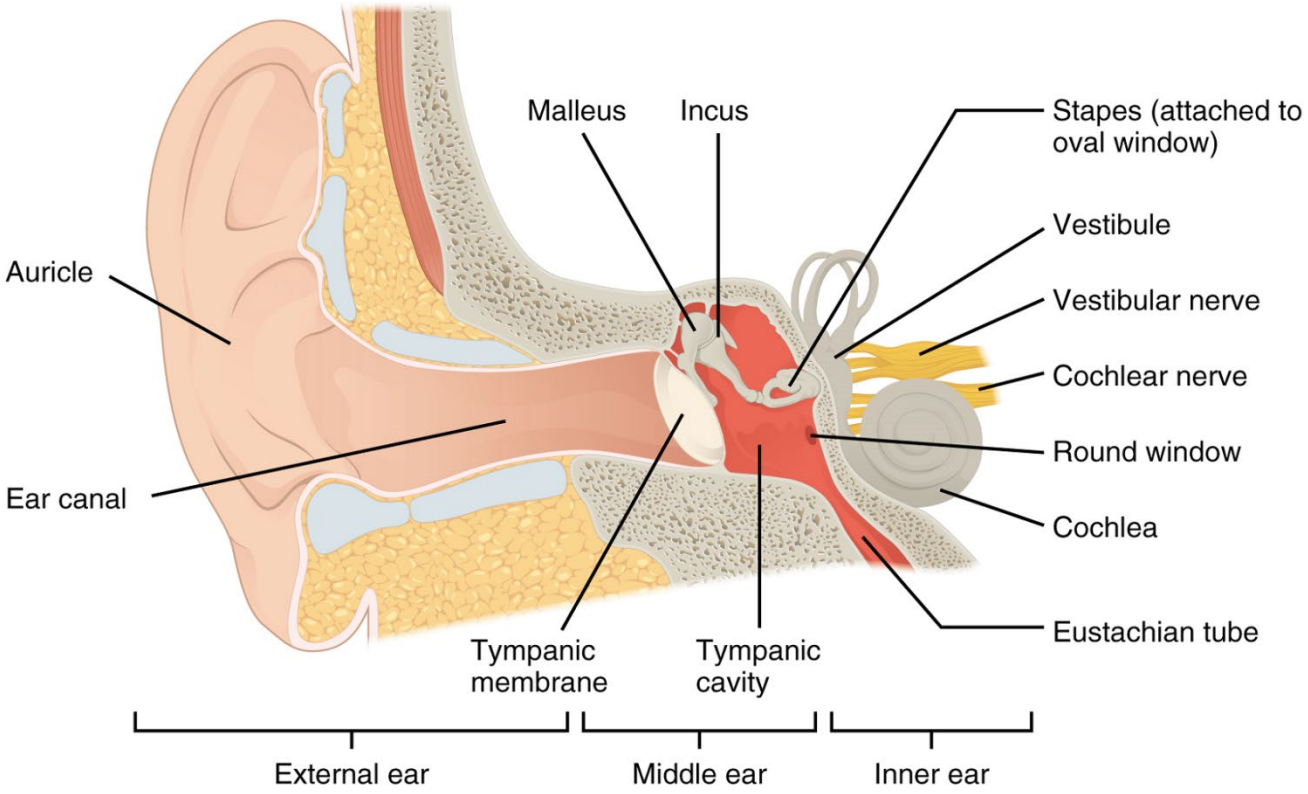
BIOLOGY 1103/1109
Human Anatomy and Physiology I

UNIT 10

Sensation and special senses



Sensation and special senses

Objectives

Sensory system

1. List the five main categories of sense receptors in the body based on the types of stimuli they respond to.
2. Describe the structure and function of cutaneous sensors and proprioceptors.
3. Describe the structure and function of the olfactory system.
4. Describe the structure and function of the gustatory system.

The ear

5. Describe the structure and functions of the external, middle and inner ear.
6. Describe the physiology of hearing.
7. Describe the physiology of static and dynamic balance.

The eye

8. Identify the location and explain the function of each of the main components of the human eye.
9. Describe the formation of an image on the retina.
10. Describe the overall distribution and functions of the two main types of photoreceptors in the retina.
11. Describe the pathway of the nervous impulses from the photoreceptors of the retina to the brain.
12. Describe the location, structure and functions of the lacrimal apparatus.

SENSORY SYSTEM

Categories of sense receptors

- Based upon structure of receptor (which are modified neurons)
  - Free nerve ending (pain and temperature receptors of skin)
  - Encapsulate ending (pressure and touch: lamellated corpuscles in skin)
  - Specialized receptor cell (photoreceptors in eyes)

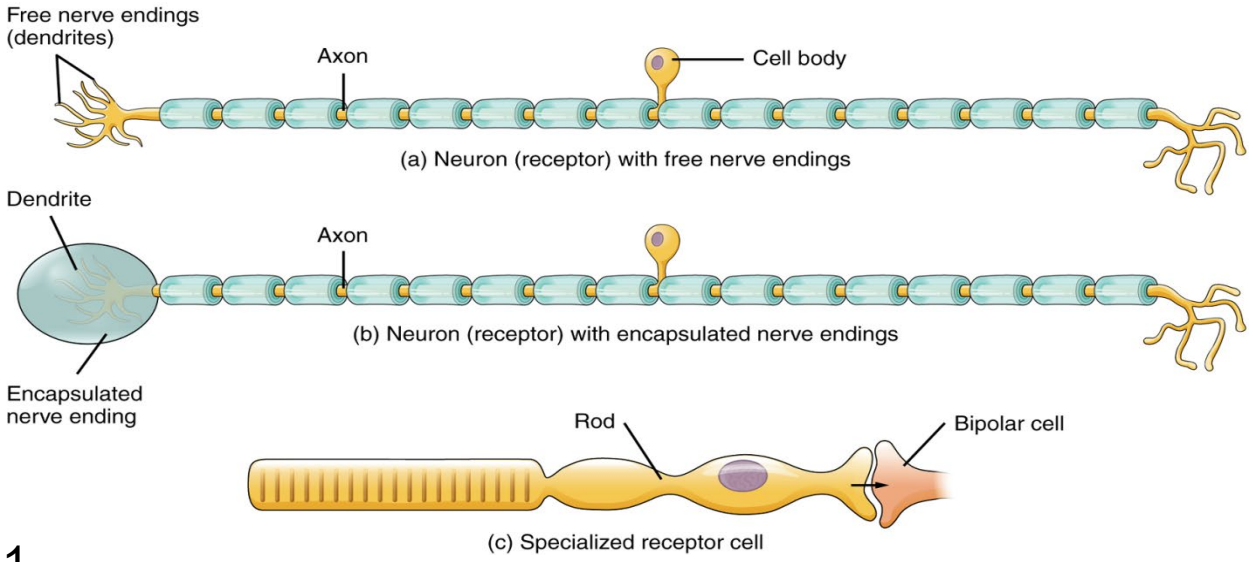


Figure 1

Categories of sense receptors

- Based on the location of the stimuli
  - Exteroceptor is located near a stimulus in the external environment (somatosensory receptors in skin)
  - Interoceptor is one that interprets stimuli from internal organs and tissues (receptors that sense the increase in blood pressure in the aorta)
  - Proprioceptor is a receptor located near a moving part of the body (in muscle)

Categories of sense receptors

- Based upon function of the receptor

Chemoreceptors

Stimulus: Chemicals

- Mouth: Taste
- Nose: Smell
- Blood vessels: Glucose, CO_2, O_2

Mechanoreceptors

Stimulus: Distortion of cell membrane

- Skin: Touch, pressure, vibration
- Blood vessels: Blood pressure
- Ear: Hearing & equilibrium

Nociceptors

Stimulus: Pain, tissue damage

- Skin, organs (exc. brain)

Thermoreceptors

Stimulus: Changes in temperature

- Skin and most body tissues:

Warm and cold receptors

Photoreceptors

Stimulus: Light

- Retina of the eye

Sensory modalities

- A general sense is one that is distributed throughout the body and has receptor cells within the structures of other organs.
- A special sense is one that has a specific organ devoted to it, namely the eye, inner ear, tongue, or nose.

- 17 different sensory modalities including: taste, smell, touch (pressure, vibration, stretch), hearing, sight, balance and temperature

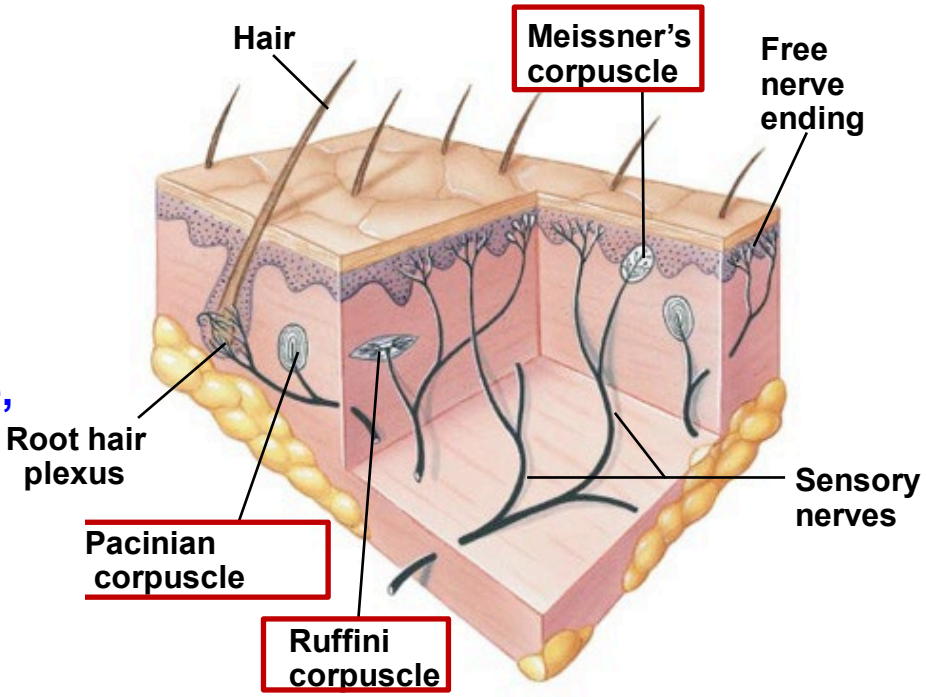
Somatosensation (Touch)

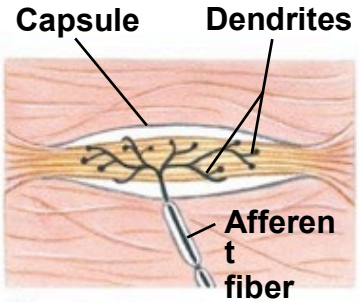
- A group of sensory modalities which is associated with touch, proprioception and interoception
- Include pressure, vibration, light touch, tickle, itch, temperature, pain and kinesthesia
- Many receptors are located in the skin and are called cutaneous receptors

General cutaneous receptors – free and encapsulated nerve endings

(a) Free nerve endings

- Pain, temperature, touch

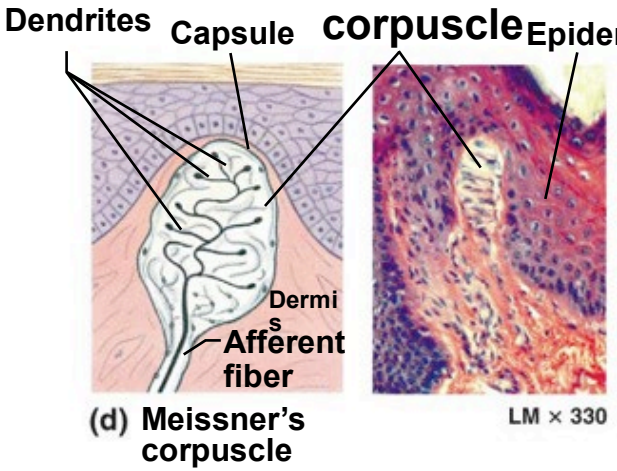




(f) Ruffini corpuscle

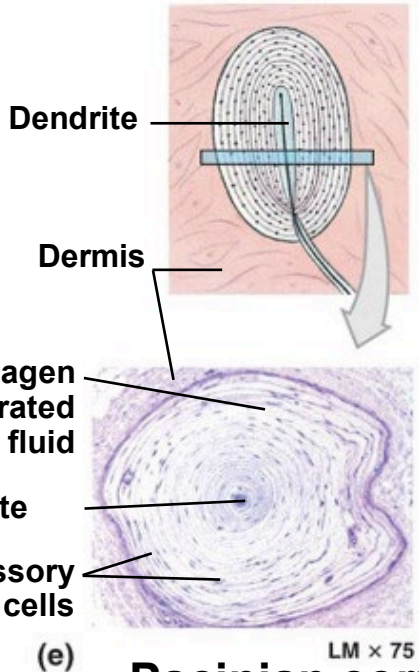
- Firm pressure and stretch

Meissner's corpuscle



(d) Meissner's corpuscle

- Light touch and low vibration



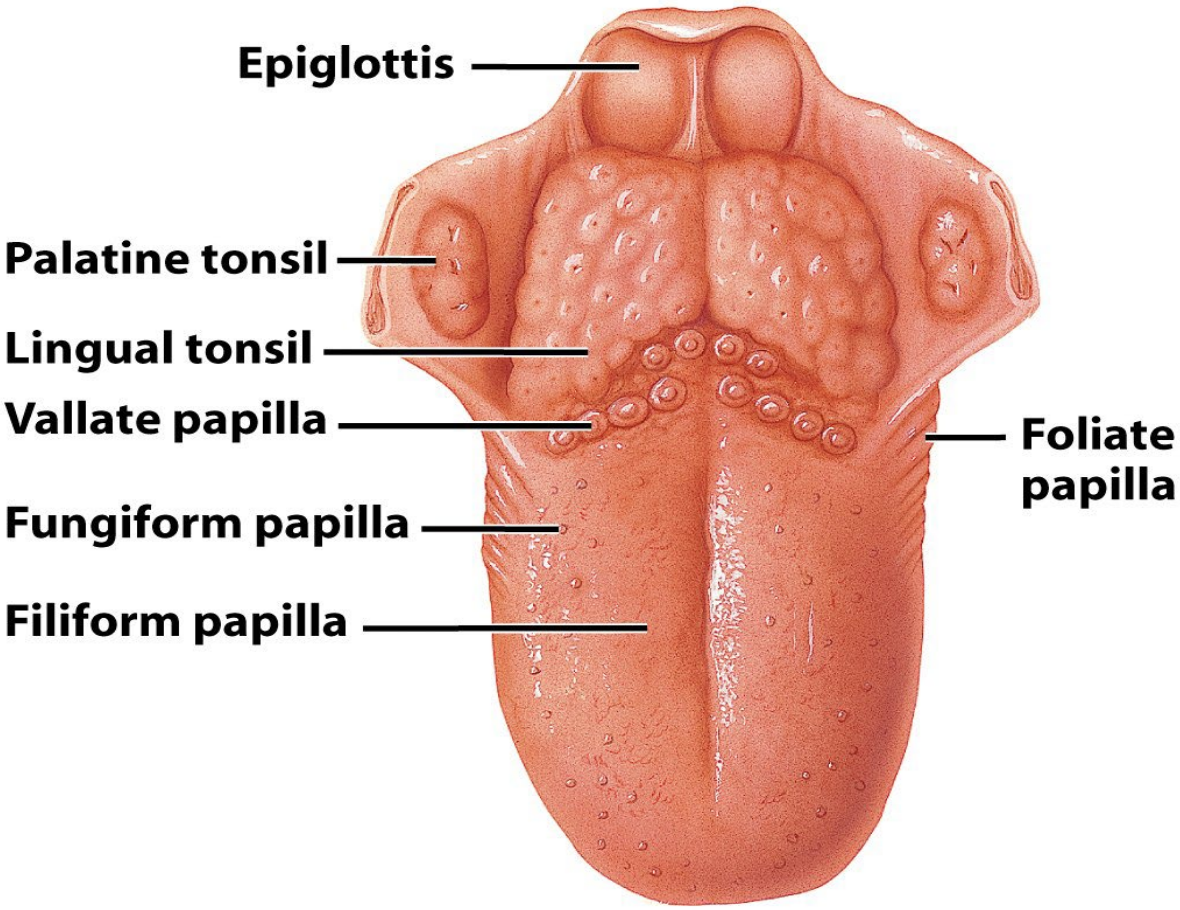
(e) Pacinian corpuscle

- Heavy pressure and vibration (Merkel cells)

Gustatory receptors

- Surface of the **tongue (soft palate, and pharynx)** covered in **papillae**

- Papillae contain **taste buds** elevated by surrounding connective tissue and epithelium, which contain **gustatory receptor cells**

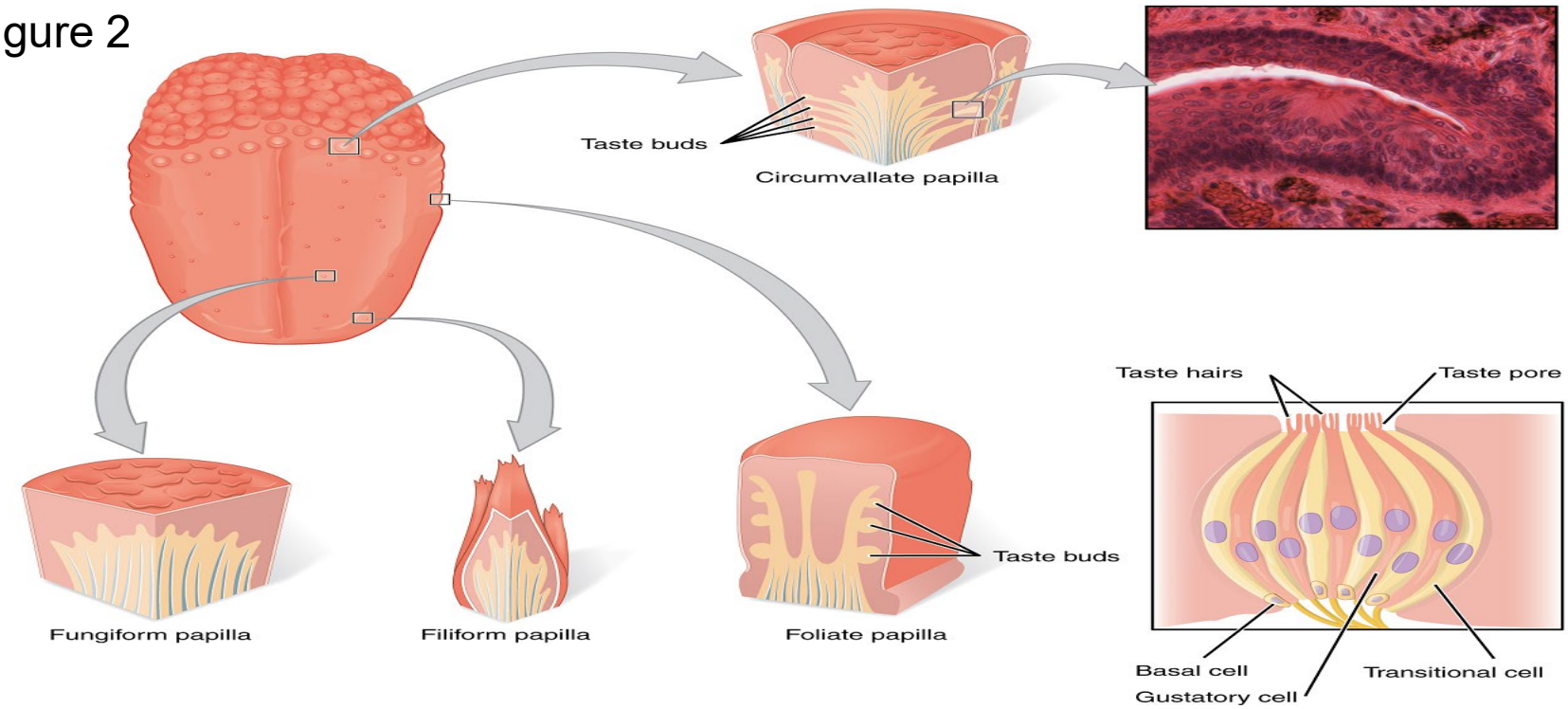


Dorsum of tongue showing location of papillae

Marieb, Figure 15.22

Taste buds

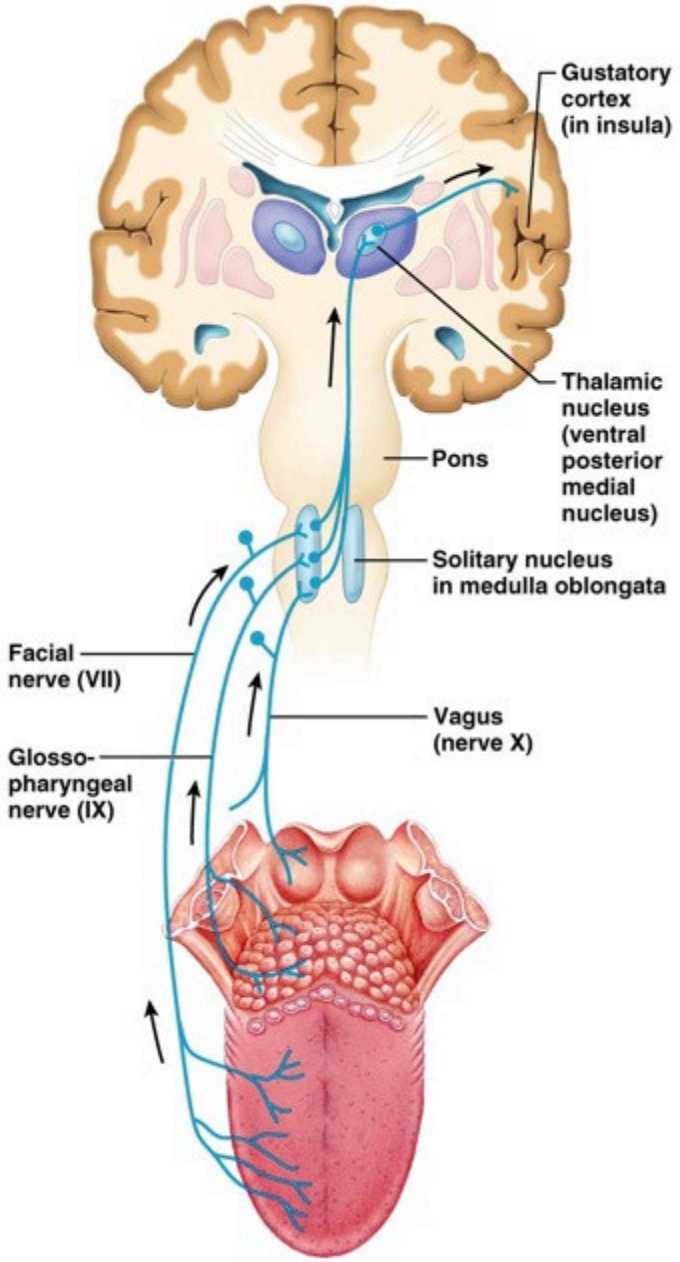
Figure 2



- **Taste bud**= Oval body composed of 4- 20 gustatory **cells** (with "hairs")
- Causes a change in membrane potential (depolarization) which then release neurotransmitters onto the dendrites of sensory neurons
- Basic taste sensations include: sour, sweet, salty, bitter, and umami
- (Note: most of your taste is through your olfactory receptors!)

Gustatory pathway

- Each gustatory cell has a single long hair projecting through a taste pore which makes contact with substances in saliva
  - Sodium ions enter cell via sodium channels, causing depolarization (salty)
  - Hydrogen ions enter via hydrogen channels, causing depolarization (sour)
  - Chemicals that cause sweet, bitter and umami tastes fit into receptors that then cause depolarization
- Gustatory cell synapses with sensory **neurons** followed by **medulla**, **thalamus** and **primary gustatory area in cerebral cortex** (parietal lobe)
- The pattern of reception of the five different tastes create the sensation of many different tastes
- Taste buds are specialized for one taste, but are spread evenly over buccal surface

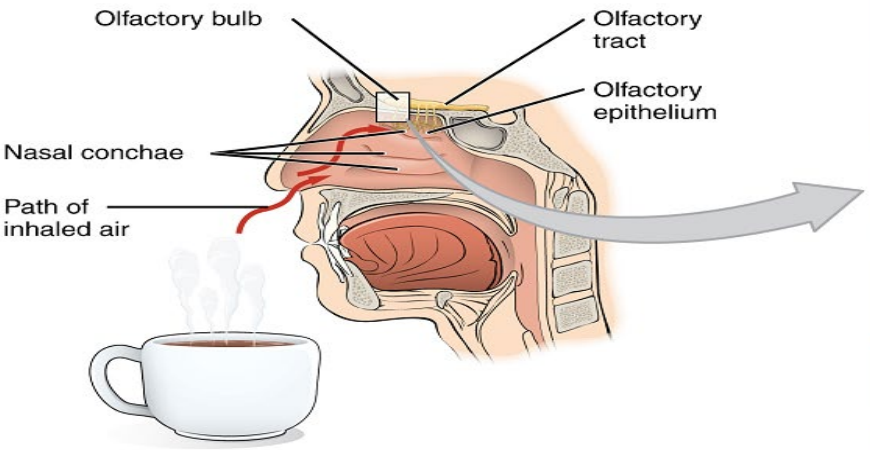


Marieb, Figure 15.23

Olfaction

- Sense of smell
- Response to a chemical stimuli
- Olfactory receptor neurons are located in a small region of the walls of the superior nasal cavity is a region called the **olfactory epithelium**
- **olfactory sensory neuron** has dendrites that extend from the apical surface of the epithelium into the mucus lining the cavity

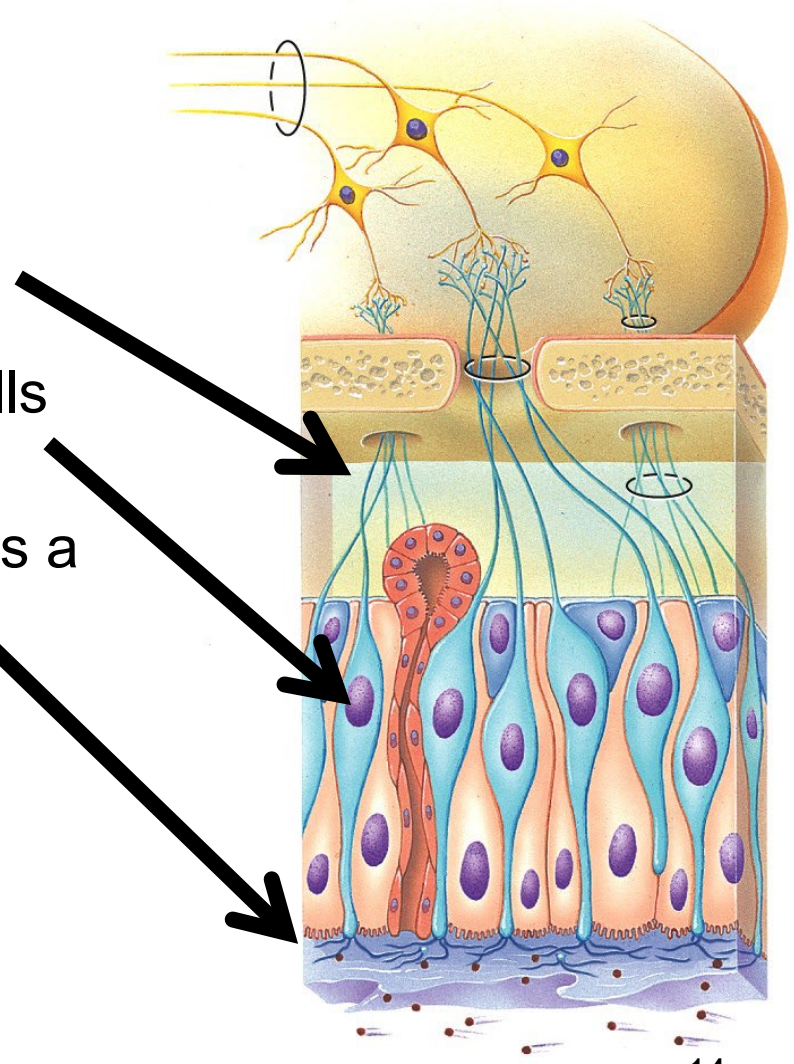
Figure 3a



Olfactory cilia

Structure of olfactory receptors

- Bipolar neurons with elongated axons and dendrites
- Cell bodies lie between supporting cells (columnar epithelial)
- The free end of each receptor contains a swelling containing 6-8 cilia
  - These cilia are involved in picking up odours



Pathway of olfactory impulses

1. Odour stimulates **olfactory receptor cell** (chemoreceptors) to produce an impulse
2. Impulse travels through an opening in the skull to the brain
3. Axon called the **olfactory** tract connect to **olfactory bulb** on frontal lode
4. Impulse then reaches **temporal lobe** of the cerebral cortex (primary olfactory area) and is interpreted as smell

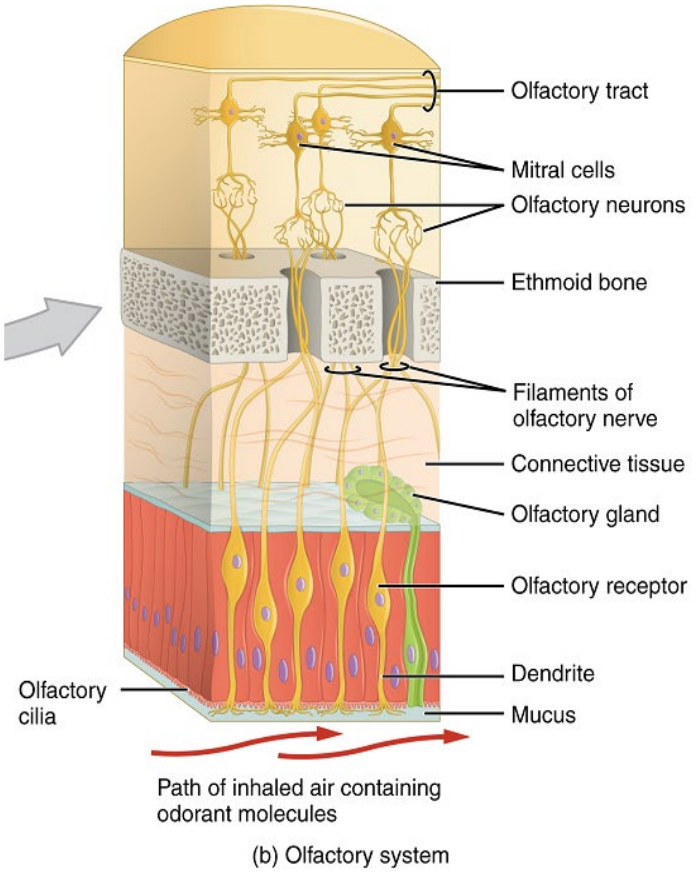


Figure 3b

VISION (THE EYE)

Eye

- Special sense of sight based upon transduction of light stimuli
- Eyes located on orbits in the skull
- Eyelids with lashes protect the eye
- Tears proceeded by lacrimal glands
- Movement of eye accomplished by extraocular muscles

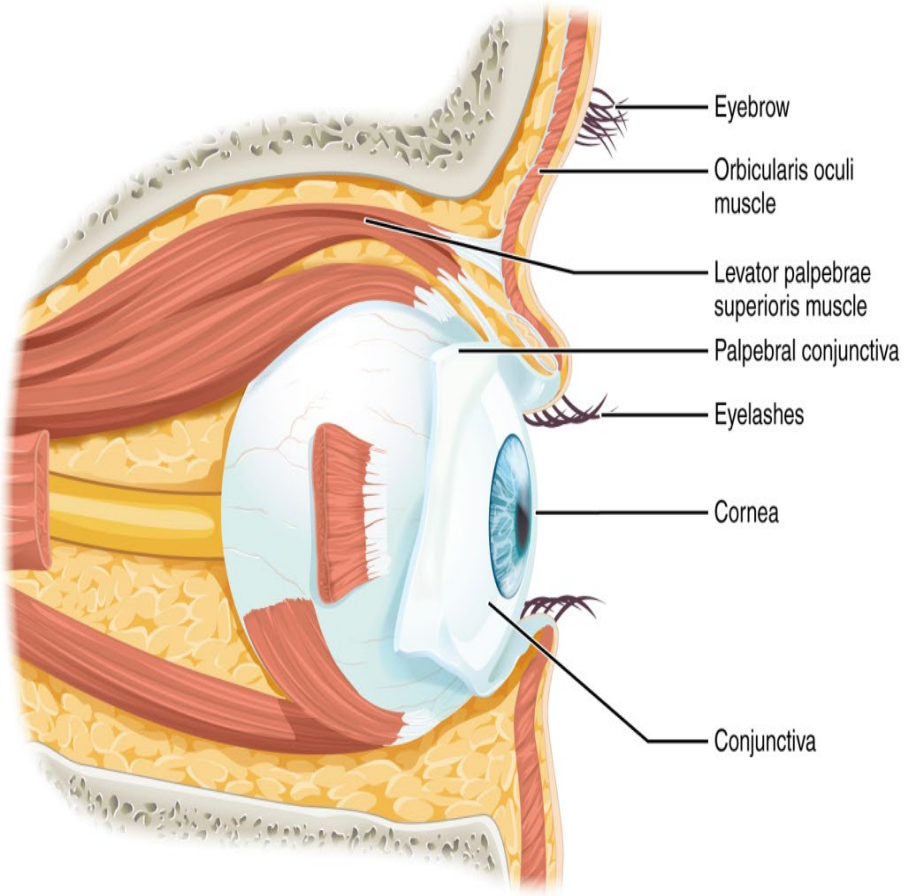
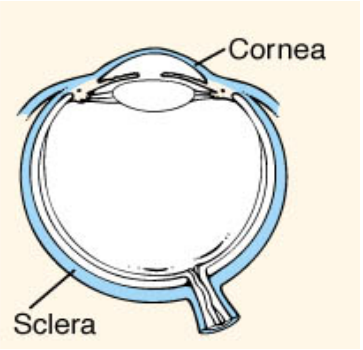


Figure 11

Eyeball wall



1. Fibrous tunic

- Outer layer
- Formed by the anterior cornea and the posterior sclera
- **Sclera:** white of the eye; a tough fibrous coat that protects the inner parts of the eye and gives shape to the eye
- **Cornea:** main function is to refract rays of light to focus them onto the retina

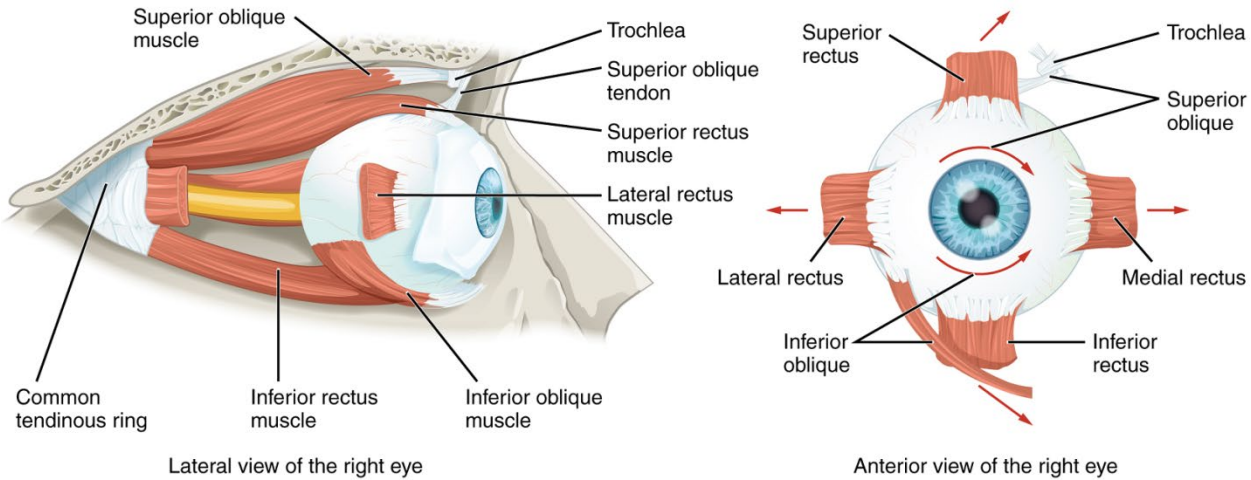
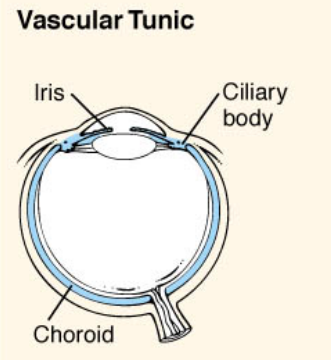


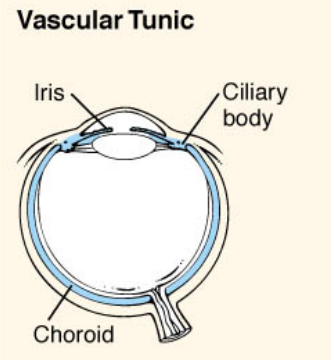
Figure 12

Eyeball wall



2. Vascular tunic

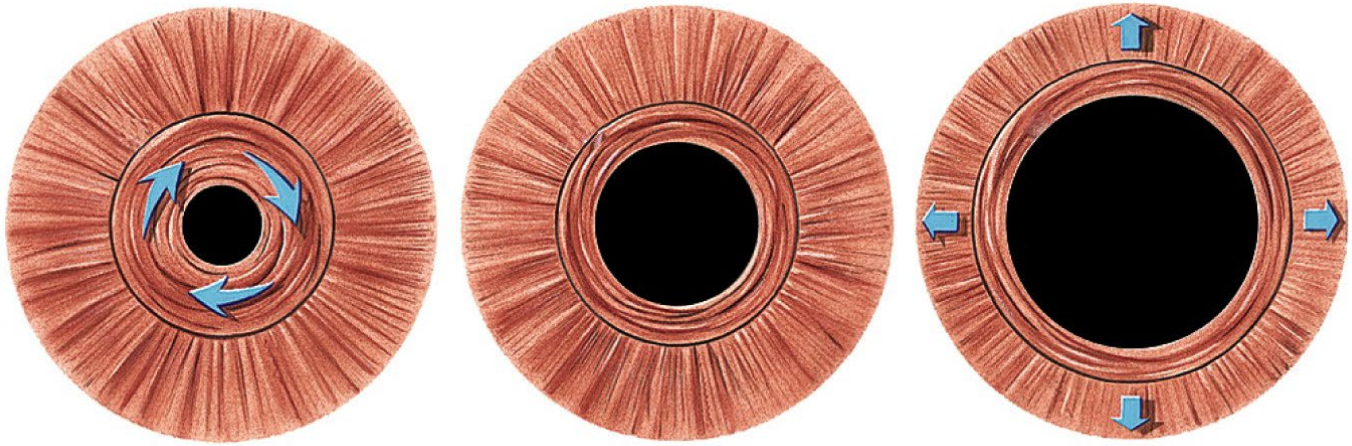
- Middle layer
- Formed by the posterior choroid, anterior ciliary body, and the iris
- **Choroid**: dark brown membrane that lines the sclera; high blood supply to nourish the retina; pigmented to absorb light rays
- **Ciliary body:** extends from the retina to the base of the iris; its muscles alter the shape of the lens for focusing; secretes aqueous humor
- **Iris**: the coloured part of the eye; a diaphragm that alters the size of the pupil



Eyeball wall

2. Vascular tunic

- **Pupil**: the opening in the centre of the iris
  - Changes in size depending on the contraction of an antagonistic pair of muscles (circular and radial muscles)
  - Allows light rays to enter the eye



Eyeball wall

3. Neural tunic/ Retina

- Inner layer
- Lines the posterior side of the eyeball
- Contains
  - (inner) nervous tissue layer
  - (outer) pigmented layer
- Involved in image formation
- Stores vitamin A
- The *nervous tissue* layer of the retina ends in a jagged border near the ciliary body, called the **ora serrata** (optic portion of the retina)
- The *pigmented layer* continues over the back of the ciliary body and the iris (ciliary portion of the retina)

Eyeball wall

3. Neural tunic/Retina

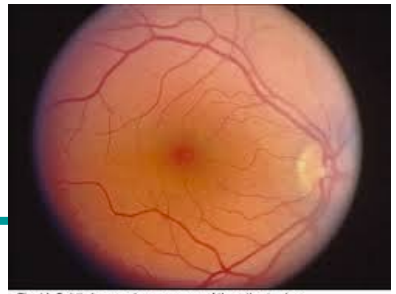


Fig. 14. Ophthalmoscopic appearance of the retina to show the macula lutea (yellow around fovea).

- The photoreceptors (rods and cones) which change their membrane potential when stimulated by light energy
- **Macula lutea**: the small area at the centre of the retina
- Fovea **:** the small depression in the centre of the macula, with the highest concentration of cones (photoreceptors)
- **Optic disc:** where the ganglion neurons bend posteriorly from the optic nerve (aka blind spot) and leave the eye as the **optic nerve**

Photoreceptors

- Neurons that translates the image on the retina into nervous impulses
- Two types:
  - **Rods:**
    - 20 times more numerous than cones
    - Dim light and peripheral vision receptors
    - Does not provide sharp images
  - Cones **:**
    - Operates in bright light
    - Provides high clarity and colour vision

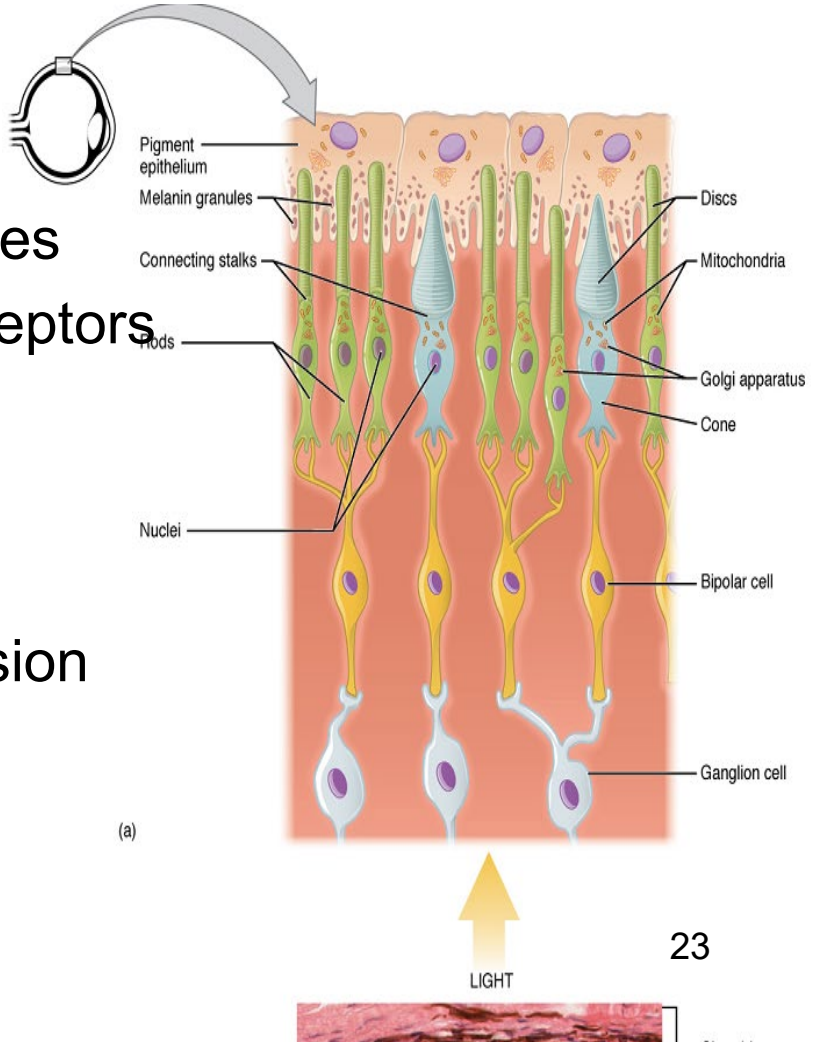
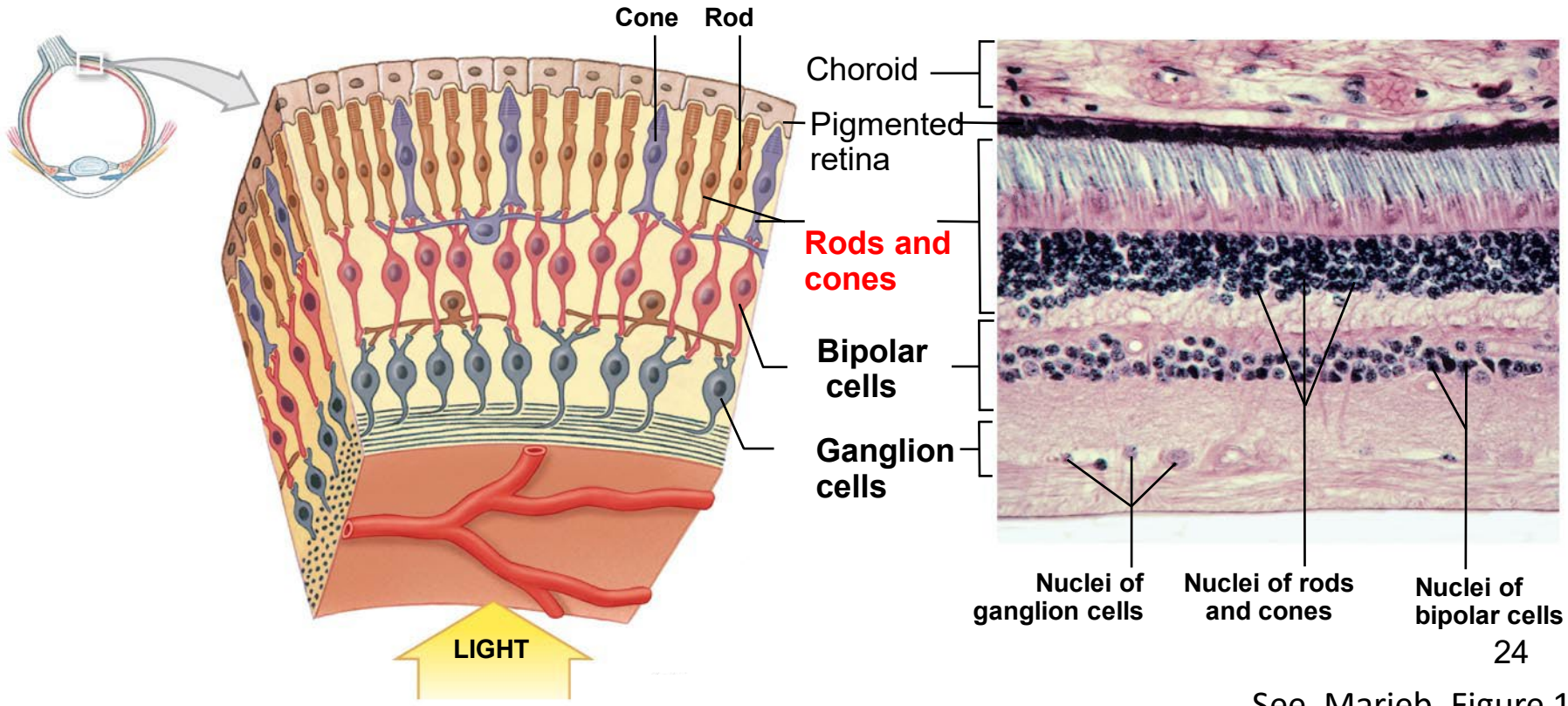


Figure 14

Photoreceptors

- Located in innermost zone of retina
- Fovea centralis has only cones
- Number of rods increase (and cones decrease) with further distance from the fovea



See Marieb, Figure 15.6

Photopigment - rods

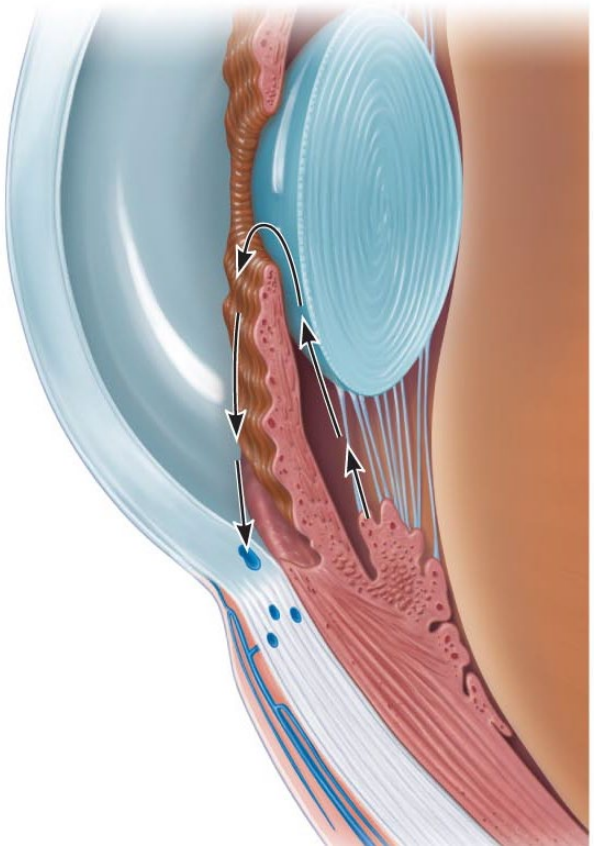
- Light is absorbed by photopigments in the dendrites of the rods and cones
- Different pigments absorb different intensities/wavelengths of light.
- When a pigment absorbs light of a particular intensity and wavelength, it causes a signal to be sent to the brain
- Pigment in rods is rhodopsin
  - Only one pigment means only one colour (grey)
- Result: in dim light we see **fuzzy images in shades of grey**

Photopigment - cones

- There are 3 types of cones, each responds to one a different colour of light
  - Red light
  - Green light
  - Blue light
- The activation of more than one type of cone leads to intermediate colours
- Called opsins (transmembrane proteins)
- Results: in bright light we see **sharp and colour images**
- Colour blindness results in the absence or deficiency of one of the three types of cones

Other parts of the eye

- Lens :
  - Completely transparent and lies posterior to the iris
  - Focuses light rays on the retina by changing shape (recall that the cornea is responsible for most light refraction)
  - Suspended in the ciliary body by suspensory ligaments
  - Divides the eye into anterior and posterior cavities

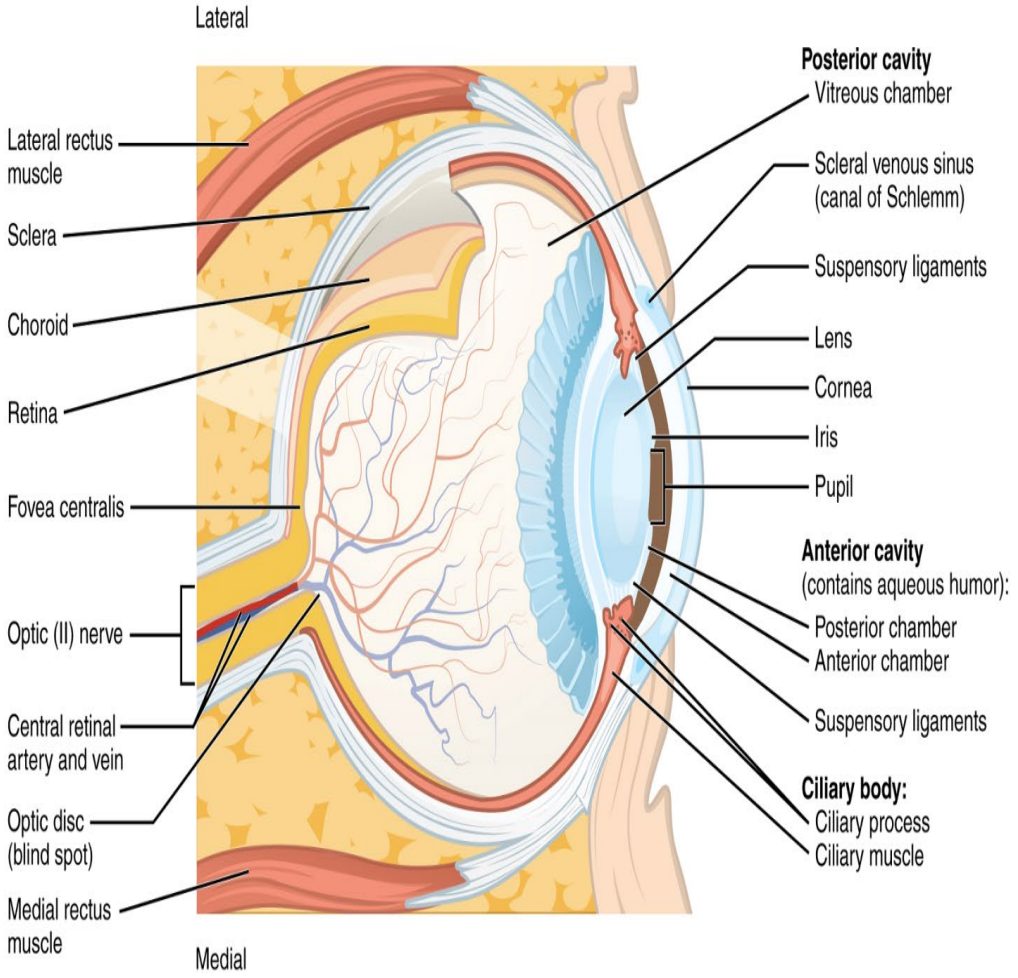


Eyeball cavities

- Anterior **cavity:** between the cornea and lens
  - Filled with **aqueous humour**
  - Similar in composition as cerebrospinal fluid
  - Functions to maintain pressure on the eyeball for clear vision
  - Also supplies the lens and cornea with nutrients

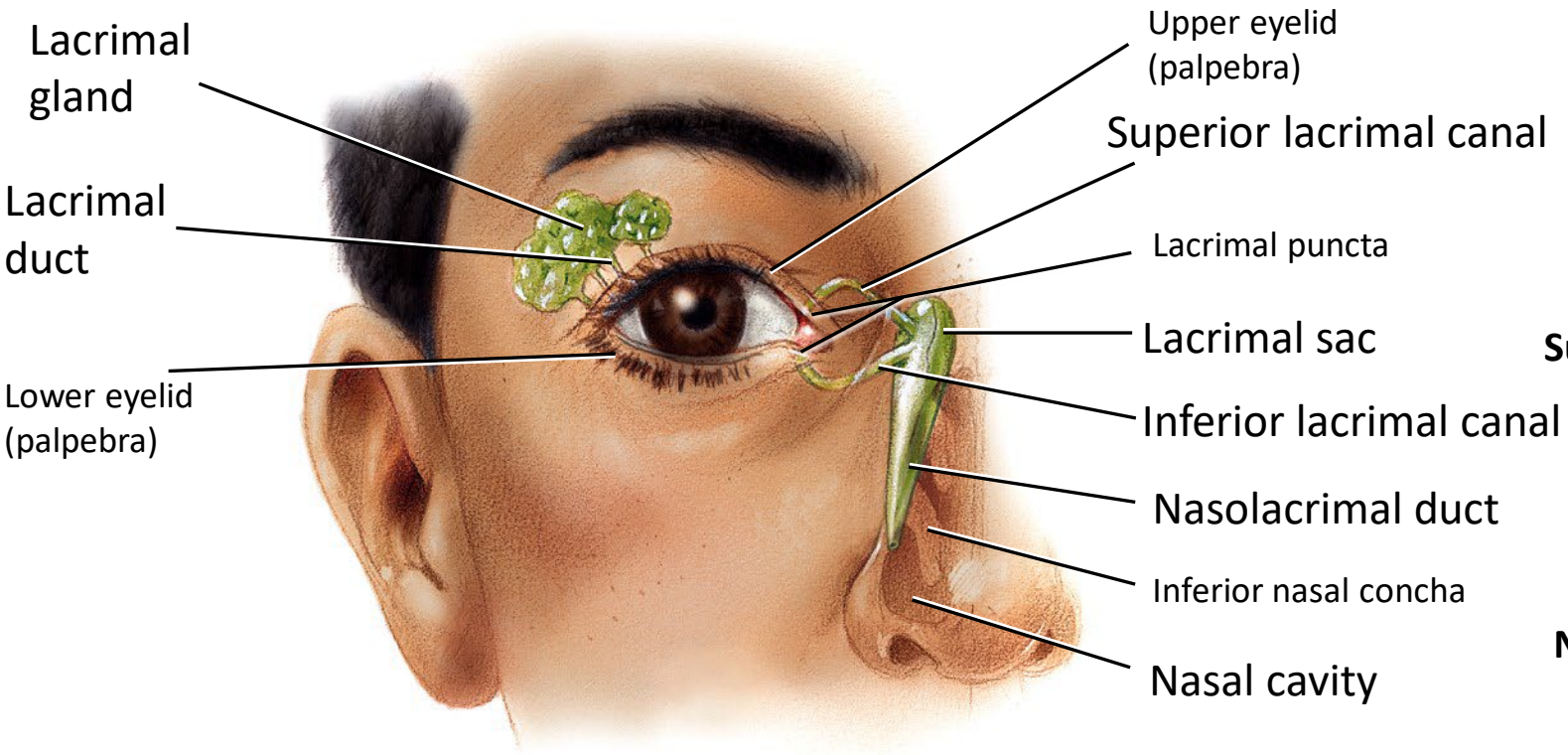
Eyeball cavities

- Posterior **cavity**: between the lens and retina
  - Filled with **vitreous humour** (a jelly-like liquid)
  - Prevents the eyeball from collapsing and to hold the retina against the choroid



Lacrimal apparatus

Manufacture and draining of tears



FLOW OF TEARS

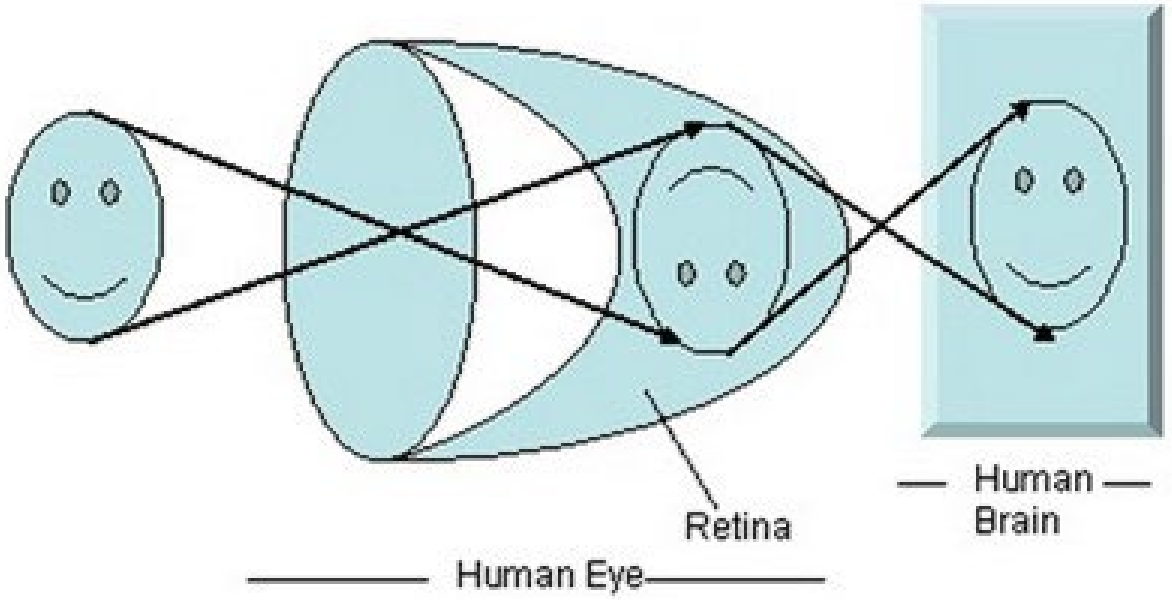
Lacrimal gland
↓
Lacrimal ducts
↓ Lacrimal puncta
Superior or inferior lacrimal canal
↓
Lacrimal sac
↓
Nasolacrimal duct
↓
Nasal cavity

- Tears = watery solution containing:
  - Salts
  - Mucous
  - Lysozyme (bactericidal enzyme)
- Functions of tears
  - Clean and moisten eyes
  - Protect against bacterial infections

Tortora Figure 17.6

Anatomy of Eye
Summary of main components and functions

Layer	Component	Function
Conjunctiva	-	Lubrication and protection of the eyeball
Fibrous tunic	Sclera	Support, protection and movement
	Cornea	Main refractive (light-bending) structure
Vascular tunic	Choroid	Blood supply & light absorption (anti-reflective)
	Ciliary Body	Altering the shape of the lens for focusing. Secretes aqueous humour
	Iris (with pupil)	Regulation of the amount of light entering
Retina	Macula lutea	Site of the fovea
	Fovea	Area of maximal visual acuity
	Optic disc	Site where the optic nerve exits
	Lens	Refractive structure: focusing
	Suspensory ligaments	Connect lens to ciliary body
	Aqueous humour	Nourishment & ocular pressure
	Vitreous humour	Support of the retina & ocular pressure

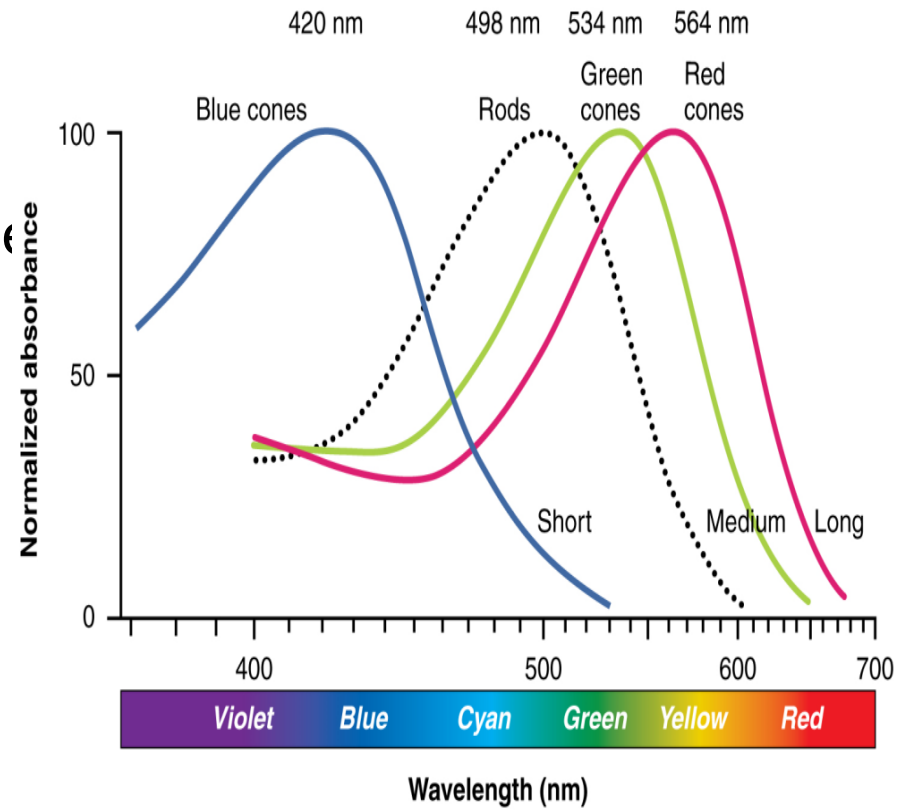


How images are formed onto the retina

PHYSIOLOGY OF THE EYE

Light

- A single unit of light is called a **photon**, packet of energy with properties of both a particle and a wave
- The energy of a photon is represented by its wavelength
- Visible light is electromagnetic radiation with a wavelength betwee 380 and 720 nm

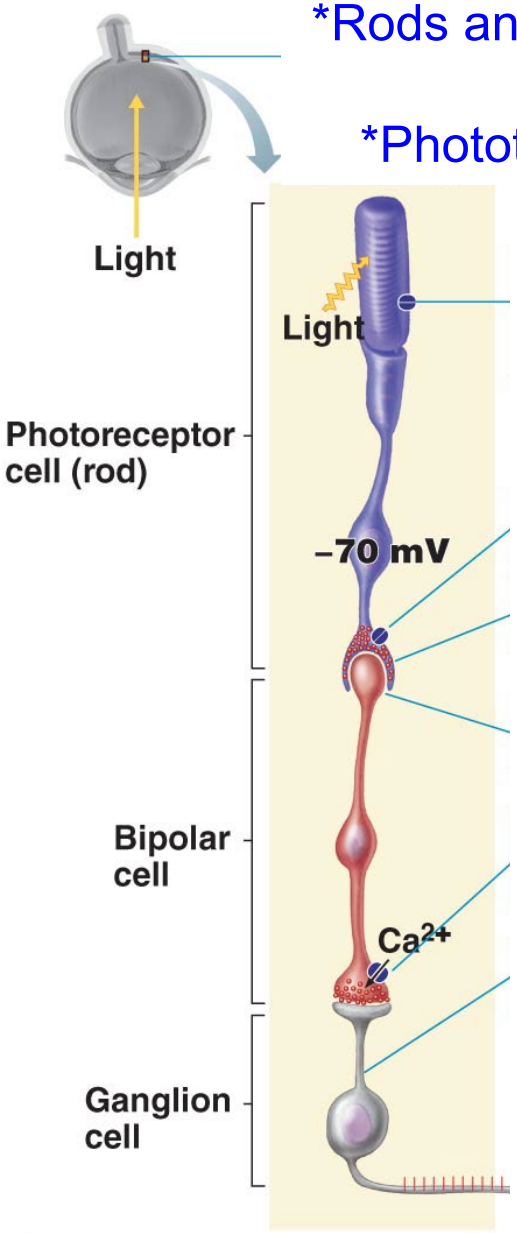


Phototransduction

Photons biochemically altered retinal, called **photoisomerization**

Rods and cones are modified neurons

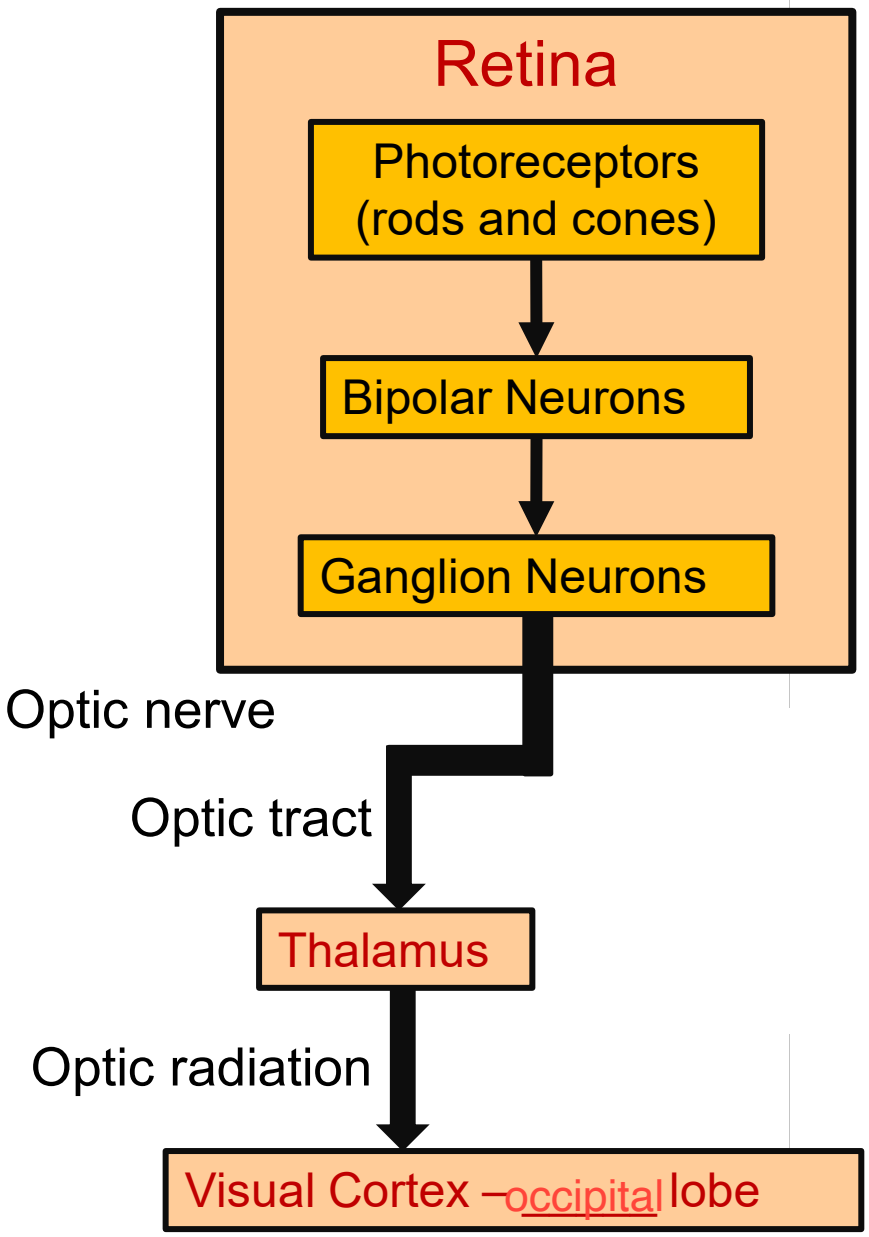
Phototransduction is complicated!

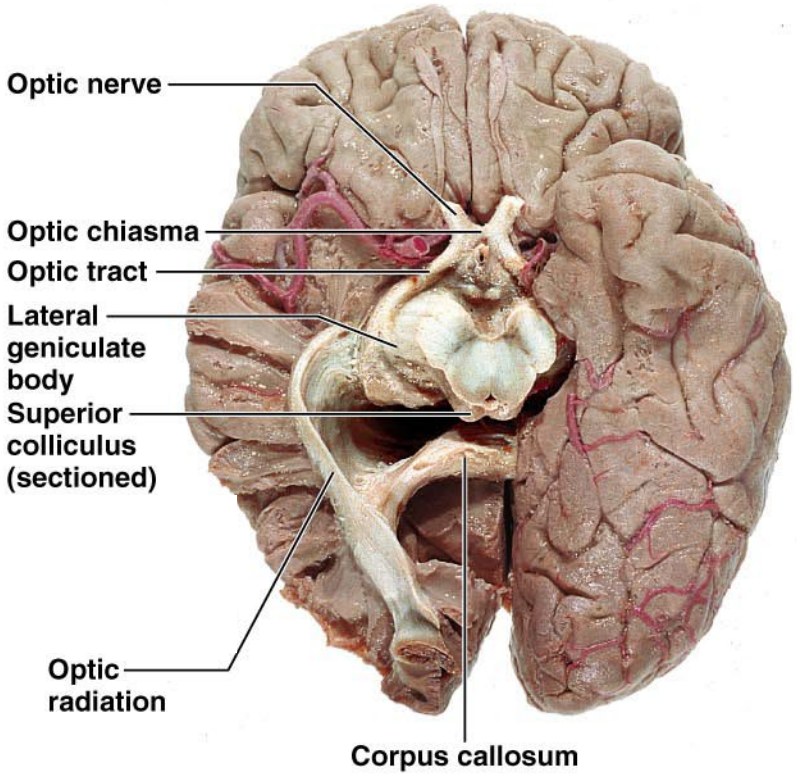


1. Light causes a change in the shape of the photopigment
2. Causes hyperpolarization of photoreceptor
3. Causes depolarization of bipolar cell
4. Causes depolarization of ganglion cell
5. Sends signal to brain

The Visual Pathway

From the retina to the brain





Pathway of visual impulses

- Rods/cones are photoreceptors that become activated upon appropriate wavelength of light
- They synapse with bipolar neurons which synapse with ganglion neurons
- The axons of the ganglion neurons bend at right angles to become the optic nerve
- Optic nerves meet at the optic chiasma
  - **Optic nerves from nasal half crossover, while optic nerves from the temporal half do not crossover**
- The optic tracts enter the brain at the diencephalon and terminate in the thalamus and midbrain
- In the thalamus, the neurons synapse with other neurons that eventually end in the occipital lobe of the cerebral cortex
- a very small number of ganglion cell axons project from the optic chiasm to the hypothalamus which response to the absence or presence of light.

Visual fields

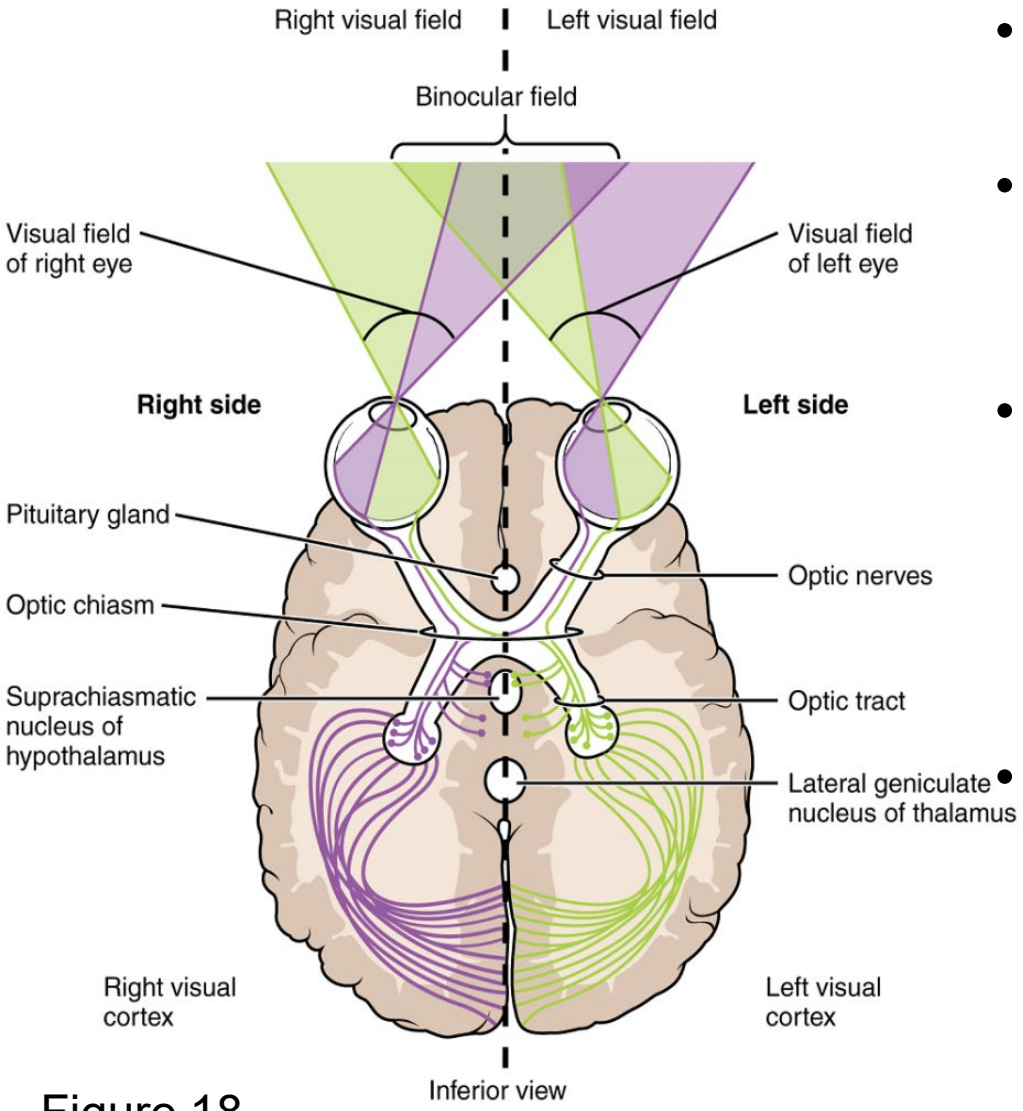
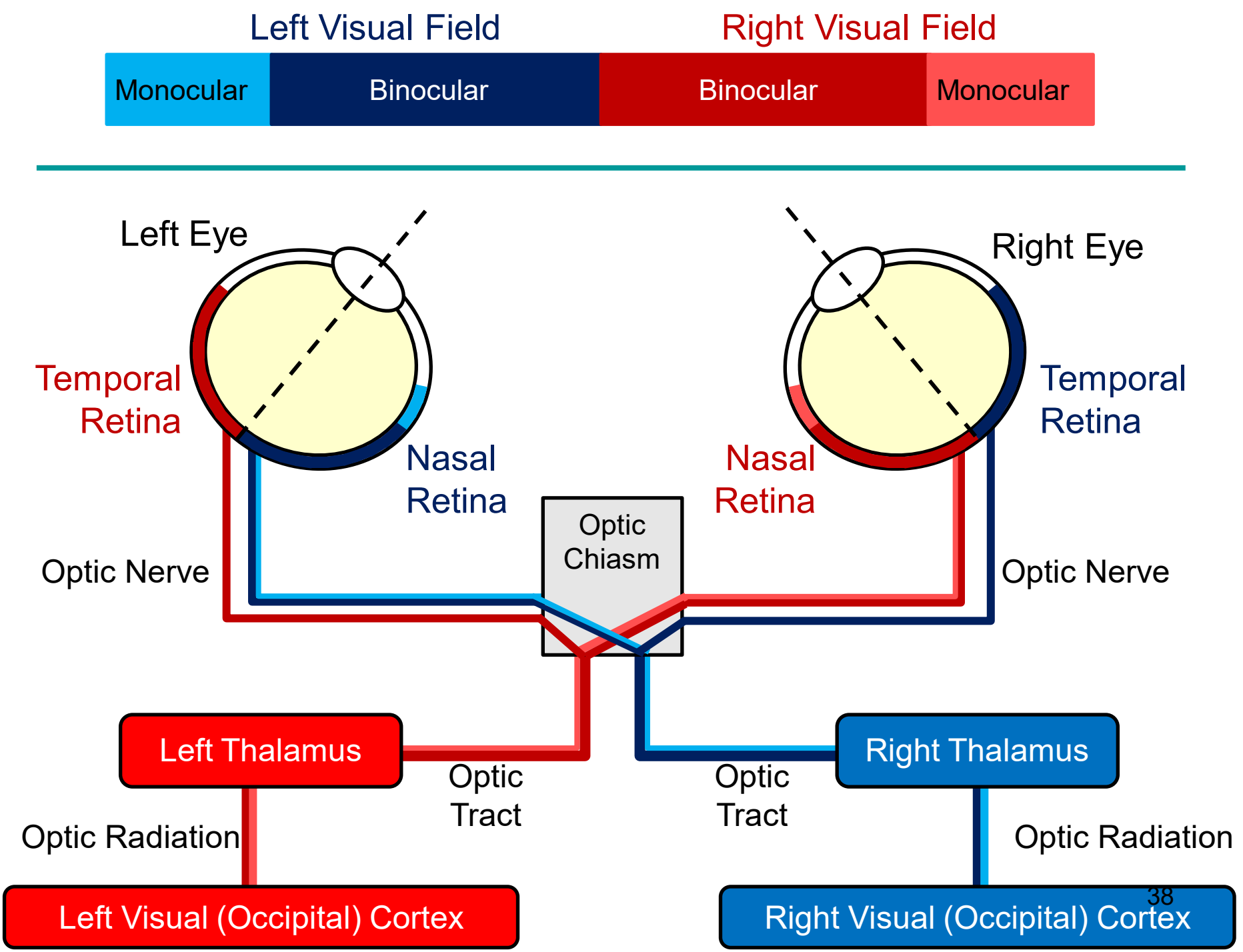


Figure 18

- Each **eye** has two visual fields: **medial** and **lateral**
- The **retina** of each eye is also divided in two halves: **nasal** and **temporal**
- Rays of light from the right side of an object refracts on the nasal half of the right retina and the temporal half of the left retina
- Rays of light from the left side of an object refracts on the nasal half of the left retina and the temporal half of the right eye


Left Visual Field
Right Visual Field
Monocular
Binocular
Binocular
Monocular
Left Eye
Right Eye
Temporal Retina
Nasal Retina
Nasal Retina
Temporal Retina
Optic Chiasm
Optic Nerve
Optic Nerve
Left Thalamus
Right Thalamus
Optic Tract
Optic Tract
Optic Radiation
Optic Radiation
Left Visual (Occipital) Cortex
Right Visual (Occipital) Cortex

What do we mean when we say that our eyes "focus" on an object?

- All of the light from that object lands on the fovea centralis of the retina.

- How do we achieve that?

A. Light refracts as it passes through cornea (fixed degree of refraction)
B. Light refracts as it passes through lens (adjustable degree of refraction)
C. Pupil changes to allow more/less light to pass through lens
D. Extrinsic eye muscles rotate eyeballs to allow light rays to pass more directly into eyes

Refraction of light rays

- Light rays **bend** as they pass from one medium to another
- This **refraction** of light allows light rays entering the eye to be pulled closer together to meet at the fovea.
- The **cornea** is responsible for the majority of refraction occurring as light rays enter the eyeball, but the cornea itself is not adjustable
- The shape and thickness of the lens can be modified to control the degree of refraction, this is called accommodation

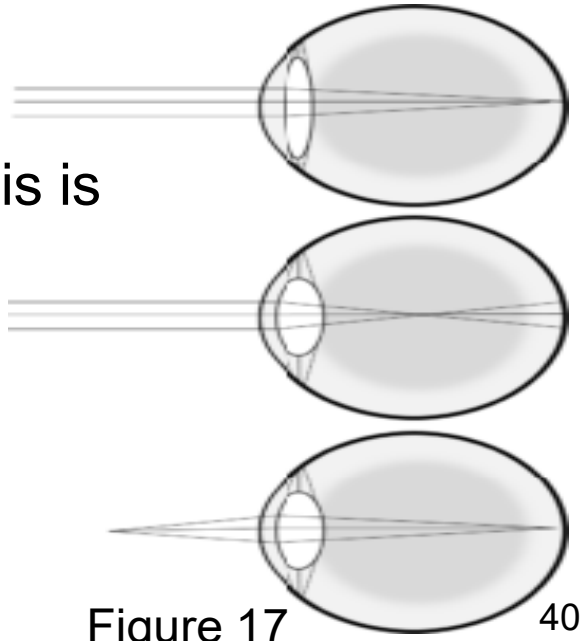
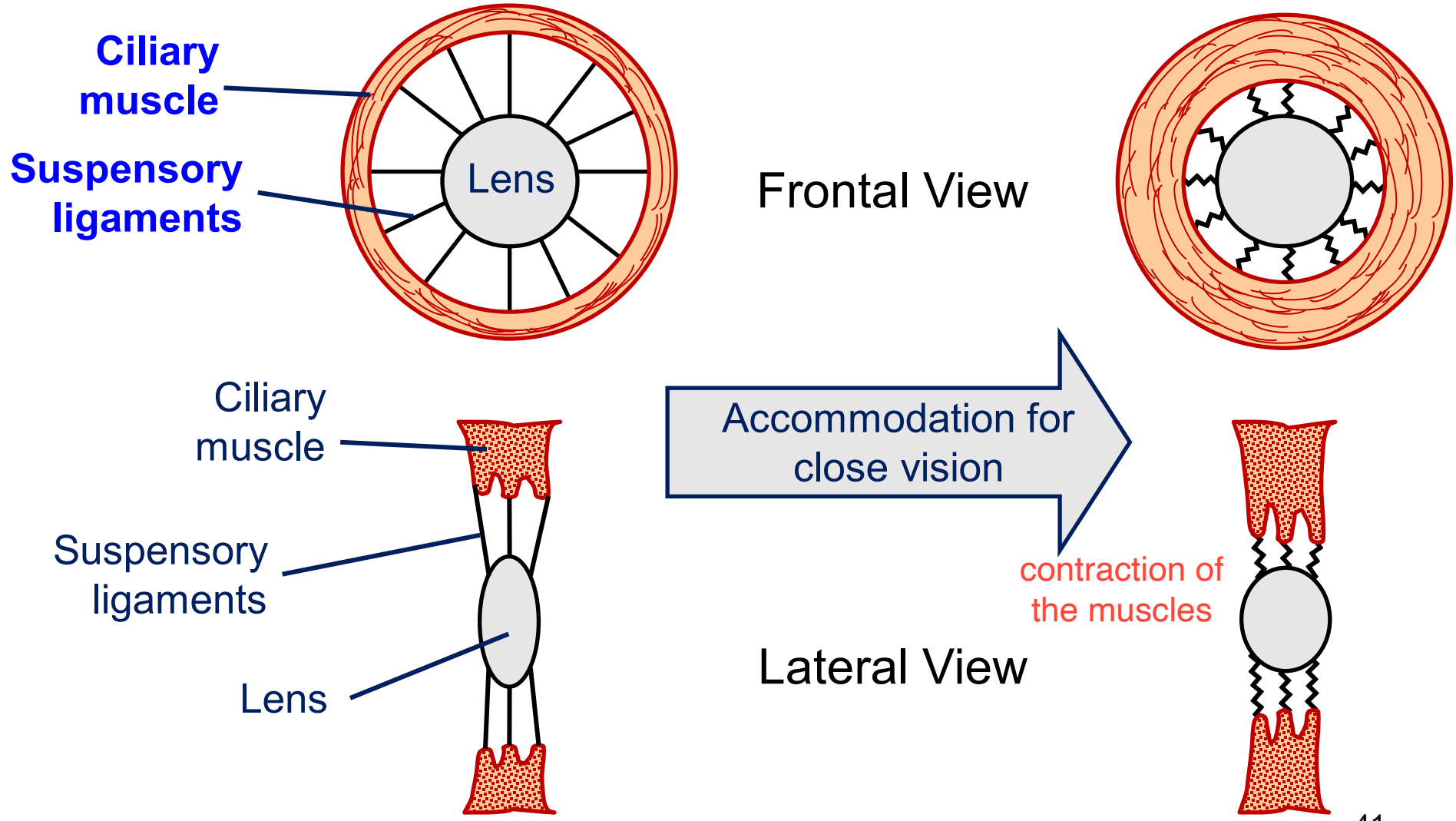


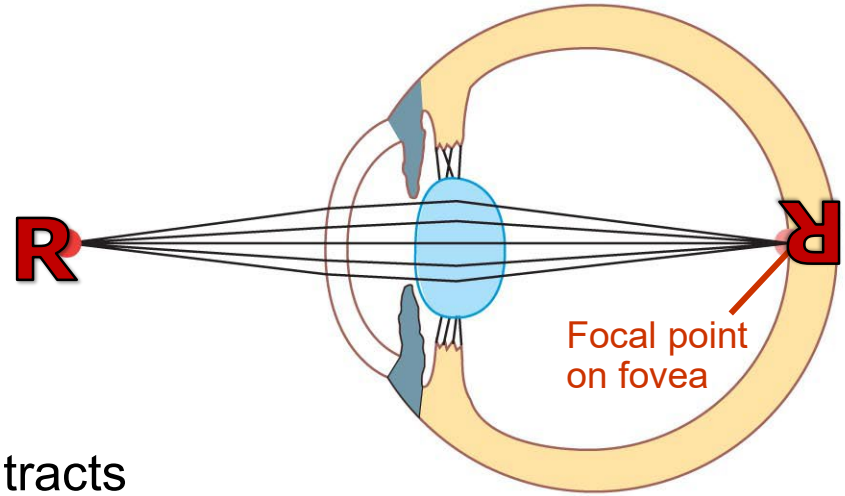
Figure 17

Accommodation of the lens



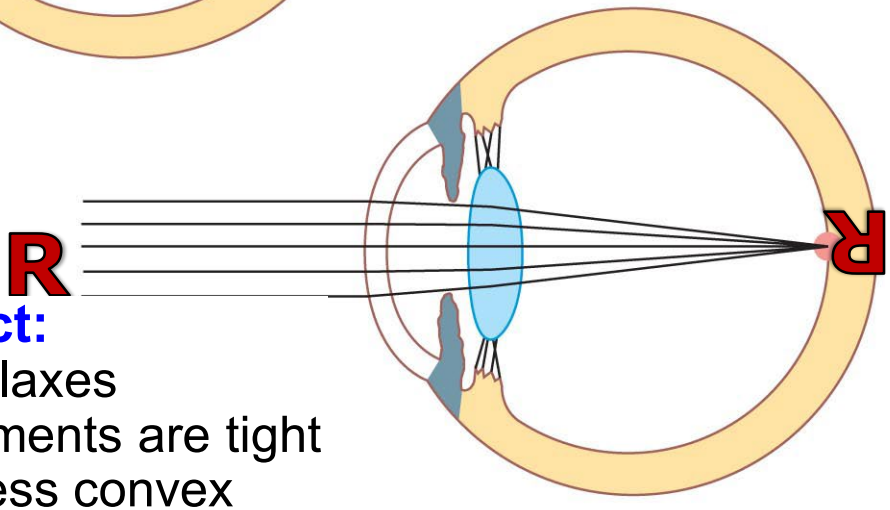
Accommodation of the lens

ciliary muscles



Close object:

- Ciliary muscle contracts
- Suspensory ligaments are loose
- Lens becomes more convex
- Light rays are refracted more



Distant object:

- Ciliary muscle relaxes
- Suspensory ligaments are tight
- Lens becomes less convex
- Light rays are refracted less

important to study

until here for midterm

AUDITION AND BALANCE (THE EAR)

The Ear: hearing and balance

- The three parts of the ear are the external, middle and inner ear
- The external and middle ear function in **hearing**
- The inner ear functions in both **hearing and equilibrium**
  - Contains receptors for hearing and balance
    - Respond to separate stimuli
    - Are activated independently

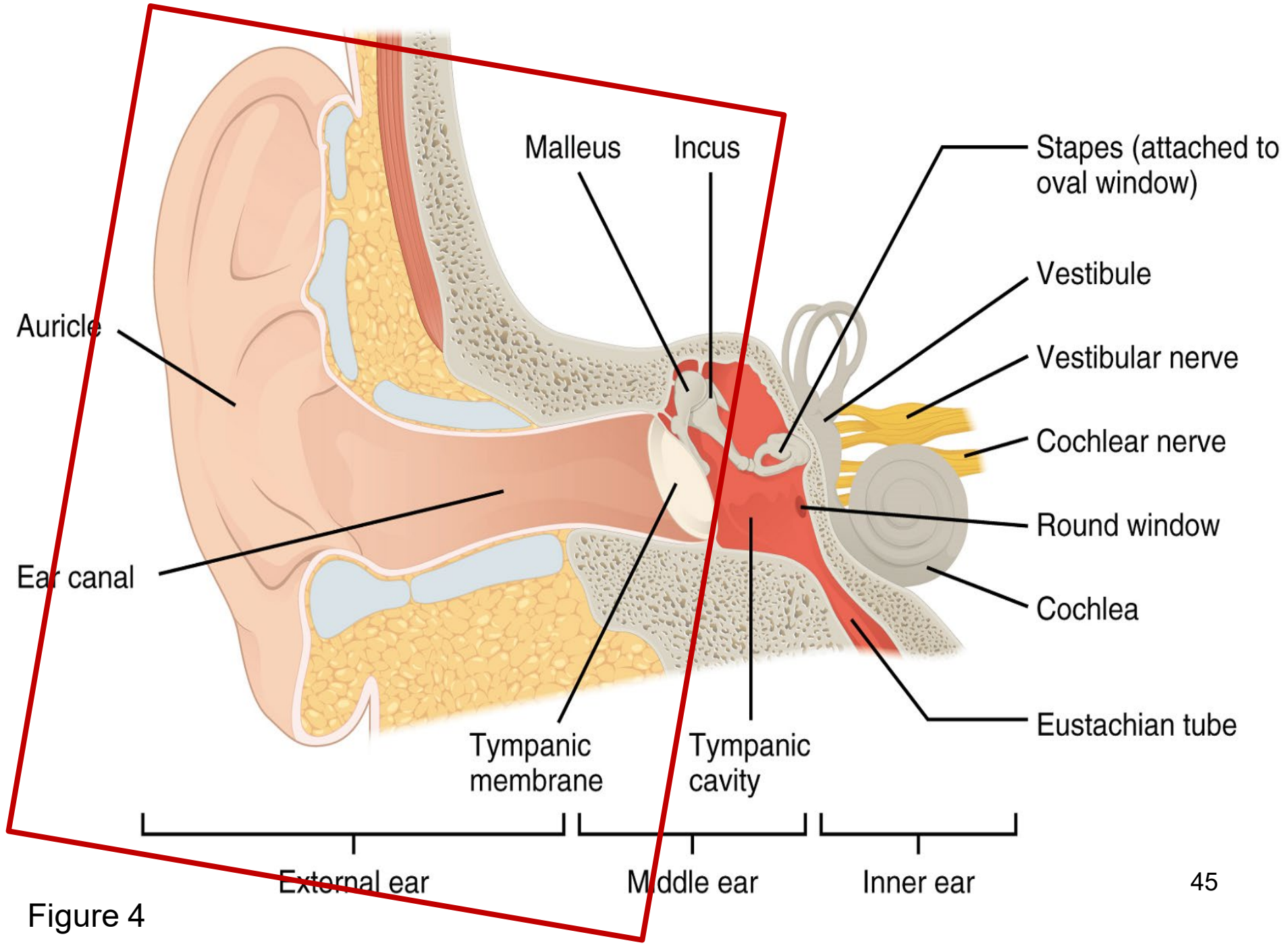
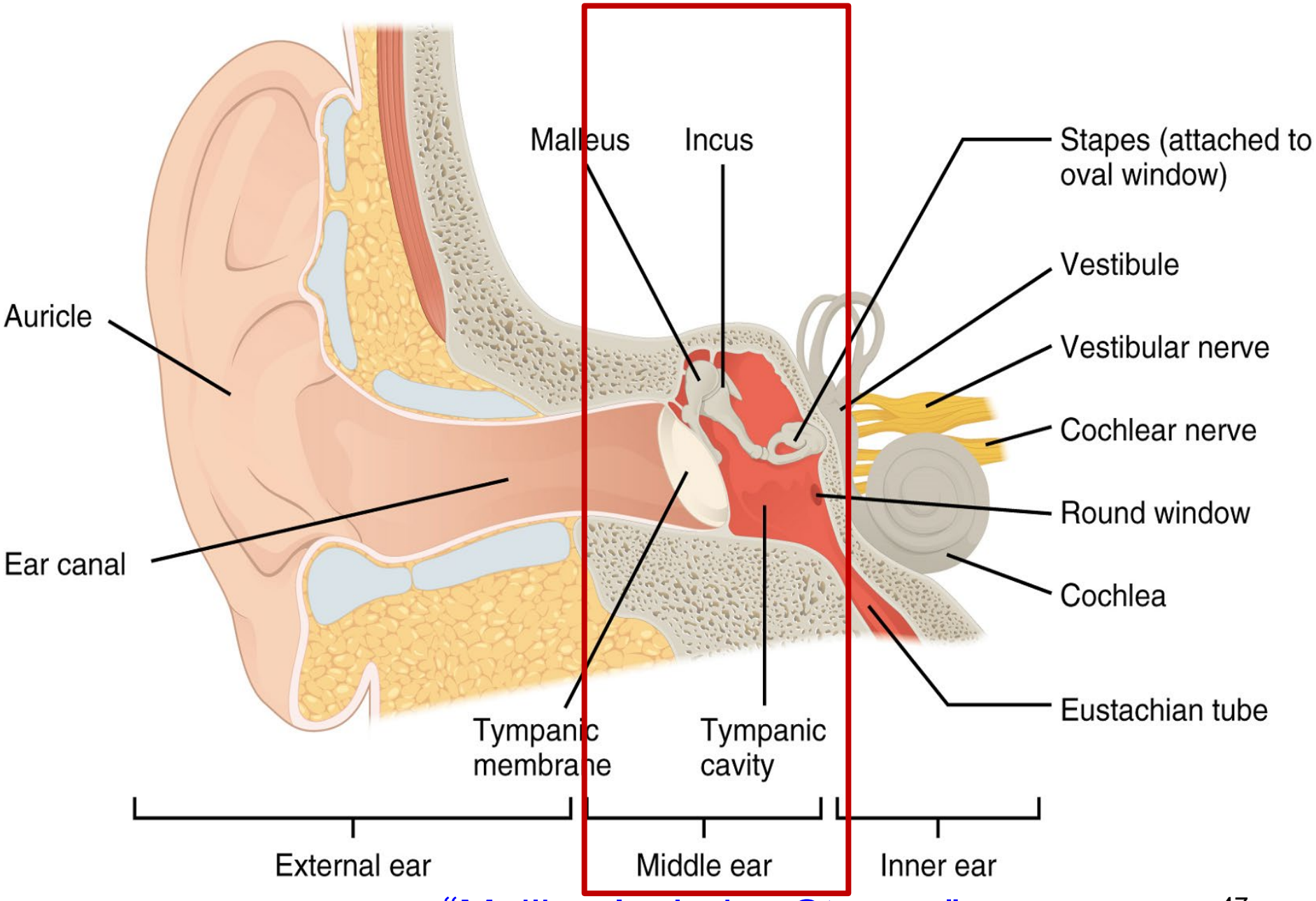

Malleus
Incus
Stapes (attached to oval window)
Vestibule
Auricle
Vestibular nerve
Cochlear nerve
Round window
Ear canal
Cochlea
Eustachian tube
Tympanic membrane
Tympanic cavity
External ear
Middle ear
Inner ear

Figure 4

External ear

- **Auricle (pinna):** flap of cartilage on the outside of the head
  - collects and transmits sound waves to middle ear
- **External auditory canal:** tube in the temporal bone; ear wax produced by ceruminous glands
  - Hairs and ear wax in external auditory canal prevent foreign materials entering ear
- **Tympanic membrane (ear drum):** fibrous connective tissue; separates external and middle ear; vibrates in response to sound



"Mailing Includes Stamps"

Figure 4

Middle ear

- Small, air-filled cavity in the temporal bone
- Five openings:
  - Tympanic membrane
  - Oval window
  - Round window
  - Eustachian tube
  - Mastoid cavity
- **Auditory ossicles** (connected to ligaments and two small muscles):
  - **Malleus (hammer)** – attached to the tympanic membrane
  - **Incus (anvil)** – in the middle
  - **Stapes (stirrup)** – fits over the oval window

Functions of middle ear

1. **Transmits** vibrations to the inner ear
2. Provides **protection** to prolonged loud noises by decreasing the sensitivity of hearing
   – due to small skeletal muscle around the ossicles
3. **Equalizing air pressure** on both sides of the tympanic membrane via the Eustachian tube (yawning or swallowing opens the Eustachian tube, allowing for pressure to equalize)
   – prevents pain, hearing impairment, ringing in ears, vertigo

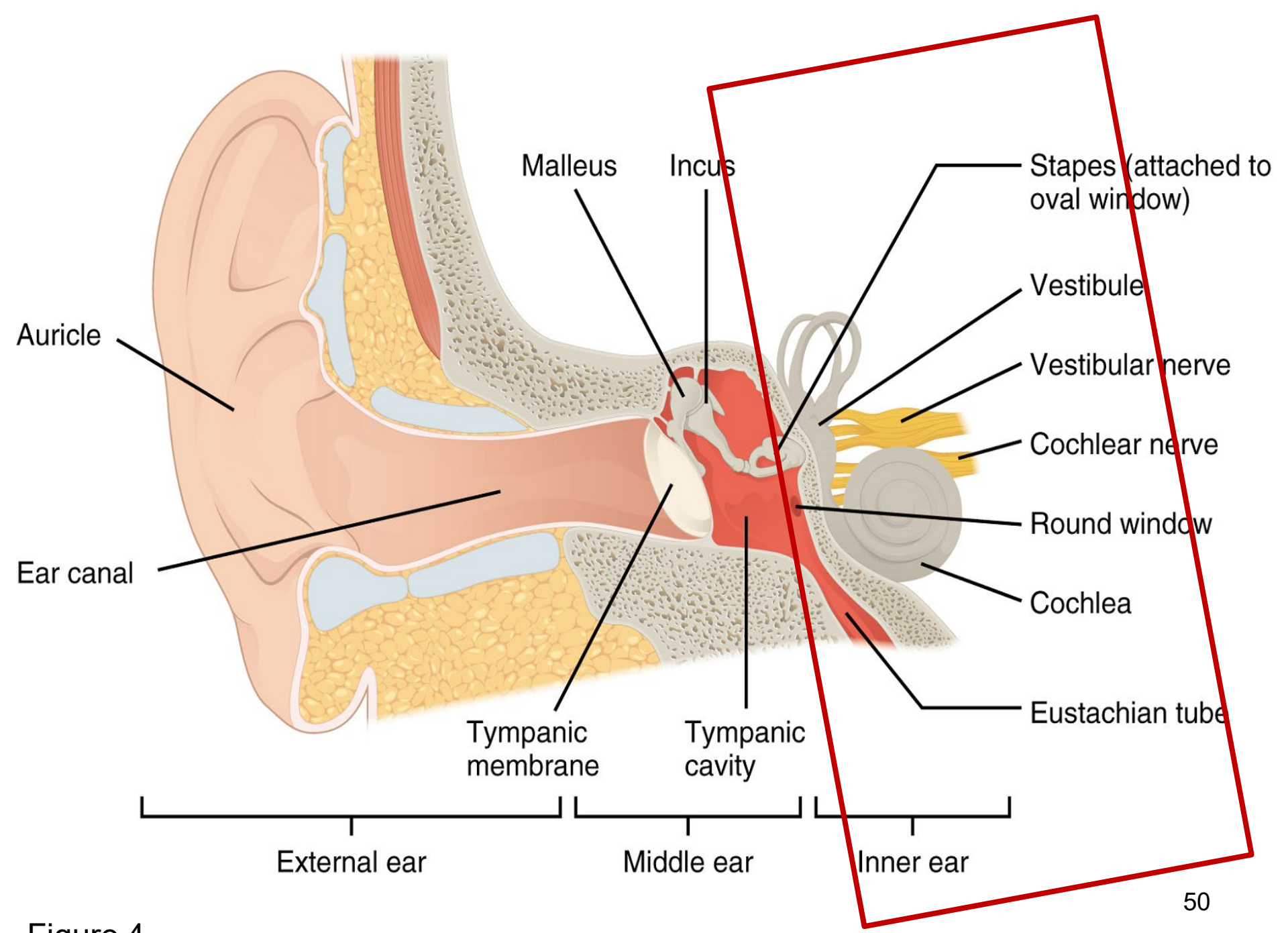
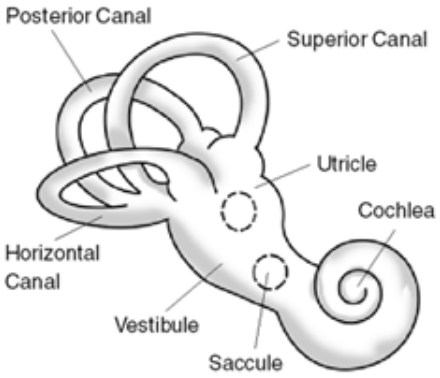

Malleus
Incus
Stapes (attached to oval window)
Vestibule
Vestibular nerve
Cochlear nerve
Auricle
Round window
Ear canal
Cochlea
Eustachian tube
Tympanic membrane
Tympanic cavity
External ear
Middle ear
Inner ear

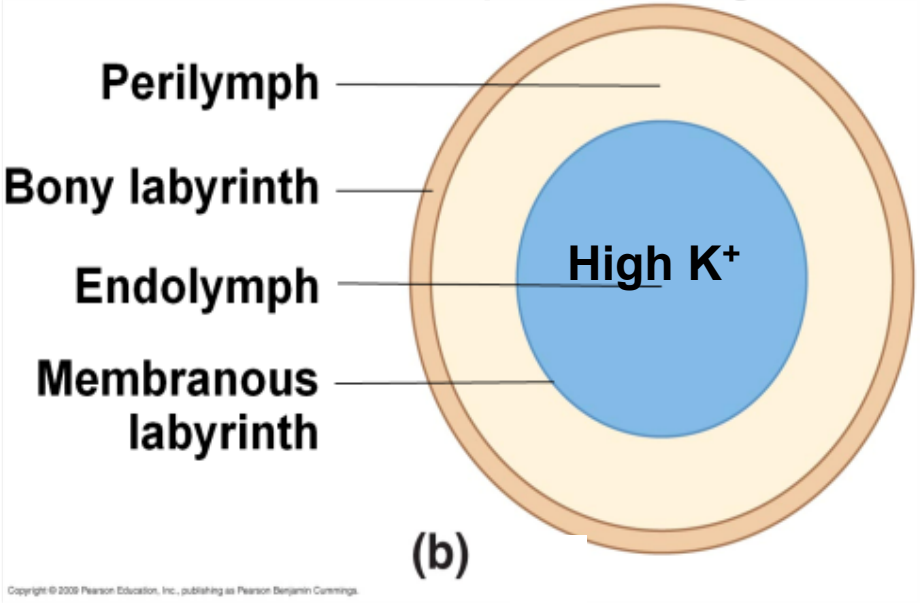
Figure 4

Inner ear

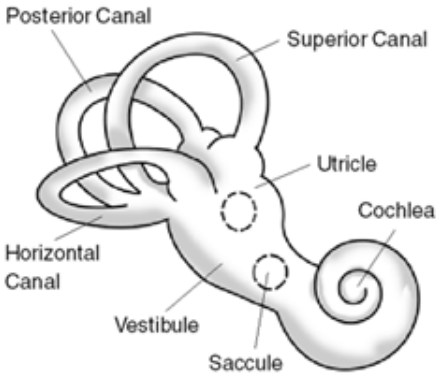


Bony labyrinth

- Channels running through the temporal bone
- Contains **vestibule** (balance), **cochlea** (hearing)
- Filled with **perilymph** (similar to cerebrospinal fluid)
- Connected to brain via the vestibulocochlear nerve
- Cochlea is attached to the stapes through the **oval window**

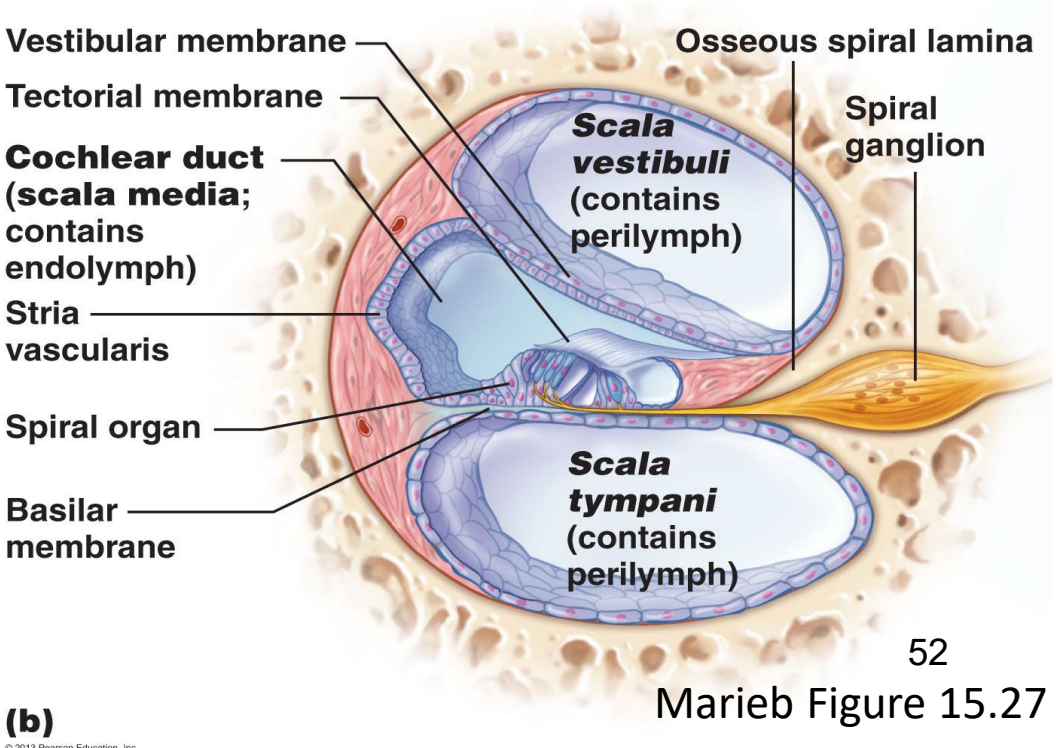


Cochlea



- A spiral, conical, bony chamber that:
  - Extends from the anterior vestibule
  - Contains the organ of Corti (hearing receptor)
  - the **cochlear duct** (scala media) is the central cavity of and contains sound-transducing neurons

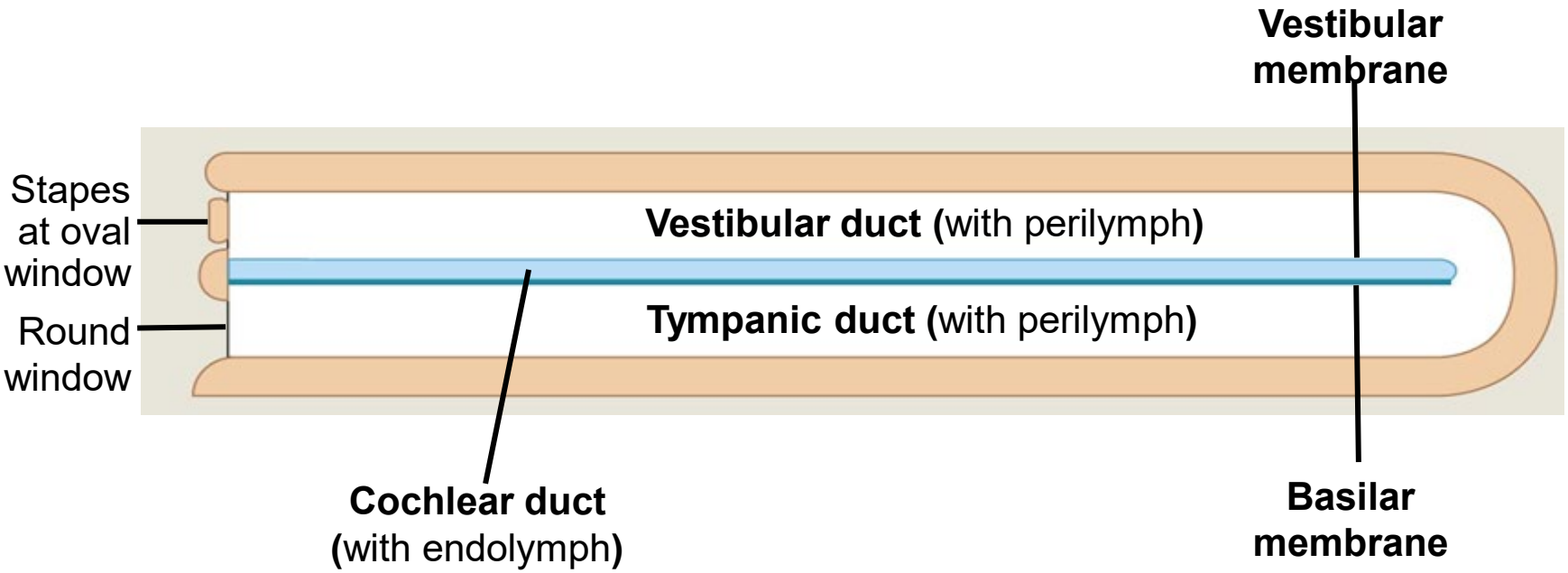
- Divided into three chambers:
  - Scala vestibuli (fluid-filled tube)
  - Cochlear duct
  - Scala tympani (ends at the round window)



Marieb Figure 15.27

Cochlea

Longitudinal Section



- The scala vestibuli begins at the oval window
- The scala tympani terminates at the round window
- The scala tympani and scala vestibuli:
  - Are filled with perilymph
- The cochlear duct is filled with endolymph
- The cochlear duct contains the **organ of** Corti, which transduces the wave motion of the two scalae into neural signals

Organ of Corti

- Outer and inner hair cells and supporting cells
- Afferent fibers of the cochlear nerve attach to the base of hair **cells**
- Inner and outer hair cells, only inner cells serve as hearing receptors
- Organized tallest to shortest, protein tether hairs together

The stereocilia:

- Protrude into the **endolymph**
- Are embedded in the **tectorial membrane**

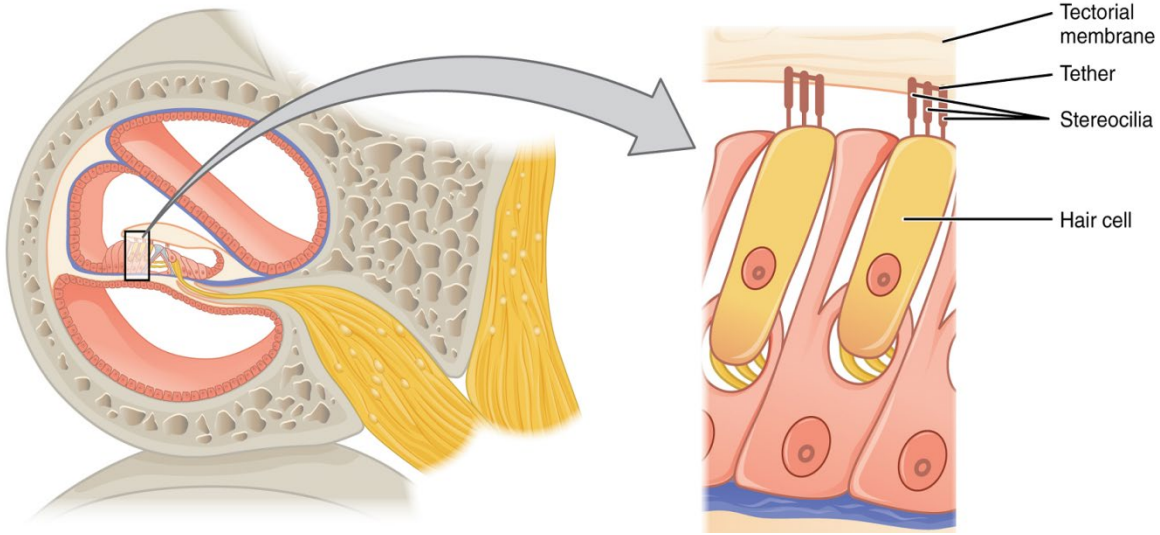


Figure 7

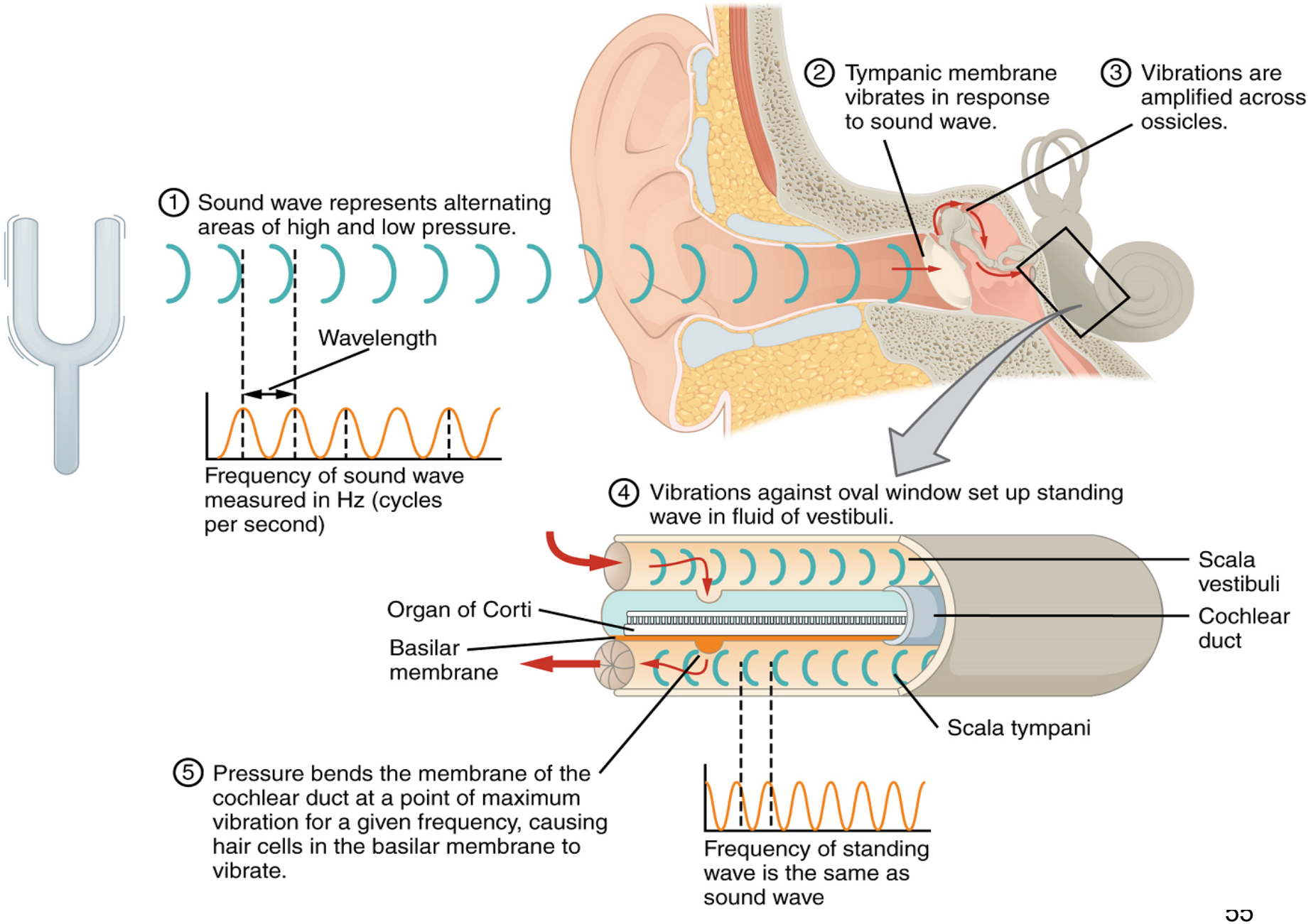
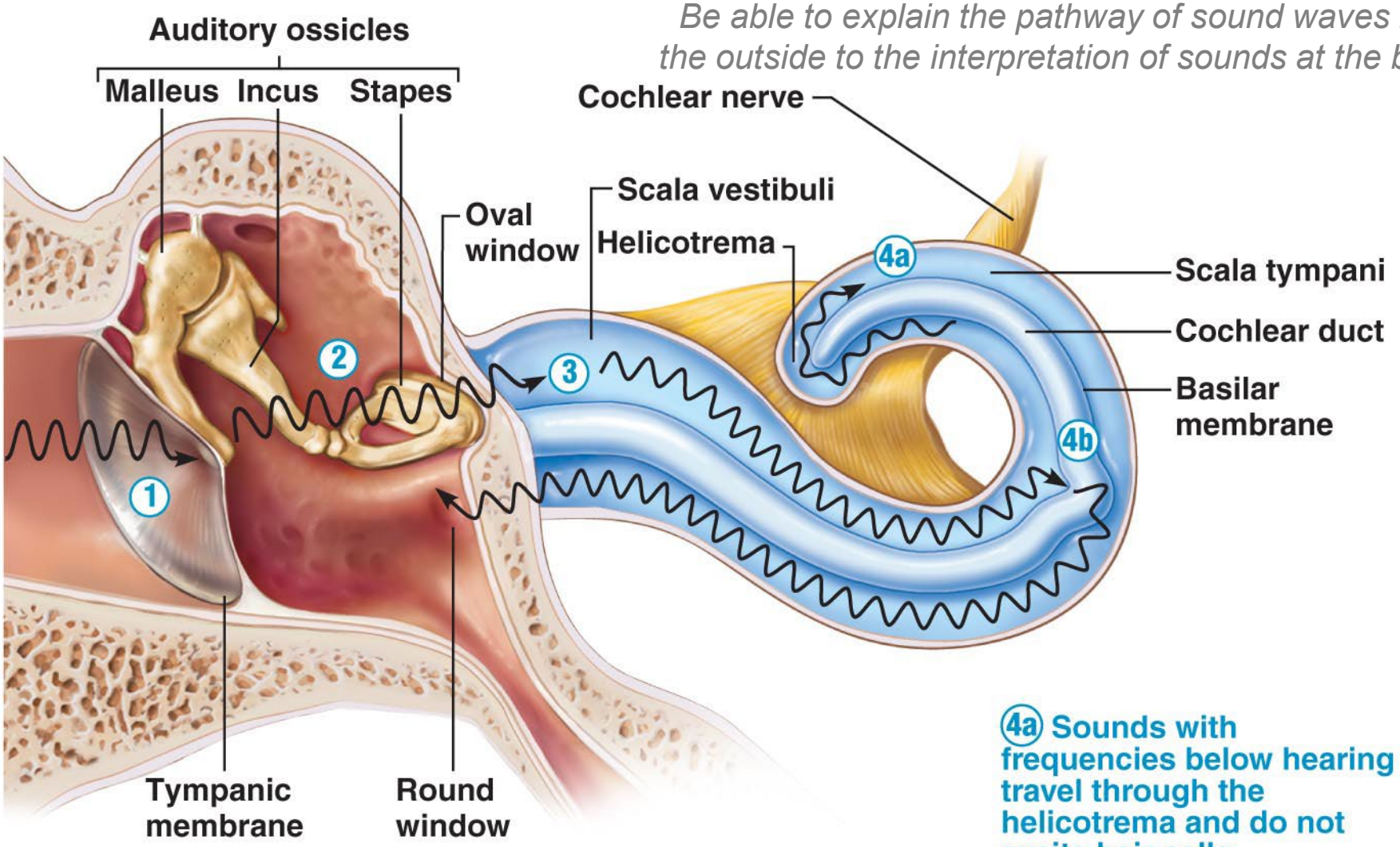

① Sound wave represents alternating areas of high and low pressure.
Wavelength
Frequency of sound wave measured in Hz (cycles per second)
② Tympanic membrane vibrates in response to sound wave.
③ Vibrations are amplified across ossicles.
④ Vibrations against oval window set up standing wave in fluid of vestibuli.
Scala vestibuli
Cochlear duct
Organ of Corti
Basilar membrane
Scala tympani
⑤ Pressure bends the membrane of the cochlear duct at a point of maximum vibration for a given frequency, causing hair cells in the basilar membrane to vibrate.
Frequency of standing wave is the same as sound wave

Figure 5

PHYSIOLOGY OF HEARING

Be able to explain the pathway of sound waves from the outside to the interpretation of sounds at the brain



(a) Route of sound waves through the ear

① Sound waves vibrate the tympanic membrane.

② Auditory ossicles vibrate. Pressure is amplified.

③ Pressure waves created by the stapes pushing on the oval window move through fluid in the scala vestibuli.

④a Sounds with frequencies below hearing travel through the helicotrema and do not excite hair cells.

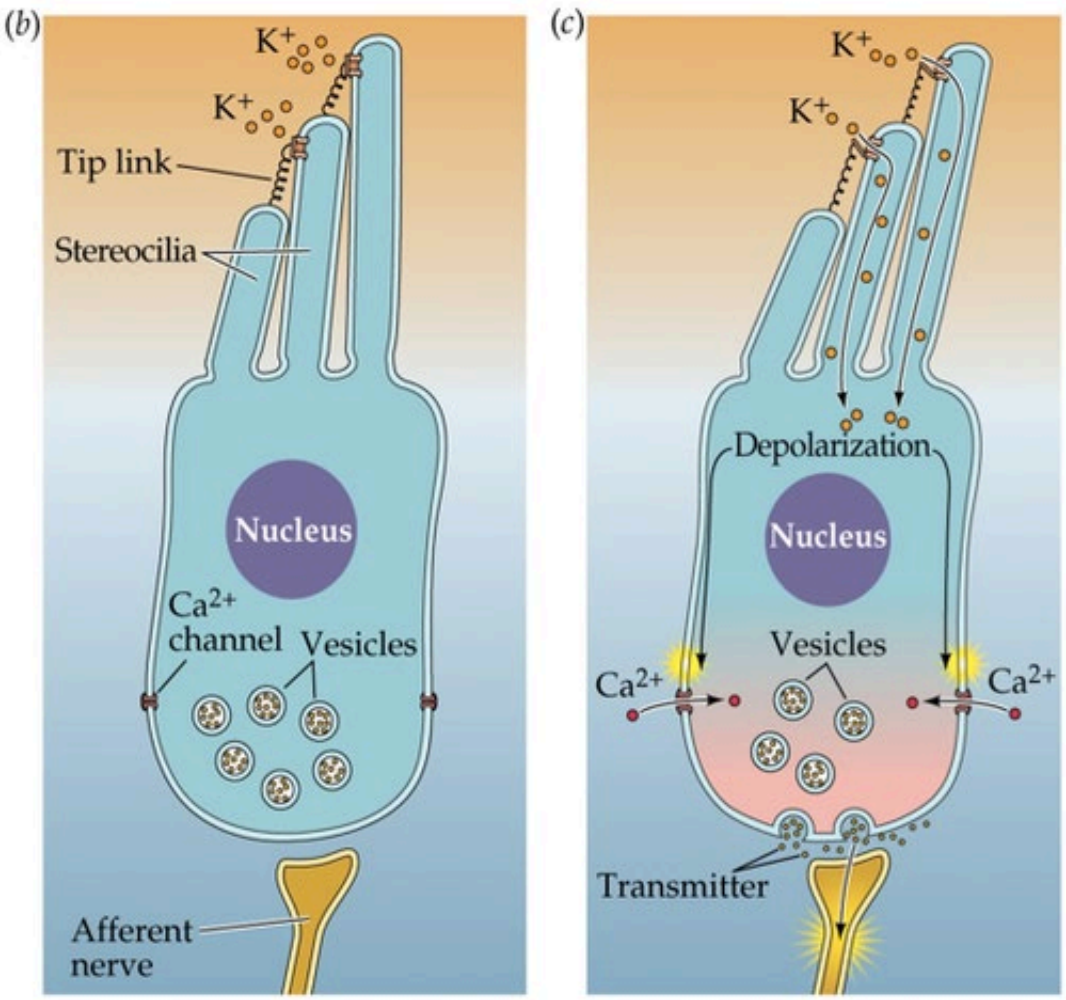
④b Sounds in the hearing range go through the cochlear duct, vibrating the basilar membrane and deflecting hairs on inner hair cells.

Marieb ,Figure 15.30

Hearing

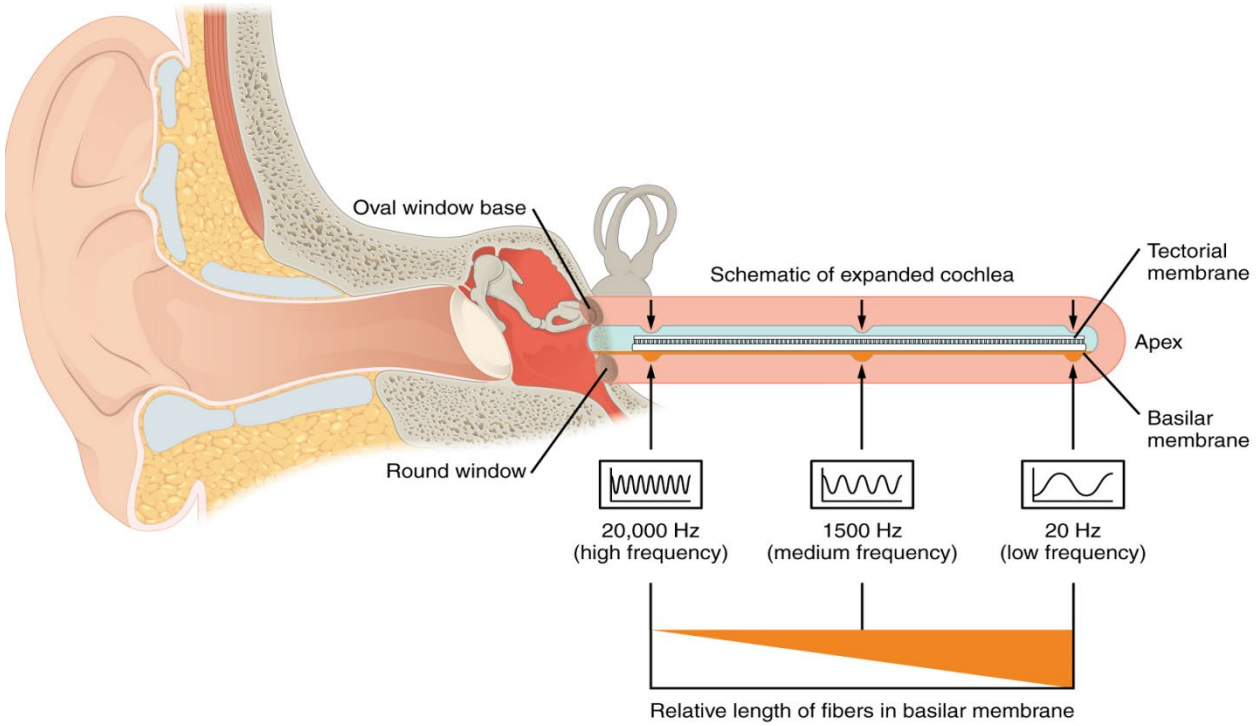
- Pressure waves of endolymph in the cochlear duct vibrate the basilar membrane causing the hair cells to move
- These vibrations bend the stereocilia either toward or away from the tallest member of each array of stereocilia.
- When towards the tallest member of their array, tension in the protein tethers opens ion channels in the cell membrane.
- This will further depolarize the cell membrane, exciting the sensory neurons and triggering nerve impulses which travel down the cochlear branch of the vestibulocochlear nerve.
- The depolarization is largely the result of K^+ ions (and Ca^{2+} ions) rushing into the hair cells from the surrounding endolymph through ion channels.
- When toward the shortest member, the tension on the tethers slackens and the ion channels close.

Hair Cell Stimulation



Frequency of sound

Figure 8



- The transmission of pressure waves through the cochlear duct and vibration of the basilar membrane depends on the frequency of the sound

a) High frequency sounds displace the basilar membrane close to the **oval window**

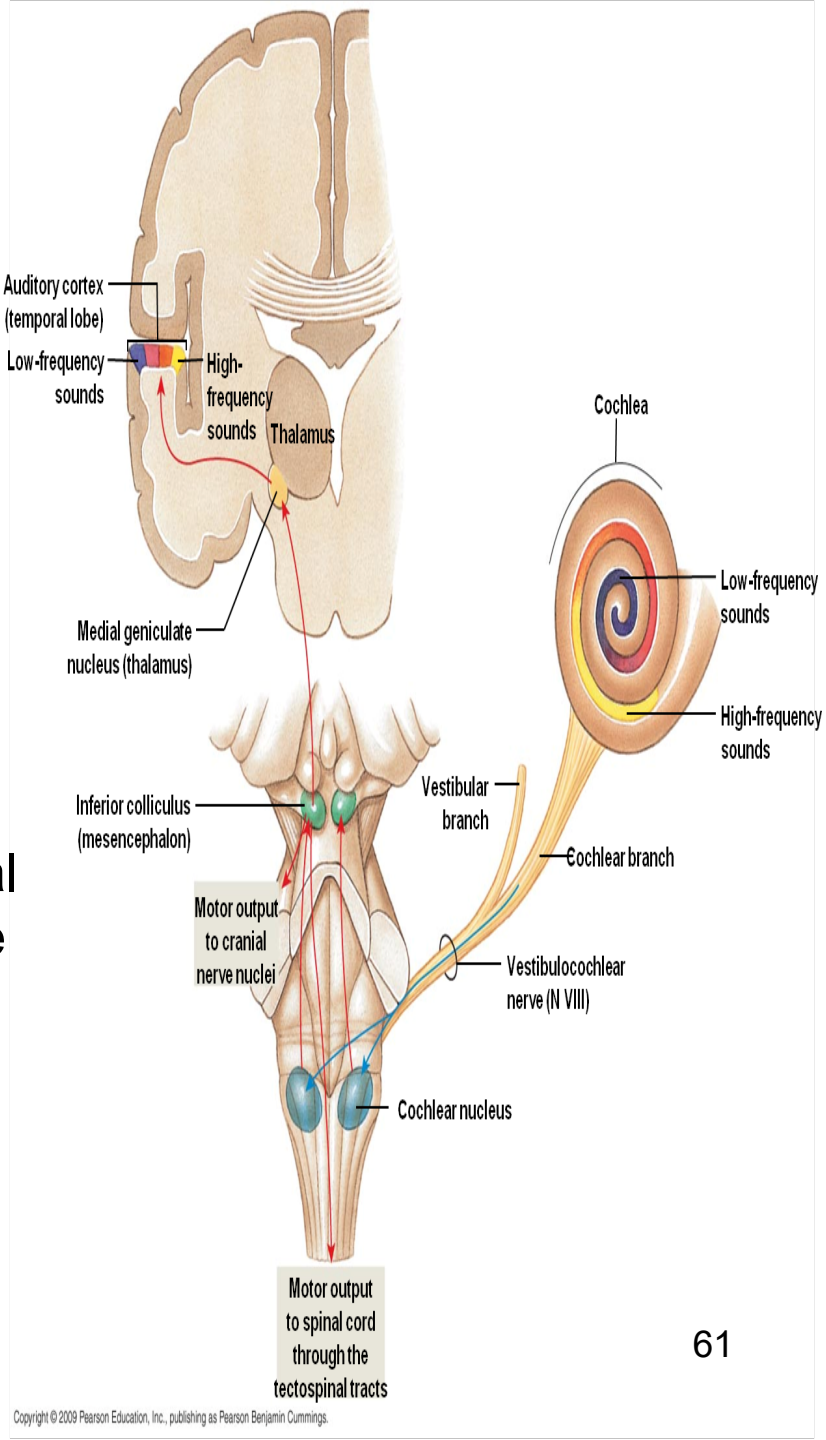
b) Low frequency sounds displace the basilar membrane near hair cells at the apex of the cochlea

Sensory pathway for audition

- The vestibulocochlear nerve, which synapses with neurons in the cochlear nuclei of the medulla oblongata.

- Axons from the midbrain then project to the thalamus.

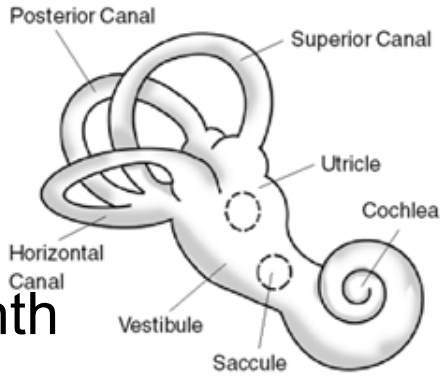
- The thalamus projects that information to the primary auditory cortex in the temporal lobe of the cerebral cortex, involved in the conscious awareness of sound.



Vestibular apparatus of inner ear: vestibule & semicircular canals

PHYSIOLOGY OF EQUILIBRIUM

Vestibule



- The central egg-shaped cavity of the bony labyrinth
- Suspended in its perilymph are two sacs that determine head position and linear acceleration: the **saccule** and **utricle**
- These sacs contain equilibrium receptors called **maculae**, which are hair cells surrounded by support cells
- Rotational movement of the head is determined by semicircular ducts
- The neural signals generated in the **vestibular ganglion** are transmitted through the vestibular branch of the vestibulocochlear nerve to the brainstem and cerebellum.

Macula

- Macula is the sensory receptor for static equilibrium, in walls of utricle and saccule
  - Contain supporting cells and hair cells
  - Each hair cell has stereocilia embedded in the otolith membrane

- **Otolith membrane**: jellylike mass studded with tiny $CaCO_3$ stones called otoliths

- Otolithic membrane moves separately from the macula in response to head movements

- Tilting the head causes the otolithic membrane to slide over the macula in the direction of gravity, causing some hair cells to depolarize

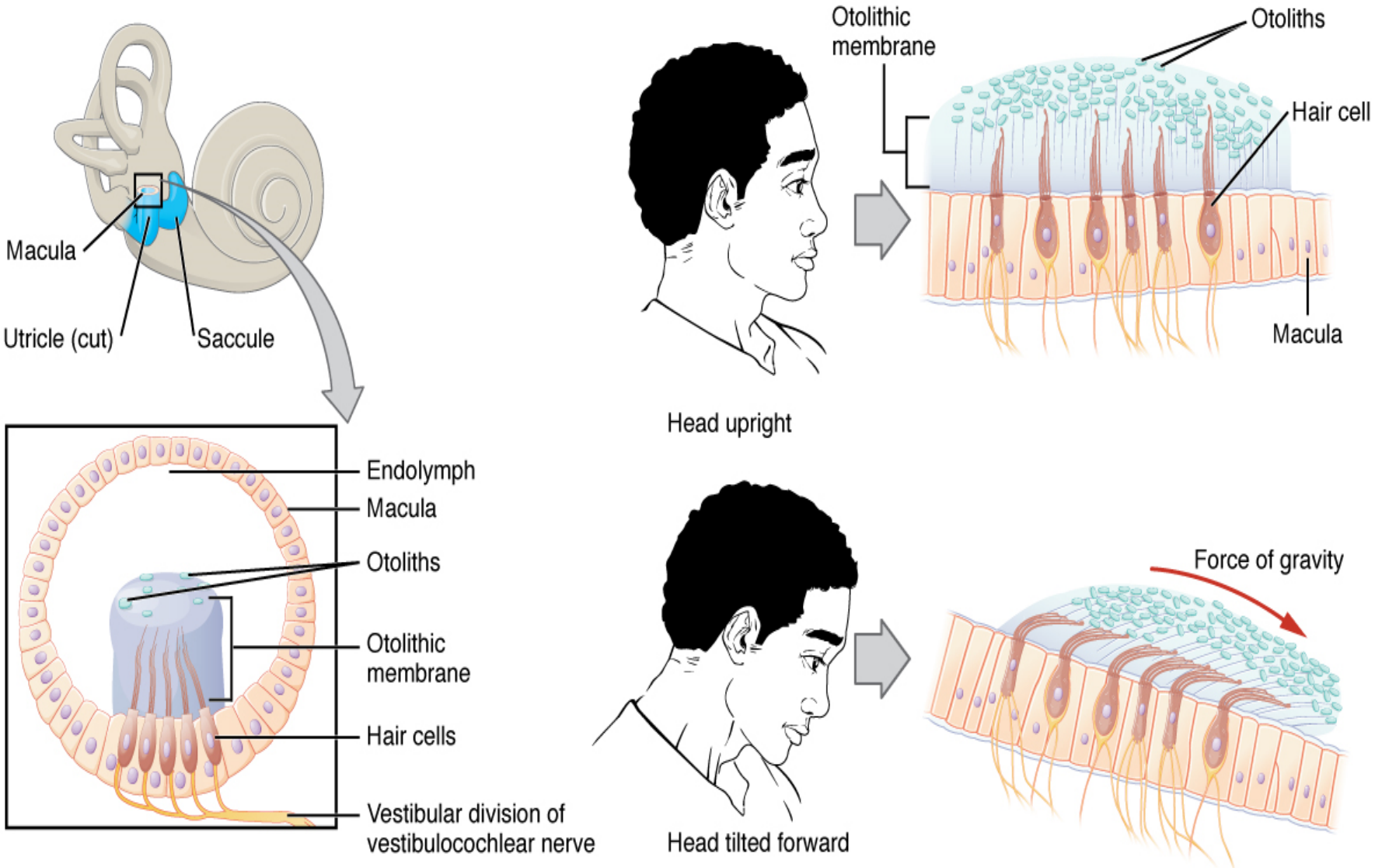

Macula
Utricle (cut)
Saccule
Endolymph
Macula
Otoliths
Otolithic membrane
Hair cells
Vestibular division of vestibulocochlear nerve
Head upright
Otolithic membrane
Otoliths
Hair cell
Macula
Head tilted forward
Force of gravity

Figure 9

Semicircular canals

- Three ring-like extensions of the vestibule
- One is oriented in the horizontal plane, whereas the other two are oriented in the vertical plane
- Within each canal is an semicircular duct. The base of each semicircular canal is an enlarged region known as the ampulla.
- Each ampulla contains a sense organ of balance named crista ampullaris
  - Responds to rotational movements (dynamic equilibrium)
- Each crista has support cells and hair cells that extend into a gelled mass called the **cupula**, which moves in opposite to the head movement

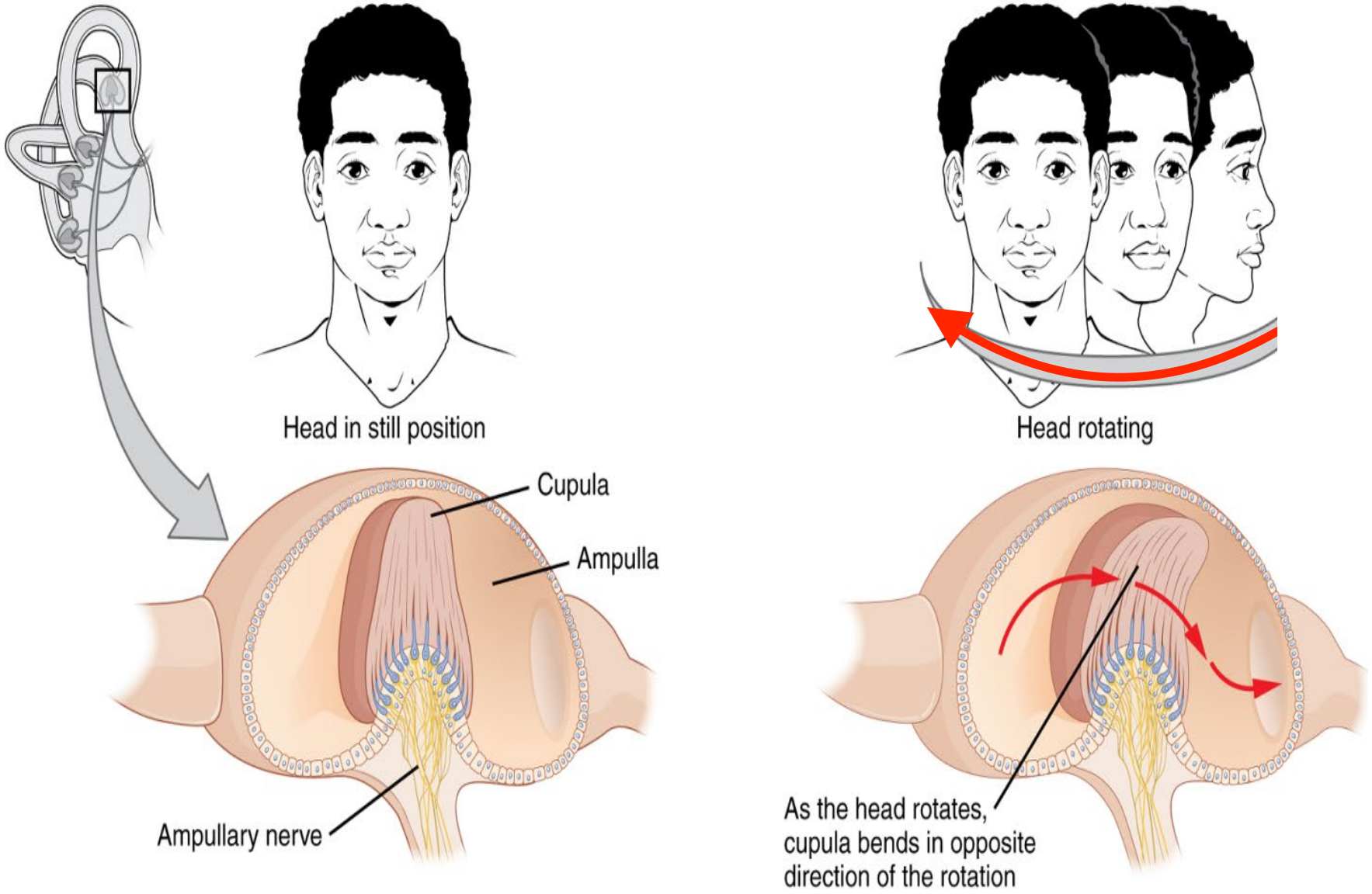

Head in still position
Head rotating
Cupula
Ampulla
Ampullary nerve
As the head rotates,
cupula bends in opposite
direction of the rotation

Figure 10

Balance sensory pathway

- Axons from in the **semicircular canals** & **vestibule** of inner ear make the **vestibular** ganglion
- The neural signals generated in the **vestibular ganglion** are transmitted through the vestibulocochlear nerve
- Most vestibular nerves axons terminate in the vestibular nuclei of the medulla oblongata
- Some vestibular nerves make connections with **cerebellum** and **cerebral cortex** to maintain balance
- Signals are immediately sent to relevant muscles to give the body stability

Sensation and special senses

Objectives

Sensory system

1. List the five main categories of sense receptors in the body based on the types of stimuli they respond to.
2. Describe the structure and function of cutaneous sensors and proprioceptors.
3. Describe the structure and function of the olfactory system.
4. Describe the structure and function of the gustatory system.

The ear

5. Describe the structure and functions of the external, middle and inner ear.
6. Describe the physiology of hearing.
7. Describe the physiology of static and dynamic balance.

The eye

8. Identify the location and explain the function of each of the main components of the human eye.
9. Describe the formation of an image on the retina.
10. Describe the overall distribution and functions of the two main types of photoreceptors in the retina.
11. Describe the pathway of the nervous impulses from the photoreceptors of the retina to the brain.
12. Describe the location, structure and functions of the lacrimal apparatus.