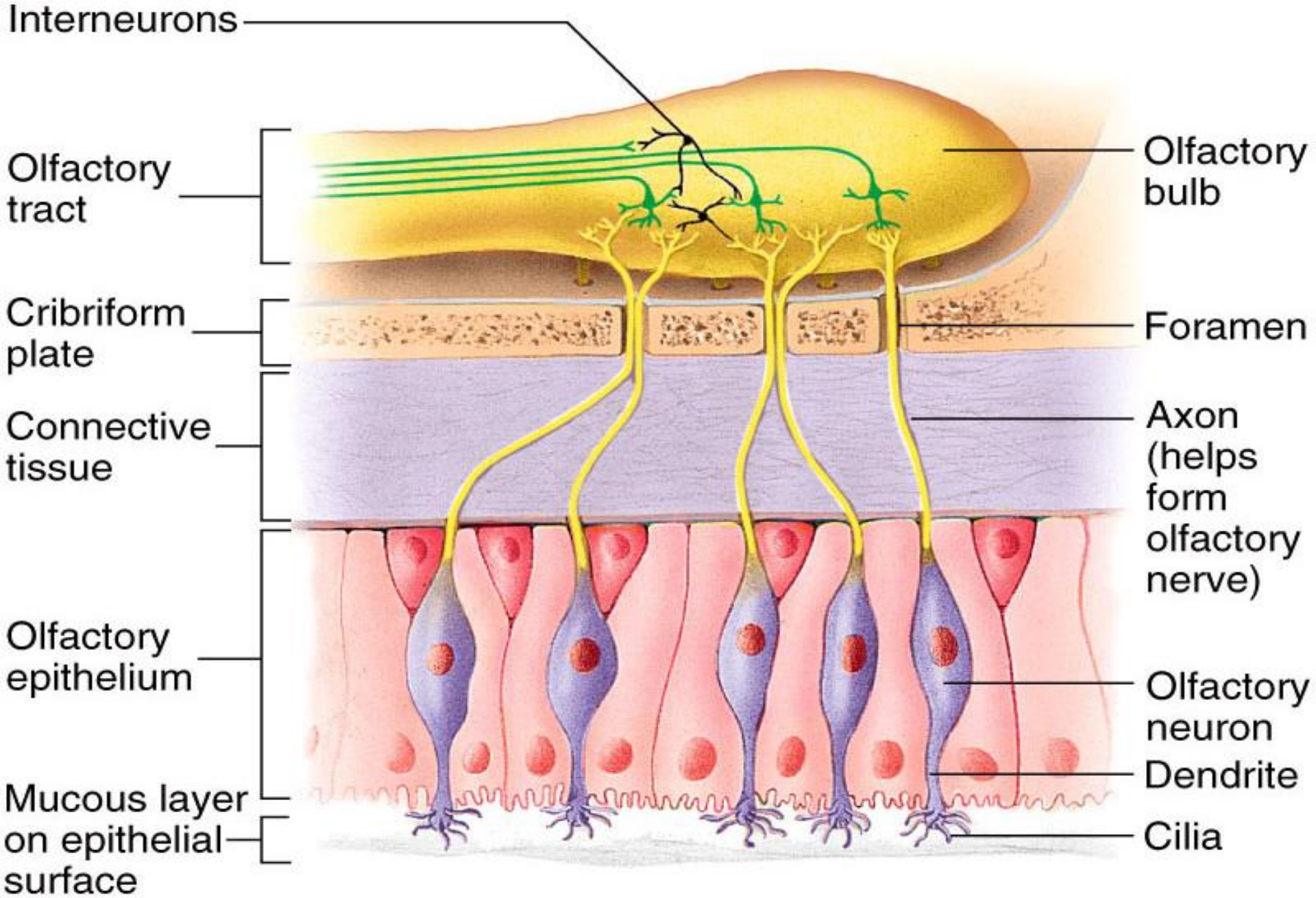
- **What is it?**

- sense of smell
- occurs in response to odorants
- receptors are located in nasal cavity and hard palate
- we can detected 10,000 different smells



How does olfaction work?

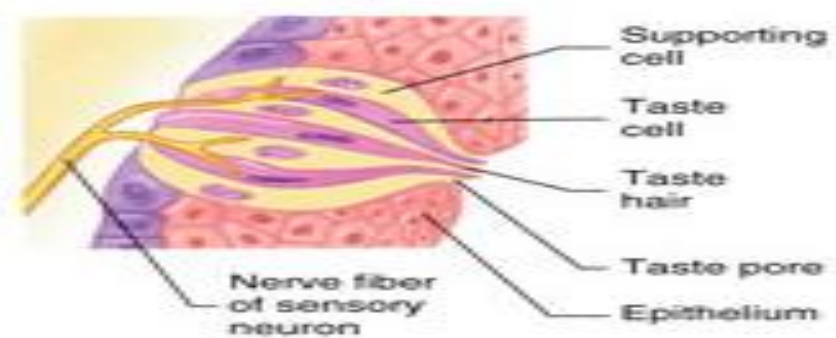
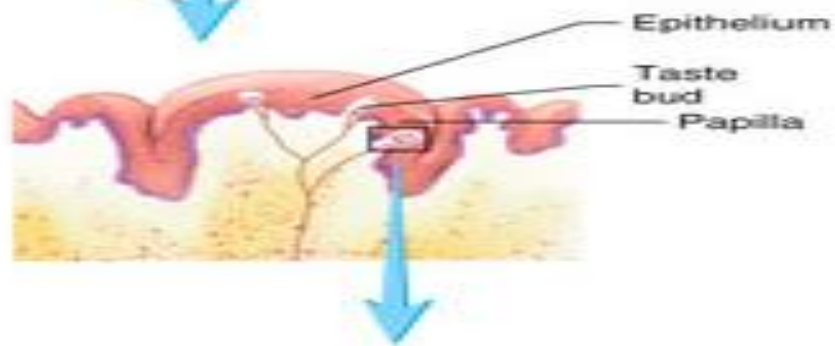
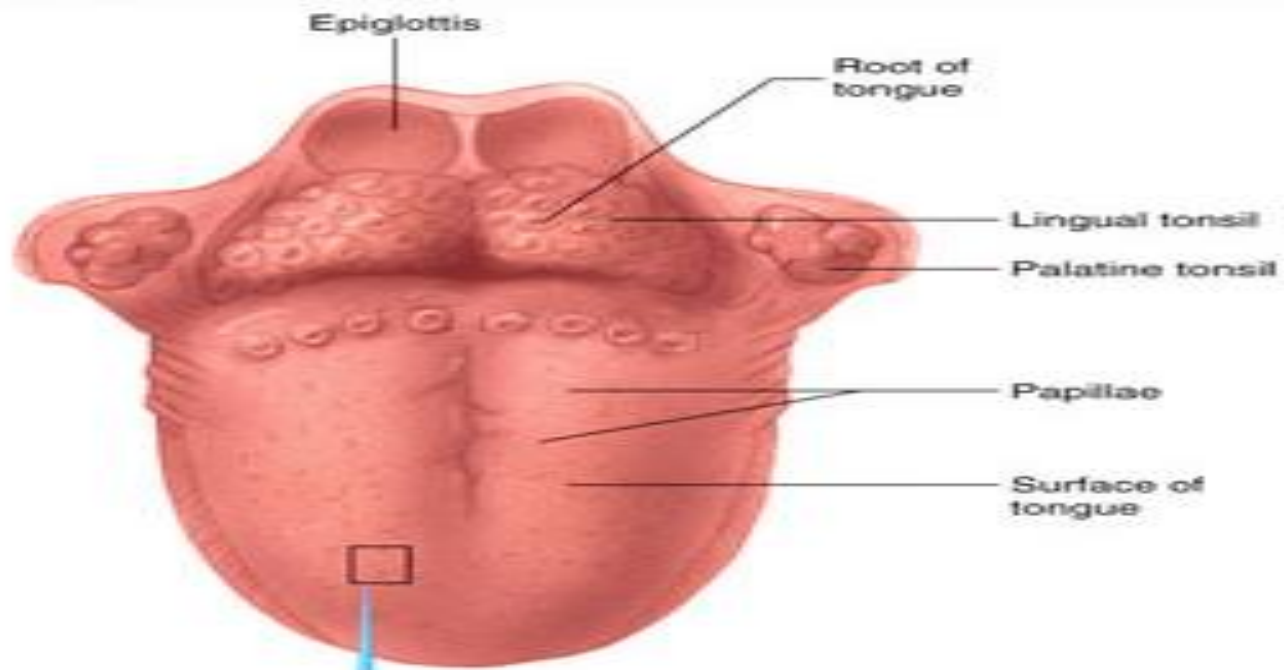
1. Nasal cavity contains a thin film of mucous where odors become dissolved.
2. Olfactory neurons are located in mucous. Dendrites of olfactory neurons are enlarged and contain cilia.
3. Dendrites pick up odor, depolarize, and carry odor to axons in olfactory bulb (cranial nerve I).
4. Frontal and temporal lobes process odor.



(b)

Taste

- **Taste buds:**
 - sensory structures that detect taste
 - located on papillae on tongue, hard palate, throat
- Inside each taste bud are 40 **taste cells**
- Each taste cell has **taste hairs** that extend into **taste pores**



How does taste work?

1. Taste buds pick up taste and send it to taste cells.
2. Taste cells send taste to taste hairs.
3. Taste hairs contain receptors that initiate an action potential which is carried to parietal lobe.
4. Brain processes taste.

Types of Tastes

- **Sweet**
- **Sour**
- **Salty**
- **Bitter**
- **Umami**

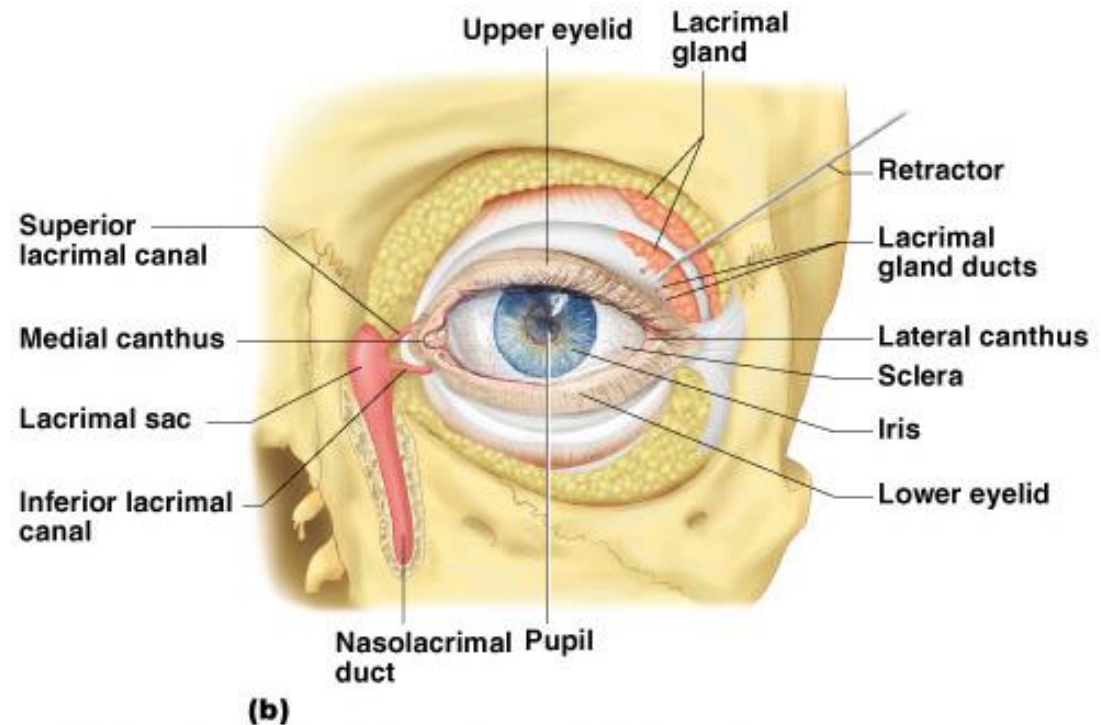
- Certain taste buds are more sensitive to certain tastes.
- Taste is also linked to smell.

The Eye and Vision

- 70 percent of all sensory receptors are in the eyes
- Each eye has over a million nerve fibers
- Protection for the eye
 - Most of the eye is enclosed in a bony orbit
 - A cushion of fat surrounds most of the eye

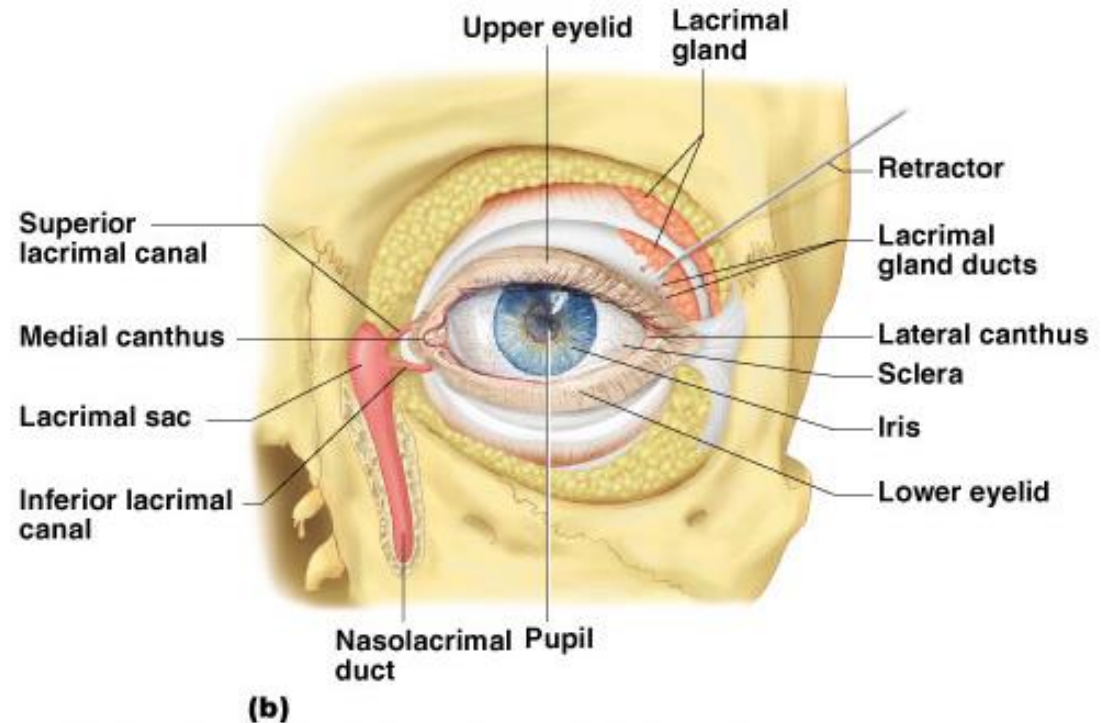
Accessory Structures of the Eye

- Eyelids
 - Meets at medial and lateral canthus
- Eyelashes



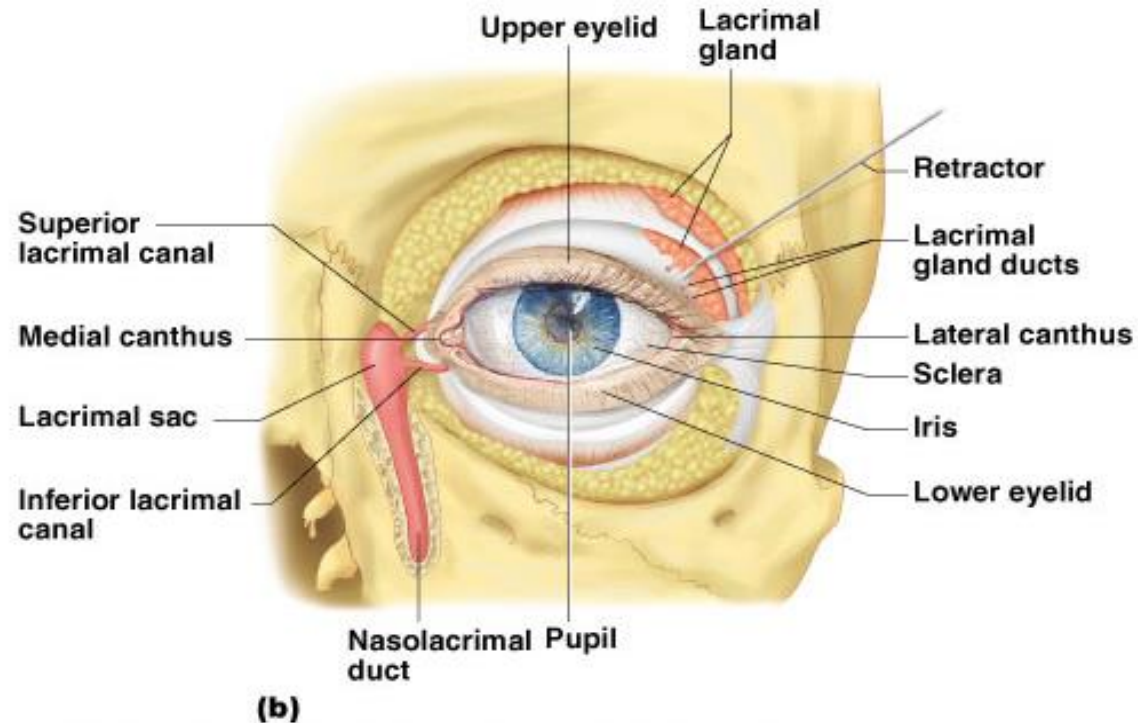
Accessory Structures of the Eye

- Eyelashes
=Meibomian glands modified sebaceous glands produce an oily secretion to lubricate the eye



Accessory Structures of the Eye

- Ciliary glands – modified sweat glands between the eyelashes



Accessory Structures of the Eye

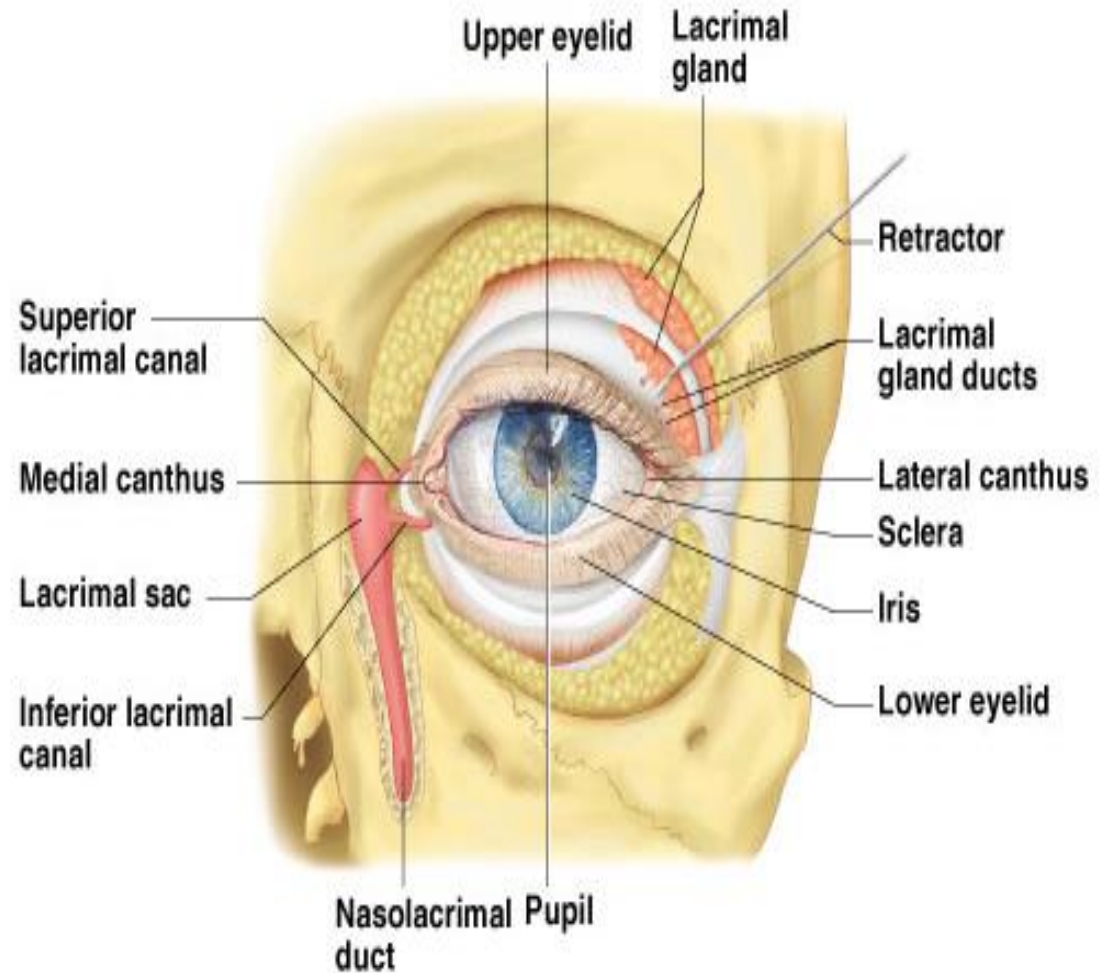
- Conjunctiva
 - Membrane that lines the eyelids
 - Connects to the surface of the eye
 - Secretes mucus to lubricate the eye

Accessory Structures of the Eye

- Lacrimal apparatus

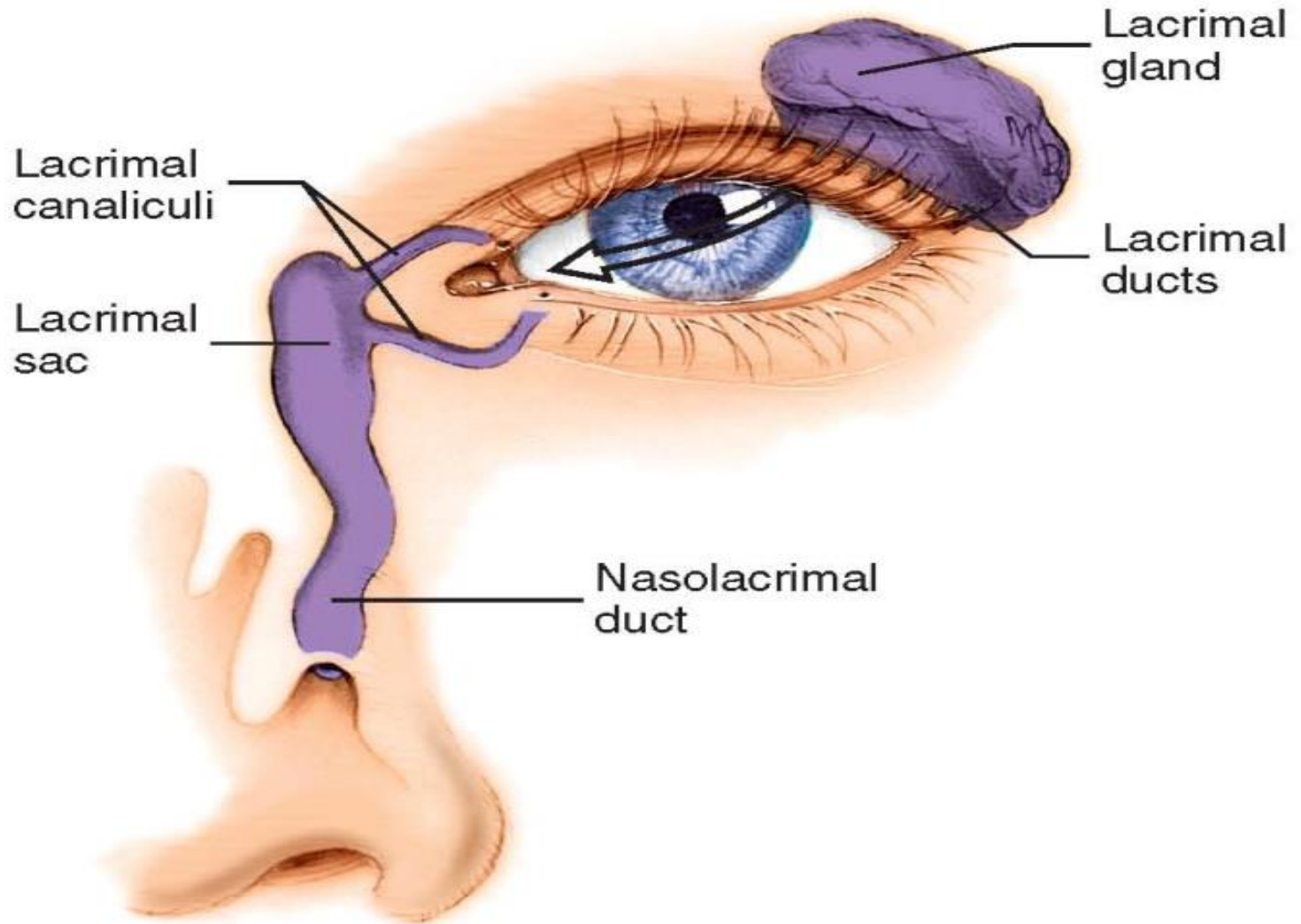
- Glands, ducts, (eye), canals, sac, nasolacrimal duct

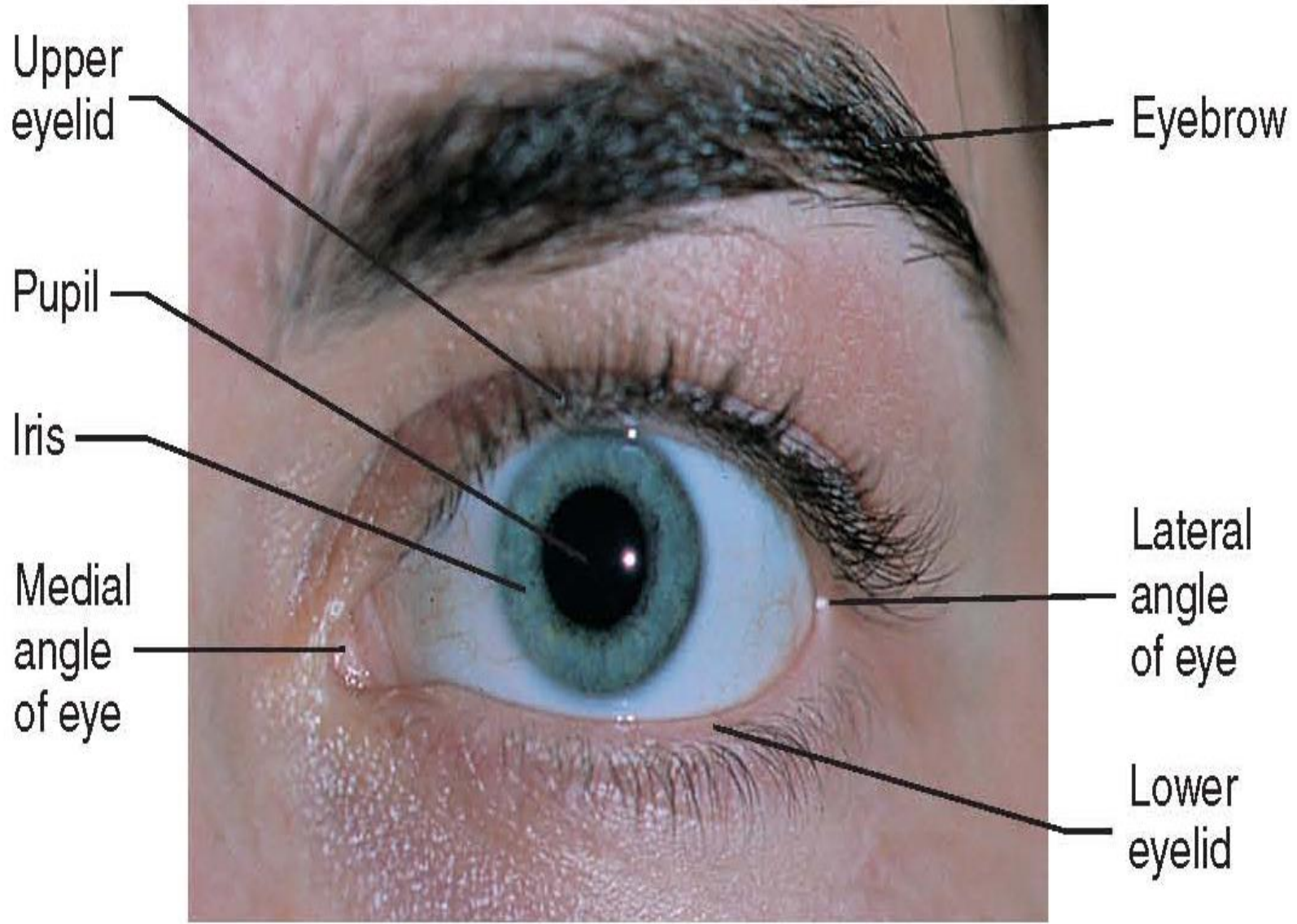
- Tears: antibodies, lysozymes, stress?



(b)

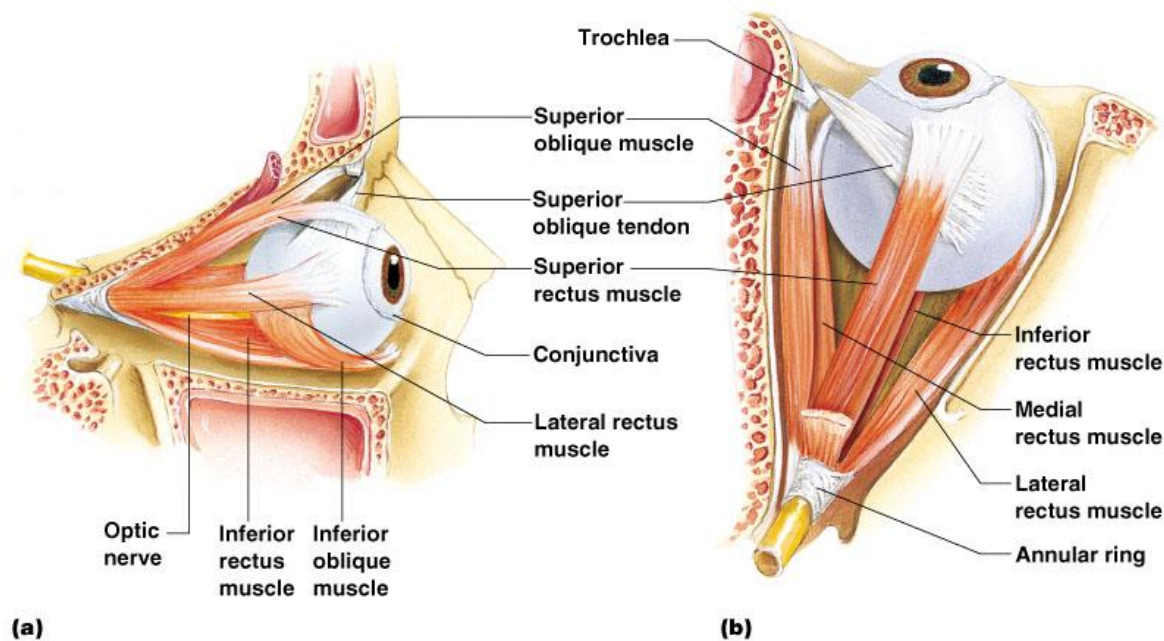
Lacrimal Apparatus



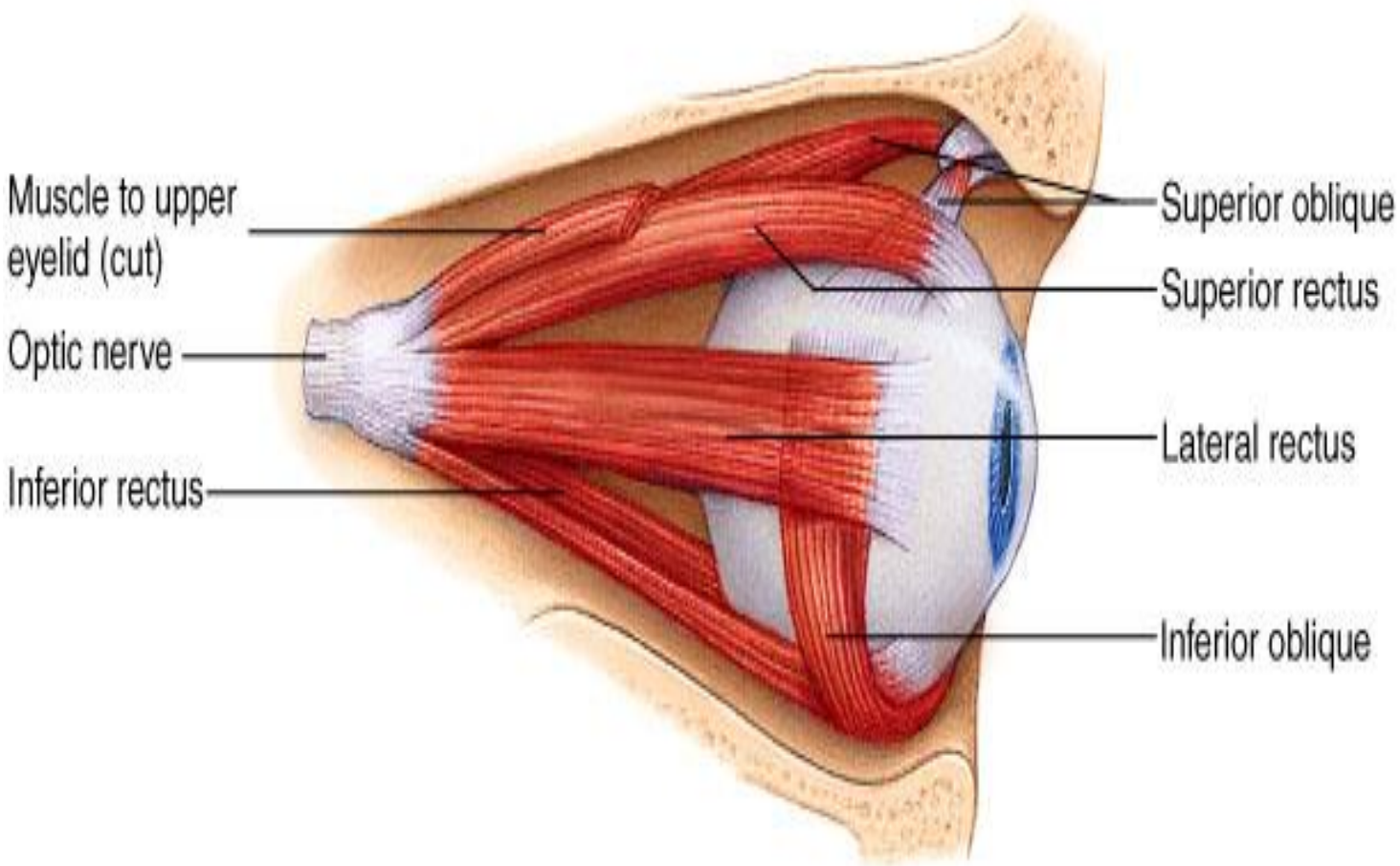


Extrinsic Eye Muscles

- Muscles attach to the outer surface of the eye
- Produce eye movements



Superior



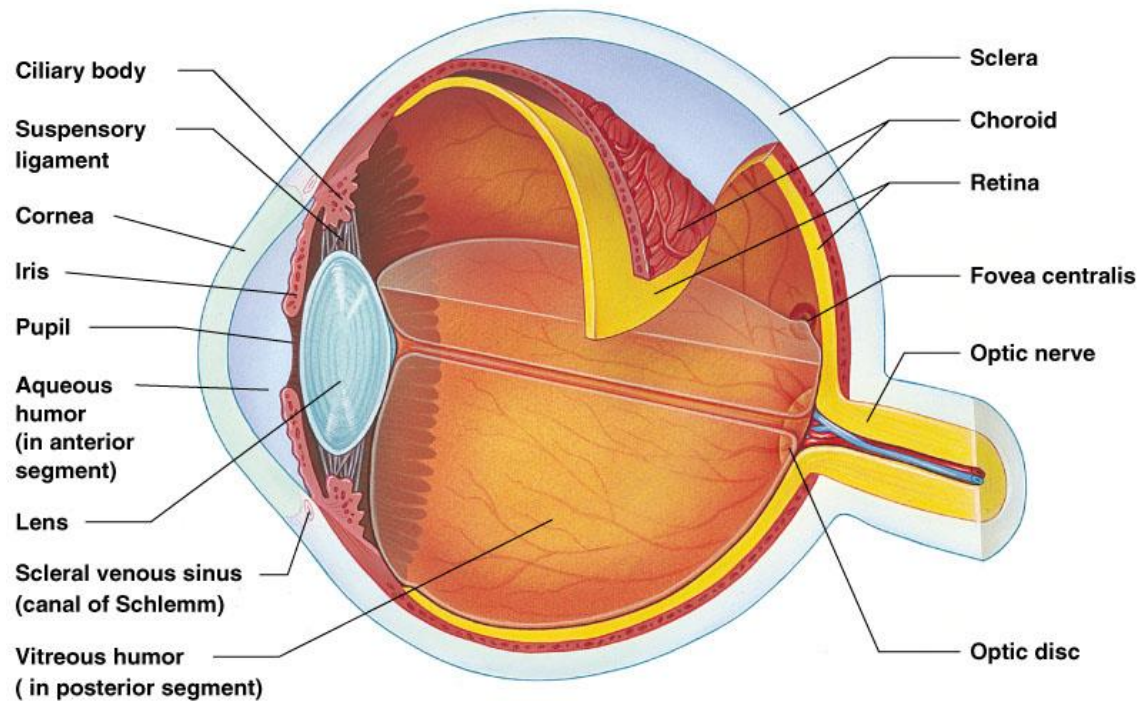
Inferior

View



Structure of the Eye

- The wall is composed of three tunics
 - Sclera&Cornea fibrous outside
 - Choroid – middle layer
 - Sensory tunic – (retina) inside layer



(a)

Figure 8.3a

The Fibrous Tunic

- Sclera
 - White connective tissue layer
 - Seen anteriorly as the “white of the eye”
- Cornea
 - Transparent, central anterior portion
 - Allows for light to pass through
 - Repairs itself easily
 - The only human tissue that can be transplanted without fear of rejection

Choroid Layer

- Blood-rich nutritive tunic
- Pigment prevents light from scattering
- Modified interiorly into two structures
 - Ciliary body – smooth muscle
 - Iris
 - Pigmented layer that gives eye color
 - Pupil – rounded opening in the iris

Sensory Tunic (Retina)

- Contains receptor cells (photoreceptors)
 - Rods
 - Cones
- Signals pass from photoreceptors and leave the retina toward the brain through the optic nerve

Neurons of the Retina

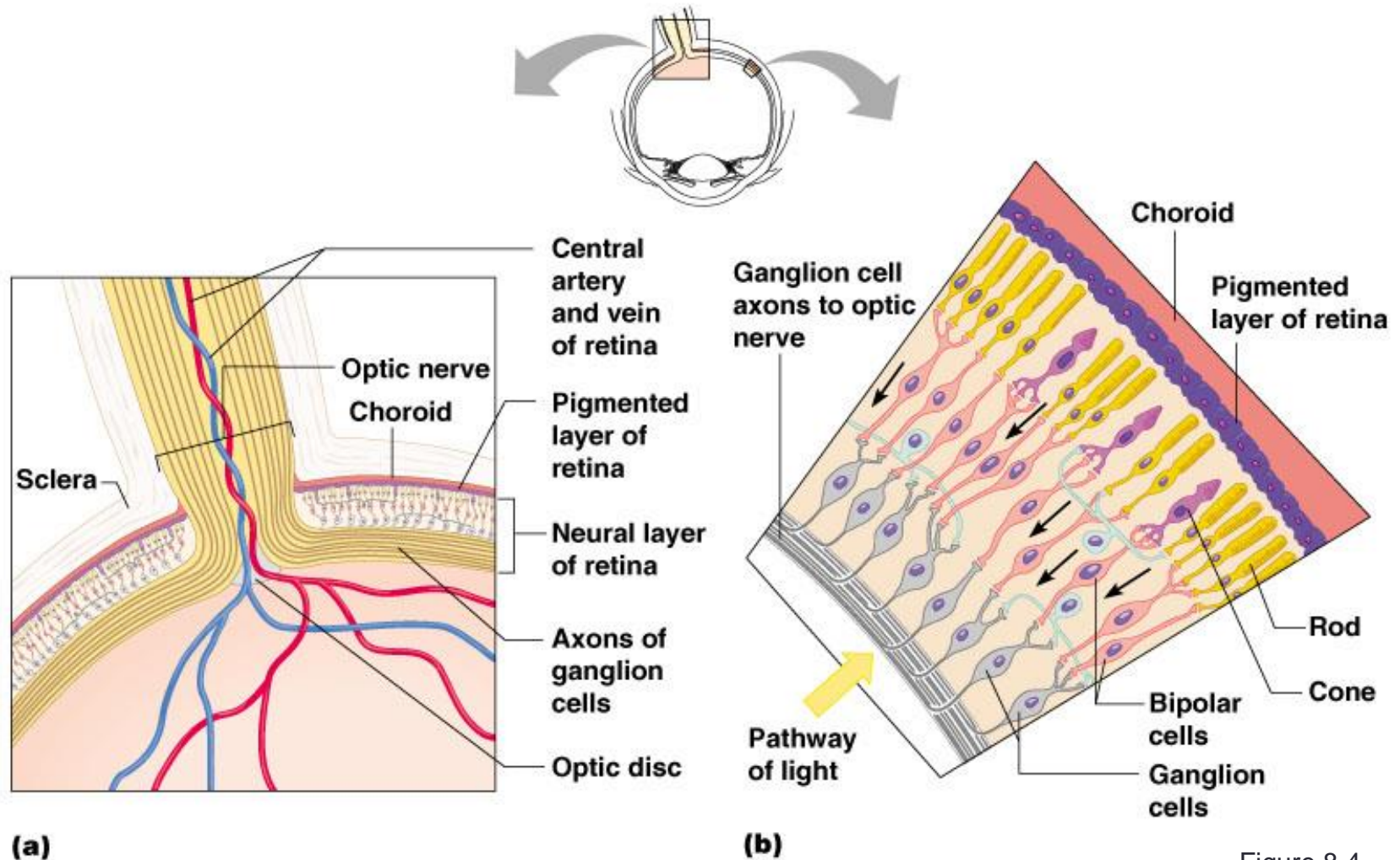


Figure 8.4

Neurons of the Retina and Vision

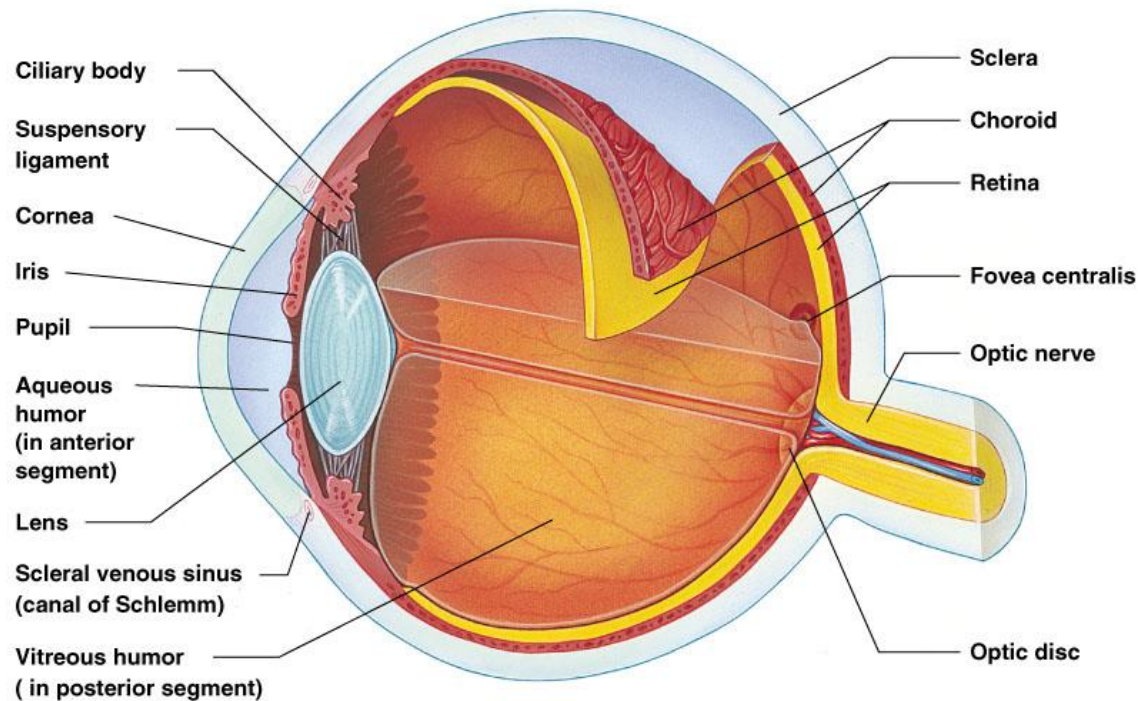
- Rods
 - Most are found towards the edges of the retina
 - Allow dim light vision and peripheral vision
 - Perception is all in gray tones

Neurons of the Retina and Vision

- Cones – 3 types detect different colors
 - Densest in the center of the retina
 - Fovea centralis – area of the retina with only cones
 - Lack of one type = color blindness
- No photoreceptor cells are at the optic disk, or blind spot

Lens

- Biconvex crystal-like structure
- Held in place by a suspensory ligament attached to the ciliary body



Internal Eye Chamber Fluids

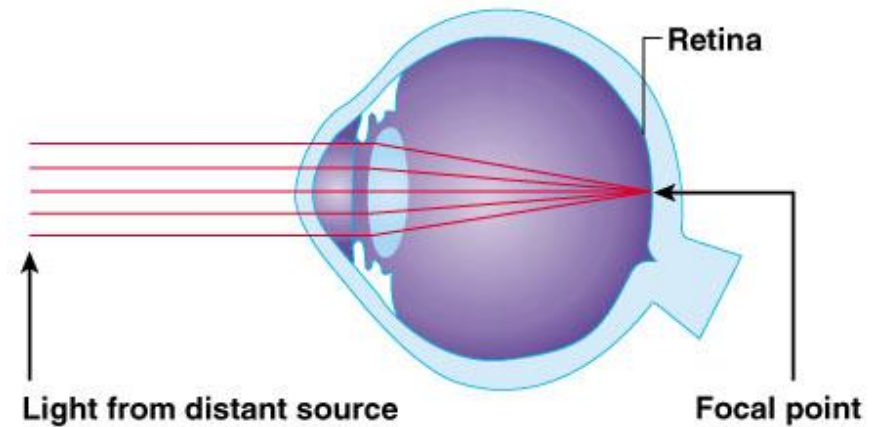
- Aqueous humor in Anterior Segment
 - Watery fluid found in chamber between the lens and cornea
 - Similar to blood plasma
 - Helps maintain intraocular pressure
 - Provides nutrients for the lens and cornea
 - Reabsorbed into venous blood
 - Blocked drainage = glaucoma

Internal Eye Chamber Fluids

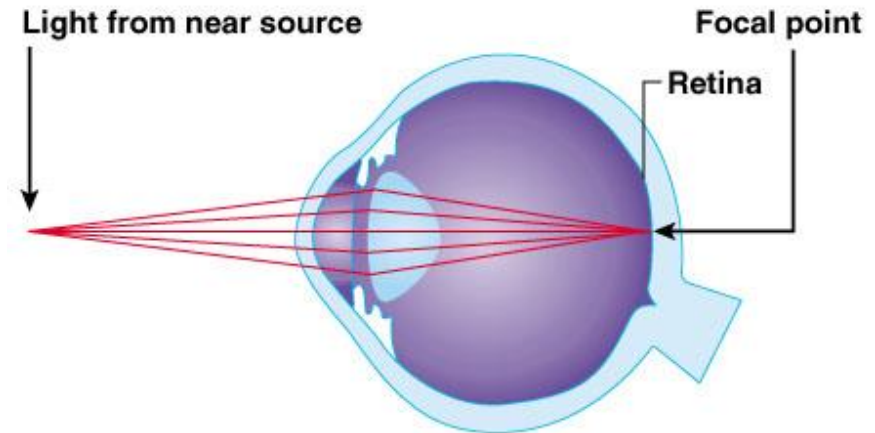
- Vitreous humor in Posterior Segment
 - Gel-like substance behind the lens
 - Keeps the eye from collapsing
 - Lasts a lifetime and is not replaced

Lens Accommodation

- Light must be focused to a point on the retina for optimal vision
- The eye is set for distance vision (over 20 ft away)
- The lens must change shape to focus for closer objects

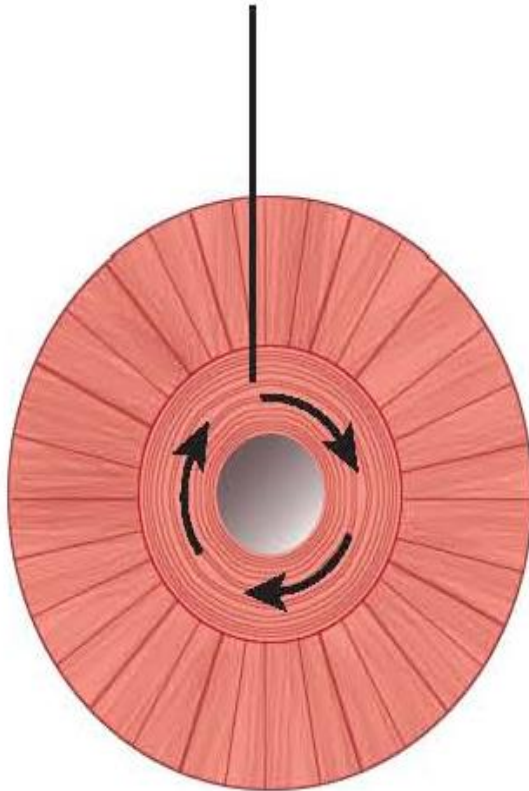


(a)

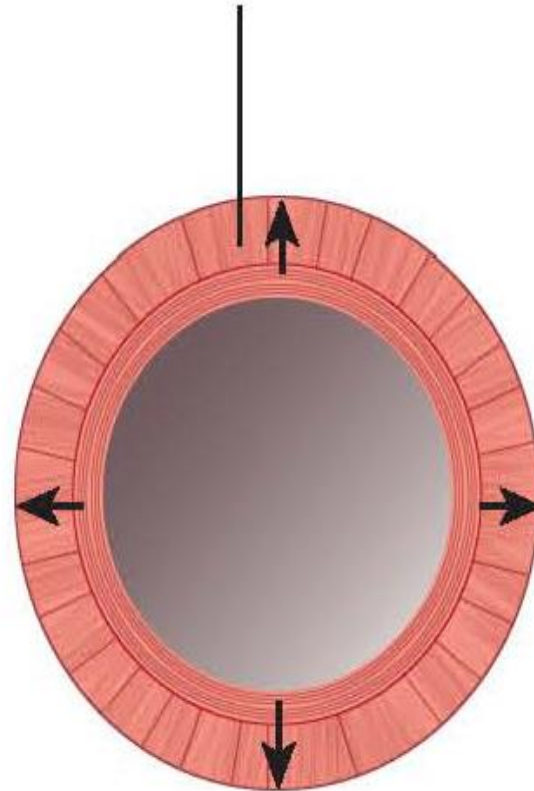


(b)

Circular
smooth
muscles



Radial
smooth
muscles



- **Macula:**

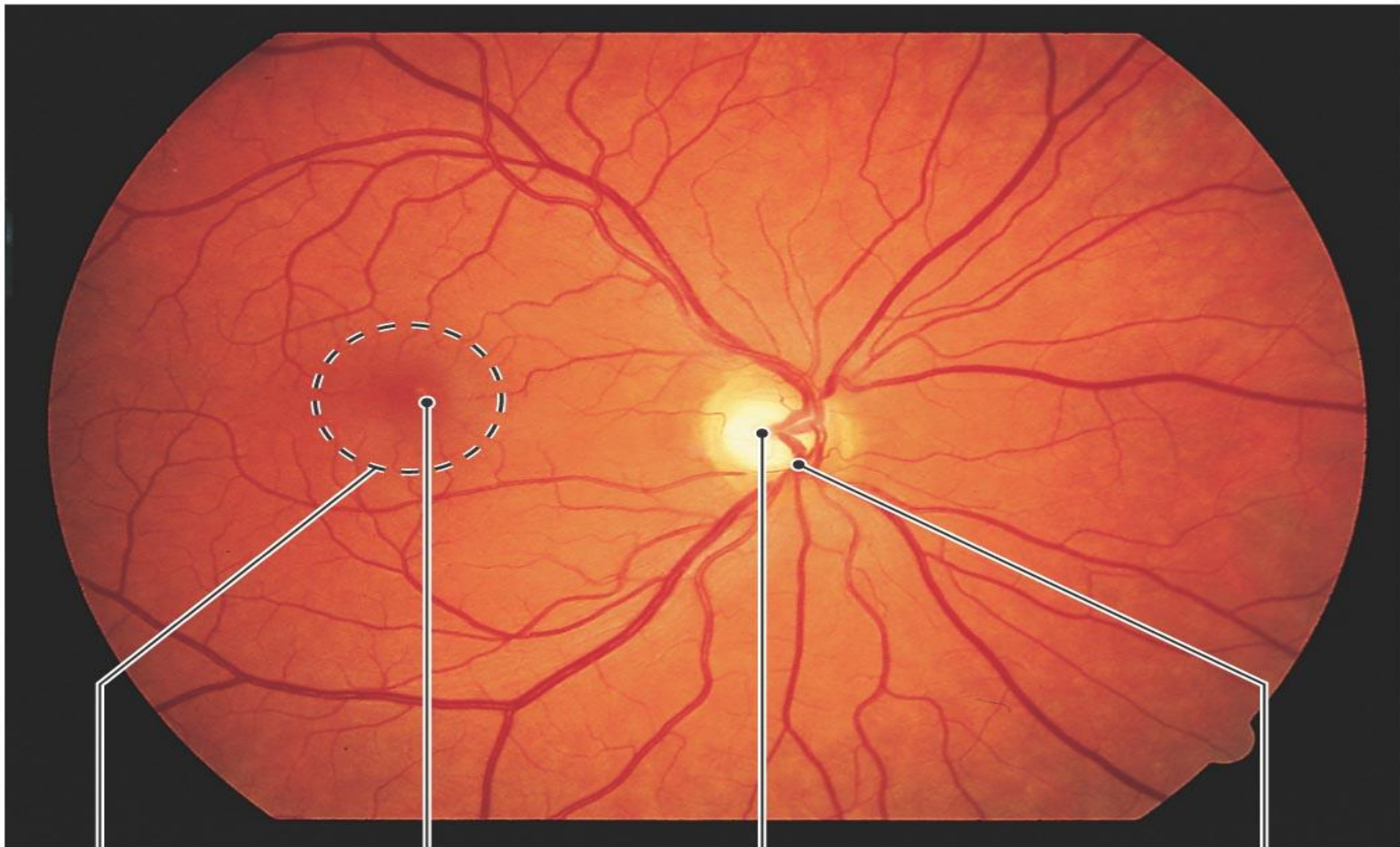
- small spot near center of retina

- **Fovea centralis:**

- center of macula
 - where light is focused when looking directly at an object
 - only cones
 - ability to discriminate fine images

- **Optic disk:**

- white spot medial to macula
- blood vessels enter eye and spread over retina
- axons exit as optic nerve
- no photoreceptors
- called blindspot



**Macula
lutea**

Fovea

**Optic disc
(blind spot)**

**Central retinal
artery and vein
emerging from
center of optic disc**

(c)

Functions of Eye

Light Refraction

Bending of light

- **Focal point:**
 - point where light rays converge
 - occurs anterior to retina
 - object is inverted

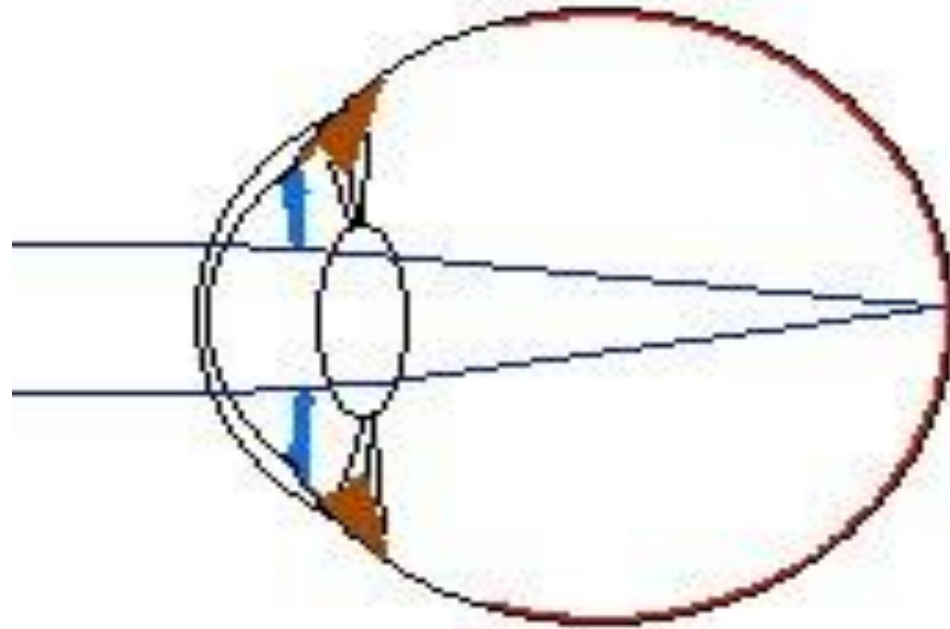
Focusing Images on Retina

- **Accommodation:**

- lens becomes less rounded and image can be focused on retina
- enables eye to focus on images closer than 20 feet

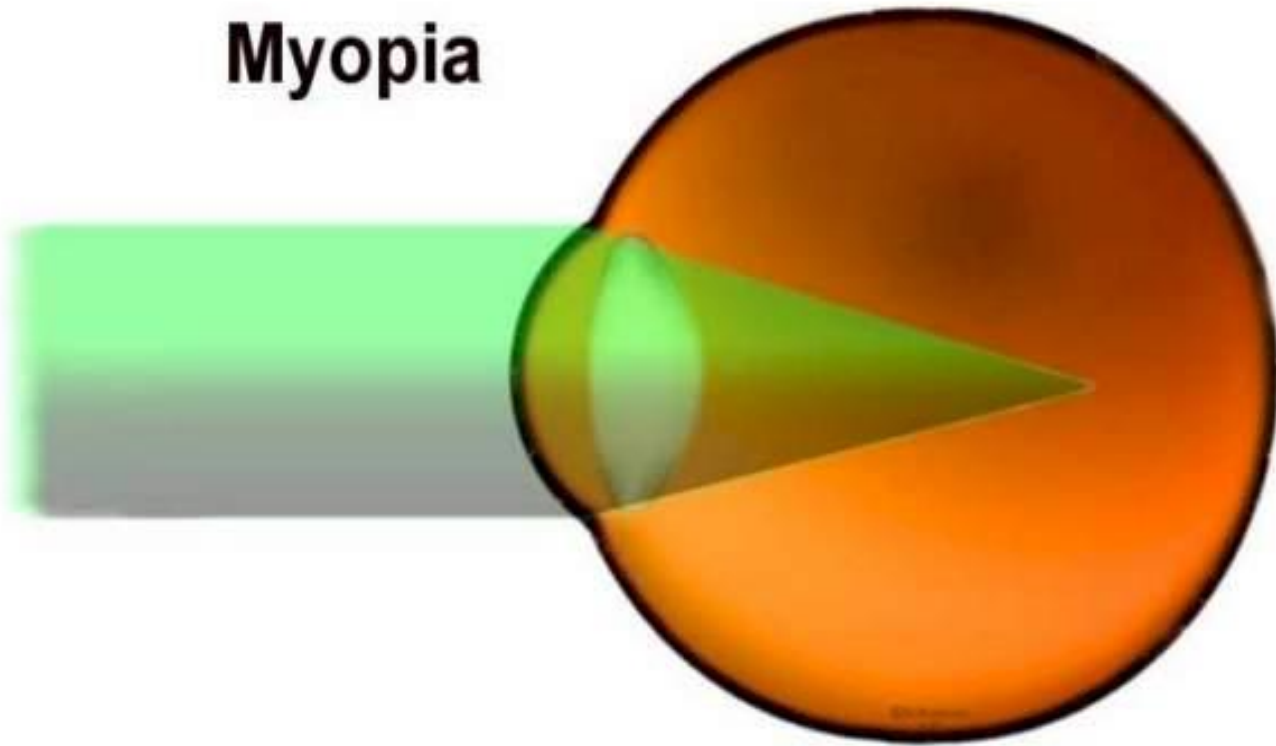
Correcting the Eye

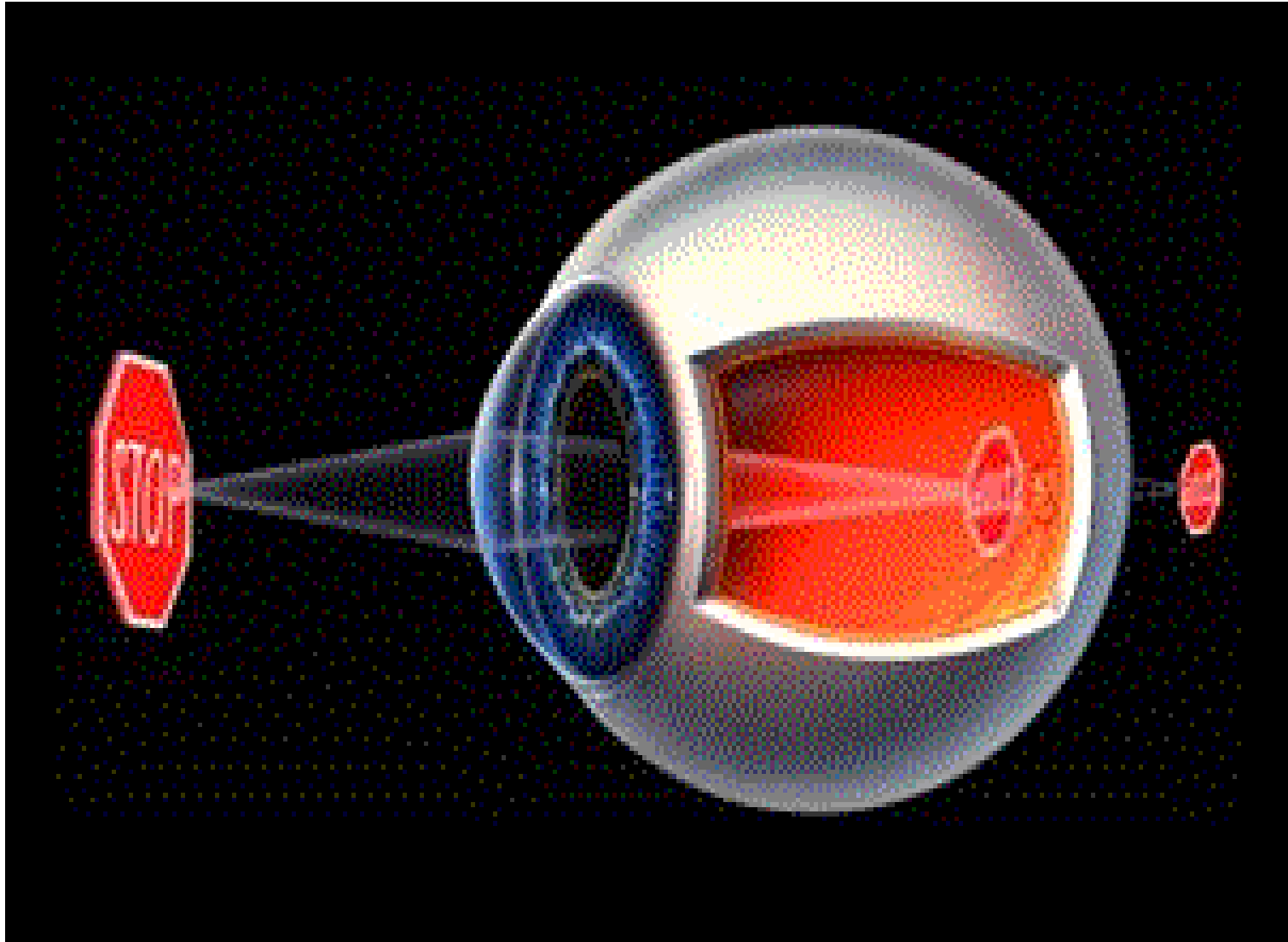
- Correct Focus = emmetropia
- Nearsightedness = myopia
 - Focus of light in front of retina
 - Eyeball too long or lens too strong
 - Distant objects are blurry
- Farsightedness = hyperopia
 - Focus of light beyond the retina
 - Short eyeball or lazy lens
 - Near objects are blurry.



Emmetropia

Myopia

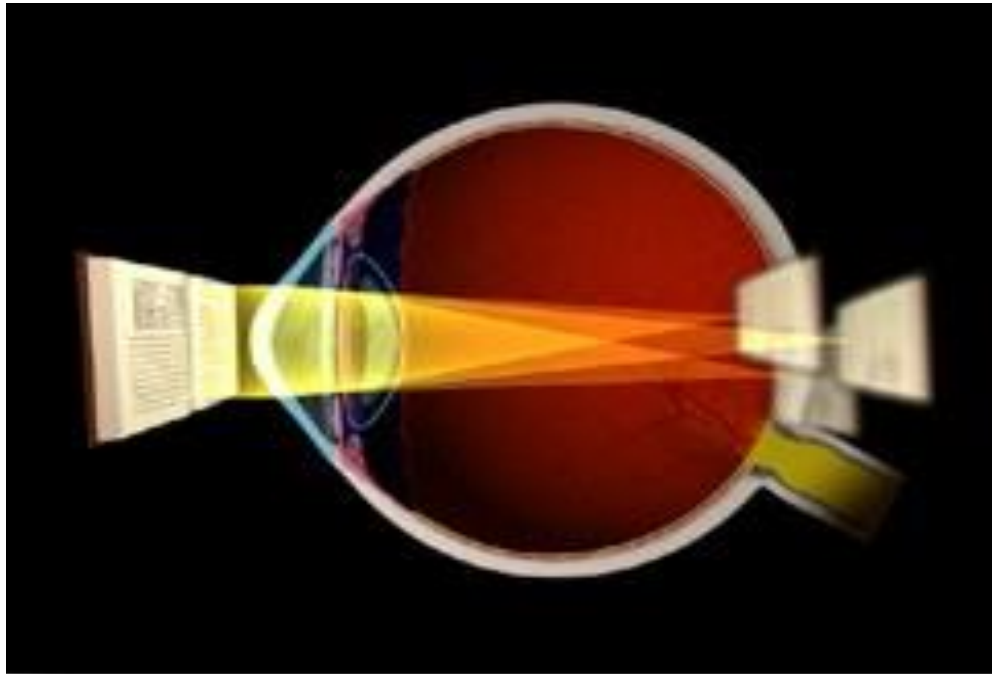




Hyperopia

Astigmatism

- Unequal curvatures in cornea & lens



Neuronal Pathway for Vision

- **Optic nerve**

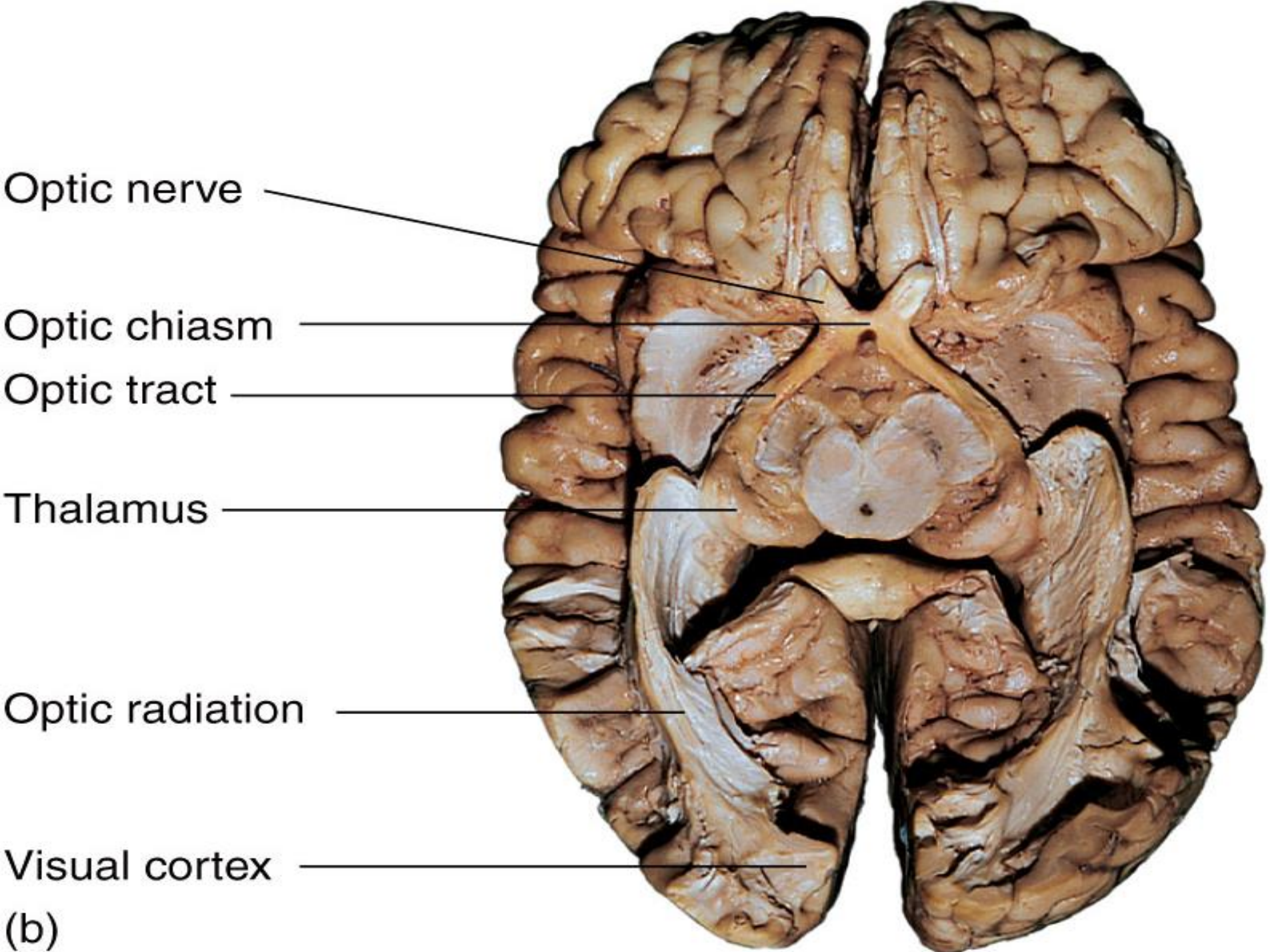
leaves eye and exits orbit through optic foramen to enter cranial cavity

- **Optic chiasm**

where 2 optic nerves connect

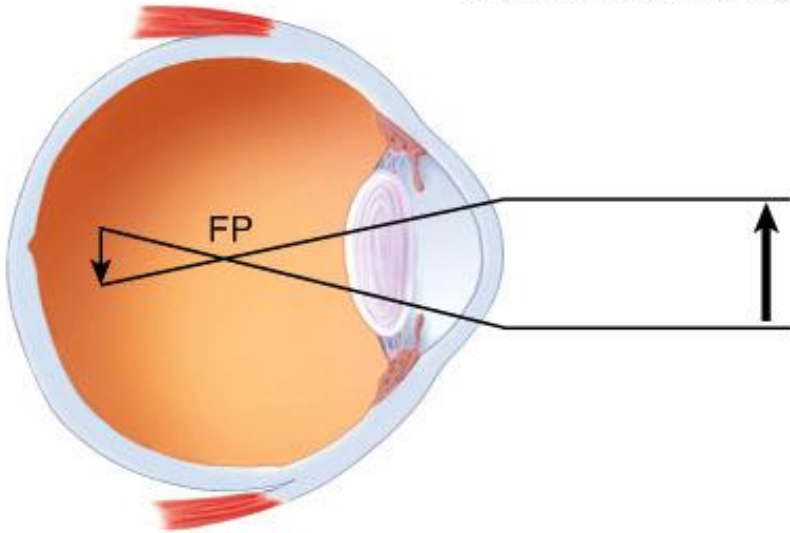
- **Optic tracts**

route of ganglion axons

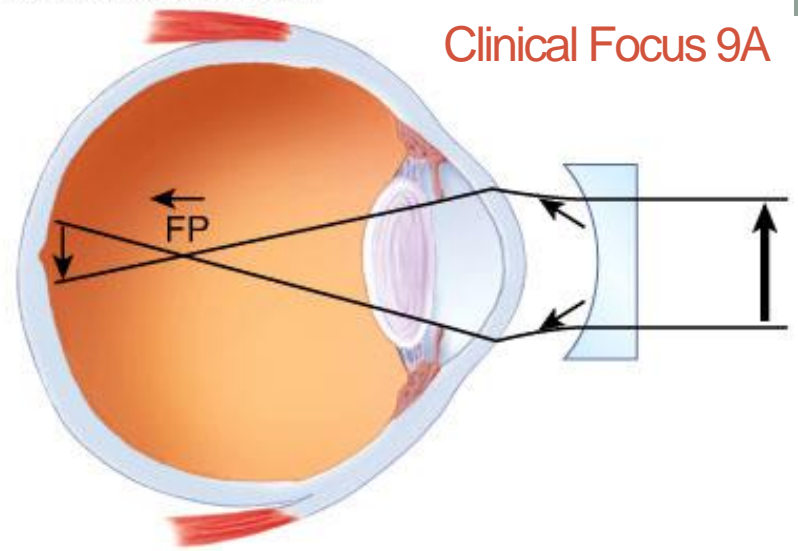


Eye Defects

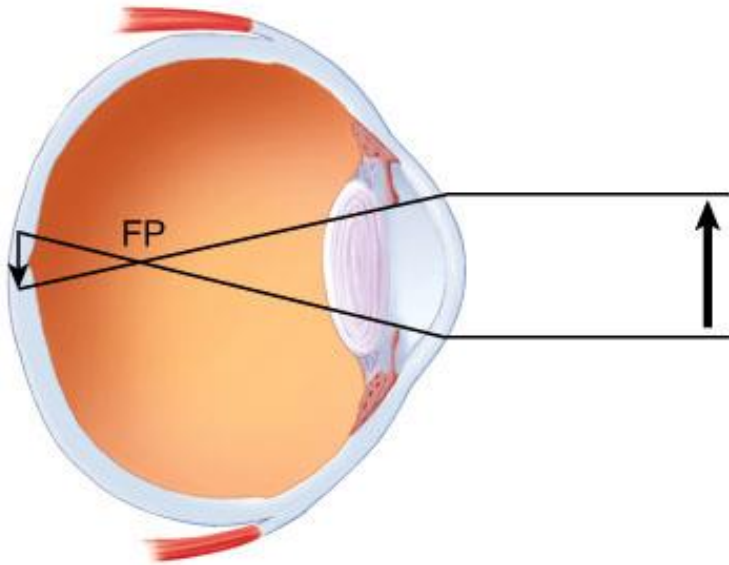
- **Myopia:**
 - nearsightedness
 - image is in front of retina
- **Hyperopia:**
 - farsightedness
 - image is behind retina
- **Presbyopia:**
 - lens becomes less elastic
 - reading glasses required



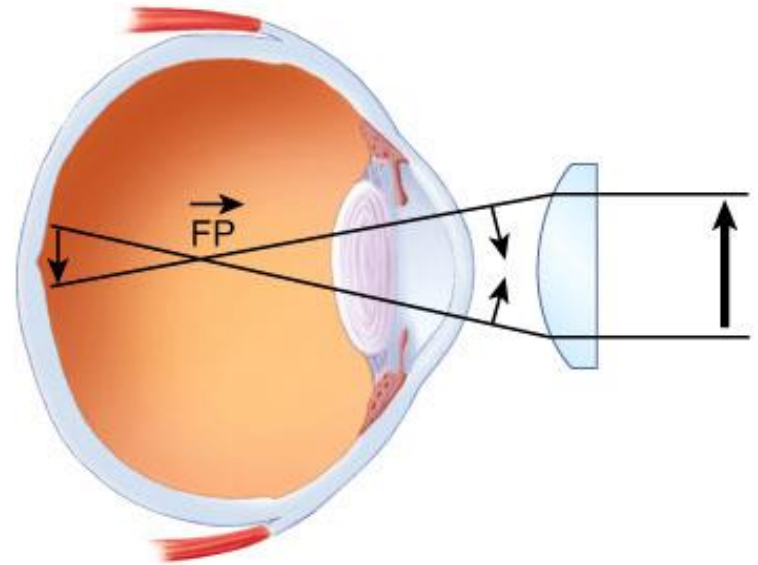
(a) Myopia (nearsightedness)



(b) Concave lens corrects myopia

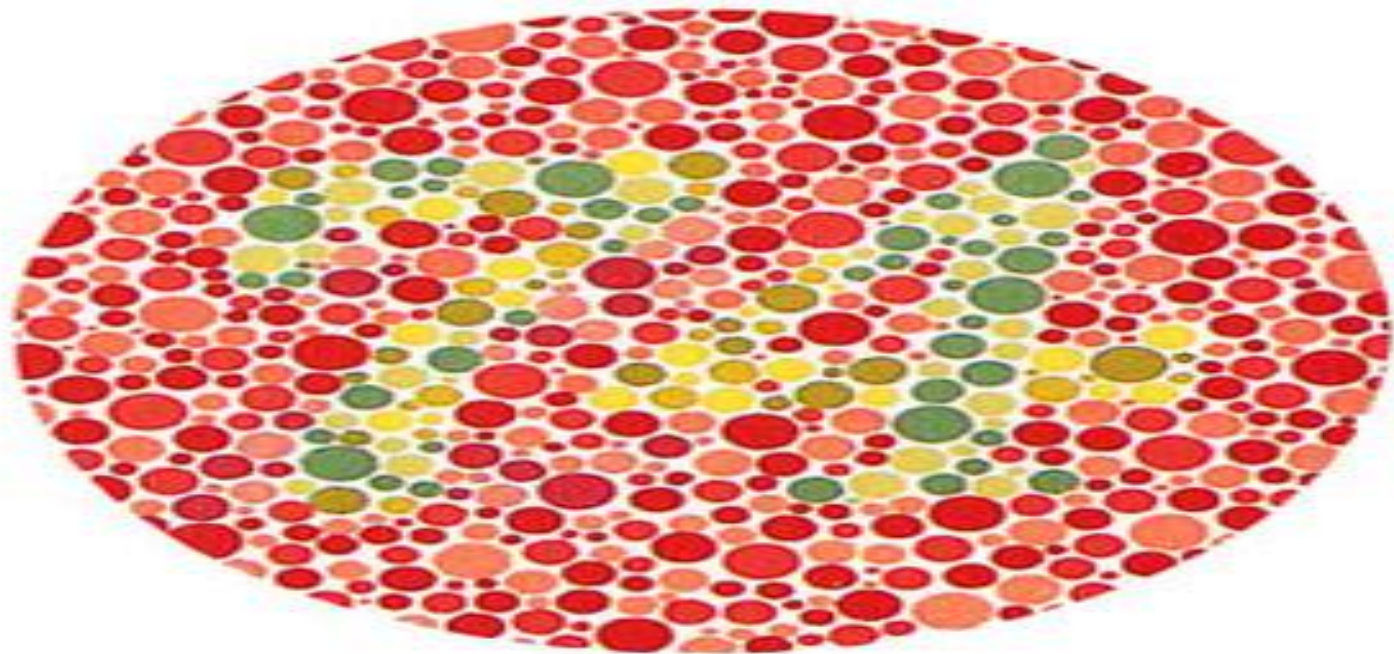


(c) Hyperopia (farsightedness)

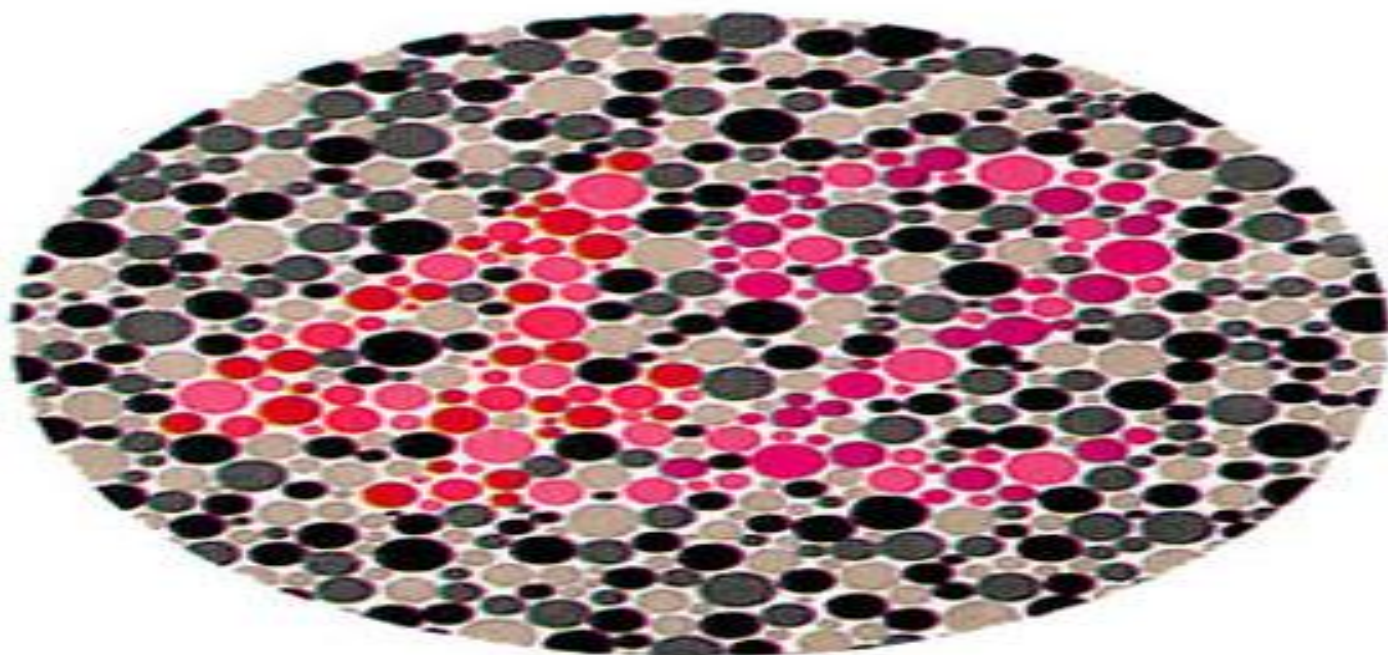


(d) Convex lens corrects hyperopia

- **Astigmatism:**
 - irregular curvature of lens
 - glasses or contacts required to correct
- **Colorblindness:**
 - absence or deficient cones
 - primarily in males
- **Glaucoma:**
 - decreased pressure in eye
 - can lead to blindness



(a)



(b)

Hearing and Balance

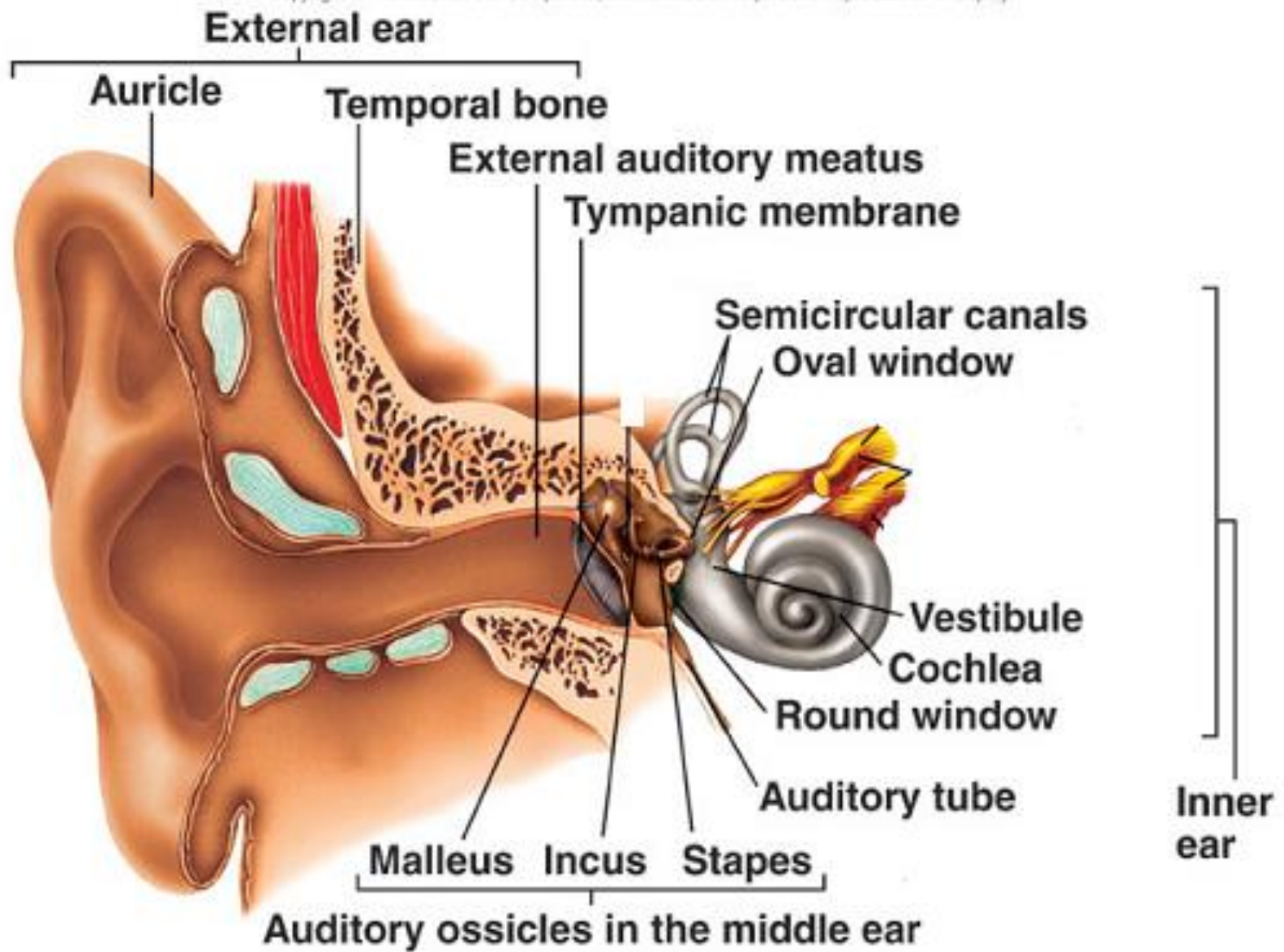
External (Outer) Ear

- Extends from outside of head to eardrum
- **Auricle:**
fleshy part on outside
- **External auditory meatus:**
canal that leads to eardrum
- **Tympanic membrane:**
 - eardrum
 - thin membrane that separates external and middle ear

Middle Ear

- Air filled chamber
- **Malleus (hammer):**
bone attached to tympanic membrane
- **Incus (anvil):**
bone that connects malleus to stapes
- **Stapes (stirrup):**
bone located at base of oval window

- **Oval window:**
separates middle and inner ear
- **Eustachian or auditory tube:**
 - opens into pharynx
 - equalizes air pressure between outside air and middle ear



Inner Ear

- Set of fluid filled chambers
- **Bony labyrinth:**
 - tunnels filled with fluid
 - 3 regions: cochlea, vestibule, semicircular canals
- **Membranous labyrinth:**
 - inside bony labyrinth
 - filled with endolymph

- **Endolymph:**

clear fluid in membranous labyrinth

- **Perilymph:**

fluid between membranous and bony labyrinth

- **Cochlea:**

- snail-shell shaped structure

- **where hearing takes place**

- **Scala vestibuli:**
 - in cochlea
 - filled with perilymph
- **Scala tympani:**
 - in cochlea
 - filled with perilymph
- **Cochlea duct:**
 - in cochlea
 - filled with endolymph

- **Spiral organ:**

- in cochlear duct
- contains hair cells

- **Tectorial membrane:**

- in cochlea
- vibrates against hair cells

- **Hair cells:**

attached to sensory neurons that when bent produce an action potential

- **Vestibular membrane:**

wall of membranous labyrinth that lines scala vestibuli

- **Basilar membrane:**

wall of membranous labyrinth that lines scala tympani

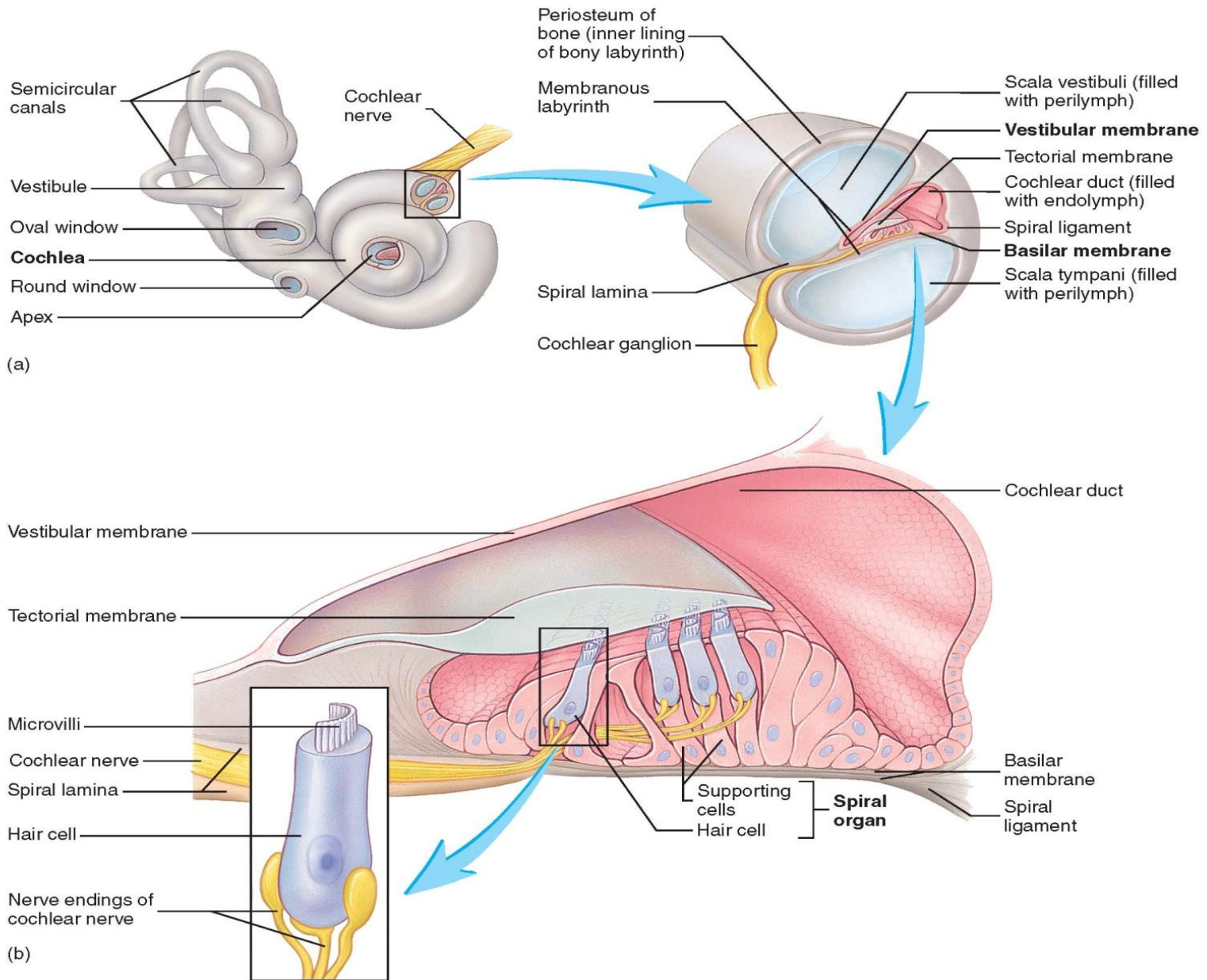


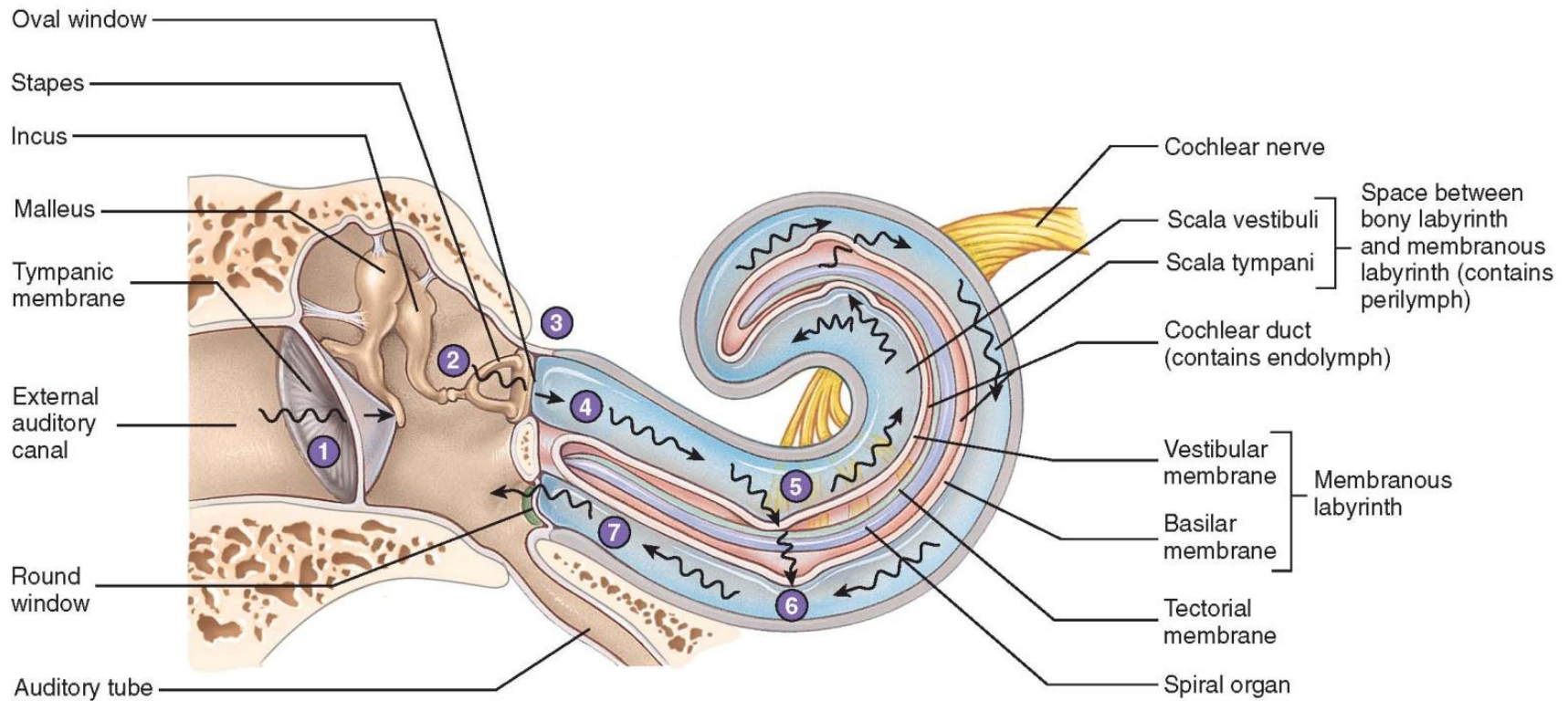
Figure 9.18 Structure of the Inner Ear

(a) Bony labyrinth. The outer surface (*gray*) is the periosteum lining the inner surface of the bony labyrinth. (b) In this cross section of the cochlea, the outer layer is the periosteum lining the inner surface of the bony labyrinth. The membranous labyrinth is very small in the cochlea and consists of the vestibular and basilar membranes. The space between the membranous and bony labyrinths consists of two parallel tunnels: the scala vestibuli and the scala tympani. (c) An enlarged section of the cochlear duct (membranous labyrinth). (d) A greatly enlarged individual sensory hair cell.

How do we hear?

1. Sound travels in waves through air and is funneled into ear by auricle.
2. Auricle through external auditory meatus to tympanic membrane.
3. Tympanic membrane vibrates and sound is amplified by malleus, incus, stapes which transmit sound to oval window.
4. Oval window produces waves in perilymph of cochlea.

5. Vibrations of perilymph cause vestibular membrane and endolymph to vibrate.
6. Endolymph cause displacement of basilar membrane.
7. Movement of basilar membrane is detected by hair hairs in spiral organ.
8. Hair cells become bent and cause action potential is created.



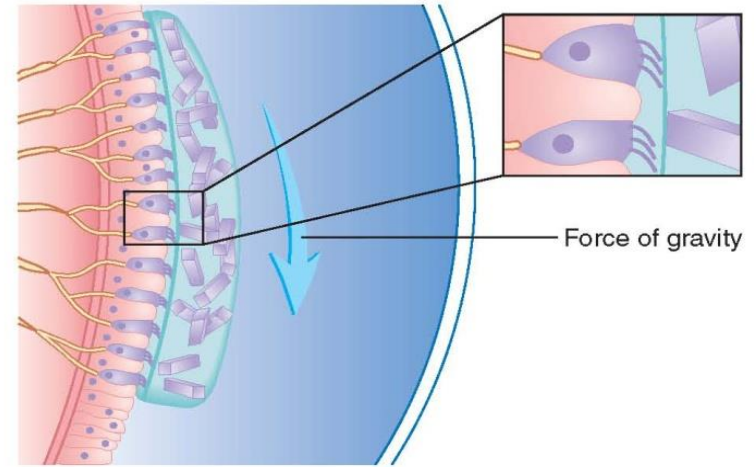
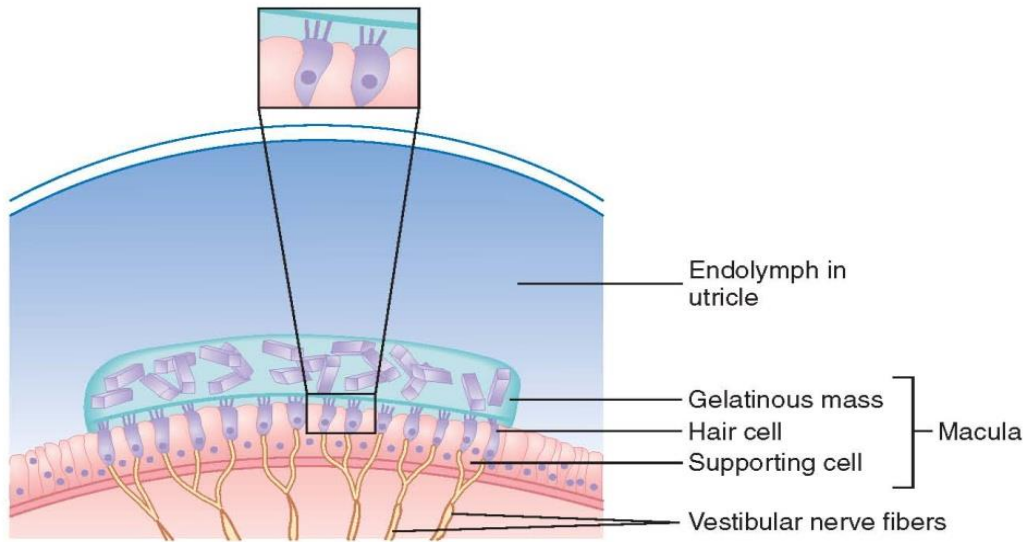
- 1 Sound waves strike the tympanic membrane and cause it to vibrate.
- 2 Vibration of the tympanic membrane causes the malleus, the incus, and the stapes to vibrate.
- 3 The foot plate of the stapes vibrates in the oval window.
- 4 Vibration of the foot plate causes the perilymph in the scala vestibuli to vibrate.
- 5 Vibration of the perilymph causes the vestibular membrane to vibrate, which causes vibrations in the endolymph.
- 6 Vibration of the endolymph causes displacement of the basilar membrane. Short waves (high pitch), cause displacement of the basilar membrane near the oval window, and longer waves (low pitch) cause displacement of the basilar membrane some distance from the oval window. Movement of the basilar membrane is detected in the hair cells of the spiral organ, which are attached to the basilar membrane. Vibrations of the perilymph in the scala vestibuli and of the basilar membrane are transferred to the perilymph of the scala tympani.
- 7 Vibrations in the perilymph of the scala tympani are transferred to the round window, where they are damped.

PROCESS Figure 9.19 Effect of Sound Waves on Middle and Inner Ear Structures

Balance (Equilibrium)

- **Static equilibrium:**
 - associated with vestibule
 - evaluates position of head relative to gravity
- **Dynamic equilibrium:**
 - associated with semicircular canals
 - evaluates changes in direction and rate of head movement

- **Vestibule:**
 - inner ear
 - contains utricle and saccule
- **Maculae:**
 - specialized patches of epithelium in utricle and saccule surround by endolymph
 - contain hair cells
- **Otoliths:**
 - gelatinous substance that moves in response to gravity
 - attached to hair cell microvilli which initiate action potentials



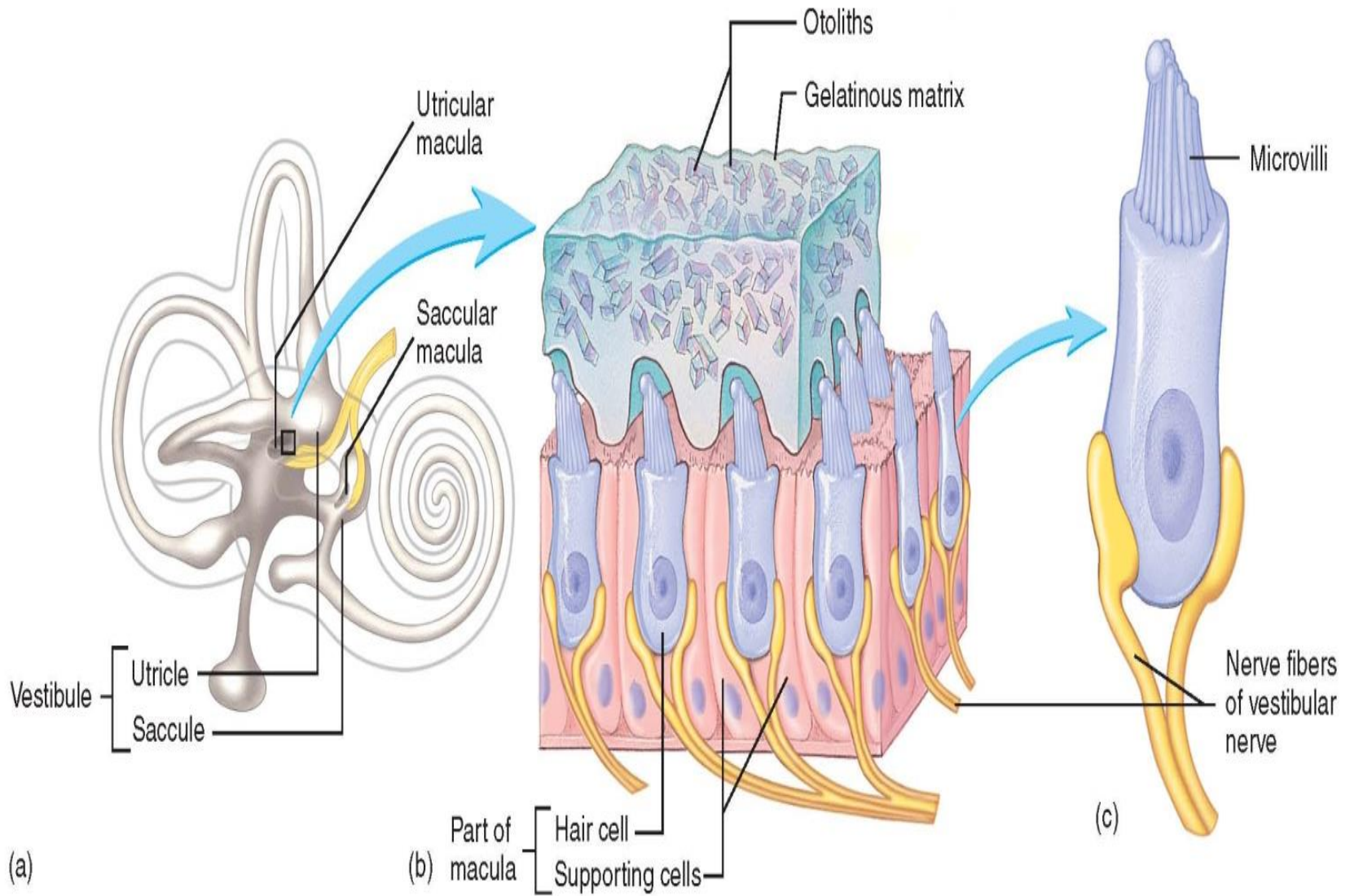
(a)



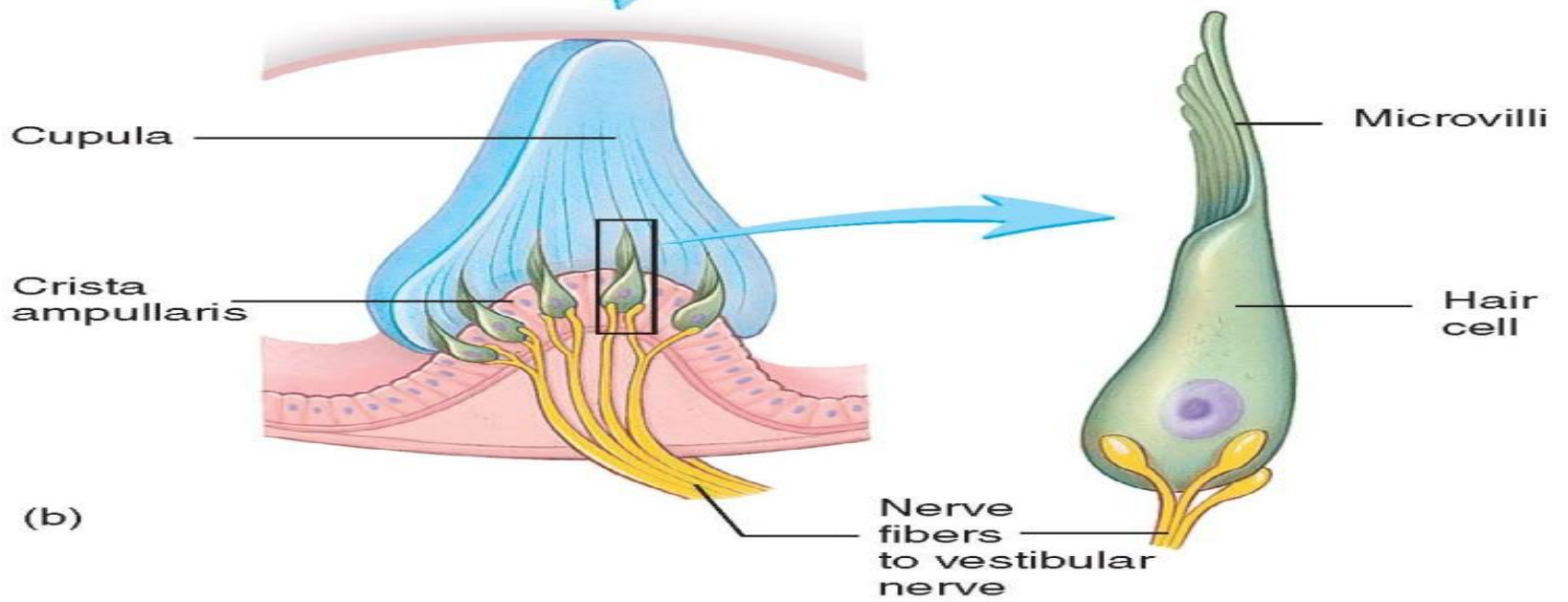
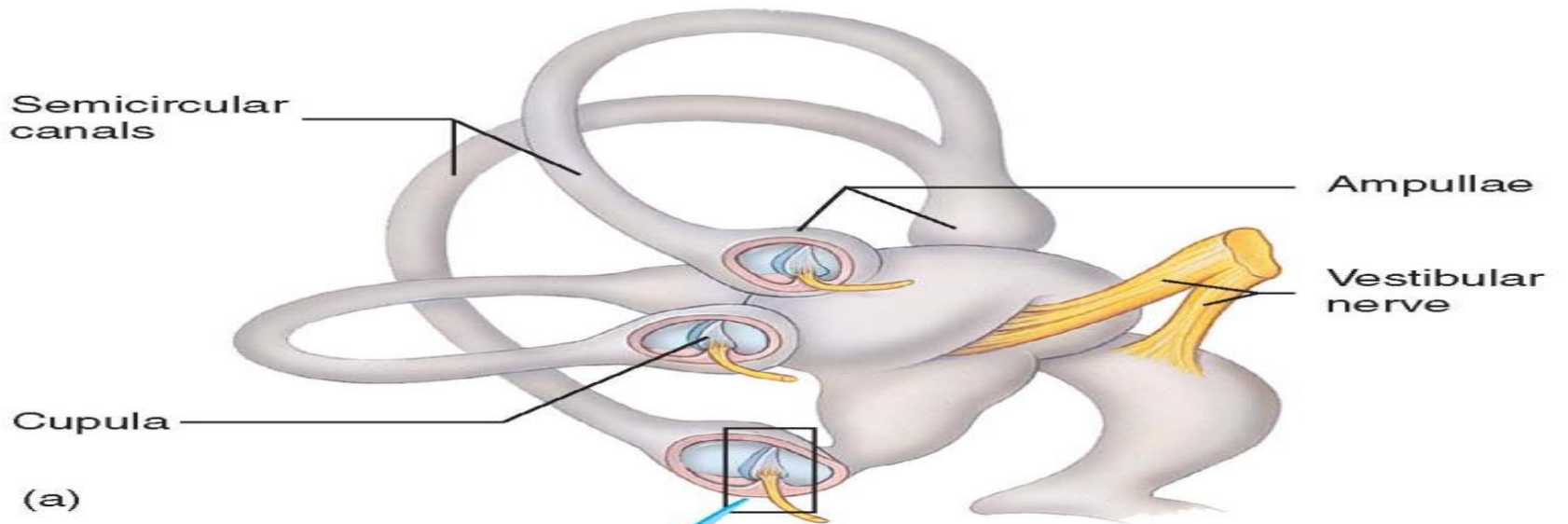
(b)

Figure 9.21 Function of the Vestibule in Maintaining Balance

(a) In an upright position, the maculae don't move. (b) When the position of the head changes, as when a person bends over, the maculae respond by moving in the direction of gravity.

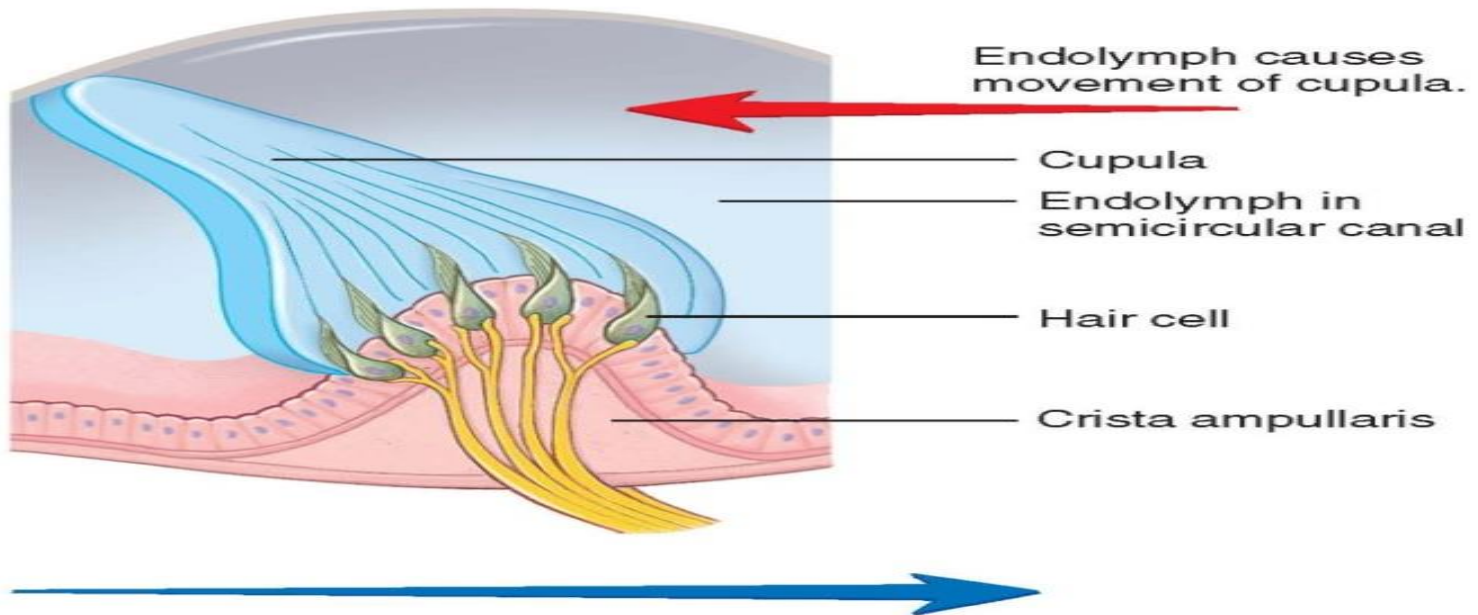


- **Semicircular canals:**
 - dynamic equil.
 - sense movement in any direction
- **Ampulla:**
base of semicircular canal
- **Crista ampullaris:**
in ampulla
- **Cupula:**
 - gelatinous mass
 - contains microvilli
 - float that is displaced by endolymph movement





(a)



(b)