Sensory Systems

Vision

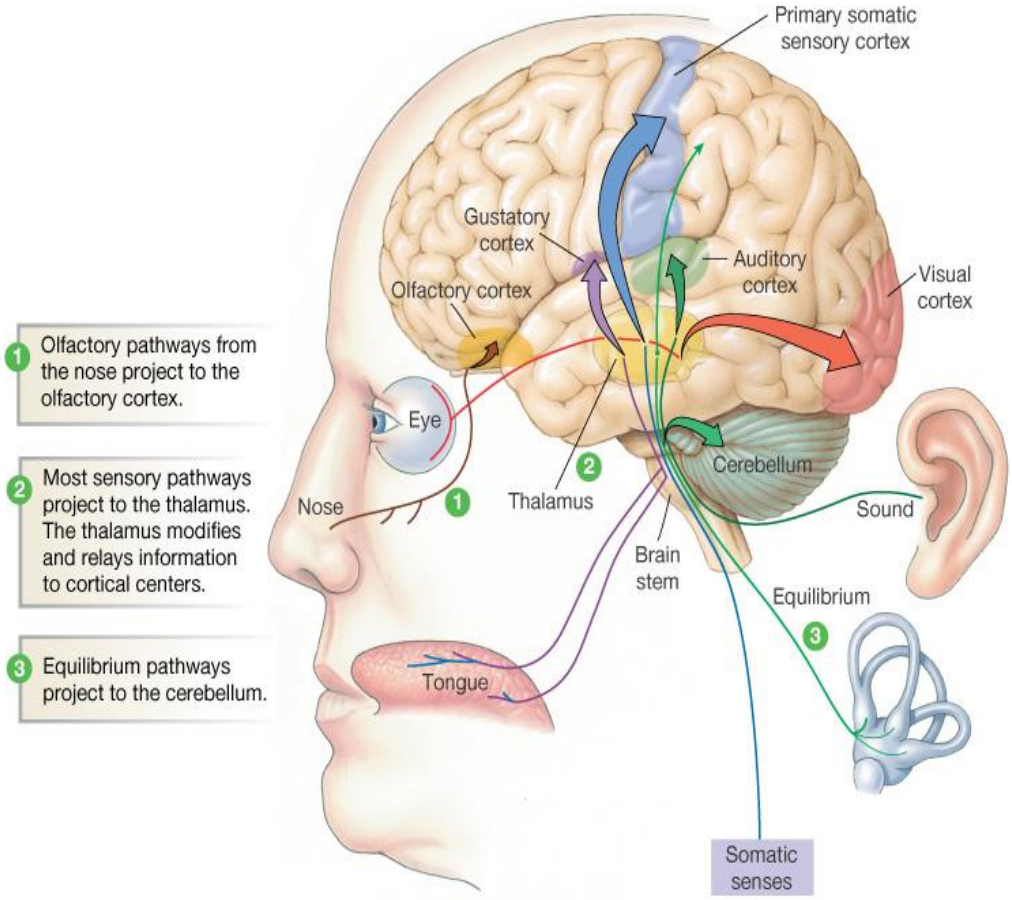
Hearing

Taste

Smell

Equilibrium

Somatic Senses



Sensory Systems

Somatic sensory

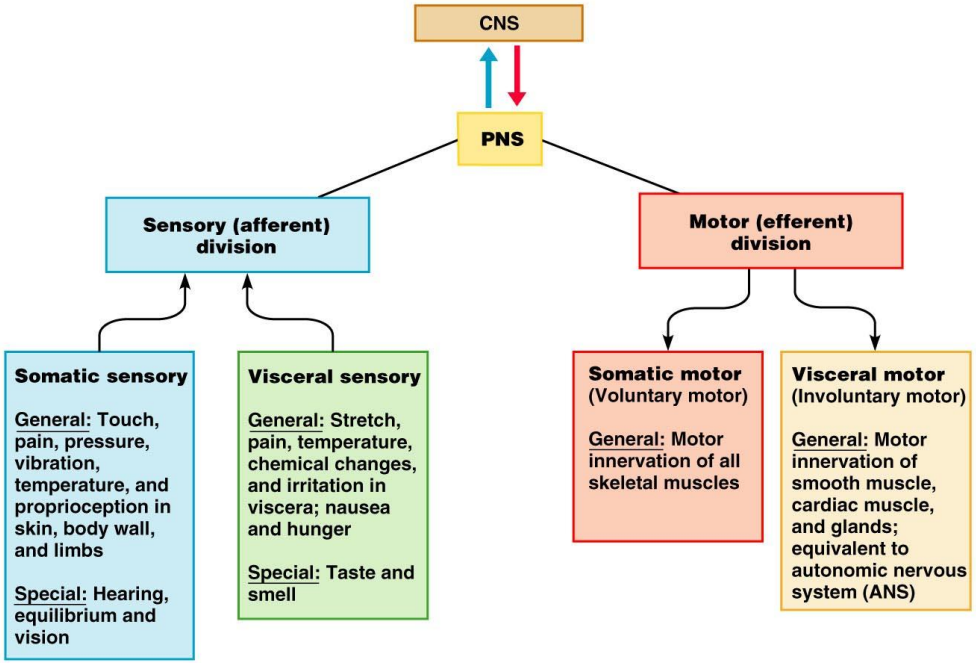
General – transmit impulses from skin, skeletal muscles, and joints

Special senses - hearing, balance, vision

Visceral sensory

Transmit impulses from visceral organs

Special senses - olfaction (smell), gustation (taste)



Properties of Sensory Systems

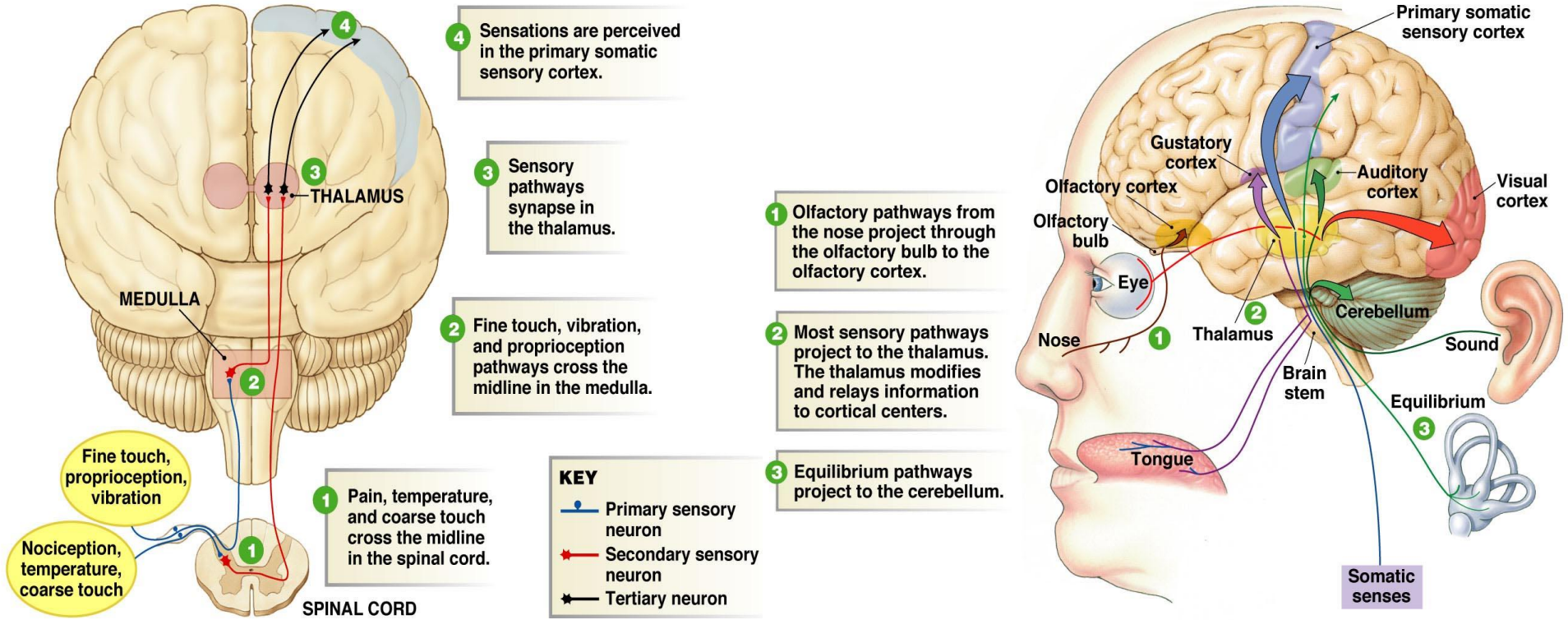
- Stimulus - energy source
  - Internal
  - External
- Receptors
  - Sense organs - structures specialized to respond to stimuli
  - Transducers - stimulus energy converted into action potentials
- Conduction
  - Afferent pathway
  - Nerve impulses to the CNS
- Translation
  - CNS integration and information processing
  - Sensation and perception – your reality

Sensory Pathways

Stimulus as physical energy □ sensory receptor acts as a *transducer*

Stimulus > threshold □ action potential to CNS

Integration in CNS □ cerebral cortex or acted on subconsciously



Classification by Function (Stimuli)

Mechanoreceptors – respond to touch, pressure, vibration, stretch, and itch

Thermoreceptors – sensitive to changes in temperature

Photoreceptors – respond to light energy (e.g., retina)

Chemoreceptors – respond to chemicals (e.g., smell, taste, changes in blood chemistry)

Nociceptors – sensitive to pain-causing stimuli

Osmoreceptors – detect changes in concentration of solutes, osmotic activity

Baroreceptors – detect changes in fluid pressure

Classification by Location

Exteroceptors – sensitive to stimuli arising from outside the body

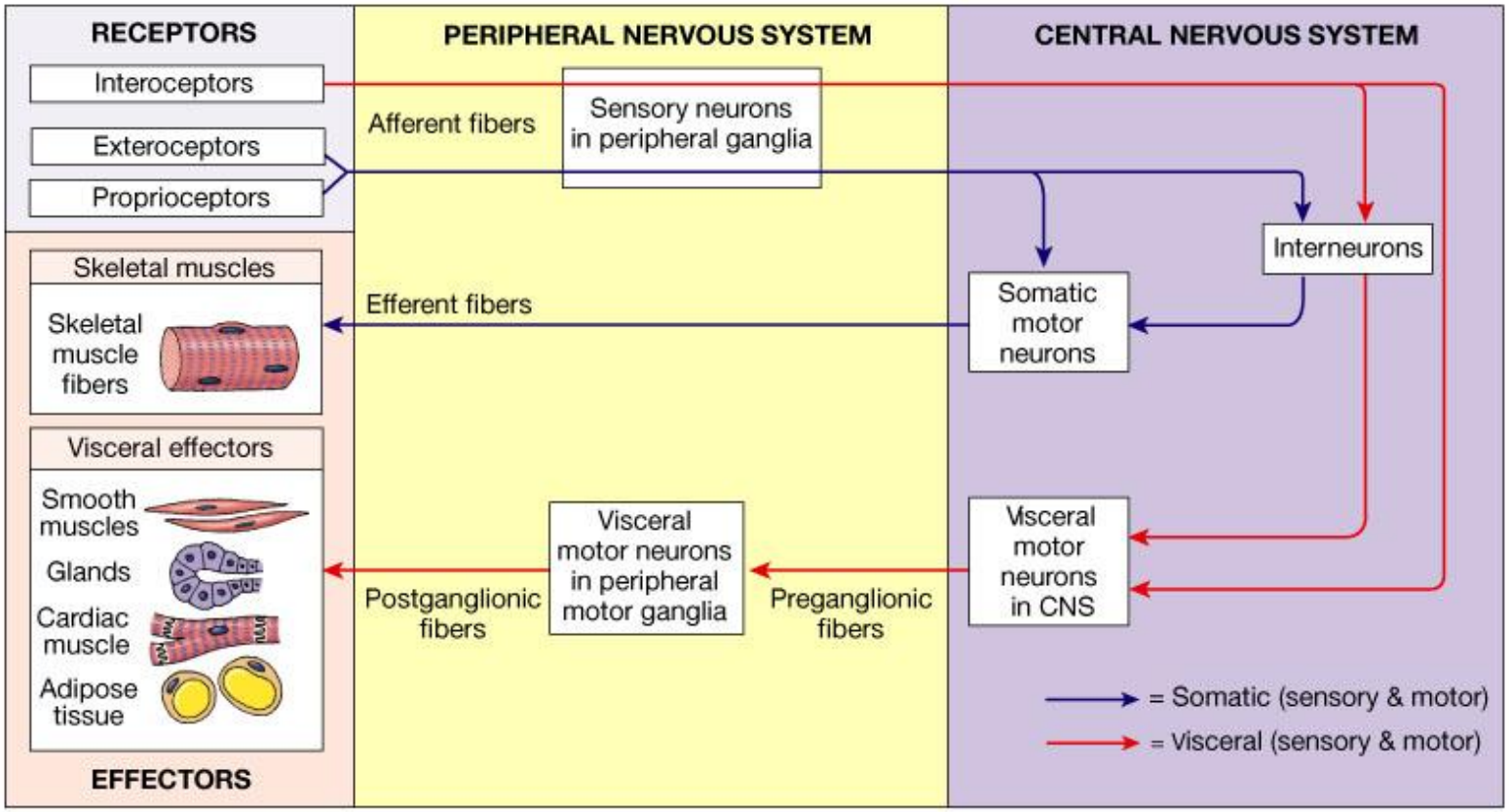
- Located at or near body surfaces
- Include receptors for touch, pressure, pain, and temperature

Interoceptors – (visceroceptors) receive stimuli from internal viscera

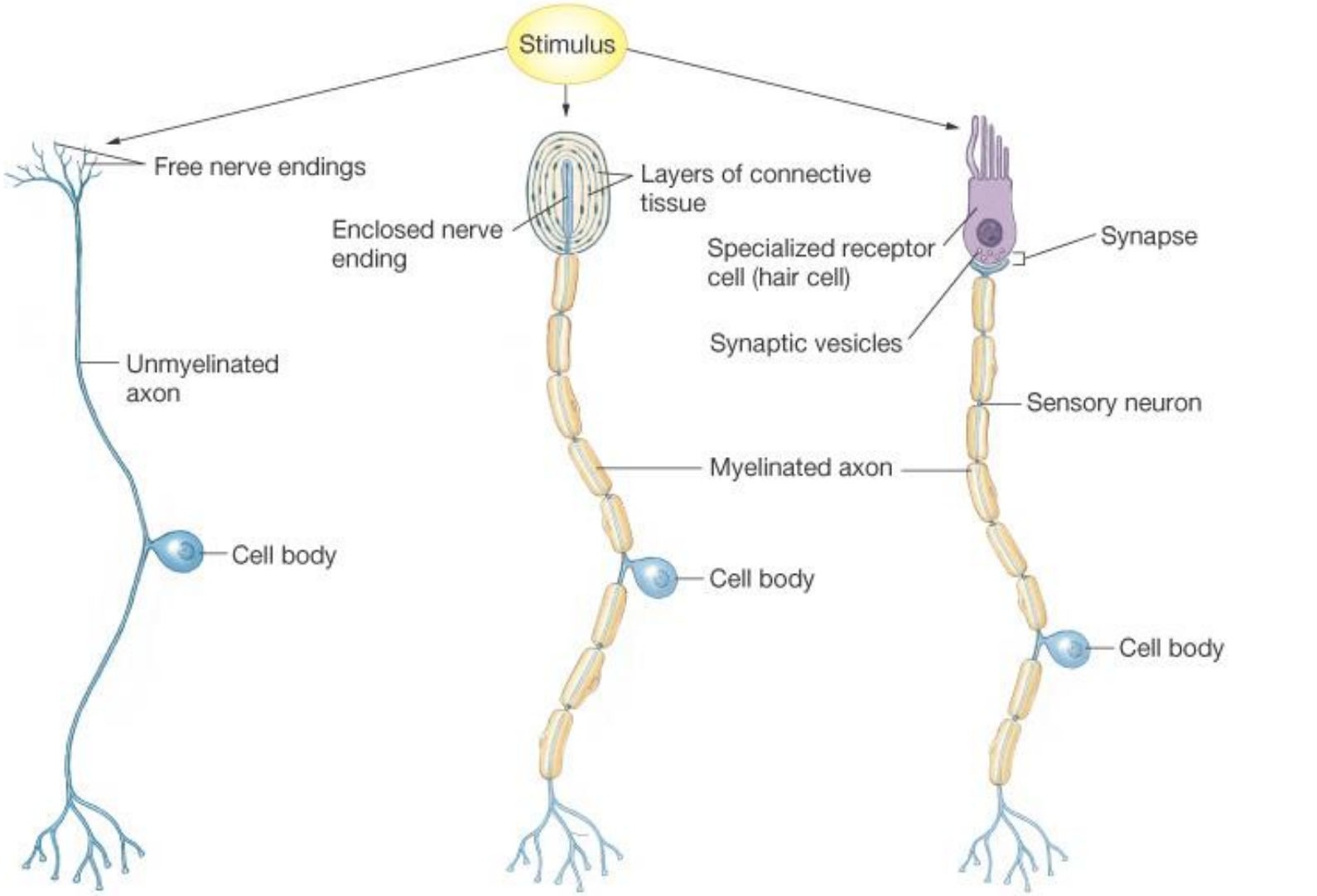
- Monitor a variety of stimuli

Proprioceptors – monitor degree of stretch

- Located in musculoskeletal organs



Classification by Structure



(a) Simple receptors are neurons with free nerve endings.

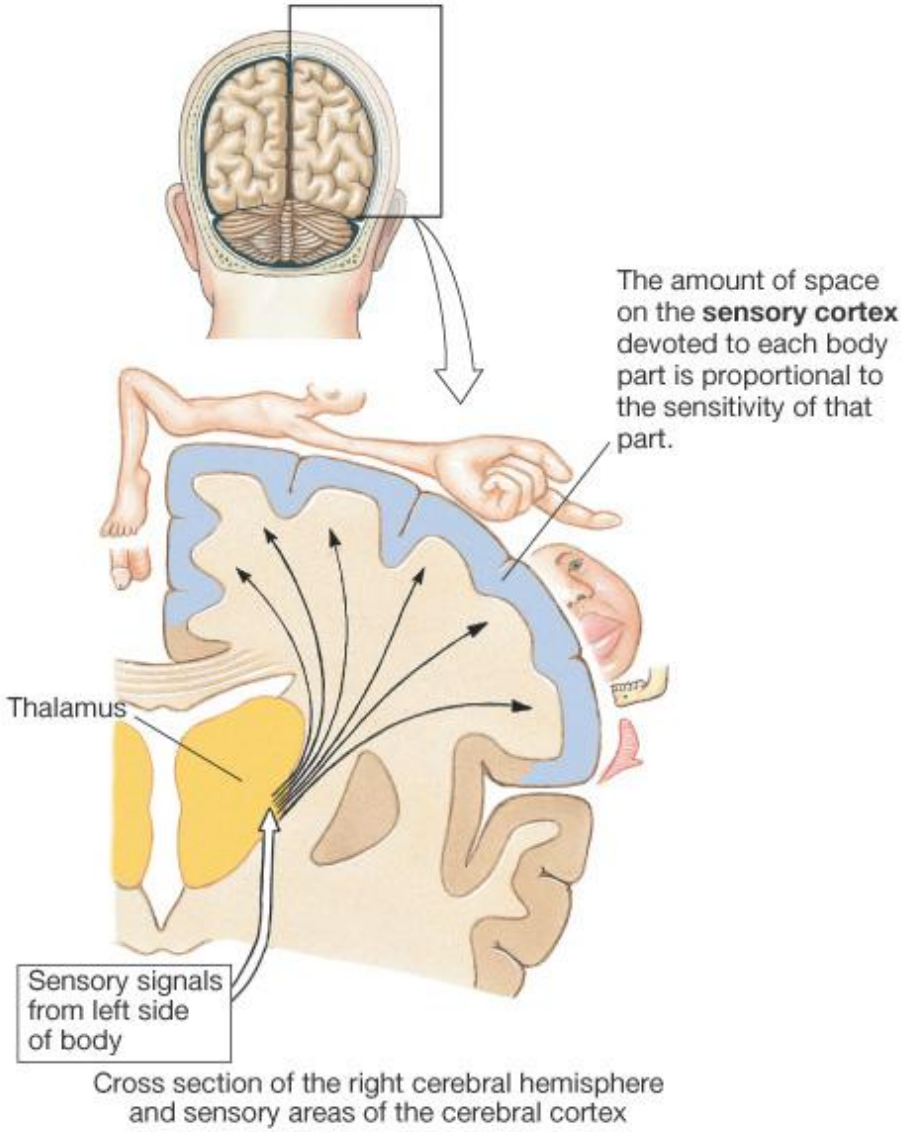
(b) Complex neural receptors have nerve endings enclosed in connective tissue capsules.

(c) Most **special senses receptors** are cells that release neurotransmitte onto sensory neurons, initiating an action potential.

Somatic Senses

General somatic – include touch, pain, vibration, pressure, temperature

Proprioceptive – detect stretch in tendons and muscle provide information on body position, orientation and movement of body in space



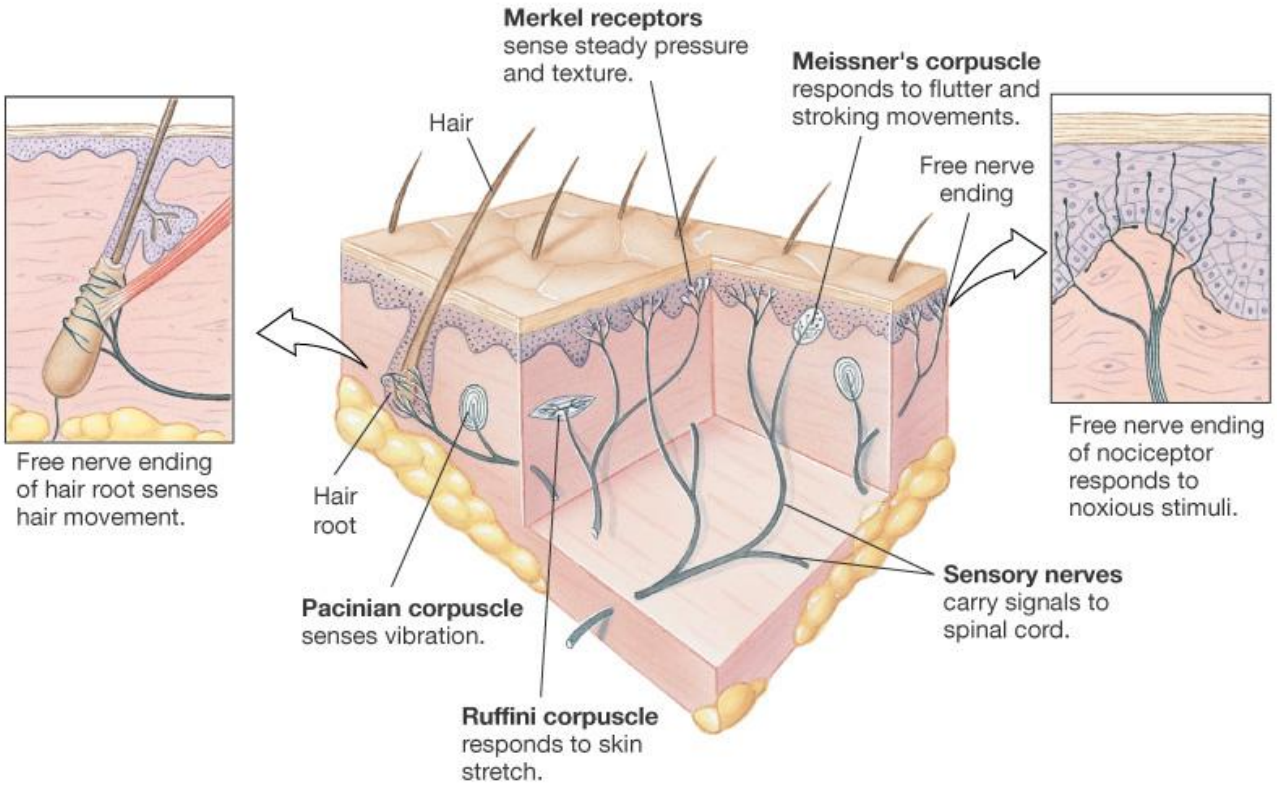
Cross section of the right cerebral hemisphere and sensory areas of the cerebral cortex

Somatic Receptors

Divided into two groups

Free or Unencapsulated nerve endings

Encapsulated nerve endings - consist of one or more neural end fibers enclosed in connective tissue



Free Nerve Endings

Abundant in epithelia and underlying connective tissue

Nociceptors - respond to pain

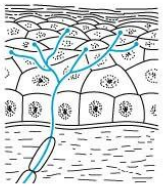
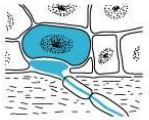
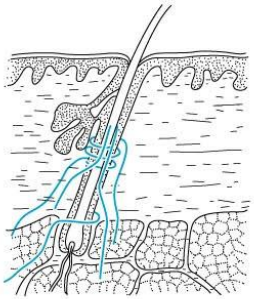
Thermoreceptors - respond to temperature

Two specialized types of free nerve endings

Merkel discs – lie in the epidermis, slowly adapting receptors for light touch

Hair follicle receptors – Rapidly adapting receptors that wrap around hair follicles

14.1 General Sensory Receptors Classified by Structure and Function

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
UNENCAPSULATED			
Free nerve endings of sensory neurons		L: Exteroceptors, interoceptors, and proprioceptors S: Nociceptors (pain), thermoreceptors (heat and cold), possibly mechanoreceptors (pressure)	Most body tissues; densest in connective tissues (ligaments, tendons, dermis, joint capsules, periostea) and epithelia (epidermis, cornea, mucosae, and glands)
Modified free nerve endings: Merkel discs		L: Exteroceptors S: Mechanoreceptors (light pressure)	Basal layer of epidermis
Hair follicle receptors		L: Exteroceptors S: Mechanoreceptors (hair deflection)	In and surrounding hair follicles

Encapsulated Nerve Endings

Meissner's corpuscles

- Spiraling nerve ending surrounded by Schwann cells
- Occur in the dermal papillae of hairless areas of the skin
- Rapidly adapting receptors for discriminative touch

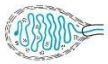
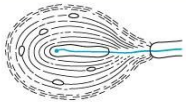
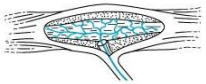
Pacinian corpuscles

- Single nerve ending surrounded by layers of flattened Schwann cells
- Occur in the hypodermis
- Sensitive to deep pressure – rapidly adapting receptors

Ruffini's corpuscles

- Located in the dermis and respond to pressure

TABLE 14.1 General Sensory Receptors Classified by Structure and Function *(continued)*

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
ENCAPSULATED			
Meissner's corpuscles		L: Exteroceptors S: Mechanoreceptors (light pressure, discriminative touch, vibration of low frequency)	Dermal papillae of hairless skin, particularly nipples, external genitalia, fingertips, eyelids
Pacinian corpuscles		L: Exteroceptors, interoceptors, and some proprioceptors S: Mechanoreceptors (deep pressure, stretch, vibration of high frequency); rapidly adapting	Subcutaneous tissue; periostea, mesentery, tendons, ligaments, joint capsules, most abundant on fingers, soles of feet, external genitalia, nipples
Ruffini endings		L: Exteroceptors and proprioceptors S: Mechanoreceptors (deep pressure and stretch); slowly adapting	Deep in dermis, hypodermis, and joint capsules

Encapsulated Nerve Endings - Proprioceptors

Monitor stretch in locomotory organs

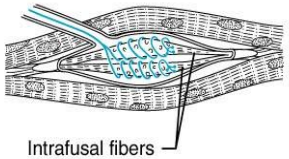
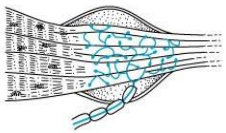
Three types of proprioceptors

Muscle spindles – monitors the changing length of a muscle, imbedded in the perimysium between muscle fascicles

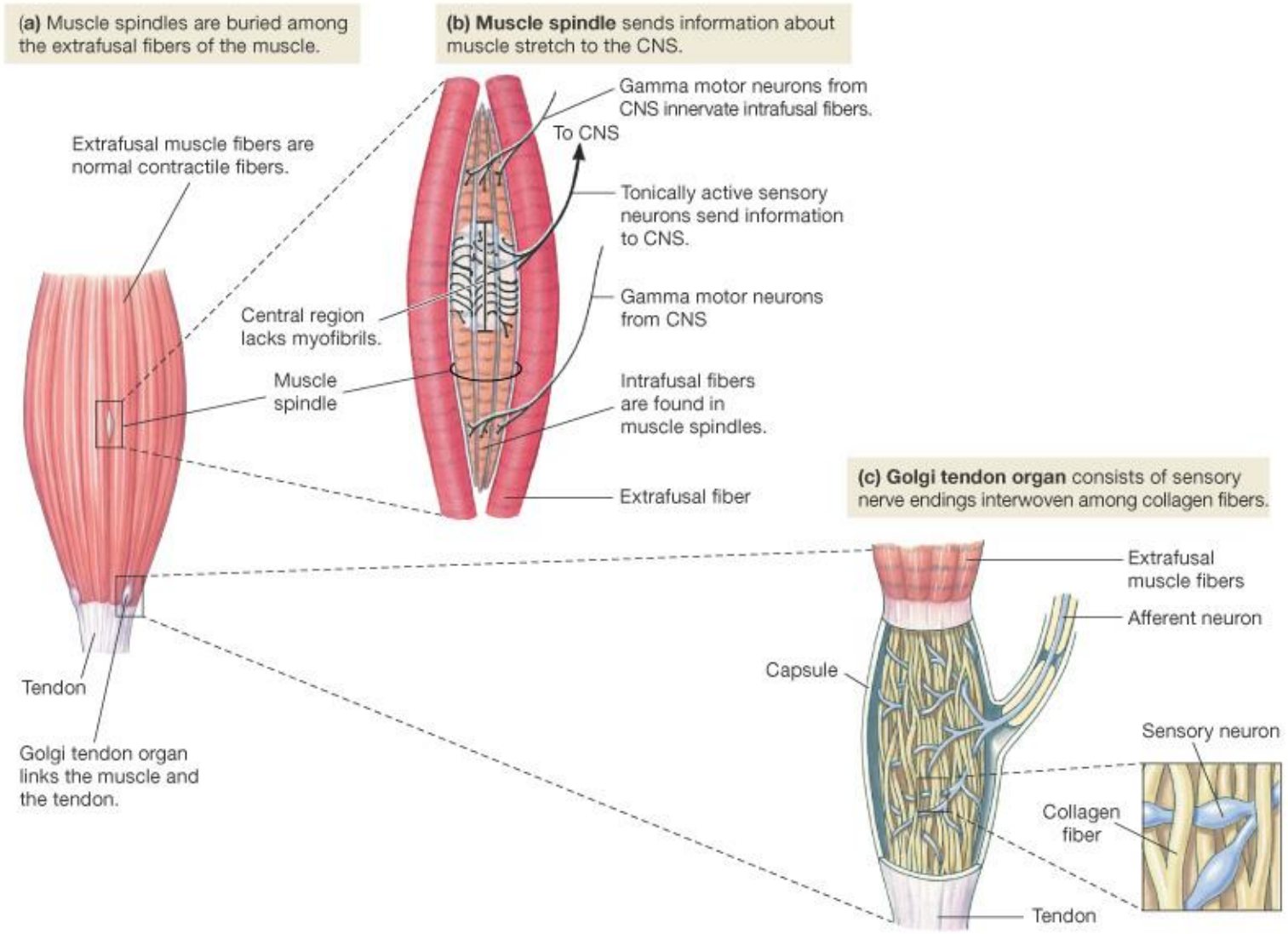
Golgi tendon organs – located near the muscle-tendon junction, monitor tension within tendons

Joint kinesthetic receptors - sensory nerve endings within the joint capsules, sense pressure and position

TABLE 14.1 General Sensory Receptors Classified by Structure and Function *(continued)*

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
PROPRIOCEPTORS			
Muscle spindles		L: Proprioceptors S: Mechanoreceptors (muscle stretch)	Skeletal muscles, particularly those of the extremities
Golgi tendon organs		L: Proprioceptors S: Mechanoreceptors (tendon stretch)	Tendons
Joint kinesthetic receptors (Pacinian and Ruffini endings, free nerve endings, and receptors resembling Golgi tendon organs)		L: Proprioceptors S: Mechanoreceptors and nociceptors	Joint capsules of synovial joints

Muscle Spindle & Golgi Tendon Organ



Special Senses

Taste, smell, sight, hearing, and balance

Localized – confined to the head region

Receptors are not free endings of sensory neurons but specialized receptor cells

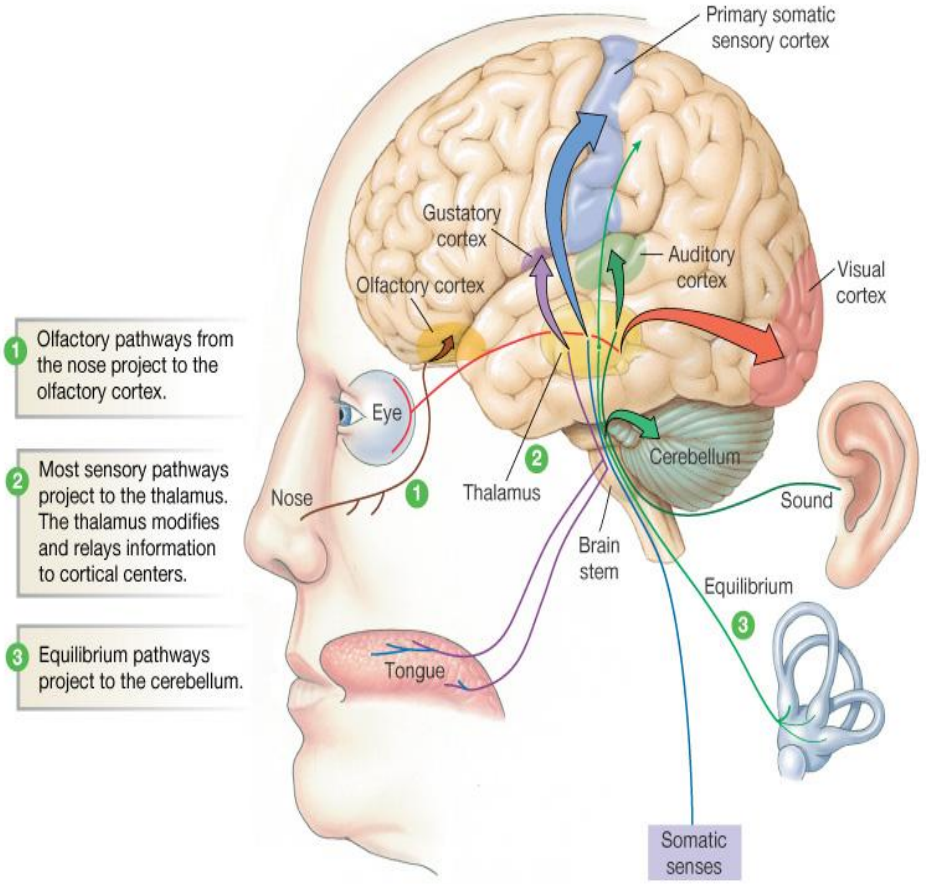


Figure 10-4: Sensory pathways

Anatomy of the Eyeball

Function of the eyeball

- Protect and support the photoreceptors
- Gather, focus, and process light into precise images

External walls – composed of three tunics (layers)

Internal cavity – contains fluids (humors)

The Fibrous Layer

Most external layer of the eyeball

Cornea

Anterior one-sixth of the fibrous tunic

Composed of stratified Squamous externally, simple squamous internally

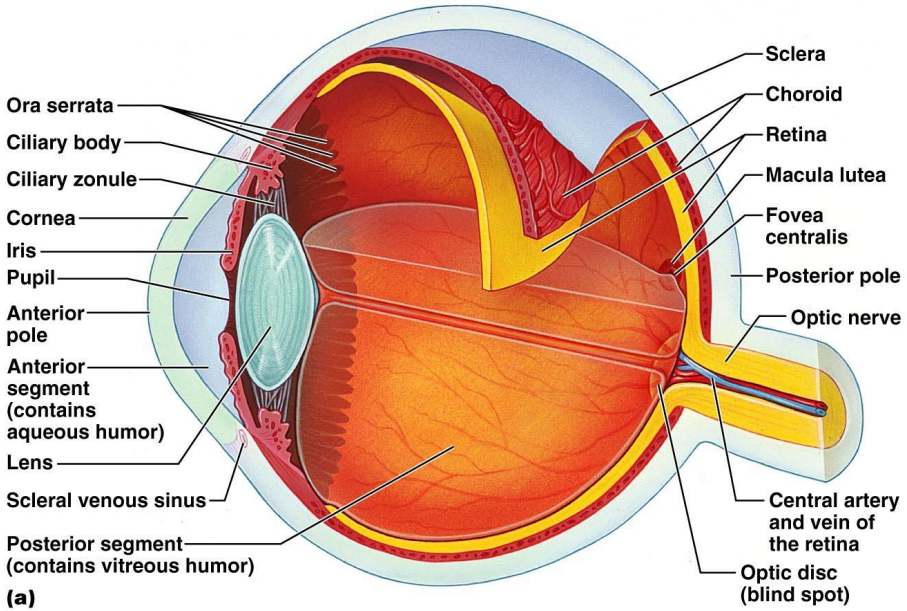
Refracts (bends) light

Sclera

Posterior five-sixths of the tunic

White, opaque region composed of dense irregular connective tissue Provides shape and an anchor for eye muscles

Scle in



The Vascular Layer

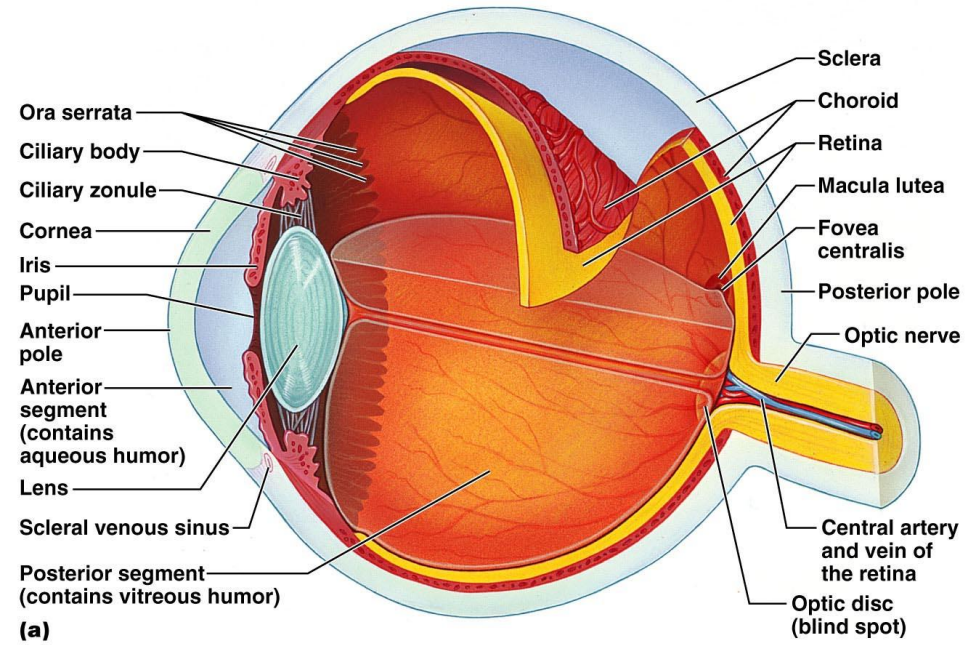
Middle layer consists of choroid, ciliary body, and iris

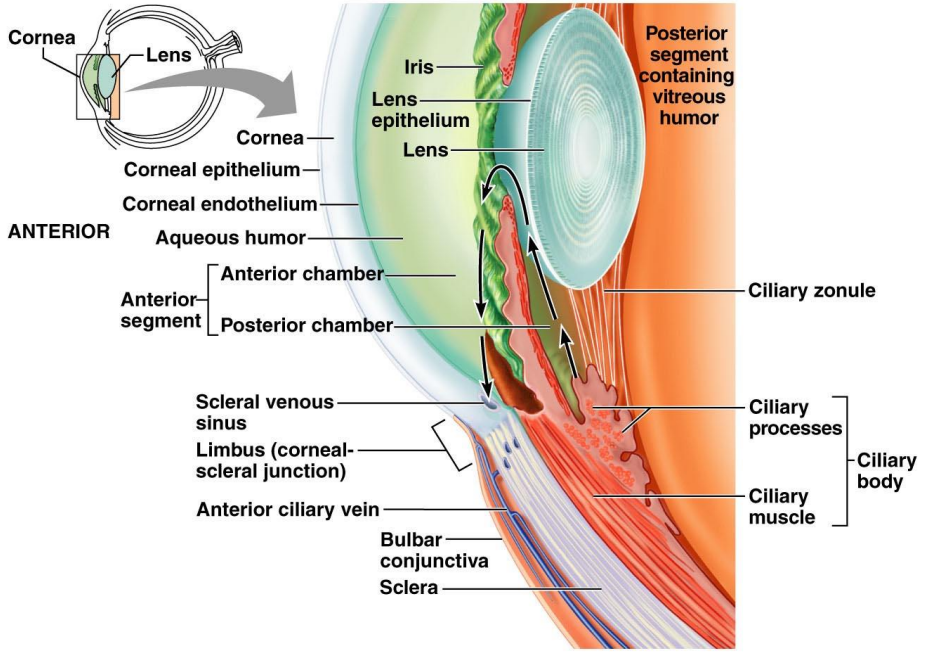
Iris and Pupil

- Composed of smooth muscle, melanocytes, and blood vessels that forms the colored portion of the eye.
- Function: It regulates the amount of light entering the eye through the pupil.
- It is attached to the ciliary body.
- Pupil is the opening in center of iris through which light enters the eye

Ciliary body

- Composed of a ring of muscle called ciliary muscle and ciliary processes which are folds located at the posterior surface of ciliary bodies
- Suspensory ligaments attach to these processes
- Function: secretes the aqueous humor
- The suspensory ligaments position the lens so that light passing through the pupil passes through





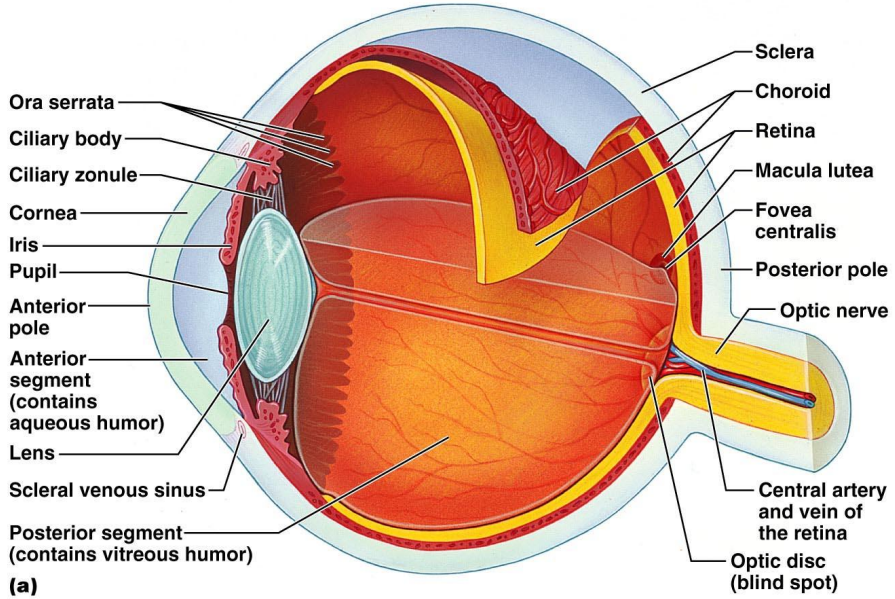
The Vascular Layer

Choroid - vascular layer in the wall of the eye.

- Dark brown (pigmented) membrane with melanocytes that lines most of the internal surface of the sclera. Has lots of blood vessels
- Lines most of the interior of the sclera.
- Extends from the ciliary body to the lens.
- Corresponds to arachnoid and pia mater

Functions:

- Delivers oxygen and nutrients to the retina.
- Absorb light rays so that the light rays are not reflected within the eye

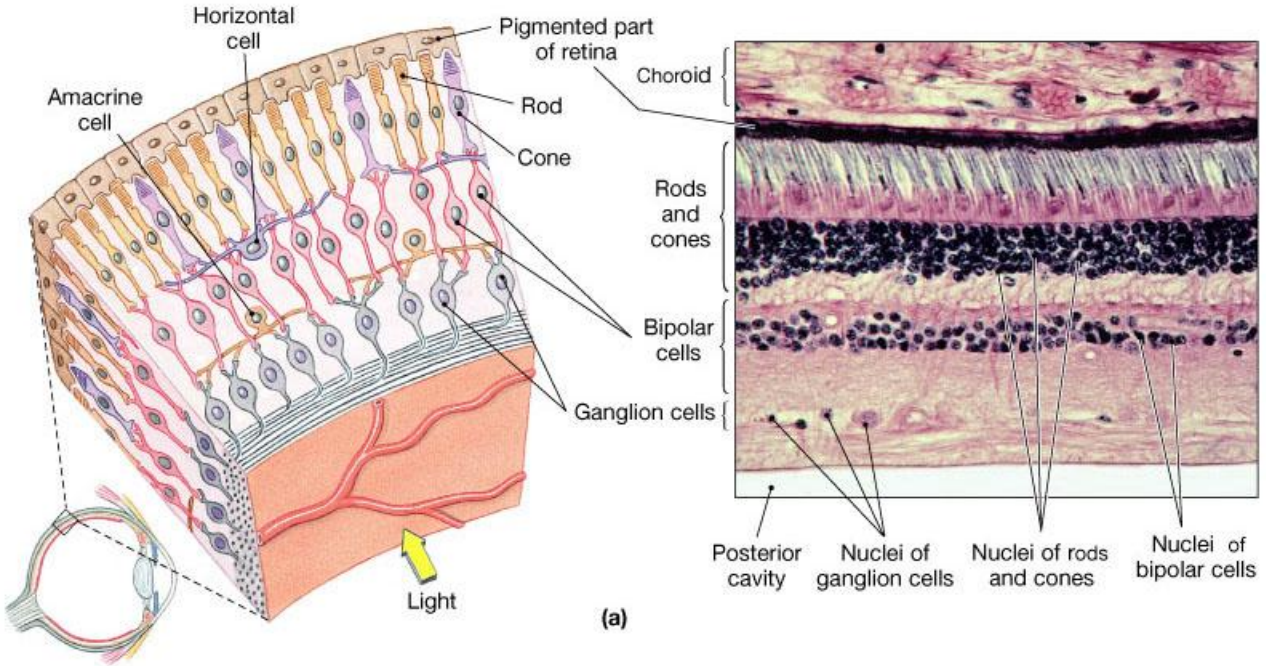


The Inner Layer (Retina)

Retina is the innermost layer of the eye lining the posterior cavity

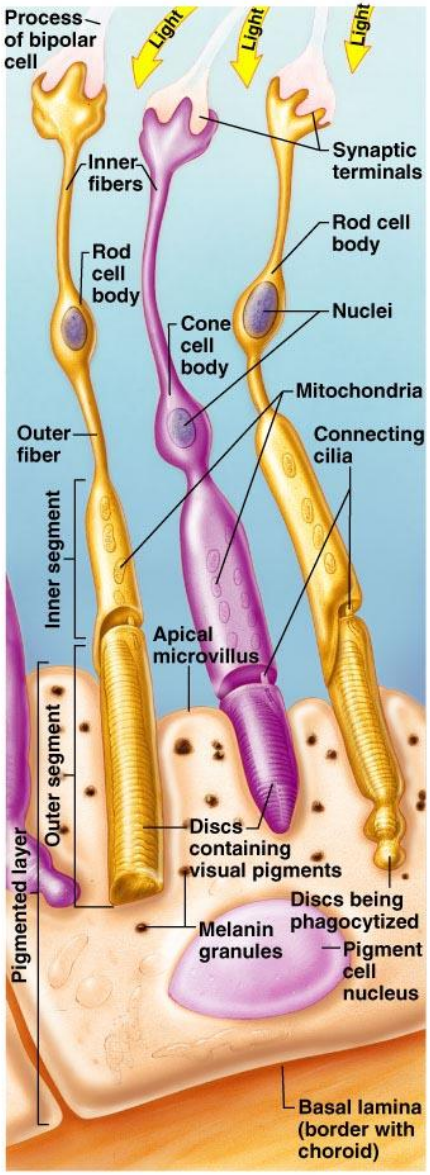
The retina contains 2 layers:

- Pigmented layer made of a single layer of melanocytes, absorbs light after it passes through the neural layer
- Neural layer – sheet of nervous tissue, contains three main types of neurons
  - Photoreceptor cells
  - Bipolar cells
  - Ganglion cells



Photoreceptors

- Two main types
  - Rod cells
    - More sensitive to light
    - Allow vision in dim light
    - In periphery
  - Cone cells
    - Operate best in bright light
    - High-acuity
    - Color vision – blue, green, red cones
    - Concentrated in fovea



Regional Specializations of the Retina

Ora serrata retinae

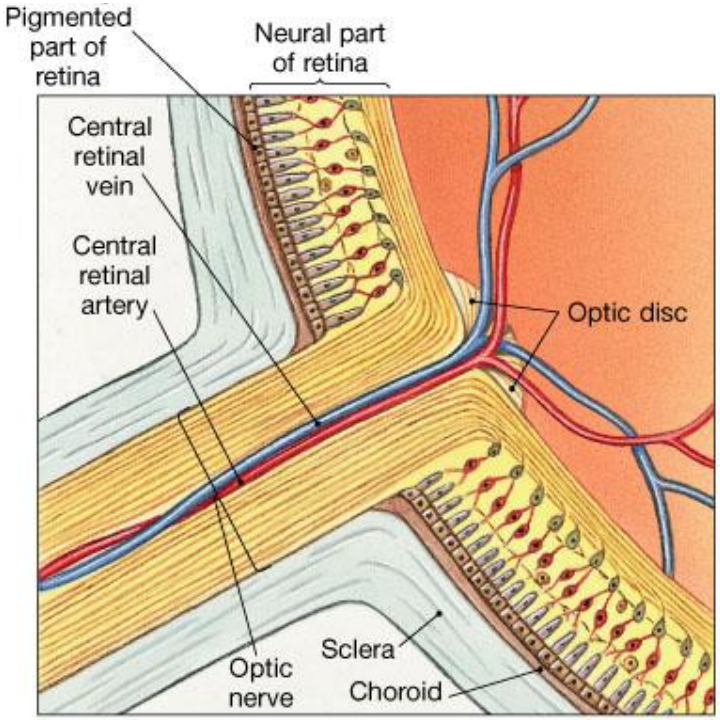
Neural layer ends at the posterior margin of the ciliary body

Pigmented layer covers ciliary body and posterior surface of the iris

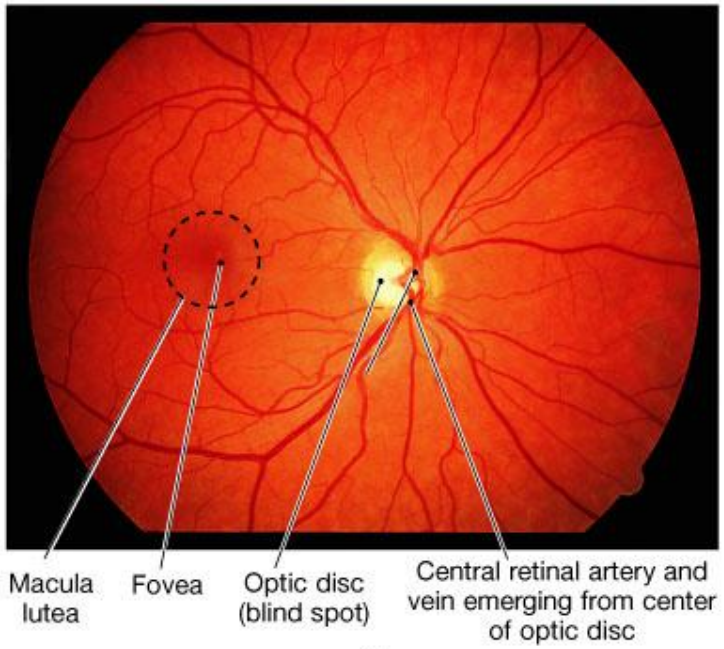
Macula lutea – contains *mostly* cones

Fovea centralis – contains only cones

Region of highest visual acuity



(b)



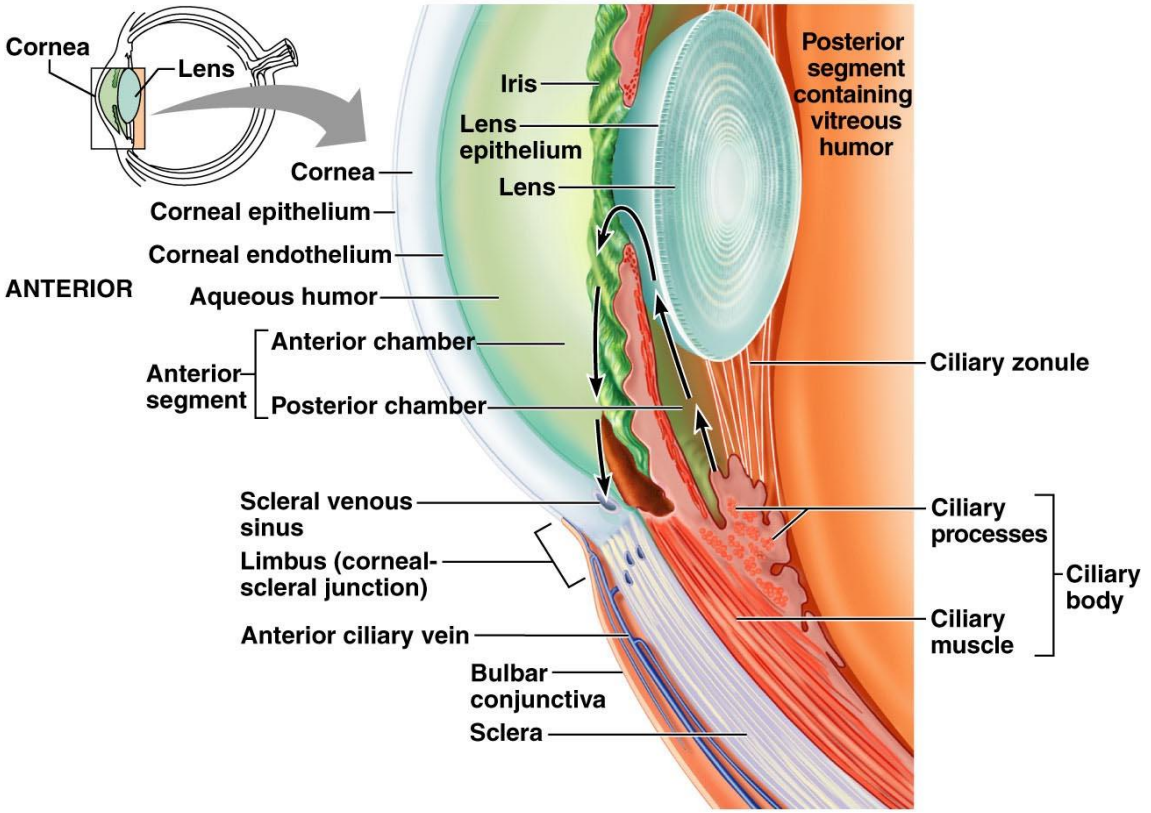
(c)

The Lens

A thick, transparent, biconvex disc

Held in place by its ciliary zonule

Lens epithelium – covers anterior surface of the lens



The Eye as an Optical Device

Structures in the eye bend light rays

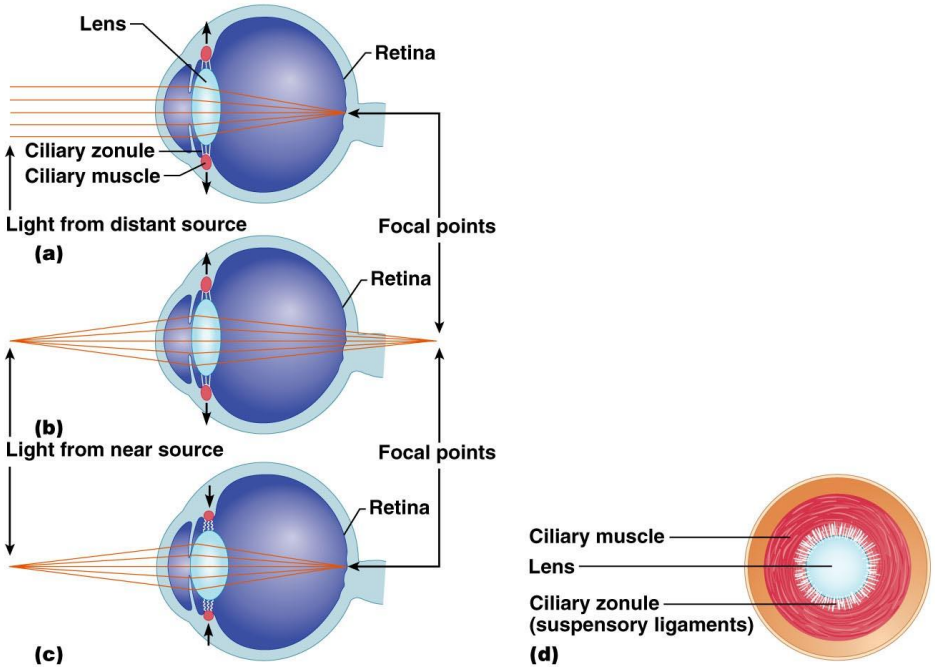
Light rays converge on the retina at a single focal point

Light bending structures (refractory media)

The lens, cornea, and humors

Accommodation – curvature of the lens is adjustable

Allows for focusing on nearby objects



Internal Chambers and Fluids

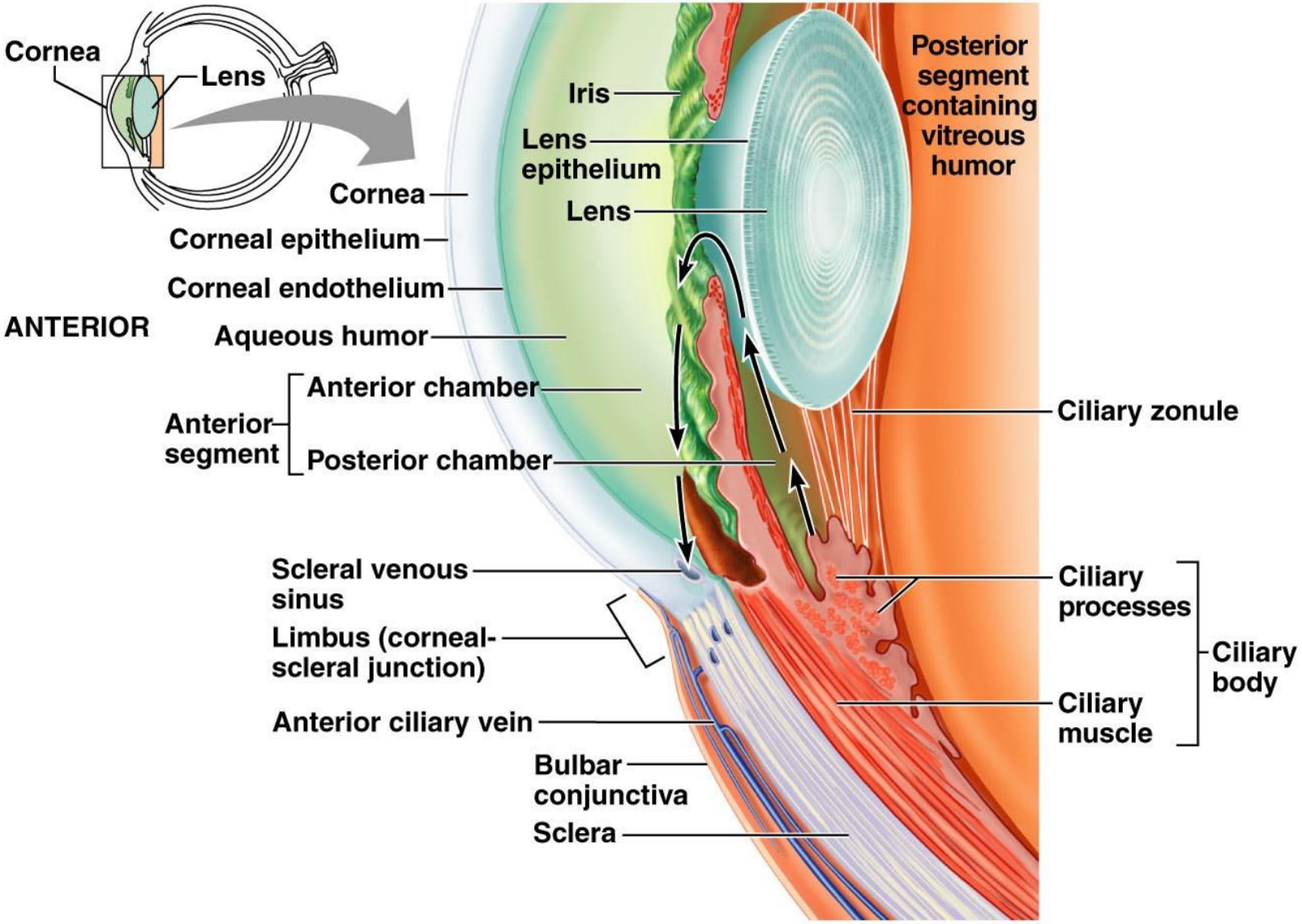


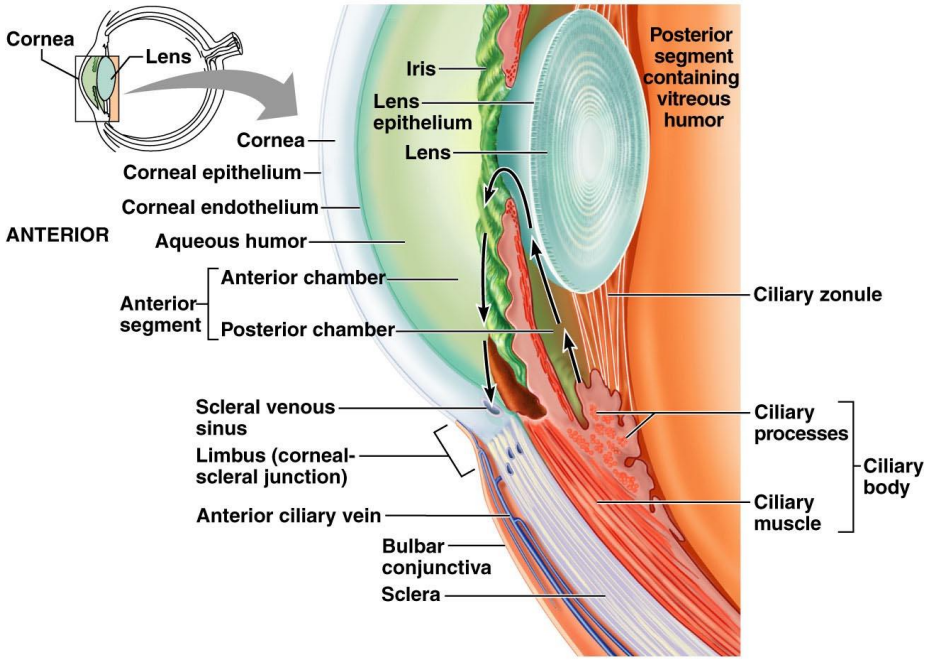
Figure 16.8

Internal Chambers and Fluids

Anterior segment

Divided into anterior and posterior chambers

- Anterior chamber – between the cornea and iris
- Posterior chamber – between the iris and lens
- Filled with aqueous humor
  - Renewed continuously
  - Formed as a blood filtrate
  - Supplies nutrients to th



Internal Chambers and Fluids

The lens and ciliary zonules divide the eye

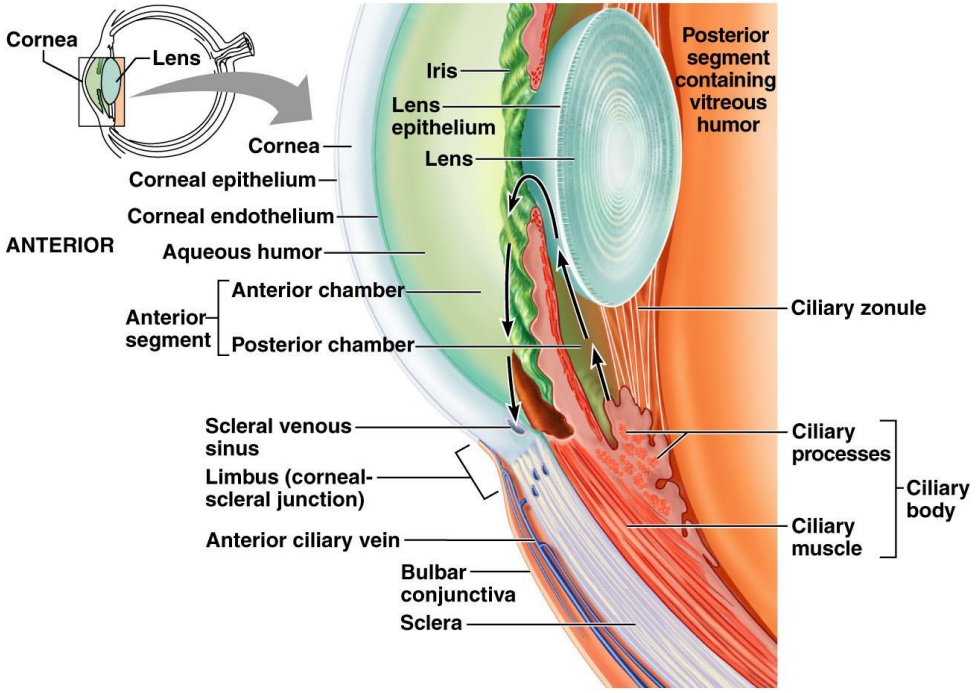
Posterior segment (cavity)

Filled with vitreous humor - clear, jelly-like substance

Transmits light

Supports the posterior surface of the lens

Helps maintain intraocular pressure



Accessory Structures of the Eye

Eyebrows – coarse hairs on the superciliary arches

Eyelids (palpebrae)

- Separated by the palpebral fissure
- Meet at the medial and lateral angles (canthi)

Conjunctiva – transparent mucous membrane

- Palpebral conjunctiva
- Bulbar (ocular) conjunctiva
- Conjunctival sac
- Moistens the eye

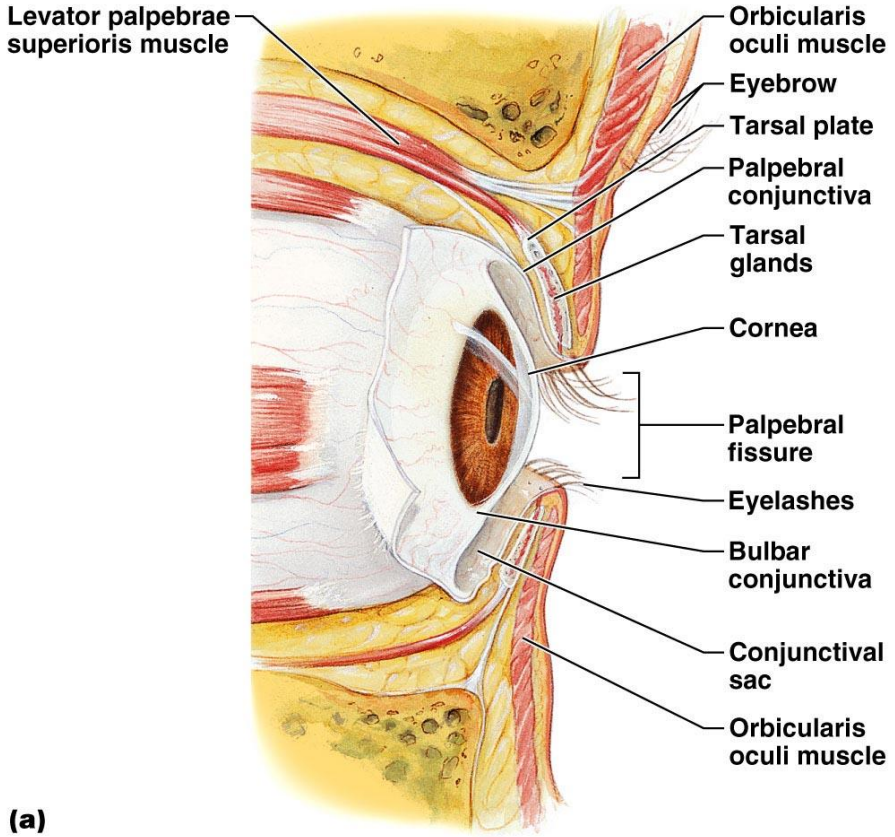


Figure 16.5a

Accessory Structures of the Eye

Lacrimal apparatus – keeps the surface of the eye moist

- **Lacrimal gland** – produces lacrimal fluid
- **Lacrimal sac** – fluid empties into nasal cavity

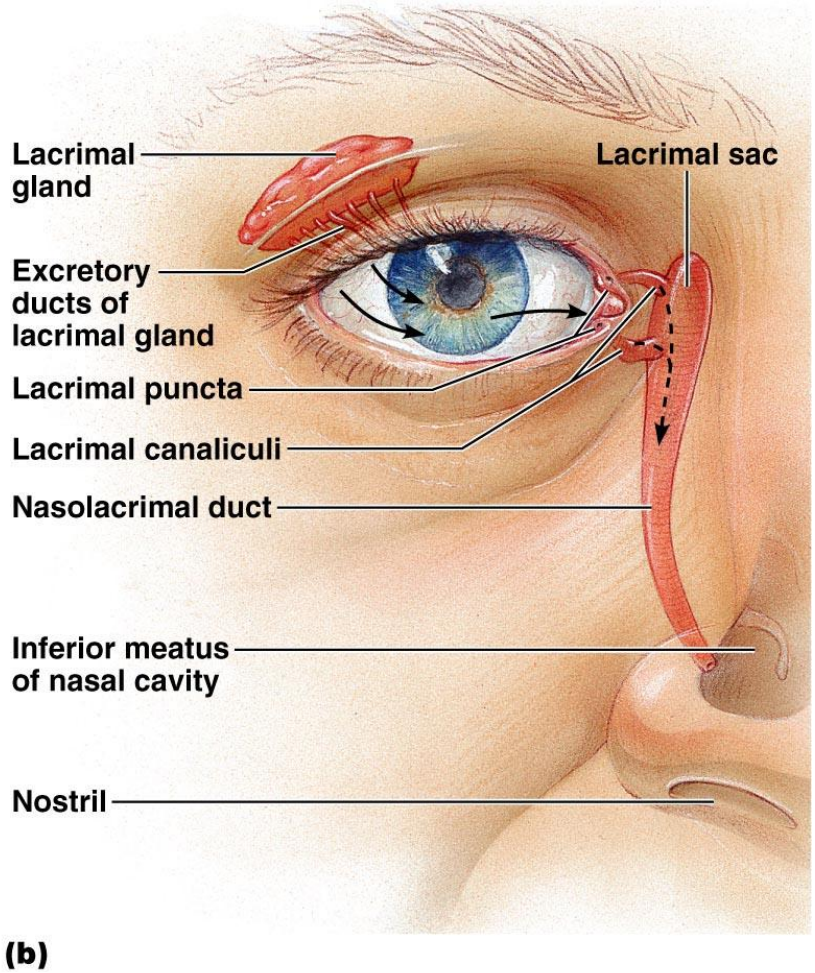
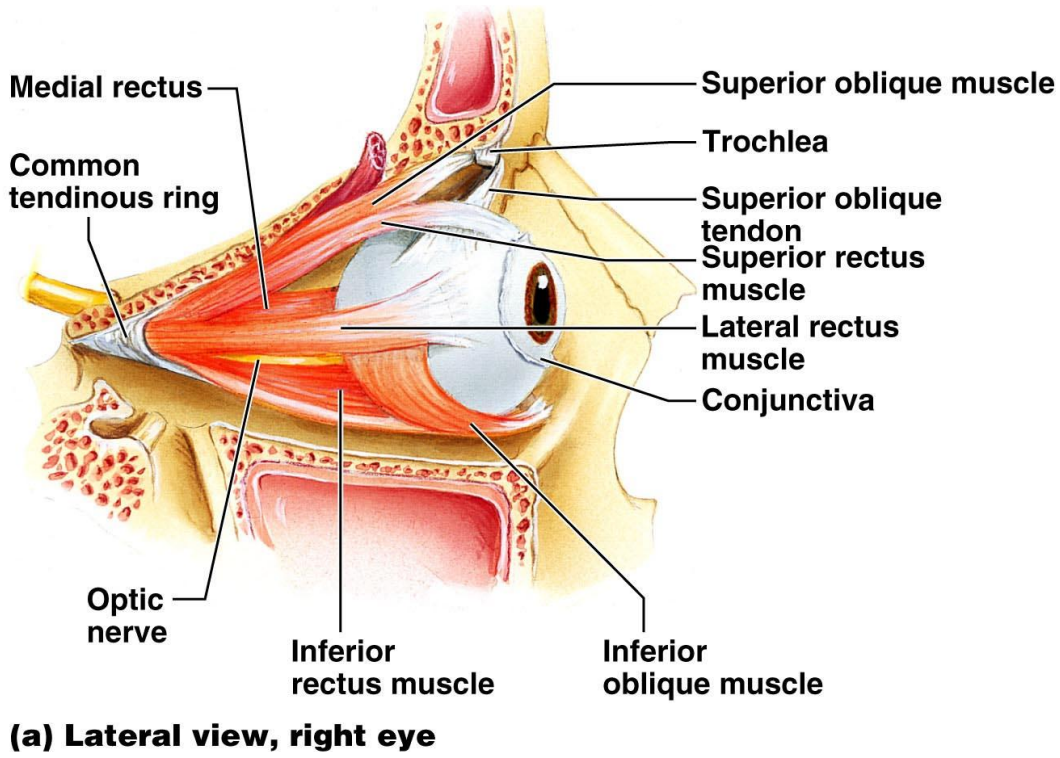


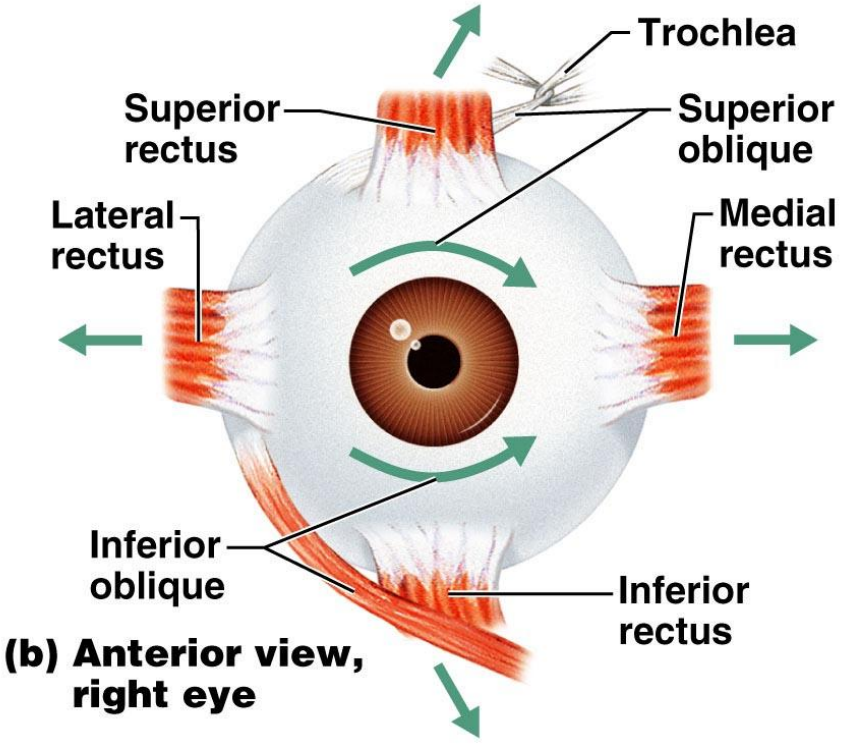
Figure 16.5b

Extrinsic Eye Muscles

Six muscles that control movement of the eye

- Originate in the walls of the orbit
- Insert on outer surface of the eyeball

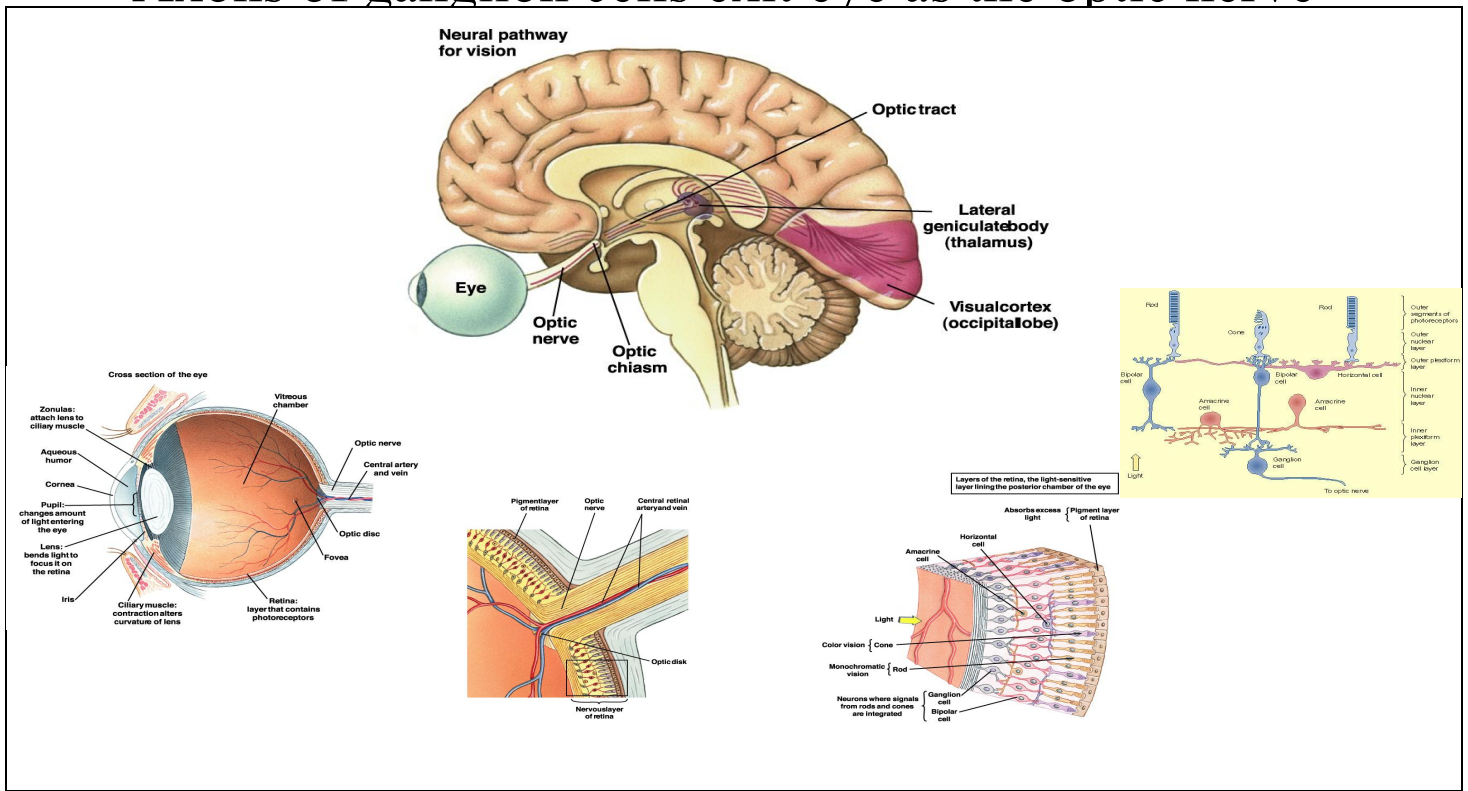




Visual Pathways to the Cerebral Cortex

Pathway begins at the retina

- Light activates photoreceptors
- Photoreceptors signal bipolar cells
- Bipolar cells signal ganglion cells
- Axons of ganglion cells exit eye as the optic nerve



Vision Integration / Pathway

- Optic nerve
- Optic chiasm
- Optic tract
- Thalamus
- Visual cortex
- Other pathways include the midbrain and diencephalon

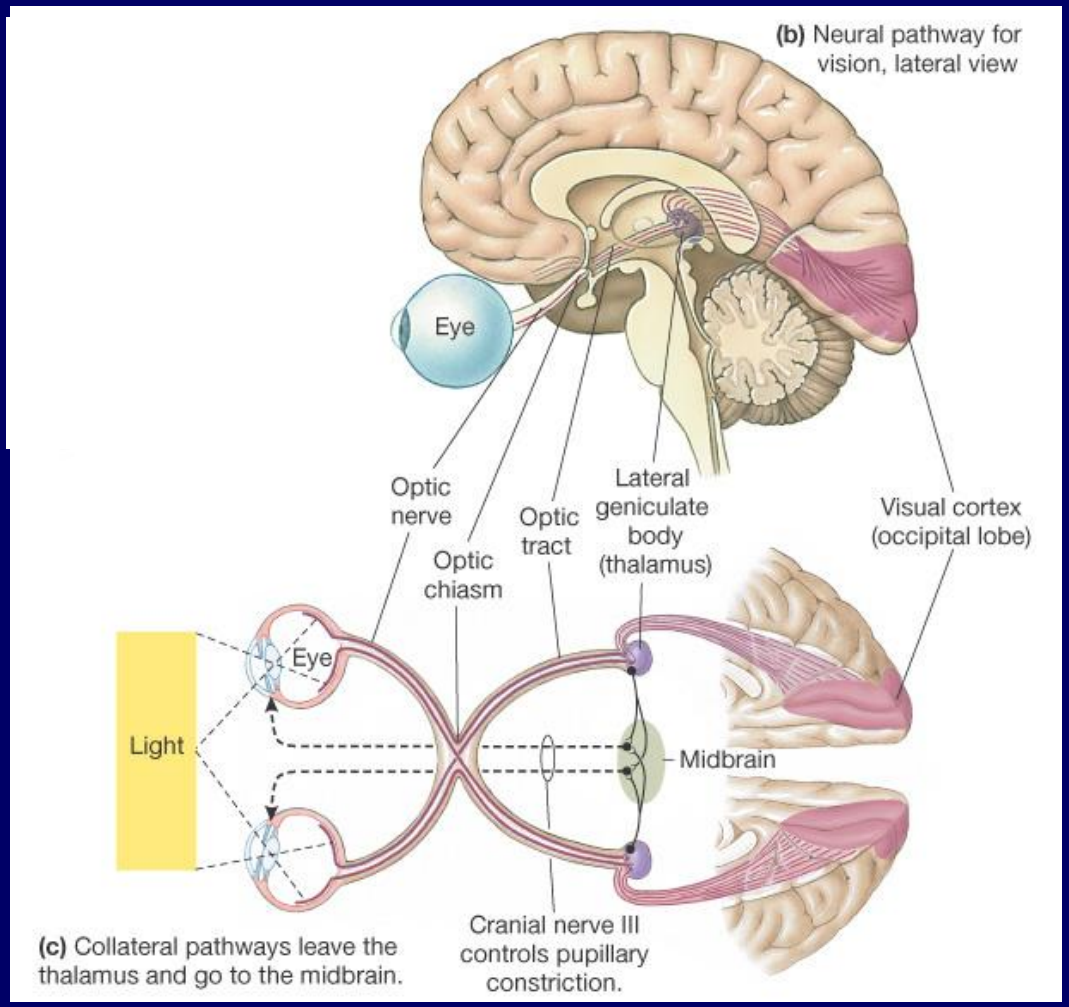


Figure 10-29b, c: Neural pathways for vision and the papillary reflex

The Ear: Hearing and Equilibrium

The ear – receptor organ for hearing and equilibrium

Composed of three main regions

- Outer ear – functions in hearing
- Middle ear – functions in hearing
- Inner ear – functions in both hearing and equilibrium

The Outer (External) Ear

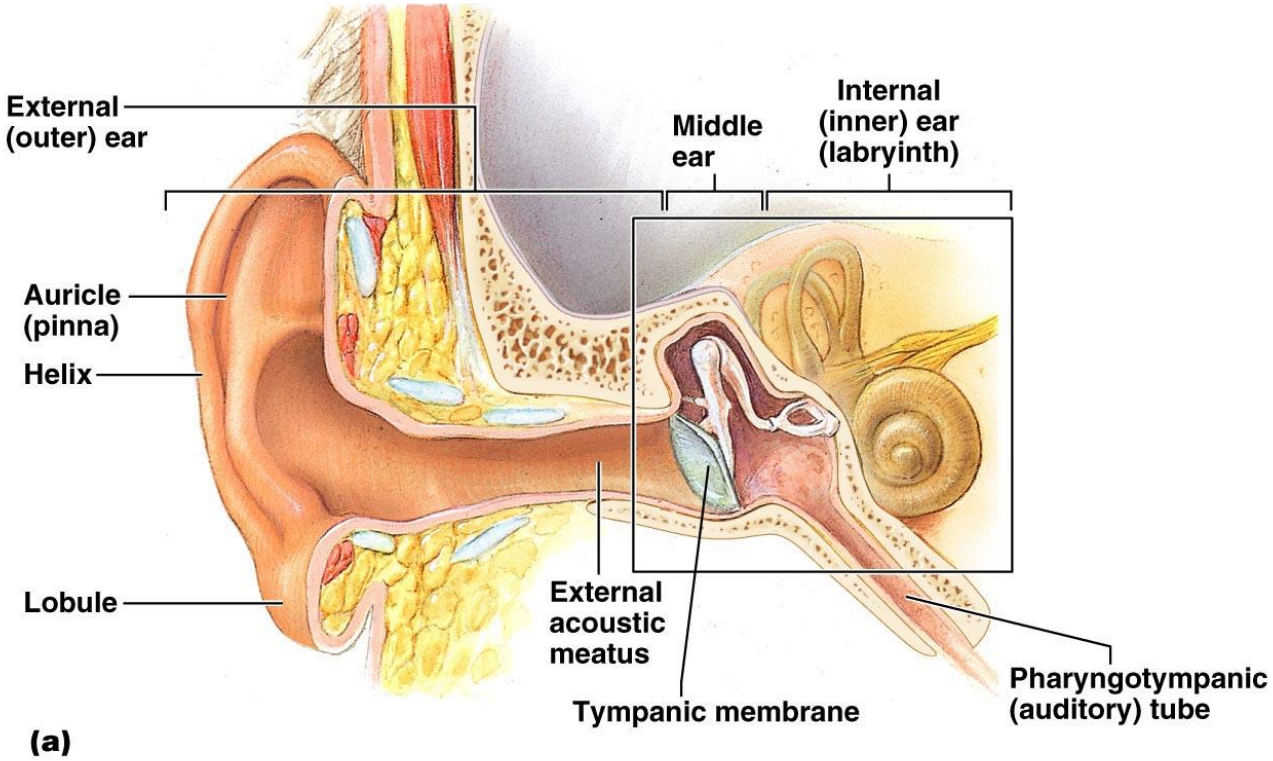
Auricle (pinna) - helps direct sounds

External acoustic meatus

- Lined with skin
- Contains hairs, sebaceous glands, and ceruminous glands

Tympanic membrane

- Forms the boundary between the external and middle ear



The Middle Ear

The tympanic cavity

A small, air-filled space

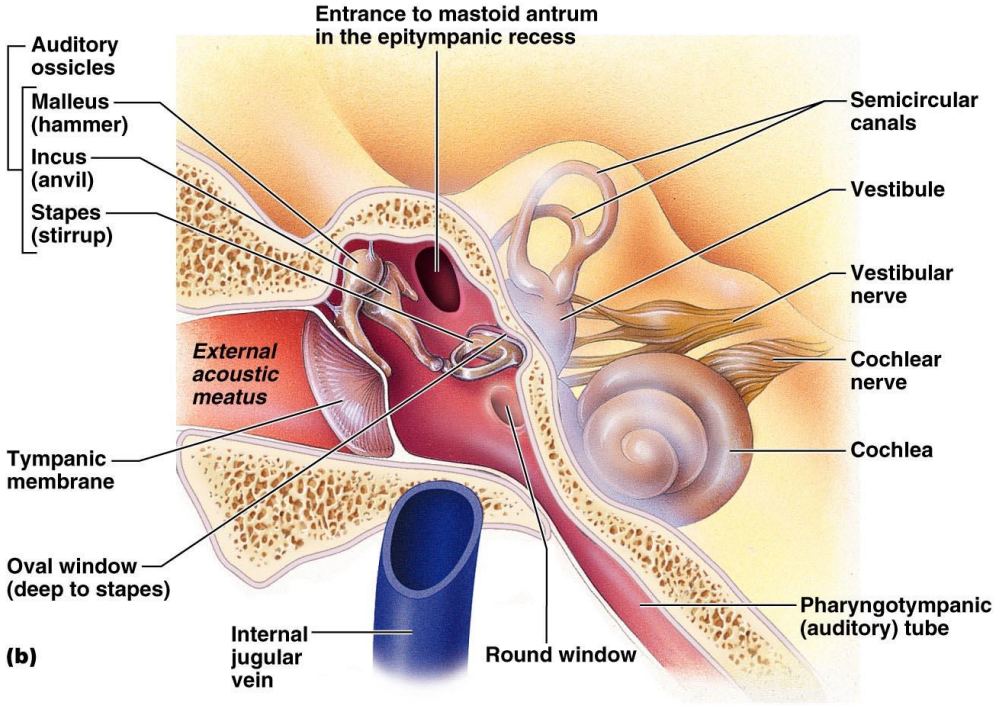
Located within the petrous portion of the temporal bone

Medial wall is penetrated by

Oval window

Round window

Pharyngotympanic tube (auditory or eustachian tube) – Links the middle ear and pharynx



The Middle Ear

Ear ossicles – smallest bones in the body

- Malleus – attaches to the eardrum
- Incus – between the malleus and stapes
- Stapes – vibrates against the oval window

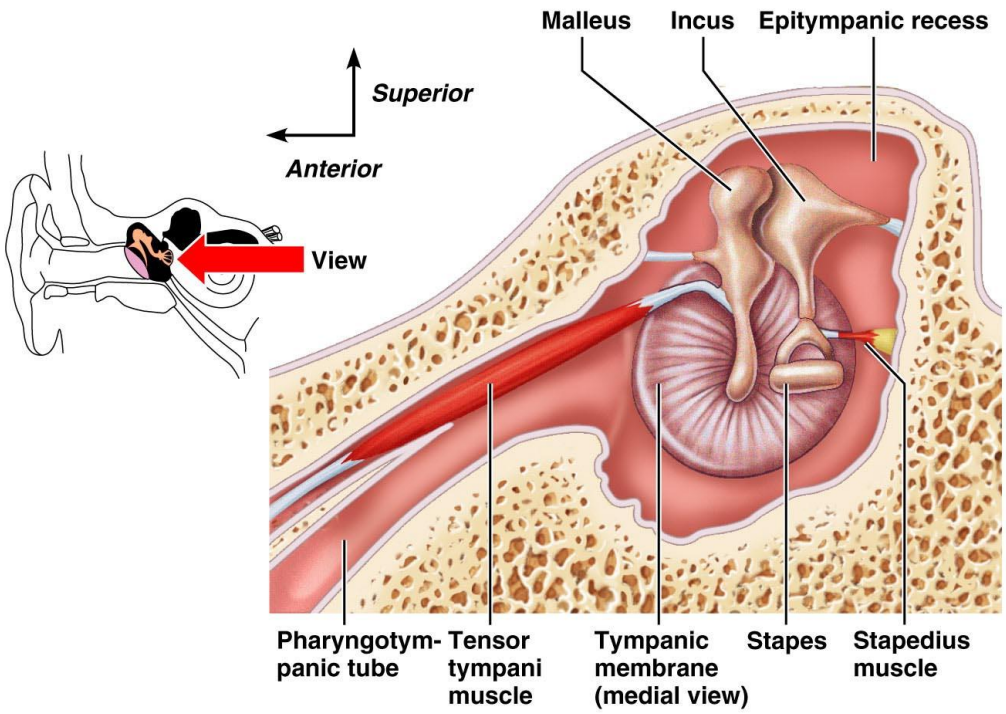


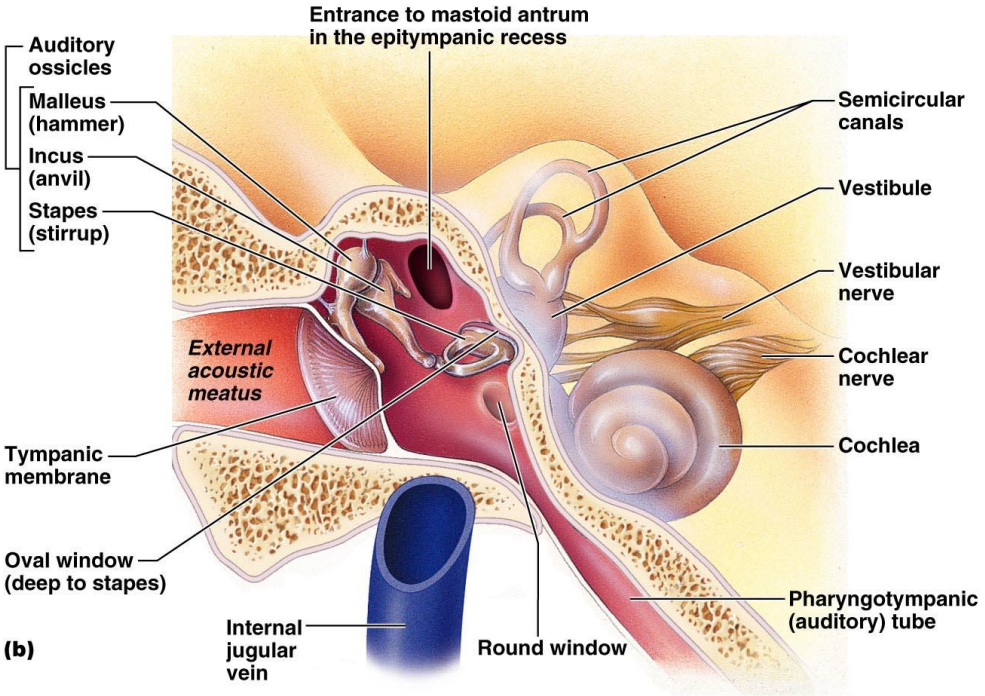
Figure 16.17

The Inner (Internal) Ear

Inner ear – also called the labyrinth

Bony labyrinth – a cavity consisting of three parts

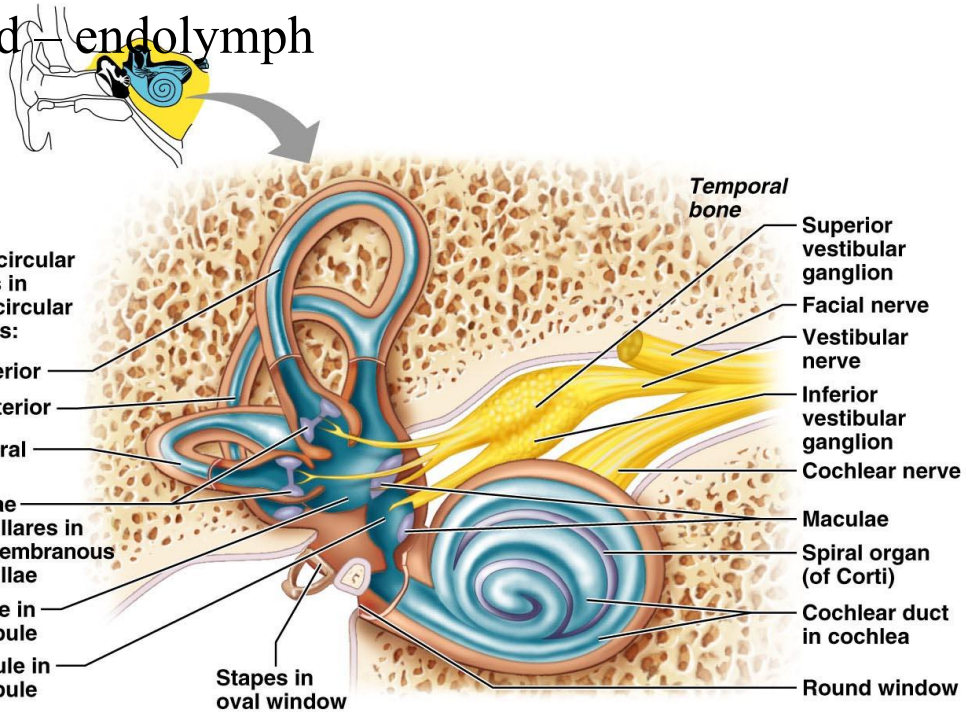
- Semicircular canals
- Vestibule
- Cochlea
- Bony labyrinth is filled with perilymph



The Membranous Labyrinth

Membranous labyrinth - series of membrane-walled sacs and ducts

- Fit within the bony labyrinth
- Consists of three main parts
  - Semicircular ducts
  - Utricle and saccule
  - Cochlear duct
- Filled with a clear fluid — endolymph



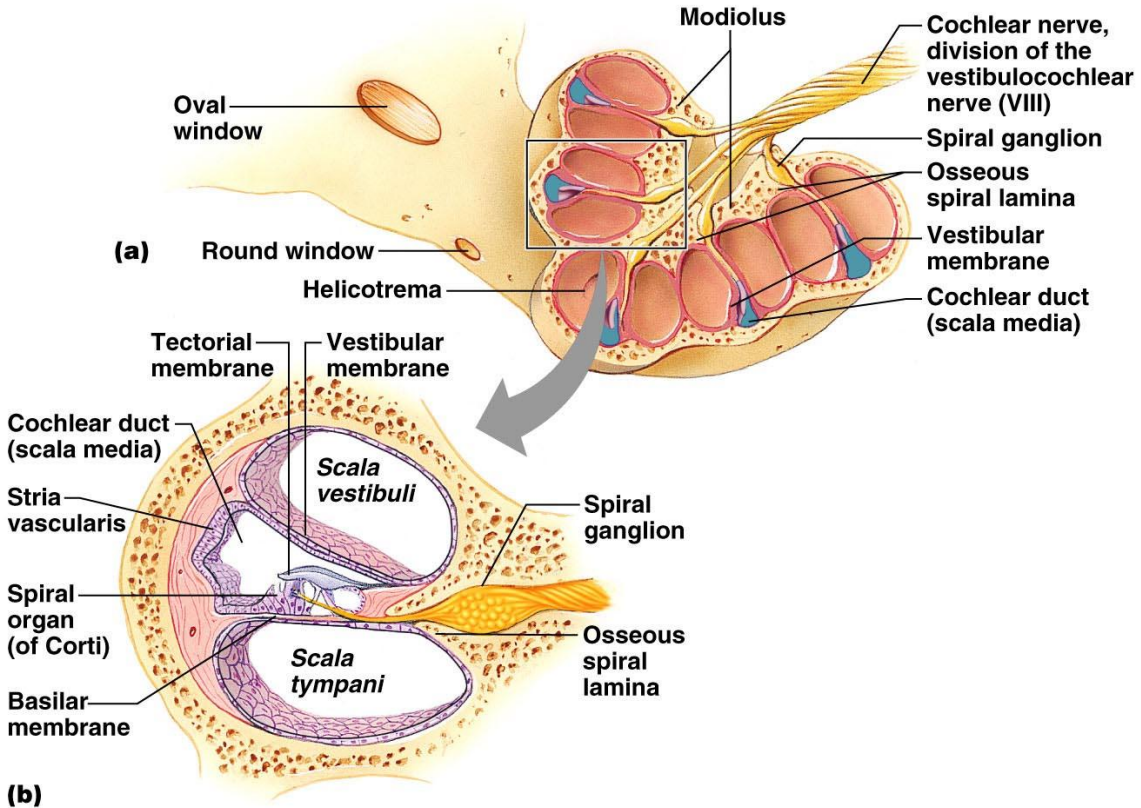
The Cochlea

A spiraling chamber in the bony labyrinth

Coils around a pillar of bone – the **modiolus**

Spiral lamina – a spiral of bone in the modiolus

The cochlear nerve runs through the core of the modiolus



The Cochlea

The **cochlear duct (scala media)** – contains receptors for hearing

Lies between two chambers

The scala vestibuli

The scala tympani

The vestibular membrane – the roof of the cochlear duct

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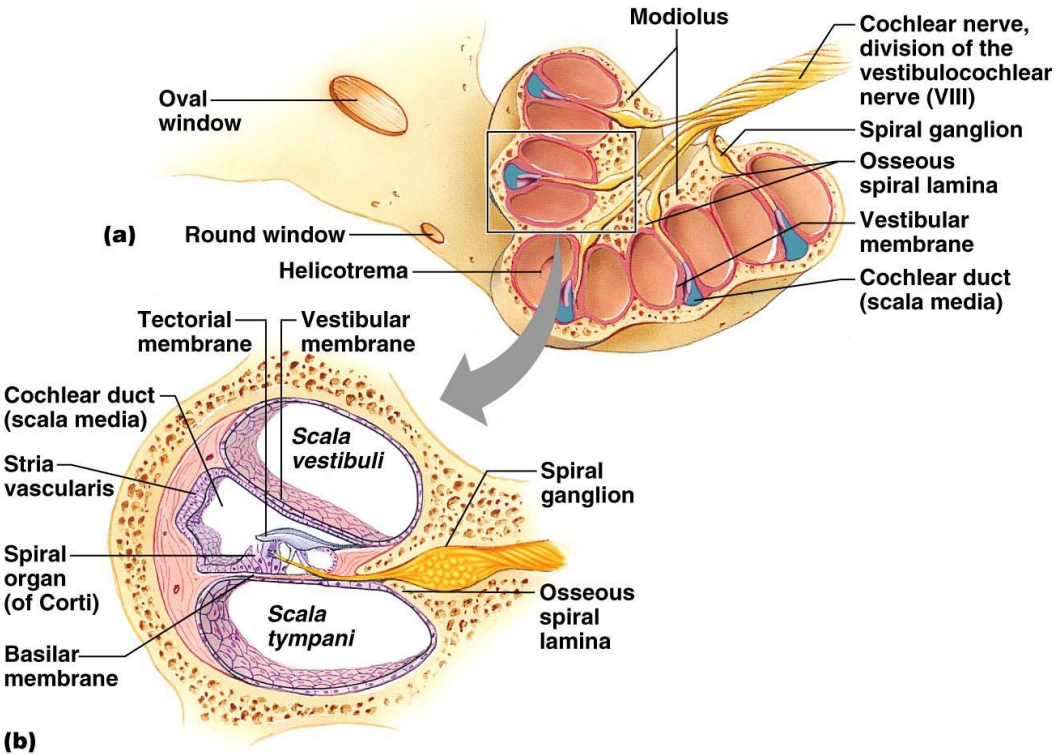
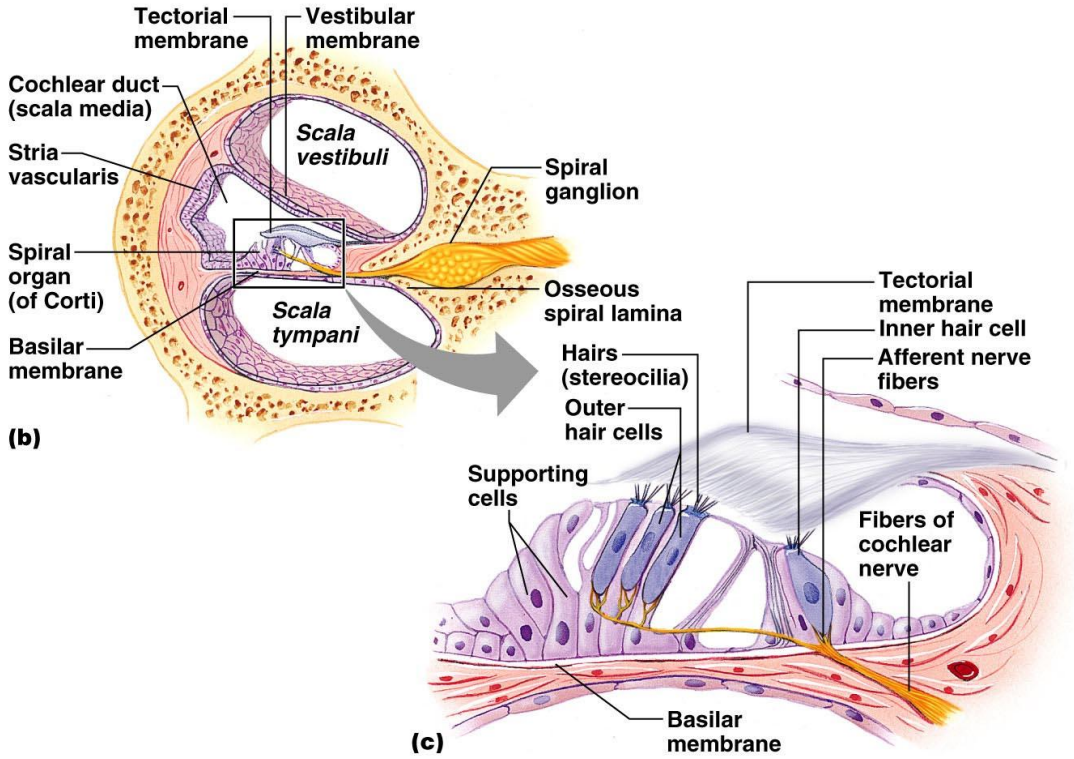


The Cochlea

The **cochlear duct (scala media)** – contains receptors for hearing

Organ of Corti – the receptor epithelium for hearing

Consists of hair cells (receptor cells)



The Role of the Cochlea in Hearing

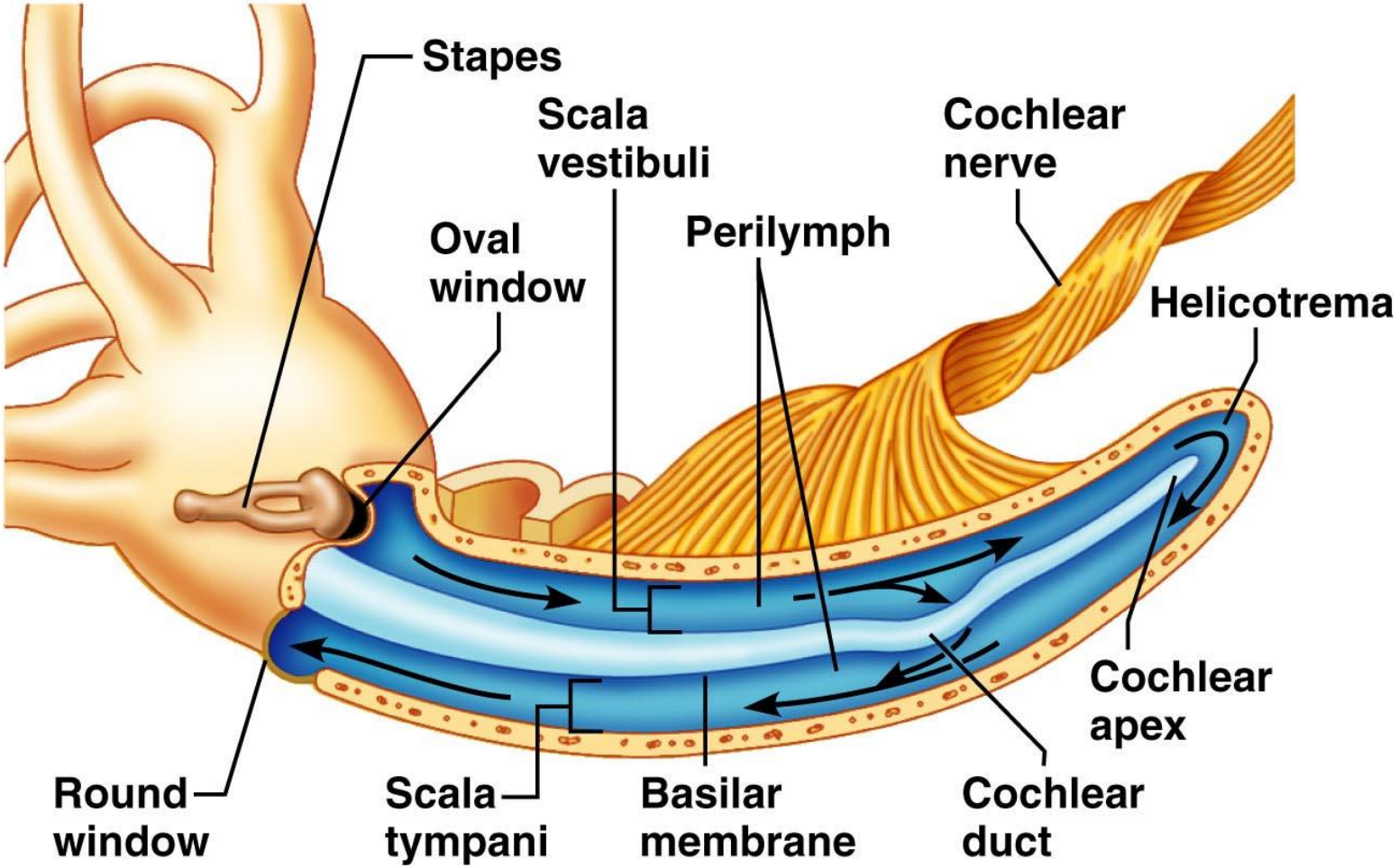
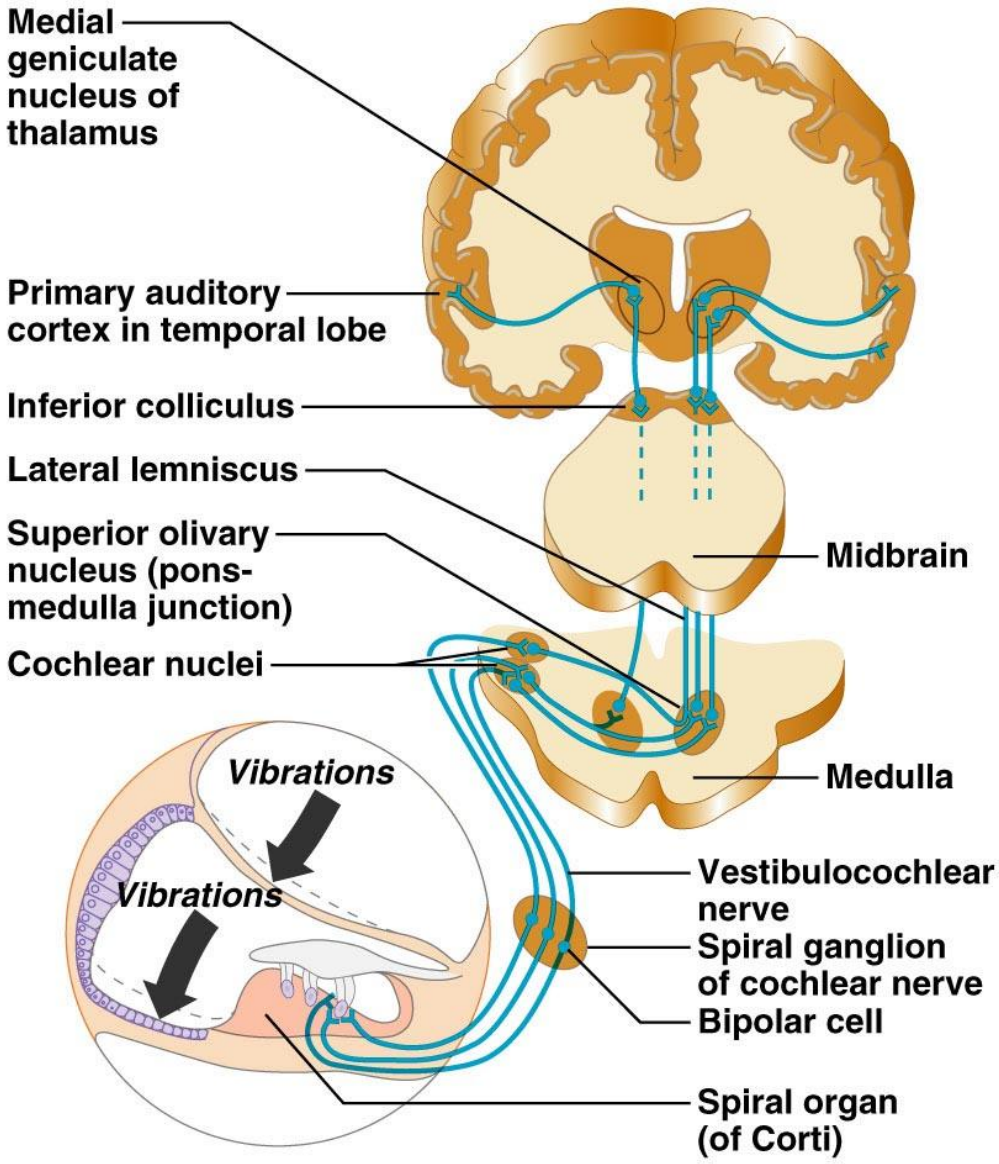


Figure 16.20

Auditory Pathway from the Organ of Corti

The ascending auditory pathway

Transmits information from cochlear receptors to the cerebral cortex



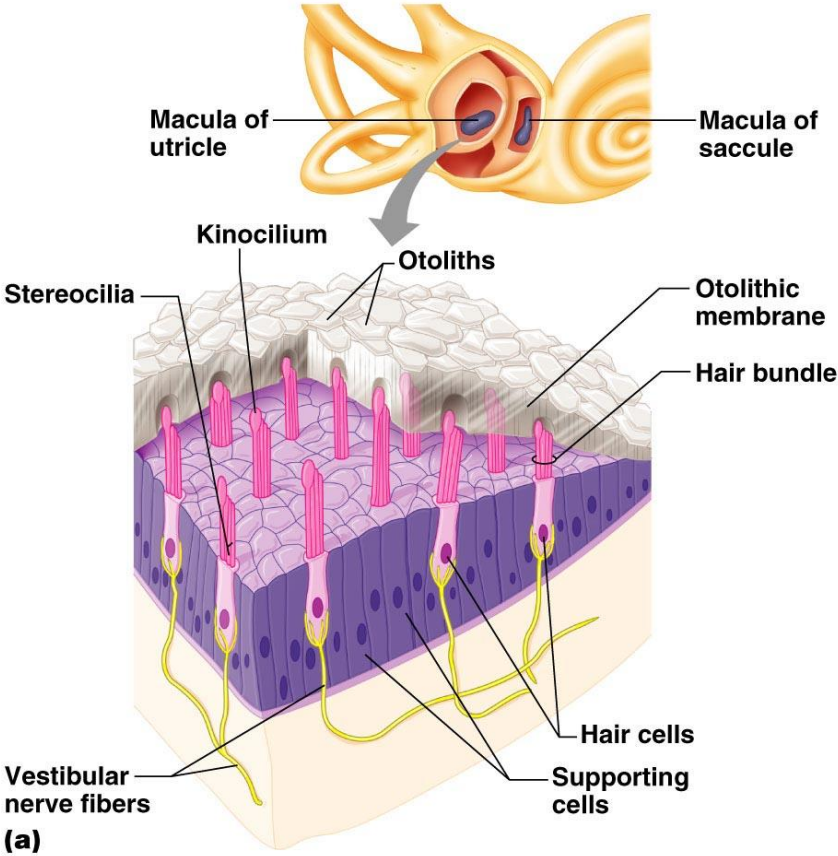
The Vestibule

Utricle and saccule – suspended in perilymph

- Two egg-shaped parts of the membranous labyrinth
- House the **macula** – a spot of sensory epithelium

Macula – contains receptor cells

- Monitor the position of the head when th
- Contains columnar supporting cells
- Receptor cells – called **hair cells**
  - Synapse with the vestibular nerve



Anatomy and Function of the Maculae

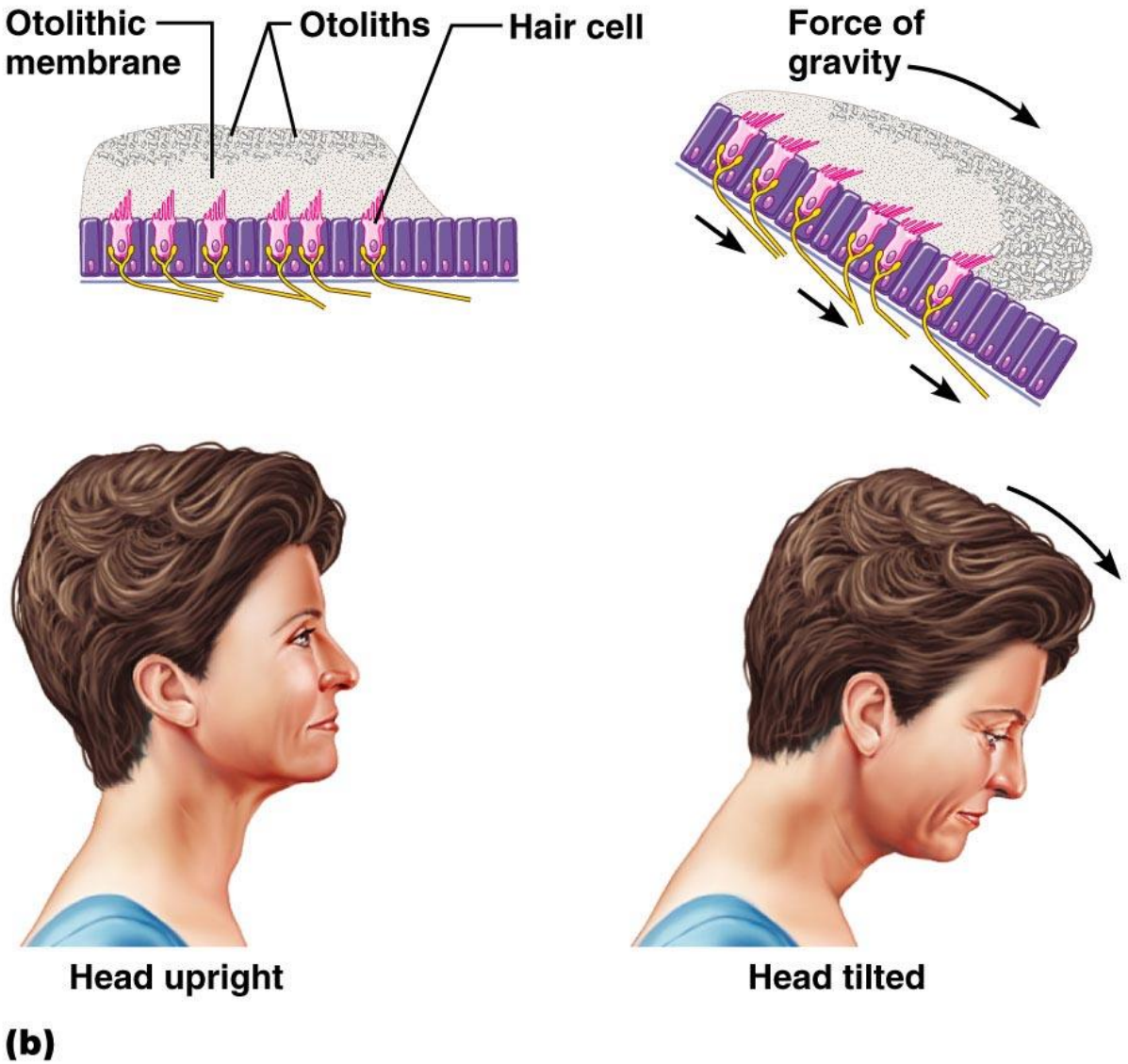


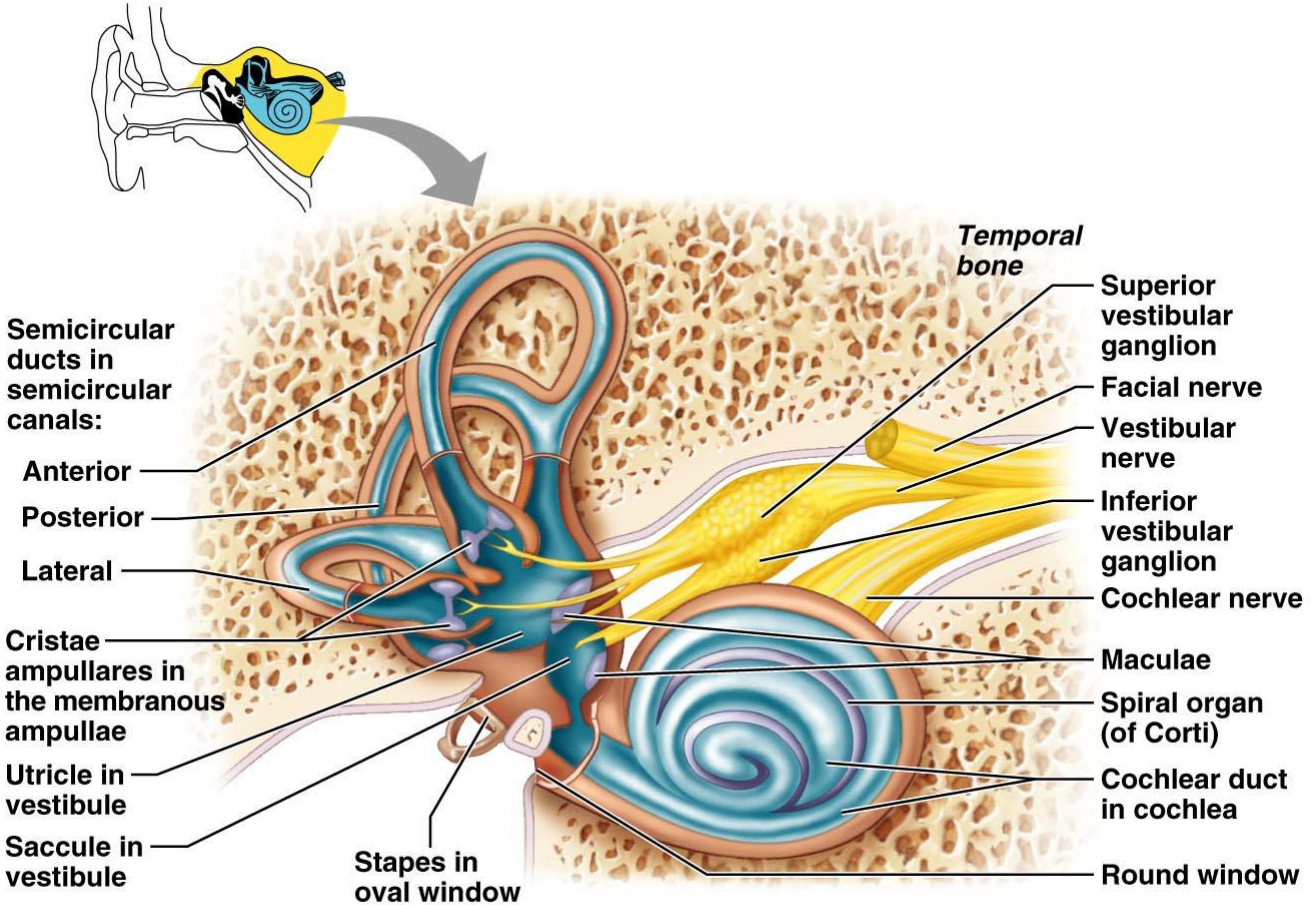
Figure 16.21b

The Semicircular Canals

Lie posterior and lateral to the vestibule

Anterior and posterior semicircular canals lie in the vertical plane at right angles

Lateral semicircular canal lies in the horizontal plane



The Semicircular Canals

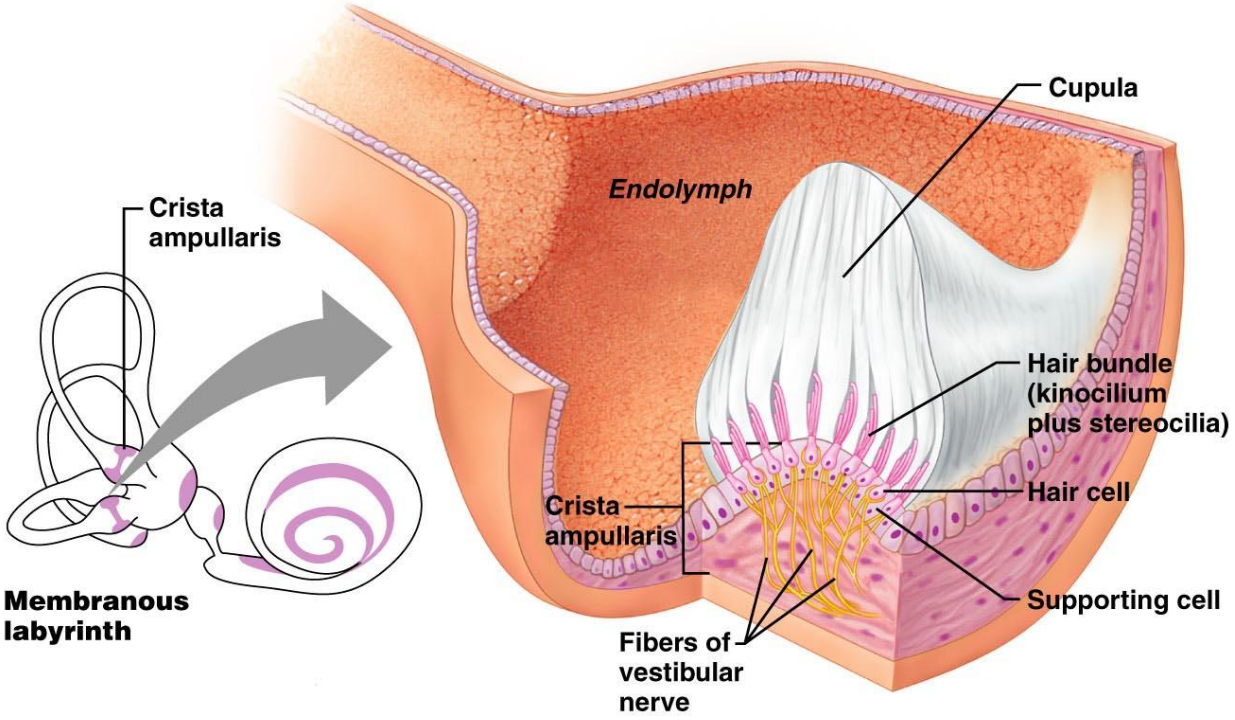
Semicircular duct – snakes through each semicircular canal

Membranous ampulla – located within bony ampulla

Houses a structure called a **crista ampullaris**

Cristae contain receptor cells of rotational acceleration

Epithelium contains supporting cells and receptor hair cells



(a) Anatomy of a crista ampullaris

Structure and Function of the Crista

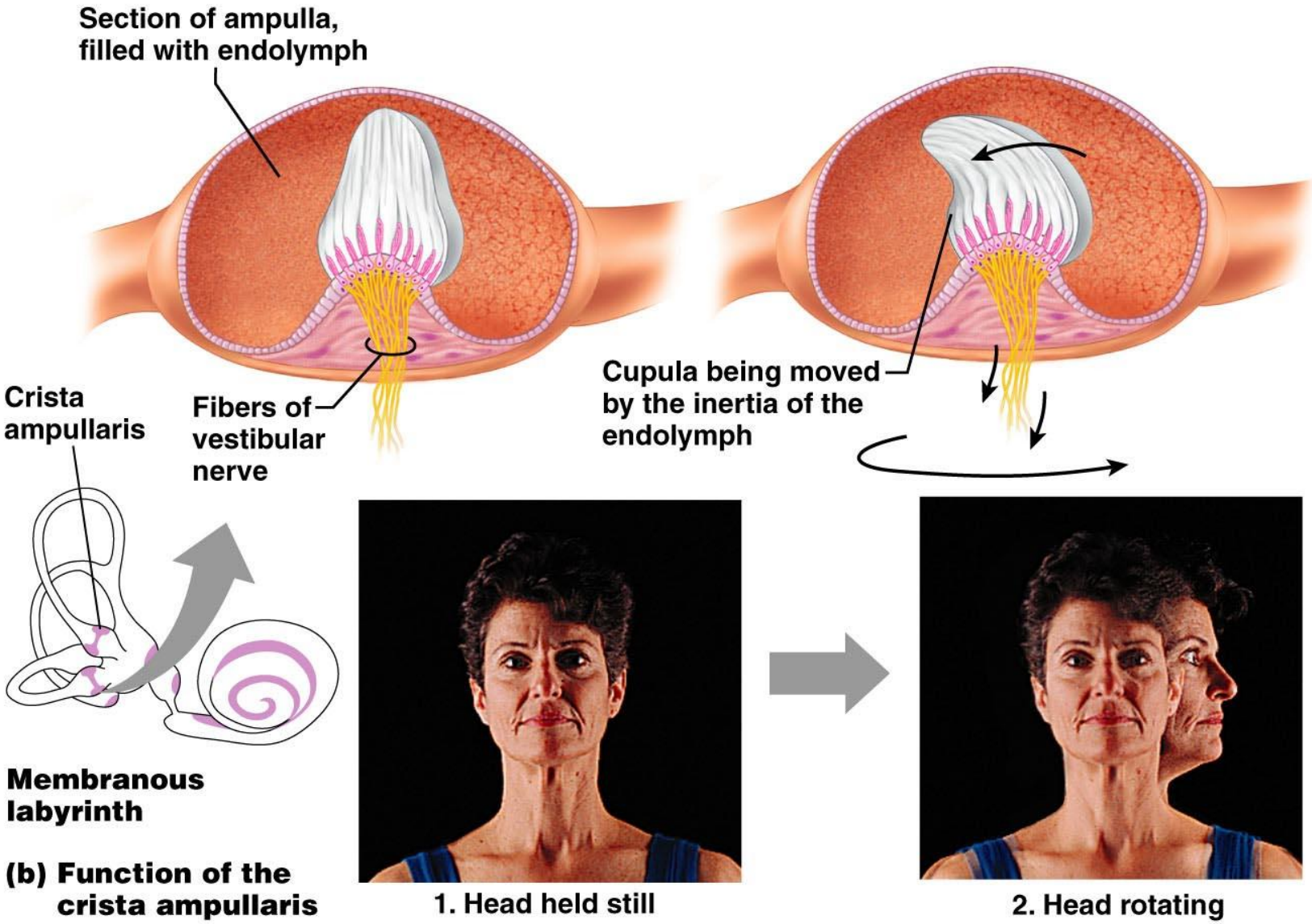


Figure 16.22b

The Chemical Senses: Taste and Smell

Taste – gustation

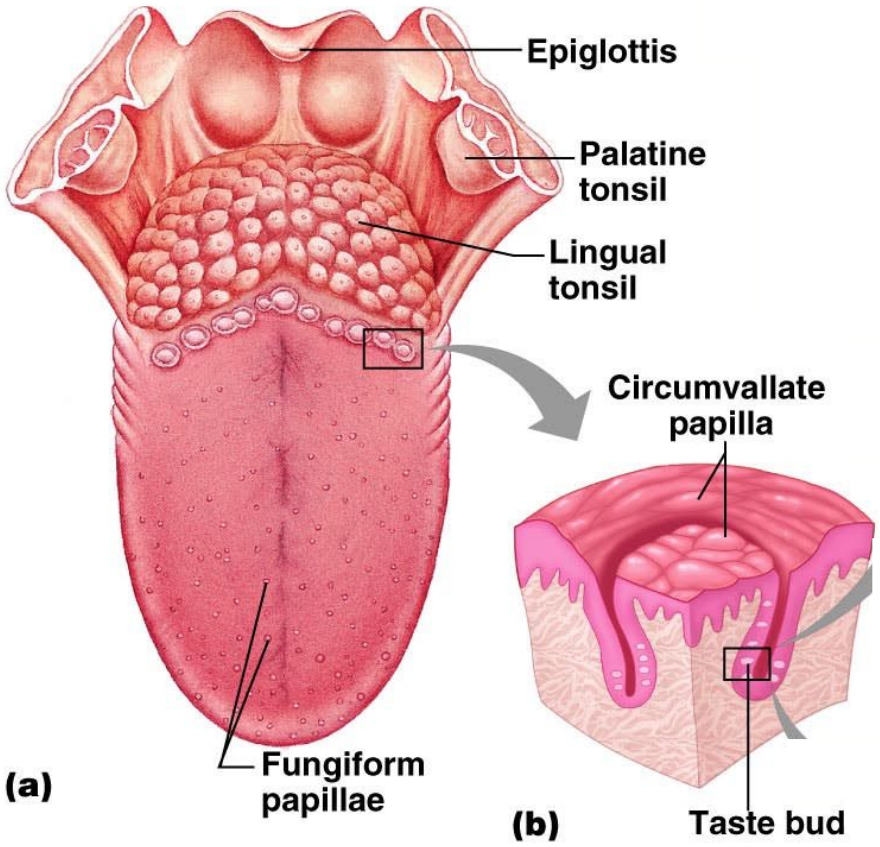
Smell – olfaction

Receptors – classified as **chemoreceptors**

Respond to chemicals

Taste – Gustation

- Taste receptors
  - Occur in taste buds
    - Most are found on the surface of the tongue
    - Located within tongue papillae
  - Two types of papillae (with taste buds)
    - Fungiform papillae
    - Circumvallate papillae



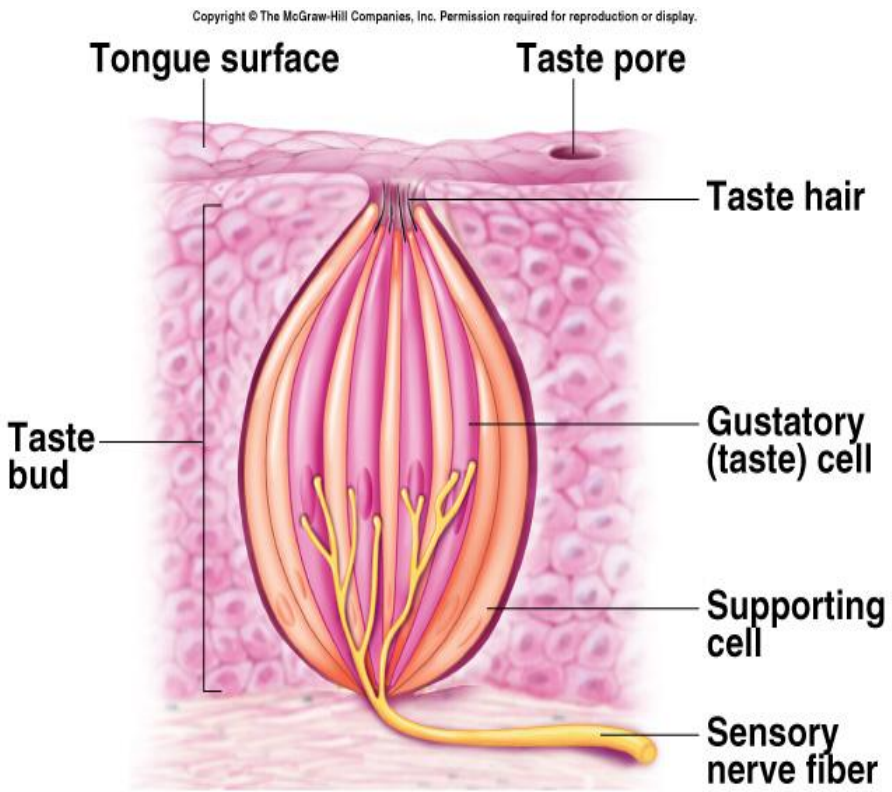
Taste Buds

Collection of 50 –100 epithelial cells

Contain three major cell types (similar in all special senses)

- Supporting cells
- Gustatory cells
- Basal cells

Contain long microvilli – extend through a taste pore



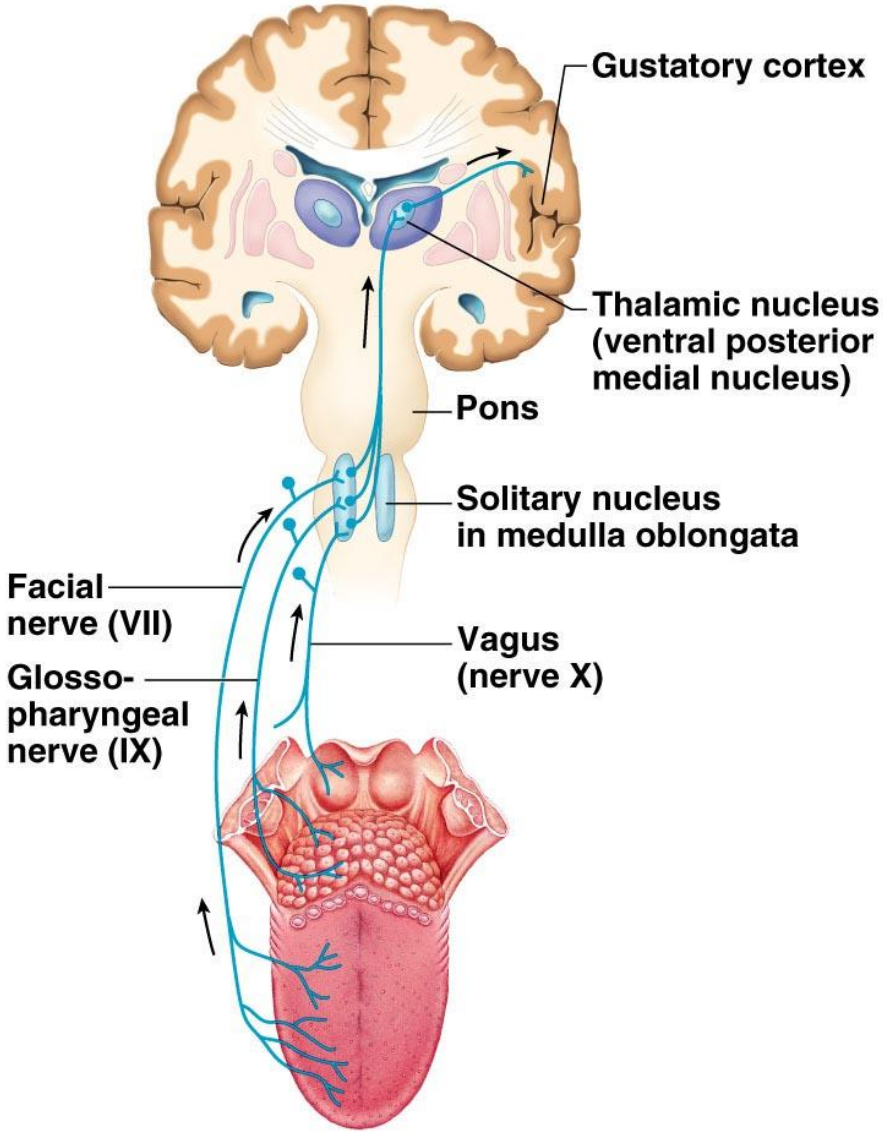
Taste Sensation and the Gustatory Pathway

- Four basic qualities of taste
  - Sweet, sour, salty, and bitter
  - A fifth taste – umami, “deliciousness”
- No structural difference among taste buds

Gustatory Pathway from Taste Buds

Taste information reaches the cerebral cortex

- Primarily through the facial (VII) and glossopharyngeal (IX) nerves
- Some taste information through the vagus nerve (X)
- Sensory neurons synapse in the medulla
  - Located in the solitary nucleus



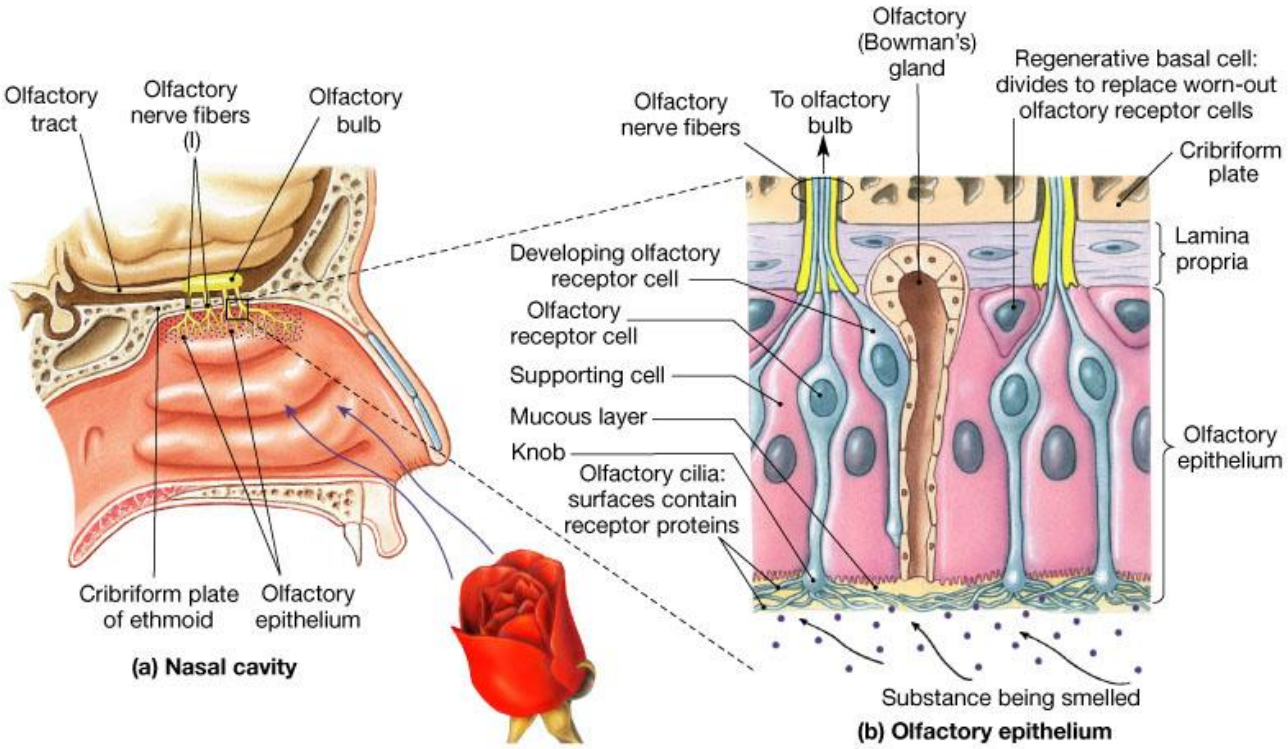
Smell (Olfaction)

Olfactory epithelium with olfactory receptors, supporting cells, basal cells

Olfactory receptors are modified neurons

Surfaces are coated with secretions from olfactory glands

Olfactory reception involves detecting dissolved chemicals as they interact with odorant binding proteins



Olfactory Receptors

Bipolar sensory neurons located within olfactory epithelium

- Dendrite projects into nasal cavity, terminates in cilia
- Axon projects directly up into olfactory bulb of cerebrum
- Olfactory bulb projects to olfactory cortex, hippocampus, and amygdaloid nuclei