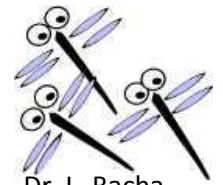


Chapt. 15: The Special Senses



Anatomy & Physiology I Dr. L. Bacha
Chapter Outline (Marieb & Hoehn 2013)

List the 5 special senses:

The Eye and Vision

- * what is the shape and diameter of the adult eye?
 - what fraction of the eye's surface is visible?

Accessory Structures of the Eye

- * list the accessory structures of the eye and locate them on Figs. 15.1 to 15.3:

Eyebrows

- * what are their functions?

Eyelids

- * what is another name for eyelids?
 - define **tarsal plates**:
- * name the two muscles that run within the eyelids and list their functions:

- * the eyelid muscles are activated reflexively to cause what to happen every 3 to 7 seconds?
 - what are the functions of reflex blinking?

- * what is the significance of the richly innervated follicles of the **eyelash** hairs?

* where are the **tarsal glands** and where do their ducts open?

- they are modified sebaceous glands; what are the functions of the oily secretion that they produce?

Conjunctiva

* describe the conjunctiva?

- what does the palpebral conjunctiva line?
- what does the bulbar conjunctiva cover?

Lacrimal Apparatus

* the **lacrimal apparatus** consists of what?

* where does the lacrimal gland lie?

- the lacrimal gland releases what fluid?

- lacrimal secretion (lacrimal fluid) flows through a duct system shown in Fig. 15.2. It is swept over the eye by blinking the eyelids. It drains into two small openings in the medial corner of each eye called lacrimal puncta, then drains through a duct system into the nasolacrimal duct. The nasolacrimal duct opens into what part of what cavity?

- what does lacrimal fluid contain?

- list functions of lacrimal fluid:

So, why does the nose run when someone cries a lot?



Extrinsic Eye Muscles

* there are six straplike extrinsic eye muscles that control what?

* each originates on the bone of the orbit and inserts into the sclera

* list the six extrinsic muscles (and identify each in Fig. 15.3):



Structure of the Eyeball

* list the three layers of the wall of the eyeball (layers are also called tunics, which means "coats"):

Layers Forming the Wall of the Eyeball

1. **Fibrous Layer**

- the outermost layer; it is composed of what?
- what are the two regions of the fibrous layer?

Sclera

- the firm, opaque, white layer that covers the posterior 5/6 of the eye
- what is the nickname of the sclera?

- list the functions of the sclera:

Cornea

- covers the anterior 1/6 of the eye
- features:
 - * colorless and transparent; avascular
 - * is well supplied with nerve endings, most of which are receptors for what?

Limbus = the junction of the sclera and cornea

- contains the scleral venous sinus into which aqueous humor drains

2. **Vascular Layer**

- the middle layer; what is another name for the vascular layer?
- it is composed of what three regions?

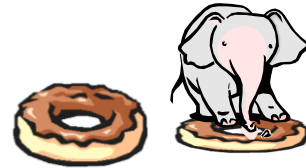
Choroid

- describe the choroid:

- what do its blood vessels nourish?
- composed of loose CT
- its brown pigment (melanin) is produced by what cells?
 - what is the function of the melanin in the choroid?

👁️ Ciliary body

- anterior continuation of the choroid; a thickened ring of tissue that encircles what?
- the ciliary body contains:
 - * **ciliary muscles**
 - what type of muscle tissue forms the ciliary muscles?
 - what do the ciliary muscles control?
 - * **ciliary processes**
 - ciliary processes are folds of the posterior surface of the ciliary body near the lens
 - the ciliary processes contain blood capillaries that produce a fluid called **aqueous humor**
 - the **suspensory ligaments (ciliary zonule; zonular fibers)** extend from what to what?
 - what is the function of the suspensory ligaments, which form a halo of fine fibers that encircles the lens?



👁️ Iris

- the most anterior part of the vascular layer
- it is the "colored part" of the eye that is seen by looking through the cornea
- what is it shaped like?
- it lies between what two structures?
- with what is it continuous posteriorly?
- what is the **pupil**?
- the iris has smooth muscles that regulate the amount of light that passes through the pupil by controlling the size of the pupil (see Fig. 15.5):
 - (1) **circular muscle** (sphincter papillae; constrictor muscle)
 - when does this muscle contract and what does contraction do to the size of the pupil?
 - the circular muscle is innervated by the parasympathetic nervous system
 - (2) **radial muscle** (dilator papillae; dilator muscle)
 - when does this muscle contract and what does contraction do to the size of the pupil?
 - the radial muscle is innervated by the sympathetic nervous system



Why do you think the pupil appears black?

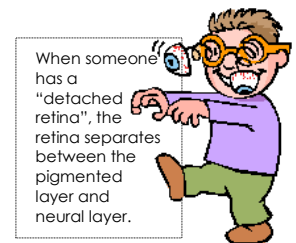
- the iris contains melanin; what color does the iris of the eye appear if the iris contains a lot of brown pigment?
- if the iris has a small amount of pigment?

3. Inner Layer (*Retina*)

- name the two layers of the retina:

PIGMENTED LAYER OF THE RETINA

- a single-layer of melanin-containing epithelial cells between the choroid and the neural layer of the retina
- the pigmented layer extends anteriorly, covering the ciliary body and the posterior iris
- what are the functions of the pigmented cells of this layer?



NEURAL LAYER OF THE RETINA

- name the junction where the neural layer of the retina ends at the posterior margin of the ciliary body:
- name the three main types of neurons that compose the neural layer and see Fig. 15.6:

a. photoreceptors

- * there are two types of photoreceptor cells: **rods** and **cones**
- * the rods and cones contain chemicals called **visual pigments** that are sensitive to light
 - which are sensitive to dim light, rods or cones?
 - which function in bright light and are responsible for color vision and visual acuity?

b. bipolar cells

- * bipolar cells transmit impulses from the photoreceptor cells to ganglion cells

c. ganglion cells

- * ganglion cells receive impulses from the bipolar cells
- * they have long axons that converge at a small area in the posterior part of the eye called the **optic disc** where the optic nerve exits the eye (locate the optic disc in Figures 15.4 and 15.6)
 - what is the optic disc also called?

· why is it called that?

* the axons of the ganglion cells form the **optic nerve** (cranial nerve II; CN II), which continues from the optic disc to the brain

- describe the **macula lutea**:

- what is the **fovea centralis**?

- how does the fovea centralis greatly enhance visual acuity?

- the fovea contains only what?

- what is the only part of the eye that has a sufficient cone density to provide detailed color vision?

- so, anything we wish to view critically is focused on what?

Internal Chambers and Fluids

Posterior segment (vitreous chamber)

* large posterior area behind the lens

* name and describe the fluid that fills the posterior segment:

* what are the 3 functions of vitreous humor?

- is vitreous humor produced continuously throughout life?

Anterior segment

* anterior to the lens; it is partially subdivided by the iris into two chambers; name the two chambers of the anterior segment and describe the position of each:

* locate the anterior segment and the anterior and posterior chambers in Fig. 15.8

* name and describe the fluid that fills the entire anterior segment:

- aqueous humor is continuously produced as a blood filtrate from the capillaries of the ciliary processes → flows through the posterior chamber → pupil → anterior chamber → drains into the blood at the scleral venous sinus, which encircles the eye at the limbus
- what does aqueous humor maintain and what are its other functions?

Lens

• describe the lens:

• what is the lens enclosed in?

• it is held in place just posterior to the iris by **suspensory ligaments (ciliary zonule; zonular fibers)** that encircle the lens and span between the ciliary processes of the ciliary body and the capsule of the lens

• the lens has great elasticity; is the lens avascular?

• name the two regions of the lens:

• the lens epithelium on the anterior surface of the lens gives rise to the lens fibers; the lens fibers are long cells that form the bulk of the lens and are packed tightly together like layers of an onion
- name the transparent proteins that the lens fibers contain:

Optics and the Eye

Overview: Light and Optics

× *Wavelength and Color*

- read about wavelength and color
- our eyes respond to the part of the spectrum called what?

× *Refraction and Lenses*

- read about refraction and lenses
- when light travels from one transparent medium into another with a different density, what happens to its speed?
- because of these changes in speed, what occurs?
- if the lens surface is convex, the light rays are bent so that they do what?

- describe the image formed by a convex lens, called a **real image**:



Focusing of Light on the Retina

- as light passes from air into the eye, it moves sequentially through what structures to excite photoreceptors?

- during its passage, light is bent three times; list these three times:

- the refractory power of the cornea is constant; why is the lens most important to allow fine focusing?

👁 *Focusing for Distant Vision*

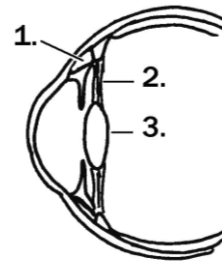
- what is the **far point of vision**?

- what is the far point for the normal eye?

- what is another term for “normal” eye?
- **viewing a distant object** (20' or >) **and when the eye is at rest** (see Fig. 15.13a):

light rays coming from far objects to the eye are nearly parallel when they enter the eye and don't need to be refracted very much to focus on the retina

1. Are the ciliary muscles in the ciliary body contracted or relaxed?
 - the ciliary muscles relax when sympathetic input to them increases and parasympathetic input decreases
2. Suspensory ligaments are taut
3. The lens is stretched thin and more flattened
 - does the flat lens refract light very much?



👁️ **Focusing for Close Vision**

- light from close objects (20 feet away) does what?
- for this reason, adjustments must be made to restore focus. List the three processes that must occur simultaneously:

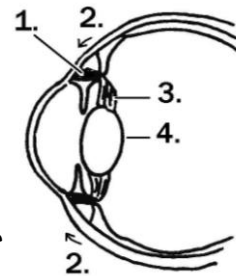
1. Accommodation of the lenses

- define **accommodation**:

- **accommodation (to view a close object)** (<20'): (see Fig. 15.13b)

* light rays coming from close objects to the eye diverge and must be refracted more to come into focus on the retina

1. Stimulation by parasympathetic nerves from the oculomotor nerve (CN III) cause the ciliary muscles in the ciliary body to contract.
2. The ciliary body is pulled forward toward the lens.
3. This releases tension on the suspensory ligaments.
4. The lens assumes a more spherical form (due to its elasticity). The spherical lens has a more convex surface, and causes a greater degree of refraction of light.



* what is the **near point of vision** and what does it represent?

* what is the near point for the normal eye in young adults?

2. Constriction of the pupils

- during accommodation of the lens, the pupil constricts
- this prevents light rays from entering the eye through the periphery of the lens , which would cause blurred vision
- with a constricted pupil, light entering the eye tends to pass more through the center of the lens and is more accurately focused than light passing through the edges.

3. Convergence of the eyeballs

- the visual goal is to always keep the object being viewed focused on what?
- when we fixate on a close object, what do our eyes do?
- define **convergence**:

Photoreceptors and Phototransduction

- define **phototransduction**:

Functional Anatomy of the Photoreceptors

- define **outer segments** of the rods and cones:
- **visual pigments** (photopigments) are integral proteins in the plasma membrane of the outer segments
 - what happens to them as they absorb light?
 - all photopigments associated with vision contain two parts:
 - light-absorbing **retinal** and one of 4 possible types of **opsins**
 - depending on the type of opsin to which retinal is bound, retinal absorbs different wavelengths of light

Comparing Rod and Cone Vision

✓ RODS

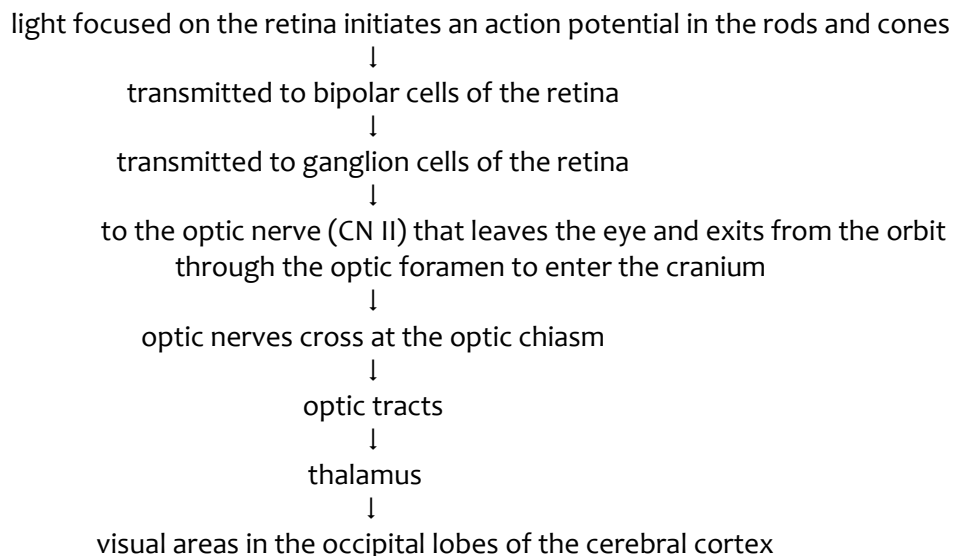
- are very sensitive, meaning that they respond to what?
- this makes them best suited for what?
- they are specialized for black and white vision (shades of gray)
- contain the photopigment called **rhodopsin**
- light strikes rhodopsin → splits into opsin and retinal → initiates a nerve impulse → impulse is transmitted by the optic nerve (CN II) to the visual cortex of the cerebrum

✓ CONES

- function in bright light and are specialized for color vision and visual acuity
- the **central fovea** is the area of sharpest vision of the retina; It contains a high concentration of cones but no rods
- each cone contains one of three types of **cone photopigments** (formed by retinal and one of 3 different types of opsin), which absorb either red light, green light, or blue light
- light strikes photopigment in cones → chemical change in the photopigment → initiates a nerve impulse → impulse is transmitted by the optic nerve (CN II) to the visual cortex of the cerebrum

The Visual Pathway to the Brain

Examine Fig. 15.6b on p. 550, then Fig. 15.19 on p. 564 as you follow this pathway:



The Chemical Senses: Taste and Smell

- what is **olfaction**?
- what is **gustation**?
- the receptors for taste and smell are **chemoreceptors**; to what do chemoreceptors respond?

The Olfactory Epithelium and the Sense of Smell

- where is **olfactory epithelium** located?
- The Olfactory Pathway (see Fig. 15.20)
 - sensory impulses from the **olfactory epithelium** are conducted through the olfactory foramina in the cribriform plate of the ethmoid by bundles of axons that form the **olfactory nerves** (cranial nerve I) → to **olfactory bulbs** of the cerebrum of the brain → to the **olfactory tracts** → to the **olfactory cortex** of the cerebral hemispheres (and other parts of the brain)



Taste Buds and the Sense of Taste

- **taste receptors** are located in **taste buds** (see Fig. 15.22)
 - most taste buds are associated with lingual papillae of the tongue
- Basic Taste Sensations: list the 5 basic qualities of taste sensations:

- The Gustatory Pathway (see Fig. 15.23)



- taste information from the tongue is found primarily in what two cranial nerve pairs?
- dissolved chemicals bind to **taste receptors** of taste buds → this initiates sensory impulses that are conducted by the cranial nerves → impulses reach the **gustatory cortex** of the cerebrum

The Ear: Hearing and Balance

Structure of the Ear

List the three major areas of the ear and what each area is involved in:

External Ear

- list the two parts of the external ear:



auricle

- the part visible outside of the head; what is it also called?
- describe the auricle:

- what is the auricle composed of?

external acoustic meatus (external auditory canal)

- describe the external acoustic meatus:

- the entire canal is lined with skin bearing what?

- what do **ceruminous glands** secrete and what is the function of the secretion?

tympanic membrane

- what is the other name for the tympanic membrane?
- what is its boundary between?
- describe the tympanic membrane:

Middle Ear

- what is the middle ear also called?
- it is an air-filled mucosa-lined cavity in what specific part of the skull?

- its boundaries include the tympanic membrane and a bony wall with what two openings?

- **auditory tube** (eustachian tube; pharyngotympanic tube)
 - ✈ it is an air passageway that links what two specific parts?

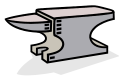
✈ what is the function of this passageway and why is it important?

- three **auditory ossicles** span across the tympanic cavity:



malleus (*meaning "hammer"*)

- the "handle" of the malleus is secured to what?
- the head of the malleus articulates with what bone (shown in Fig. 15.25)?



incus (*meaning "anvil"*) – articulates with the malleus and stapes



stapes (*meaning "stirrup"*)

- articulates with the incus at one end; the base of the stapes fits into what?

- what do the ossicles transmit?

• name the two tiny skeletal muscles that are associated with the ossicles:

- in response to very large sounds, these muscles contract reflexively to limit what?



What are the
smallest synovial
joints in the body?!

Internal Ear

- what is the internal (inner) ear also called and why?

- it is located in what bone of the skull?

- list the two major divisions of the internal ear:

- **bony labyrinth**

- describe the bony labyrinth:

- why are the views of the bony labyrinth typically seen in textbooks somewhat misleading?

- **membranous labyrinth**

- describe the membranous labyrinth:

- are the bony labyrinth and membranous labyrinth filled with fluid?

- list the three regions of the bony labyrinth:

We will fill in the table below in class:

| Bony Labyrinth | Corresponding part(s) of the Membranous Labyrinth |
|-----------------------|----------------------------------------------------------|
| | |
| | |
| | |

Vestibule

- describe general location and the shape of the vestibule:

- name the two membranous sacs suspended in the fluid of the vestibule:

- what do the saccule and utricle house?

- to what do the maculae respond?

Semicircular Canals

- there are three semicircular canals at right angles to each other

- each contains a membranous **semicircular duct**; each of these ducts has an enlarged swelling at one end called an **ampulla**, which houses what?

- what do these receptors respond to?

Cochlea

- describe the shape and size of the cochlea:

- running through the center like a wedge-shaped worm is what structure?

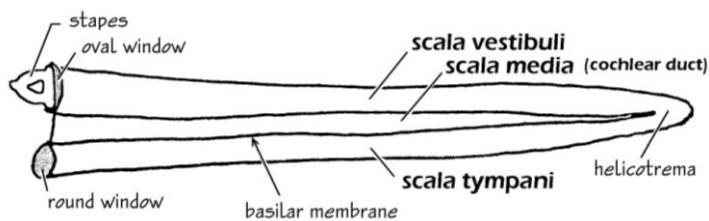
- name the receptor organ for hearing that the cochlear duct houses:



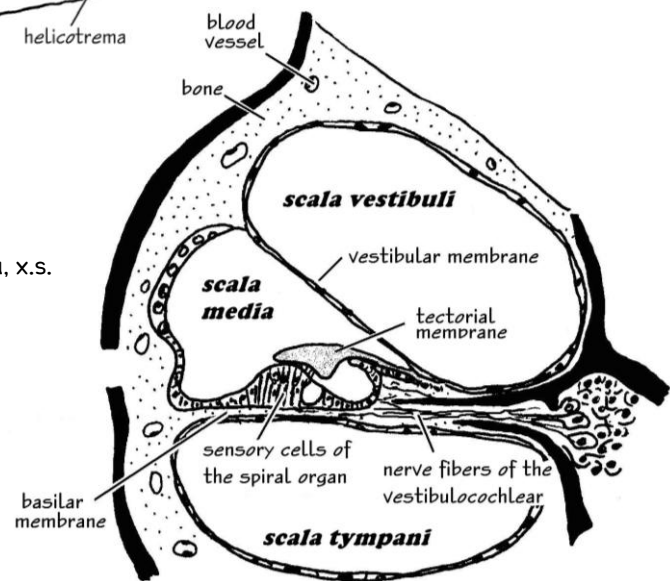
and now for some detail of the cochlea:

- the cochlea is in the form of a spiral carved out of the temporal bone (so that an impression of it would resemble a snail shell!)
- the cochlea is divided internally into three fluid-filled passageways (see Fig. 15.27):
 1. **scala vestibuli** - extends from the oval window to the helicotrema
 2. **scala media** (the **cochlear duct**) - middle passageway; part of the membranous labyrinth
 3. **scala tympani** - extends from the helicotrema to the round window
- **helicotrema** is the point at which the scala vestibuli and scala tympani are continuous with each other
- the **basilar membrane** forms the floor of the cochlear duct
 - what does the basilar membrane support?
- ♥ the **spiral organ** (organ of Corti) is formed by sensory **hair cells**:
 - these sensory hair cells have of stereocilia, which are long **microvilli**
 - the tips of the microvilli are embedded in the **tectorial membrane**, which is a gelatinous shelf that drapes over the spiral organ
 - the bases of the hair cells are associated with the **cochlear branch** of the **vestibulocochlear nerve** (CN VIII) that leads to the brain

uncoiled cochlea:



Cochlea, x.s.



Physiology of Hearing

♥ definitely read the single sprawling sentence that sums up the mechanics of human hearing!

Overview: Properties of Sound

♥ read about **sound**, **frequency**, **wavelength**, and **amplitude** on pages 575 to 576

- what is the frequency range of human hearing?

Read the information on pages 577 and 579

Here is my summary of the pathway of sound waves that leads to hearing:

1. Sound vibrations are collected by the auricle and travel through the external acoustic meatus to the tympanic membrane.
2. The tympanic membrane vibrates.
3. This causes the malleus to vibrate, and the vibrations are transmitted to the incus and then the stapes.
4. The stapes pushes in and out on the oval window, producing waves in the fluid of the scala vestibuli, which are transmitted through the fluid of the cochlear duct to the fluid of the scala tympani.
5. Waves in the fluid distort the basilar membrane and the microvilli of the sensory hair cells become bent against the stationary tectorial membrane.
6. This induces an action potential (impulse) that is carried by the cochlear branch of the vestibulocochlear nerve to the **auditory cortex of the brain**, where the signals are interpreted as sound.

The round window vibrates due to waves in the perilymph and acts as a pressure releasing valve.

Note: Different parts of the basilar membrane are distorted, depending on the pitch of the sound (high vs. low frequency).



Equilibrium and Orientation

- what does the equilibrium sense respond to?
- it depends not only on inputs from the internal ear, but also on what else?
- what specific structures form the **vestibular apparatus**?

- what do the receptors in the vestibule monitor, and this is called our sense of what?



• define **static equilibrium** (☆ *from the glossary in the back of the book*):

- what do the receptors in the semicircular canals monitor, and this is called our sense of what?

• define **dynamic equilibrium** (☆ *from the glossary in the back of the book*):

The Maculae

- the **saccul** and **utricle** are part of the membranous labyrinth located in the vestibule of the bony labyrinth
- the utricle and saccul each have one sensory receptor organ called a **maculae** (*singular is macula*) that monitor the position of the head in space (static equilibrium)
 - these receptors monitor what and play a key role in what?

- they respond to linear acceleration forces, which means what?

Anatomy of a Macula

- each macula contains sensory **hair cells** with stereocilia (long microvilli) that are embedded in a jelly-like membrane called the **otolithic membrane** (see Fig. 15.34)
- the otolithic membrane is studded with tiny crystals of calcium carbonate called what?
- the sensory hair cells are associated with the vestibular branch of vestibulocochlear nerve (CN VIII)

Activating Maculae Receptors

If the head is tipped, otoliths, and therefore the otolithic membrane in which they are embedded, move in response to gravity.

- This causes the microvilli of the sensory hair cells that project into the otolithic membrane to bend, initiating a nerve impulse.
- The nerve impulse is carried to the vestibular region of the brain by the vestibular branch of the vestibulocochlear nerve (CN VIII)
- The brain is informed of the changing position of the head relative to gravity.

· so, the maculae help us to maintain normal head position with respect to gravity; they also contribute to dynamic equilibrium by responding to linear acceleration and deceleration



The Crista Ampullaris

- semicircular ducts are part of the membranous labyrinth and each one is located within a semicircular canal of the bony labyrinth
- what is the **crista ampullaris**?

Anatomy of the Crista Ampullaris

- does the crista ampullaris contain hair cells?
- what is the gel-like mass called?

Activating Crista Ampullaris Receptors

- so, each ampulla of a semicircular canal has an elevation called a **crista ampullaris** with sensory **hair cells** that have stereocilia (long microvilli); the microvilli are embedded in a gelatinous mass called a **cupula**

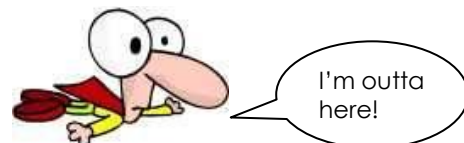
- the sensory hair cells are associated with the vestibular branch of the vestibulocochlear nerve (CN VIII)

As the head begins to rotate in one direction, the movement of the fluid in the semicircular ducts displaces the cupula.

- This bends the microvilli of the hair cells, initiating a nerve impulse.
- The nerve impulse is carried to the vestibular region of the brain by the vestibulocochlear nerve.



THE END



13.

