Chapter 17: The Special Senses (Vision and Hearing)

Chapter Objectives

EYES

1. Describe the accessory structures of the eye: eyelids, eyelashes and eyebrows, lacrimal apparatus, and the extrinsic eye muscles.
2. Describe the components and the functions of the fibrous tunic.
3. Describe the structural constituents of the three regions of the vascular tunic, while emphasizing how these allow performance of their distinct duties.
4. Describe the major features and layers of the nervous tunic.
5. Discuss the functions of the two types of photoreceptor cells.
6. Describe the structure of the optic disc.
7. Describe the structure and function of the lens.
8. Describe the cavities and chambers of the inner eye and the materials that occupy each chamber.
9. Discuss how the light refracts or bends as it passes through the eye.
10. Define accommodation.
11. List and discuss the refraction abnormalities.
12. Describe the structures of rod and cone photoreceptors as well as the location and differences between photopigments.
13. List the steps of the configuration changes that occur to the photopigments upon absorption of light.
14. Discuss the sequence of interactions between photopigments, sodium channels (Dark current), photoreceptor membrane potential, glutamate release, and changes in the membrane potential of connected bipolar cells.

EARS

15. Describe the structures of the external ear.
16. Describe the structures of the middle ear and their functions.
17. Describe the bony labyrinth and membranous labyrinth of the inner ear. List the fluids found in each one.
18. Describe the functions of the vestibule, semicircular canals and cochlea of the inner ear.
19. Describe the internal structure of the cochlea, including the scala, helicotrema, and cochlear duct structures.
20. List the steps as sound is transmitted through the structures of the ear and then converted into nerve impulses.

**Chapter Lecture Notes**

**Accessory Structures**

**Eyebrows and Eyelashes** *(Fig 17.5)*

**Eyelids (palpebrae)**

Conjunctiva – connective tissue + epithelium with goblet cells *(Fig 17.6)*

Lines insides of eyelids and covers sclera up to cornea but does not cover cornea; the epithelium of conjunctiva is continuous with the epithelium of the cornea

Conjunctiva has blood vessels

Conjunctivitis is inflammation of the conjunctiva also known as pinkeye because the blood vessels become dilated

**Lacrimal apparatus** - produces tears from lacrimal gland and drains them from the eye via lacrimal canaliculi and nasolacrimal duct inside nasal cavity *(Fig 17.6)*

**Extrinsic eye muscles** - innervated by cranial nerves III, IV, VI *(Fig 11.5)*

Superior rectus
Inferior rectus
Lateral rectus
Medial rectus
Superior oblique
Inferior oblique

**Structure of the Eyeball** *(Table 17.1)*

**Fibrous tunic** - sclera (posterior) and cornea (transparent and anterior) *(Fig 17.7)*

Sclera - dense collagenous connective tissue with elastic fibers - "white" of eye

Cornea - covers the iris - epithelium of conjunctiva is continuous with epithelium of cornea

Canal of Schlemm (Scleral Venous Sinus) - venous canal between the sclera and cornea
Vascular tunic - choroid, ciliary body, suspensory ligament, iris

Choroid - has blood vessels and melanocytes (choroid means membrane which suggests that this layer is thin)

Blood vessels function to nourish retina

Melanin serves to prevent light scattering by absorbing scattered light

Ciliary body

Ciliary processes of the ciliary body have capillaries that produce aqueous fluid

Ciliary muscles attach to the lens via the suspensory ligaments

Ciliary muscles control the shape of the lens to accommodate focusing on near and far objects

Iris – colored portion of eye

Pupil - opening in center of iris

Size of pupil controlled by the radial muscles and circular muscles in the iris (Fig 17.8)

Nervous tunic = retina = 3 zones of neurons (Figs 17.9 & 17.10)

Photoreceptors (bipolar) - Rods and cones (Fig 17.14)

Shape of dendrites determine type of photoreceptor

Rods - specialized for vision in dim light

Cones - specialized for vision in bright light, color vision, sharp vision

Cones densely concentrated in fovea centralis - small pit in center of macula lutea

Macula lutea = yellow spot in the exact center of the posterior portion of the retinae

Rods are absent from the fovea centralis

Area of highest visual acuity

Bipolar neurons

Ganglion neurons

Axons form the optic nerve
Optic disc (blind spot) – site where optic nerve and blood vessels exit the eyeball (no rods or cones present) (Figs 17.9 & 17.10)

Lens - protein fibers

Loss of transparency = cataracts

Compartments - lens divides anterior cavity from posterior cavity (Fig 17.11)

Anterior cavity

Anterior chamber – Cornea to the iris

Posterior chamber – iris to the suspensory ligaments

Aqueous humor found in the anterior cavity is produced from capillaries in ciliary processes

Aqueous humor helps maintain intraocular pressure

Drained into canal of Schlemm

Blockage of drainage can lead to glaucoma

Posterior cavity

Posterior cavity is filled with vitreous humor

Vitreous humor helps maintain intraocular pressure and shape of the eyeball

Refraction

Light is refracted by cornea, aqueous humor, lens, vitreous humor (Fig 17.12)

Accommodation – Increase in curvature of lens for near vision

Refraction abnormalities (Fig 17.13)

Myopia (near-sightedness) – eyeball too long to focus properly

Hyperopia (far-sightedness) – eyeball too short to focus properly

Astigmatism – the cornea or lens has an irregular curvature

Presbyopia – lack of proper accommodation in older people

Physiology of Vision

Photoreceptors and photopigments
Photopigments – a colored protein that undergoes structural changes when it absorbs light (embedded in the plasma membrane of the dendrites of the rods and cones)

Rhodopsin (rods) and cone photopigments (Fig 17.14)

Opsin – glycoprotein

Retinal – a Vitamin A derivative

Generation of nerve impulses in response to light

In the dark, ligand-gated Na⁺ channels are open causing the photoreceptor to be partially depolarized (-30mV) due to inflow of Na⁺ (dark current) (Fig 17.16)

Glutamate (an inhibitory neurotransmitter) is continually being released from the photoreceptor in response to the partial depolarization

In light, retinal absorbs light and goes from bent to straight (isomerization) and the retinal releases from opsin (bleaching) (Fig 17.15)

Isomerization leads to the closing of the Na⁺ channels

Glutamate release is stopped and inhibition of the bipolar neuron halts, exciting the bipolar neuron

The bipolar neuron sends an action potential to the brain via the ganglion neurons and the optic nerve

The retinal is bent again and then rebinds to opsin (regeneration)

Parts of the Ear

External ear (Fig 17.18)

Pinna = auricle

External auditory meatus - contains ceruminous glands

Terminates at tympanic membrane (eardrum)

Middle ear (Fig 17.19)

Middle ear bones = malleus, incus, stapes

Eustachian tube = auditory tube
Opens into pharynx and enables equalization of air pressure between outside air and middle ear (equalizes pressure on both sides of tympanic membrane)

Eustachian tube provides route for throat infection to invade middle ear

Oval window – at base of the stapes

Round window

Tensor tympani and stapedius muscles – protects the ear from loud noises by limiting movement and vibration of the tympanic membrane and stapes, respectively

Inner ear - has a bony labyrinth and a membranous labyrinth which is inside the bony labyrinth

The bony labyrinth contains perilymph which is similar in composition to cerebrospinal fluid

The membranous labyrinth contains endolymph which is high in K⁺

Vestibule and semicircular canals – equilibrium (Fig 17.20)

Cochlea – hearing (Fig 17.21)

Scala vestibuli – ends at oval window

Scala tympani – ends at round window

Connected in middle of cochlea by the helicotrema

Cochlear duct (scala media)

Vestibular membrane – separates cochlear duct from scala vestibule

Basilar membrane – separates cochlear duct from scala tympani

Organ of Corti (spiral organ) – on basilar membrane and has the inner ear hair cells

Tectorial membrane – projects over and in contact with the inner ear hair cells

Physiology of Hearing

Sound waves strike the tympanic membrane causing it to vibrate – slowly for low-pitched sounds and rapidly for high-pitched sounds

The vibrations are transmitted through the middle ear bones to the oval window (Fig 17.22)

Fluid pressure waves are transmitted down the scala vestibuli, through the helicotrema, down the scala tympani, and eventually to the round window
The fluid pressure waves are transmitted to the cochlear duct causing the basilar membrane to vibrate, which moves the inner ear hair cells against the tectorial membrane. Bending of the hair cells ultimately leads to generation of nerve impulses. Each segment of the basilar membrane is “tuned” for a particular pitch – high-pitched near the oval window; low-pitched near the helicotrema.