The Eye and Ear
Outline of class lecture
After studying this chapter you should be able to:
1. List and describe the accessory structures of the eye.
2. Describe the structures and functions of the fibrous tunic.
3. Explain what LASIK stands for and what the procedure entails.
4. Describe the structures and functions of the vascular tunic.
5. Describe the structures and functions of the nervous tunic.
6. Describe the structures of the lens
7. Explain the interior structures of the eye.
8. Describe the structures of the outer, middle ear and inner ear.
9. Explain the mechanism of hearing
10. Describe the structure and functions of the vestibular apparatus and its role in maintaining equilibrium.
11. Discuss the following disorders: Conjunctivitis, sty, chalazion or cyst, strabismus, pterygium.
12. Discuss the Clinical Applications from the study guide and be able to describe the disorders from the Applications to Health located at the end of this chapter.

Specialists in the Field
• Ophthalmology:
  • Ophthalmologist: Physician (M.D.) who specializes in the diagnosis and treatment of eye disorders.
    − Can prescribe drugs, corrective lenses, and perform surgery.
  • Optometrist: Doctor of optometry (O.D.)
    − Examine and diagnose eye diseases - glaucoma, cataracts, and retinal diseases and, in certain states in the U.S., to treat them.
    − Treat visual defects by prescribing corrective lenses
  • Optician: Technician who fits, adjusts, and dispenses corrective lenses prescribed by an ophthalmologist or optometrist.

Accessory Structures of the Eye
• Includes: Eyelids, eyelashes, eyebrows, lacrimal apparatus, and extrinsic eye muscles

Eyelashes and Eyebrows
• Help protect the eyeballs from foreign objects, perspiration, and direct rays of the sun.

Eyelids (palpebre)
• Eyelid functions:
  − Protect the eyes from excessive light and foreign objects
  − Shade the eyes during sleep

• Eyelid components:
  − Palpebral fissure: Space between upper and lower eyelids
  − Tarsal plate: CT that gives form and support to eyelid
  − Meibomian (tarsal) glands: Specialized sebaceous glands imbedded in tarsal plates.
    − Lipid rich secretions keep eyelids from sticking to each other and lubricate the eye
  − Chalazion or cyst:
    − Sty: Results from an infection of sebaceous ciliary glands at the base of eyelash hair follicles.
• **Conjunctiva**: Protective mucous membrane composed of stratified columnar epithelium with numerous goblet cells.
  - **Palpebral conjunctiva**:
  - **Bulbar conjunctiva**: Passes from eyelids to line anterior surface of eyeball up to the cornea where it merges with the stratified squamous epithelium of the cornea.
    - **Blood shot eyes** are due to dilation of blood vessels of the bulbar conjunctiva.
  - **Conjunctivitis (“pink-eye”)**: Inflammation of the conjunctival membrane due to pathogenic infection, allergy, or by physical/chemical irritation.
• **Lacrimal caruncle**: Reddish elevation that contains sebaceous (oil) glands and sudorierous (sweat) glands.
  - Whitish material that sometimes collects at the medial corner of the eyes is from these glands as well as other glands of the eyelids and from debris.

**Lacrimal Apparatus**
• **Lacrimal gland**: Secretes lacrimal fluid (tears) through 6-12 lacrimal ducts that empty onto the surface of the conjunctiva.
  - **Tears**: Contain an anti-bacterial enzyme called lysozyme, water, and a salt mixture.
    - Drain into 2 small openings called **lacrimal puncta**, which lead to the **lacrimal canals**.
• **Lacrimal canals (2/eye)**: Drain into the **lacrimal sac**
• **Nasolacrimal duct**: Drains lacrimal fluid from lacrimal sac into the **nasal cavity** to help moisten the mucous membrane.

**Extraocular Muscles**
• **Six extrinsic skeletal muscles** move each eye
  - **4 recutus muscles**: superior, inferior, lateral, and medial.
  - **2 oblique muscles**: superior and inferior
• (IV): innervates the superior oblique muscle
• (VI): innervates the lateral rectus muscle
• (III): innervates the superior, inferior, and medial rectus muscles, and the inferior oblique muscle

**Disruption of Binocular Vision results in diplopia (double vision)**

**Strabismus**:
• is a misalignment of the visual axes and loss of binocular vision; afflicts 5% of the population
• due to an underacting or overacting eye muscle, abnormal innervation, physical trauma, or a central processing problem
• can result in permanent loss of vision in the “weaker” eye if not corrected during early childhood
• Initial therapy usually includes intermittent patching of the good eye before more invasive procedures such as surgery.
Structures of the Eyeball
Wall of the eye consists of three layers:
1. **Fibrous tunic (outer)**
2. **Vascular tunic (middle)**
3. **Nervous Tunic or Retina (Inner)**

**Fibrous Tunic (outer layer)**
- **Fibrous tunic:** Consists of the sclera and cornea.
- **Sclera:** The “white” of the eye and consists of dense irregular CT
  - Receives insertions of extraocular muscles
  - Functions to support and protect the internal eye parts
  - Continuous with the cornea
- **Cornea:** Transparent, avascular structure that forms the anterior surface of the eyeball.
  - Curved convex surface assists the lens in focusing light.
  - **Limbus:**
    - Contains the **scleral venous sinus** where the aqueous humor drains into.
- **Cornea consist of:**
  - **Corneal epithelium**
  - Stratified squamous nonkeratinized epithelium
  - **Cornea stroma**
    - Thickest corneal layer
    - Parallel collagenous fibers and fibroblasts (Dense regular CT).
  - **Corneal endothelium**
    - Lines the posterior aspect of the cornea
    - Simple squamous epithelium
LASIK
- LASIK (Laser-Assisted In-Situ Keratomileusis): Refractive surgery to correct the curvature of the cornea for conditions such as farsightedness, nearsightedness, and astigmatism.
  - **Procedure:**
    - The underlying cornea is reshaped with a laser
    - Corneal flap is repositioned over the treated area and the flap reattaches to rest of cornea within 24 hours.

Pterygium (tur RIDGE ium)
- A benign thickening of the conjunctiva that grows onto the cornea. Eventually is may cause vision disruption by interfering with the normal smooth surface of the cornea.
  - Most commonly caused by sun exposure.

Vascular Tunic (Middle Layer)
- Consists of three Parts:
  - **Choroid**
    - Lines most of the internal sclera and is highly vascular with dark pigment produced by melanocytes.
      - Blood vessels provide oxygen and nourishment to the retina
      - Black pigment functions to absorb stray light rays
  - **Ciliary Body**
    - The anterior expansion of the choroid and consists of
      - Extends from the oro serrata, the jagged anterior margin of the retina, to a point just posterior to the sclero-corneal junction
  - **Ciliary processes**
    - **Suspensory ligaments** arise form the processes and insert into the lens capsule, functioning to anchor it in place
    - Secretes aqueous humor (plasma filtrate) into the posterior chamber. The aqueous humor passes from the posterior chamber through the pupil into the anterior chamber, where it provides nourishment to the avascular lens and cornea. The fluid is then drained into the scleral venous sinus (canal of Schlemm), which returns it to the venous blood.
• **Glaucoma** is a condition in which there is an over production or an inadequate drainage of aqueous humor that can lead to excessive accumulation of fluid, which results in increased **intraocular pressure**. This may produce damage to the retina and loss of vision.

  - **Ciliary Muscle**
    - Circular band of smooth muscle that alters the shape of the lens, adapting it for near or far vision
    - **Contraction**: Releases tension on the **suspensory ligaments** and thus the lens – the lens becomes more rounded, allowing the eye to focus on nearby objects
      - With advancing age, the lens loses its elasticity thereby gradually losing the ability to accommodate and person cannot focus on small close objects – referred to as **presbyopia**
    - **Relaxation**: Increases tension on the **suspensory ligaments** and thus the lens – the lens flattens, allowing the eye to focus on far away objects

• **Iris**
  - The colored portion of the eye that lies anterior to the **ciliary body** and separates the anterior and posterior chambers.
    - **Anterior chamber**: Space between the cornea and iris
    - **Posterior chamber**: Space between the iris and lens
  - Regulates the amount of light entering the eyeball by contraction/relaxation of smooth muscle that surrounds the pupil.
    - **Pupil**:

**Nervous Tunic or Retina (inner layer)**

• **Nervous tunic** or **retina** contains two portions:

  - **Pigment Epithelium**
    - Sheet of melanin-containing epithelial cells that lies between the choroid and the neural portion of the retina.
    - **Function**: Synthesize melanin, which absorbs stray light after the rods and cones have been stimulated.
      - Albinos often need to wear sunglasses because bright light isn’t absorbed by this layer and the choroid and can cause a glare due to light scattering.
  - **Neural layer (photoreceptive layer)**
    - Functions to process visual data and transmits nerve impulses to the primary visual cortex of the brain.

• **Contains three layers of retinal neurons:**
  1. **Photoreceptor layer**: Contains neurons (rods and cones) that are sensitive to light.
    - **Rods** (120 million/retina): Specialized for vision in dim light, such as moonlight
      - **Cones** (6 million/retina): Specialized for color vision and sharpness of vision - stimulated in brighter light
      - **Fovea centralis** is a small depression within the **macula lutea** and contains the densest concentration of cones.
    - **Rods** and **cones** contain **photopigments** that absorb light and begin the process of nerve impulse generation.
2. Bipolar cell layer

3. Ganglion cell layer
   - Ganglion cell axons extend posteriorly to the **optic disc (blind spot)** and exit the eyeball as the **optic nerve**.
   - Transmit signals of vision to the midbrain and thalamus and then to the visual cortex.
   - **Optic disk (blind spot):** Region where the axons of ganglion neurons exit the eyeball as the **optic nerve**
     - Area contains no rods or cones; thus we cannot see an image that strikes this region and hence the name.

Lens

- **Lens:** Lies posterior to the iris and pupil and helps focus images on the retina for clear vision.
  - Held in position by **zonular fibers (suspensory ligaments)** that are attached to lens capsule.
- **Lens consists of:**
  - Proteins called **crystallins**, arranged like the layers of an onion; is perfectly transparent and lacks blood vessels.
  - **Lens capsule**

Interior of the Eye

- The lens divides the interior of eye into two cavities – the **Anterior Cavity** and **Posterior Cavity** (vitreous chamber)
- **Anterior Cavity** – anterior to the lens
  - Two portions:
    - **Anterior chamber:**
    - **Posterior chamber:** Between the iris and lens
  - **Aqueous humor:**
    - Continually secreted by **ciliary processes** into the posterior chamber, then flows to the anterior chamber and is drained by the **scleral venous sinus (Canal of Schlemm)**
    - Is the vascular link to the cornea and lens – helps to nourish the avascular lens and cornea.
• Posterior Cavity (Vitreous Chamber) – Between the lens and retina.
  • Vitreous body (humor)
    • Jelly-like substance composed of mainly of water, collagen, and hyaluronic acid
    • Formed during embryonic development and is not replaced thereafter – or cold possible be replaced at a very slow rate.
  • Function: Contributes to **intraocular pressure**, helps to prevent the eyeball from collapsing, and holds the retina flush against the internal portions of the eyeball.

**Anatomy of the Ear**
• Ear is divided into 3 Regions:
  1. **External Ear**
  2. **Middle Ear**
  3. **Internal Ear**

**External Ear consists of:**
• **Auricle (pinna)**
  • Flap of elastic cartilage covered by skin that collects and channels sound into the external auditory canal
  • **Helix:**
  • **Lobule:**

• **External auditory canal (meatus)**
  • Tube (1") that lies in the temporal bone and runs from the auricle to the eardrum
  • Line by skin containing course hairs and specialized sebaceous glands called **ceruminous glands** that produce earwax (**cerumen**)?
    • Hairs and **cerumen** help prevent dust and foreign objects from entering the ear and slows the growth of microorganisms.
• **Tympanic Membrane (eardrum)**
  – Thin, semitransparent partition between the external and middle ear
  – Consists of dense irregular CT; covered by skin on its external surface and a simple cuboidal mucous membrane on its inner surface
  – **Perforated eardrum** describes a tear in the tympanic membrane
  – Transmits sound vibrations that enter the ear to the **auditory ossicles** in the middle ear.

**Middle Ear consists of:**

• **Tympanic Cavity**
  – Small air filled cavity hollowed out of the temporal bone that houses the **auditory ossicles**
  – Connected to the **nasaopharynx** via the **auditory tube (Eustachian tube or pharyngotympanic tube)**
  • Functions to equalize air pressure within the tympanic cavity with that of atmospheric pressure so eardrum may vibrate freely.

• **Auditory Ossicles**
  – Bones that are named for their shape:
    • **Malleus** = hammer; attached to internal surface of eardrum
    • **Incus** = anvil; intermediate bone
    • **Stapes** = stirrup;
  – Vibrations of **tympanum** convert arriving sound waves into mechanical movements that are transmitted via the **auditory ossicles** to the **oval window**.
    • Because tympanum is 22 times larger and heavier than the oval window, a 1 µm movement of the tympanum produces a 22 µm deflection of the oval window
    • Amplification allows us to hear very faint sounds, but can be a problem with loud noises.
  – **Articulations** of ossicles are by way of **synovial joints** and the bones are attached to the surrounding temporal bone by ligaments.
    • **Tensor tympani muscle** (attached to malleus) and **stapedium muscle** (attached to stapes) are skeletal muscles that protect the inner ear against prolonged loud noise, but not brief ones such as a gunshot.
  – **Oval and round window**.
    • **Oval window**: Membrane-covered opening between the middle and inner ear.
    • **Round window**: Opening directly below the oval window

**Inner Ear**

• **Inner ear** provides the senses of **hearing** and **equilibrium** and consists of a number of chambers and canals in the temporal bone that can be divided into two main divisions: the **bony and membranous labyrinth**.

• **Bony Labyrinth**
  – Series of cavities within the temporal bone that is lined with periosteum and contains a fluid called **perilymph** (similar to **cerebrospinal fluid**) that surrounds the **membranous labyrinth** which contains a fluid called **endolymph**.

• **Membranous Labyrinth**
  – Lies within the bony labyrinth and contains the fluid endolymph.
• The **Bony and Membranous Labyrinth** are divided into 3 areas:

  - **Semicircular canals**: Contain receptors for movement (dynamic equilibrium).
    - Each canal lies at approximately right angles to the other two.
    - **Ampulla** is a swollen enlargement at one end of each canal and contains the **cristae ampullares**
      - **Cristae ampullares** is a sensory structure that detects angular acceleration of the head along any to the 3 axes.
  
  - **Vestibule**: Houses two interconnected sacs of the **membraneous labyrinth** called the **saccule** and **utricle** which contain receptors for position (**static equilibrium**) and linear acceleration (**dynamic equilibrium**).
    - Vestibular branch of the **vestibulocochlear (VIII) nerve** (**auditory nerve**) consists of:

  - **Cochlea**: Bony spiral canal that contains the receptors for hearing.

**Structures of the Cochlea**

- Is subdivided into **three channels** that spiral around a central bony core called the **modiolus**.
- The partitions that separate the 3 channels are shaped like the letter **Y**
  - **Osseous spiral lamina**: A shelf of bone that extends from the modiolus to the basilar membrane – forms the stem of the **Y**.
    - Branches of the **cochlear nerve (VIII)** travel along the **spiral lamina**.
  
  - **Cochlear duct (Scala media)**: Lies between the wings of the **Y** and is composed of the membraneous labyrinth
    - Contains **endolymph** and **organ of Corti** (**Spiral organ**)
    - Lies between the **basilar** and **vestibular membrane**
    - **Cochlear duct** is separated from the **scala vestibuli** by the **vestibular membrane** and from the **scala tympani** by the **basilar membrane**.

- **Scala vestibuli**: Channel above the cochlear duct which begins at the oval window and contains **perilymph**.
- **Scala tympani**: Channel below the cochlear duct that ends as the round window and contains **perilymph**.
  - The scala tympani and scala vestibuli communicate via the **helicotrema** at the apex of the cochlea.
Organ of Corti (Spiral Organ)

- **Organ of Corti**: The organ of hearing and lies on the basilar membrane
- Contains ~16,000 hair cells (receptors of hearing) that possess long stiff stereocilia (modified microvilli) on their free surface.
  - Hair cells function to convert a mechanical vibration (stimulus) into an electrical signal (nerve impulse).
  - Most stereocilia are in contact with the tectoral membrane.
  - Hair cells arranged in a series of longitudinal rows and contain two groups:
    - Inner hair cells
    - Outer hair cells

Mechanism of Hearing

1. The auricle directs sound waves into the external auditory canal
   - Sound waves travel at a rate of 768 mph.
2. Sound waves strike the tympanic membrane and cause it to vibrate at the same frequency as the incoming sound waves.
   - Eardrum vibrates slowly in response to low-frequency (low-pitched) sounds and rapidly in response to high-frequency (high-pitched) sounds.
3. The central area of the eardrum connects to the malleus. The eardrum’s vibrations are transmitted from the malleus to the incus and then to the stapes.

4. The stapes vibrates against the membrane of the oval window
   - Because tympanum is 22 times larger and heavier than the oval window, a 1 µm movement of the tympanum produces a 22 µm deflection of the oval window
     - Amplification allows us to hear very faint sounds, but can be a problem with loud noises.

5. Movement of the oval window sets up fluid pressure waves in the perilymph of the cochlea.
   - As the oval window bulges inward, it pushes on the perilymph of the scala vestibuli; these pressure waves are transmitted to the scala tympani and eventually to the round window, causing it to bulge outward into the middle ear.

6. The pressure waves cause the vestibular membrane to vibrate which in turn initiates fluid pressure waves in the endolymph of the cochlear duct.

7. The pressure waves in the endolymph cause the basilar membrane to vibrate and as a result, the hair cells or the organ of Corti move against the tectorial membrane.
   - Bending of the stereocilia is transduced into electrical impulses that travel via the cochlear nerve to the medulla oblongata and then branches go to the inferior colliculi and the thalamus
   - From the thalamus, auditory signals project to the auditory area of the temporal lobe of the cerebral cortex for auditory processing.

8. The hair cells of the organ of Corti are arranged in rows; a very soft sound may stimulate only a few hair cells in a portion of one row.
   - As the volume of a sound increases, additional hair cells are stimulated as the vibrations of the basilar membrane increase.

9. Areas of the basilar membrane vibrate at different frequencies.
   - Sound waves of high frequency are detected closer to the oval window whereas low frequency sounds have optimal vibration (resonance) further away from the oval window.

Vestibular Apparatus and Equilibrium
- Vestibular Apparatus: Provides information concerning equilibrium, which is the body’s orientation with respect to gravity and helps us stay erect when standing, know where we are in relation to gravity, and help us walk, run, and move without falling.
- Vestibular apparatus consist of two parts:
  - Vestibule:
    - Semicircular canals: Arranged as anterior, posterior and lateral canals

Types of Equilibrium
- There are two types of equilibrium: Static and Dynamic
  - Static equilibrium: Refers to maintenance of the position of the body (mainly the head) relative to the force of gravity.
    - The vestibule (utricle and saccule):
  - Dynamic equilibrium: Refers to maintenance of body positions (mainly the head) in response to sudden movements such as rotation, acceleration, and deceleration.
    - The vestibule (utricle and saccule) provides information about linear acceleration – changes in velocity when traveling horizontally or vertically.
      - We therefore have a sense of acceleration and deceleration when riding in a car, elevator, or when skipping rope.
- The semicircular canals:
  - Helps a person maintain balance when turning the head, spinning, or tumbling.

**Structures of the Vestibule: Saccule and Utricle**
- The utricle and saccule each contain a macula
  - Each macula are
    - **Macula**: Are receptors to detect the position of the head in space (for static equilibrium) and detect linear acceleration and deceleration (for dynamic equilibrium)
      - Role in static equilibrium is to maintain appropriate posture and balance.
    - **Macular consists of**:
      - **Hair cells**: Neuroepithelial cells innervated by the vestibular branch of the vestibulochchlear nerve (VIII).
        - Have numerous (70 or more) stereocilia (microvilli) and one kinocilium (normal cilium), that extends beyond the stereocilia.
      - **Supporting cells**: Support the hair cells and innervating nerves and secret the otolithic membrane.
      - **Otolithic membrane**: Gelatinous glycoprotein layer that surrounds and floats directly over the hair cells.
        - Contains small calcium carbonate crystals called otoliths (ear stones) that increase the mass of the membrane, which results in a higher inertial (resistance to change in movement)
How the Vestibule Works to Maintain Equilibrium

- Gravity, linear acceleration, or linear deceleration pulls the otolithic membrane resulting in bending of the stereocilia.
- If you tilt your head in any direction, the **otolithic membrane** is pulled by gravity in the direction of the tilt and slides over the hair cells and bends the hairs, which stimulates them.
- Similarly, if you are sitting upright in a car that suddenly accelerates forward, the **otolithic membrane**, due to its inertia, slides backward and stimulates the hair cells by bending them.
- The bending of the stereocilia of the hair cells leads to the generation of nerve impulses that are transmitted to the brain via the vestibular branch of the **vestibulocochlear (VIII) nerve**.

Structures of the Semicircular Canals

- The semicircular canals function in dynamic equilibrium.
  - The canals lie at right angles to one another in three planes which permits detection of rotational acceleration or deceleration.
- The **ampulla** contains sensory receptors known as the **crista ampullaris**.
- The crista ampullaris is the receptor for movement (dynamic equilibrium) and made up of a **crista** and a **cupula**
  - **Crista:**
  - **Cupula:** Gelatinous glycoprotein mass that covers the hair cells of the crista.
  - The cupula has a higher density than that of the surrounding endolymph and essentially rests above the receptor surface.

How the Semicircular Canals Work to Maintain Equilibrium

- When the head moves, the attached **semicircular canals** and **hair cells** move with it. The **endolymph**, however, is not attached and lags behind due to its inertia. As the moving hair cells drag along the stationary fluid, the hairs bend.
- Bending of the **stereocilia** is transduced into nerve impulses that are transmitted to the brain via the vestibular branch of the **vestibulocochlear nerve**.
  - When the endolymph stops moving, the elastic nature of the cupula allows it to return to its normal position.