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Learning Outcomes

At the end of this chapter, students will be able to:
1. Describe the various parts and functions of the eye.
2. Outline the neural pathways that transmit visual information from the rods and cones to the visual cortex.
3. Define hyperopia, myopia, astigmatism, presbyopia, and strabismus.
4. Describe the mechanism and effects of electrical responses produced by rods and cones.
5. Describe the responses of cells in the visual cortex and the functional organization of the dorsal and ventral pathways to the parietal cortex.
6. Define and explain dark adaptation and visual acuity.
7. Describe the components and functions of the external, middle, and inner ear.
8. Outline the path of auditory impulses in the neural pathways from the cochlear hair cells to the auditory cortex, and discuss the function of the auditory cortex.
9. Describe the various forms of deafness.
10. Describe the basic features of the neural elements in the olfactory epithelium and olfactory bulb.
11. Outline the pathways by which impulses generated in taste receptors reach the insular cortex.
Conscious awareness of incoming sensory information is called sensation.

Stimulus that reaches the cerebral cortex of the brain results in a sensation of that stimulus.

We are consciously aware of only a fraction of stimuli.

Stimuli are detected by receptors.

Two classes of receptors:

- general senses (temperature, pain, touch, stretch, and pressure)
- special senses (gustation, olfaction, vision, equilibrium, and audition)
Receptors

- Range in complexity from the single-celled, relatively simple dendritic ending of a neuron to complex sense organs.
- Monitor both external and internal environmental conditions and conduct information about those stimuli to the central nervous system.
- Make us aware of a specific stimulus.
Functional Categories of Sensory Receptors

- Grouped according to type of stimulus energy they transduce.
  - Chemoreceptors:
    - Chemical stimuli in environment or blood (pH, CO₂).
  - Photoreceptors:
    - Rods and cones.
  - Thermoreceptors:
    - Temperature.
  - Mechanoreceptors:
    - Touch and pressure.
  - Nociceptors:
    - Pain.
  - Proprioceptors:
    - Body position.

- Categorized according to type of sensory information delivered to brain:
  - Cutaneous receptors:
    - Touch, pressure, temperature, pain.
  - Special senses:
    - Sight, hearing, equilibrium.
Tonic vs. Phasic Receptors

- Sensory receptors may act
  - continuously (tonic receptors) or
  - merely detect changes in a stimulus (phasic receptors)
Sensory Adaptation

- **Tonic receptors:**
  - Produce constant rate of firing as long as stimulus is applied.
  - Pain.

- **Phasic receptors:**
  - Burst of activity but quickly reduce firing rate (adapt) if stimulus maintained.

- **Sensory adaptation:**
  - Cease to pay attention to constant stimuli.
Law of Specific Nerve Energies

- Sensation characteristic of each sensory neuron is that produced by its normal or adequate stimulus.
- Adequate stimulus:
  - Requires least amount of energy to activate a receptor.
- Regardless of how a sensory neuron is stimulated, only one sensory modality will be perceived.
  - Allows brain to perceive the stimulus accurately under normal conditions.
Sensory Receptors and Adaptation

- Tonic receptors are involved in maintaining our balance to keep our head upright.
- Phasic receptors signal the increased pressure on our skin if we are pinched.
- Phasic receptors can undergo a change called **adaptation**, which is a **reduction in sensitivity** to a continually applied stimulus.
Generator Potentials

- In response to stimulus, sensory nerve endings produce a local graded change in membrane potential.
- Potential changes are called receptor or generator potential.
  - Analogous to EPSPs.

Phasic response:
- Generator potential increases with increased stimulus, then as stimulus continues, generator potential size diminishes.

Tonic response:
- Generator potential proportional to intensity of stimulus.
Classification of Receptors

- **General sense** receptors are distributed throughout the skin and organs.
- **Special sense** receptors are housed within complex organs in the head.
- **Three criteria** used to describe receptors:
  - stimulus origin
  - receptor distribution
  - modality of stimulus
- Based on **stimulus location** there are **three types** of receptors:
  - exteroceptors
  - interoceptors
  - proprioceptors
Exteroceptors

- Detect stimuli from the external environment.
- Special senses are considered exteroceptors because they usually interpret external stimuli.
- Also found in the mucous membranes that open to the outside of the body, such as the nasal cavity, oral cavity, vagina, and anal canal.
Interoceptors

- Also called visceroreceptors.
  - detect stimuli in internal organs (viscera)
- Are primarily stretch receptors in the smooth muscle of these organs.
- Most of the time we are unaware of these receptors but when the smooth muscle stretches to a certain point we may become aware of these sensations.
- Also report on pressure, chemical changes in the visceral tissue, and temperature.
Proprioceptors

- Located in muscles, tendons, and joints.
- Detect body and limb movements, skeletal muscle contraction and stretch, and changes in joint capsule structure.
- Awareness of their position and the state of contraction of your skeletal muscles sent to the CNS.
Receptor Distribution (Body Location)

- **General senses**
  - structurally simple
    - somatic
    - chemicals
    - temperature
    - pain
    - touch
    - proprioception
    - pressure
    - visceral
    - chemicals
    - temperature
    - pressure
Receptor Distribution (Body Location)

- Special senses
  - structurally complex
  - located only in the head
    - gustation
    - olfaction
    - vision
    - equilibrium
    - hearing
Modality of Stimulus (Stimulating Agent)

- Chemoreceptors
- Thermoreceptors
- Photoreceptors
- Mechanoreceptors
- Baroreceptors
- Nociceptors
Cutaneous Sensations

- Mediated by dendritic nerve endings of different sensory neurons.
- Free nerve endings:
  - Temperature: heat and cold.
    - Receptors for cold located in upper region of dermis.
    - Receptors for warm located deeper in dermis.
    - More receptors respond to cold than warm.
      - Hot temperature produces sensation of pain through a capsaicin receptor.
        » Ion channels for Ca\(^{2+}\) and Na\(^{+}\) to diffuse into the neuron.
Cutaneous Sensations (continued)

- Nociceptors (pain):
  - Use substance P or glutamate as NT.
  - $\text{Ca}^{2+}$ and $\text{Na}^+$ enter through channel, depolarizing the cell.

- Encapsulated nerve endings:
  - Touch and pressure.
  - Receptors adapt quickly.

- Ruffini endings and Merkel’s discs:
  - Sensation of touch.
  - Slow adapting.
Receptive Fields

• Area of skin whose stimulation results in changes in the firing rate of the neuron.
  – Area of each receptor field varies inversely with the density of receptors in the region.

• Back and legs have few sensory endings.
  – Receptive field is large.

• Fingertips have large # of cutaneous receptors.
  – Receptive field is small.
Tactile Receptors

- Most numerous type of receptor.
- Mechanoreceptors that react to touch, pressure, and vibration stimuli.
- Located in the dermis and the subcutaneous tissue.
- Exhibit varying degrees of intricacy.
  - simple, dendritic ends that have no connective tissue wrapping
  - complex structures that are wrapped with connective tissue or glial cells
Tactile Receptors

- **Unencapsulated**
  - free nerve endings
  - root hair plexuses
  - tactile discs

- **Encapsulated**
  - Krause bulbs
  - lamellated corpuscles
  - Ruffini corpuscles
  - tactile corpuscles

- Krause bulbs are
  - located primarily in the mucous membranes of the oral cavity, nasal cavity, vagina, and anal canal
  - detect light pressure stimuli
Two-Point Touch Threshold

- Minimum distance at which 2 points of touch can be perceived as separate.
  - Measures of distance between receptive fields.
- Indication of tactile acuity.
  - If distance between 2 points is less than minimum distance, only 1 point will be felt.
Neural Pathways for Somatesthetic Sensations

- Sensory information from proprioceptors and cutaneous receptors are carried by large, myelinated nerve fibers.
  - Synapse in medulla.
- 2\textsuperscript{nd} order neuron ascends medial lemniscus to thalamus.
- Synapses with 3\textsuperscript{rd} order neurons, which project to sensory cortex.
  - Lateral spinothalamic tract:
    - Heat, cold, and pain.
  - Anterior spinothalamic tract:
    - Touch and pressure.
Gustation – Sense of Taste

- Gustatory receptors are housed in specialized taste buds on the surface of the tongue.
- Dorsal surface of the tongue
- 4 types of papillae:
  - filiform
  - fungiform
  - vallate
  - foliate
4 Types of Papillae

- Filiform
  - distributed on the anterior two-thirds of the tongue surface
  - do not house taste buds and have no sensory role in gustation
- Fungiform papillae
  - primarily located on the tip and sides of the tongue
  - contain only a few taste buds each
- Vallate (circumvallate) papillae are the
  - least numerous yet the largest
  - arranged in an inverted V shape on the posterior dorsal surface of the tongue
  - each is surrounded by a deep, narrow depression
  - most of our taste buds are housed within the walls of these
- Foliate
  - not well developed on the human tongue
  - extend as ridges on the posterior lateral sides
  - house only a few taste buds during infancy and early childhood
Taste

- **Gustation:**
  - Sensation of taste.
- **Epithelial cell receptors clustered in barrel-shaped taste buds.**
  - Each taste bud consists of 50-100 specialized epithelial cells.
- **Taste cells are not neurons, but depolarize upon stimulation and if reach threshold, release NT that stimulate sensory neurons.**
Taste (continued)

- Each taste bud contains taste cells responsive to each of the different taste categories.
- A given sensory neuron may be stimulated by more than 1 taste cell in # of different taste buds.
- One sensory fiber may not transmit information specific for only 1 category of taste.
- Brain interprets the pattern of stimulation with the sense of smell; so that we perceive the complex tastes.
Taste Receptor Distribution

- **Salty:**
  - $\text{Na}^+$ passes through channels, activates specific receptor cells, depolarizing the cells, and releasing NT.
  - Anions associated with $\text{Na}^+$ modify perceived saltiness.

- **Sour:**
  - Presence of $\text{H}^+$ passes through the channel.
• Sweet and bitter:
  – Mediated by receptors coupled to G-protein (gustducin).
Gustatory Pathway from Taste

Figure 16.2
Gustatory Discrimination

- The tongue detects five basic taste sensations:
  - salty
  - sweet
  - sour
  - bitter
  - umami
- Types of taste
  - Sweet
  - Sour
  - Salty
  - Bitter
  - Glutamate (MSG)

- Gustatory (taste) pathway to brainstem & cerebral cortex via two cranial nerves:
  - VII (Facial n.) – anterior 2/3 of tongue
  - IX (Glossopharyngeal n.) – posterior 1/3 tongue and pharynx
Olfaction – Sense of Smell

- **Olfactory nerves**
  - (also called olfactory receptor cells) to detect odors
- **Supporting cells**
  - sandwich the olfactory nerves and sustain and maintain the receptors
- **Basal cells**
  - function as stem cells to replace olfactory epithelium components
- **Olfactory system can recognize as many as 50–60 different primary odors as well as many thousands of other chemical stimuli.**
Smell (Olfaction)

- Receptors are part of the olfactory epithelium
- Olfactory epithelium composed of:
  - Cell bodies of olfactory receptor cells
  - Supporting cells – columnar cells
  - Basal cells – form new olfactory receptor cells
Smell (Olfaction)

- Axons of olfactory epithelium
  - Gather into bundles – filaments of the olfactory nerve
  - Pass through the cribriform plate of the ethmoid bone
  - Attach to the olfactory bulbs
Smell (olfaction)

- Olfactory apparatus consists of receptor cells, supporting cells and basal (stem) cells.
  - Basal cells generate new receptor cells every 1-2 months.
  - Supporting cells contain enzymes that oxidize hydrophobic volatile odorants.
- Bipolar sensory neurons located within olfactory epithelium are pseudostratified.
  - Axon projects directly up into olfactory bulb of cerebrum.
    - Olfactory bulb projects to olfactory cortex, hippocampus, and amygdaloid nuclei.
      - Synapses with 2nd order neuron.
    - Dendrite projects into nasal cavity where it terminates in cilia.
- Neuronal glomerulus receives input from 1 type of olfactory receptor.
The Sense of Vision

- **Visual receptors** (photoreceptors) in the eyes to detect light, color, and movement.
- **Accessory structures** of the eye.
  - provide a superficial **covering** over its anterior exposed surface (conjunctiva)
  - prevent **foreign objects** from coming into contact with the eye (eyebrows, eyelashes, and eyelids)
  - keep the exposed surface **moist, clean, and lubricated** (lacrimal glands)
Smell (continued)

- Odorant molecules bind to receptors and act through G-proteins to increase cAMP.
  - Open membrane channels, and cause generator potential; which stimulate the production of APs.
  - Up to 50 G-proteins may be associated with a single receptor protein.
  - Dissociation of these G-proteins releases may G-subunits.
    - Amplify response.
Figure 16.3a, b

Olfactory Receptors

(a) Nasal conchae
(b) Olfactory epithelium, Frontal lobe of cerebrum, Olfactory tract, Olfactory bulb, Inhaled air, Mitral cell, Glomeruli, Cribiform plate of ethmoid bone, Filaments of olfactory nerve, Lamina propria connective tissue, Axon, Basal cell, Olfactory receptor cell, Supporting cell, Dendrite, Olfactory cilia, Mucus, Route of inhaled air containing odor molecules.
Nerve pathways of olfaction

- Left olfactory bulb (termination of olfactory nerve)
- Olfactory tract (to olfactory cortex of cerebrum)
- Olfactory NERVE (N I)
- Cribriform plate of ethmoid
- Olfactory epithelium

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- **Olfactory bulb** is in forebrain
- In bulb nerve axons branch and synapse with mitral cells (neurons in clusters of "glomeruli")
- Mitral cells send signals via *olfactory tract*
- 1000 types of smell receptors (approx.)
- Convergence of many receptor cell signals onto one glomerulus registers a signature pattern
- Brain recognizes the pattern: sent to unclus (olfactory center) and limbic area

**Anosmia**: absence of the sense of smell
- Trauma
- Colds or allergies producing excessive mucus
- Polyps causing blockage
- 1/3 are from zinc deficiency
The Eye and Vision

• Visual organ – the eye
• 70% of all sensory receptors are in the eyes
• 40% of the cerebral cortex is involved in processing visual information
The Sense of Vision

- **Visual receptors** (photoreceptors) in the eyes to detect light, color, and movement.
- **Accessory structures** of the eye.
  - provide a superficial **covering** over its anterior exposed surface (conjunctiva)
  - prevent **foreign objects** from coming into contact with the eye (eyebrows, eyelashes, and eyelids)
  - keep the exposed surface **moist, clean, and lubricated** (lacrimal glands)
• Eyelid **tarsal plates** give structure
  – Where **orbicularis oculi** muscles attach (close eyes)
• **Levator palpebrae superioris** muscle
  – Lifts upper lid voluntarily (inserts on tarsal plate)
The Fibrous Tunic

• Most external layer of the eyeball
  – Composed of two regions of connective tissue
    • Sclera – posterior five-sixths of the tunic
      – White, opaque region
      – Provides shape and an anchor for eye muscles
    • Cornea – anterior one-sixth of the fibrous tunic
    • Limbus – junction between sclera and cornea
    • Scleral venous sinus – allows aqueous humor to drain
1. Tears are produced in the lacrimal gland.
2. Tears disperse across eye surface.
3. Fluid enters the lacrimal canaliculi and collects in the lacrimal sac.
4. Fluid from the lacrimal sac drains through the nasolacrimal duct.
5. Fluid enters the nasal cavity.
Extraocular (extrinsic) eye muscles: 6 in #

“EOMs intact” means they all work right

• Four are *rectus* muscles (straight)
  – Originate from common tendinous or anular ring, at posterior point of orbit

• Two are oblique: *superior and inferior*
Extraocular (extrinsic) eye muscles

Cranial nerve innervations:

- Lateral rectus: VI (Abducens n.) – abducts eye outward
- Medial, superior, inferior rectus & inf oblique: III (Oculomotor n.) – able to look up and in if all work
- Superior oblique: IV (Trochlear n.) – moves eye down and out
Innervation
Medial View of the Eye

Figure 16.7a
• Eyelid **tarsal plates** give structure
  – Where **orbicularis oculi** muscles attach (close eyes)
• **Levator palpebrae superioris** muscle
  – Lifts upper lid voluntarily (inserts on tarsal plate)
Posterior View of the Anterior Half of the Eye
The Vascular Tunic

• Ciliary body – thickened ring of tissue – encircles the lens
• Composed of ciliary muscle
  – Ciliary processes – posterior surface of the ciliary body
  – Ciliary zonule (suspensory ligament)
    • Attached around entire circumference of the lens
The Vascular Tunic

• The middle coat of the eyeball
• Composed of choroid, ciliary body, and iris
• Choroid – vascular, darkly pigmented membrane
  – Forms posterior five-sixths of the vascular tunic
  – Brown color – from melanocytes
  – Prevents scattering of light rays within the eye
• Choroid corresponds to the arachnoid and pia mater
The Vascular Tunic

Figure 16.8
The Iris

- Visible colored part of the eye
- Attached to the ciliary body
- Composed of smooth muscle
- Pupil – the round, central opening
  - Sphincter pupillae muscle (constrictor or circular)
  - Dilator pupillae muscle (dilator or radial)
- Act to vary the size of the pupil
Fibrous tunic
- Sclera
- Cornea

Vascular tunic
- Iris
- Ciliary body
- Choroid

Neural tunic
- Retina
Optic Disc

- Optic disc lacks photoreceptors.
- Called the blind spot because no image forms there.
- Just lateral to the optic disc is a rounded, yellowish region of the retina called the macula lutea containing a pit called the fovea centralis (the area of sharpest vision).
  - contains the highest proportion of cones and almost no rods
The Sensory Tunic (Retina)

• Retina – the deepest tunic
• Composed of two layers
  – Pigmented layer – single layer of melanocytes
  – 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
  – Cone cells – operate best in bright light
    • Enable high-acuity, color vision

• Considered neurons
Photoreceptors

Figure 16.11
Regional Specializations of the Retina

- Macula lutea – contains mostly cones
- Fovea centralis – contains only cones
  - Region of highest visual acuity
- Optic disc – blind spot
Retina through ophthalmoscope

- Macula: at posterior pole
- Fovea: maximal visual acuity (most concentrated cones)
- Optic disc: optic nerve exits
- Vessels
Blood Supply of the Retina

- Retina receives blood from two sources
  - Outer third of the retina – supplied by capillaries in the choroid
  - Inner two-thirds of the retina – supplied by central artery and vein of the retina
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
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 the lens and cornea
Internal Chambers and Fluids

Figure 16.8
The Lens
A thick, transparent, biconvex disc
Held in place by its ciliary zonule
Lens Epithelium

capsule
epithelium
fibers
Optic Disc

- Optic disc lacks photoreceptors.
- Called the blind spot because no image forms there.
- Just lateral to the optic disc is a rounded, yellowish region of the retina called the macula lutea containing a pit called the fovea centralis (the area of sharpest vision).
  - contains the highest proportion of cones and almost no rods
Cavities and Chambers of the Eye

- The internal space of the eye is subdivided by the lens into **two separate cavities**.
  - anterior cavity
  - posterior cavity
- The anterior cavity is
  - the space anterior to the lens and posterior to the cornea
- The iris of the eye subdivides the anterior cavity further into **two chambers**.
  - anterior chamber is between the iris and cornea
  - posterior chamber is between the lens and the iris
(a) Lens shape for distant vision

- Ciliary muscles relaxed
- Lens flattened
- Suspensory ligaments taut

(b) Lens shape for near vision (accommodation)

- Ciliary muscles contract, moving ciliary body toward lens
- Lens thickened, more spherical
- Suspensory ligaments relaxed
Aqueous Humor

- The anterior cavity contains aqueous humor.
  - removes waste products and helps maintain the chemical environment within the anterior and posterior chambers of the eye
  - secreted into the posterior chamber
  - then it flows through the posterior chamber
  - around lens
  - down through the pupil
  - into the anterior chamber
Vitreous Humor

- Posterior cavity is posterior to the lens and anterior to the retina.
- **Transparent, gelatinous vitreous body** which completely fills the space between the lens and the retina.
The eye is an optical device: predominantly the lens

(to a lesser degree, not shown here, the cornea also)

Note: images are upside down and reversed from left to right, like a camera

a. Resting eye set for distance vision: parallel light focused on retina
b. Resting eye doesn’t see near objects because divergent rays are focused behind retina
c. Lens accommodates (becomes rounder) so as to bend divergent rays more sharply, thereby allowing convergence on the retina
Visual Pathways

- Each optic nerve conducts visual stimulus information.
- At the optic chiasm, some axons from the optic nerve decussate.
- The optic tract on each side then contains axons from both eyes.
- Visual stimulus information is processed by the thalamus and then interpreted by visual association areas in the cerebrum.
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
Visual Pathways

- Most visual information travels to the cerebral cortex
- Responsible for conscious “seeing”
- Other pathways travel to nuclei in the midbrain and diencephalon
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
Visual Pathways to the Cerebral Cortex

- Optic tracts send axons to:
  - Lateral geniculate nucleus of the thalamus
    - Synapse with thalamic neurons
    - Fibers of the optic radiation reach the primary visual cortex
Visual Pathways to the Brain and Visual Fields

Figure 16.15a
Green is area seen by both eyes, and is the area of stereoscopic vision.

**Visual pathways**

At optic chiasm, medial fibers from each eye (which view lateral fields of vision) cross to opposite side. Optic tracts (of crossed and uncrossed, sensing opposite side of visual field of both eyes) synapse with neurons in lateral geniculate of thalamus. These axons form the optic radiation and terminate in the primary visual cortex in the occipital lobe. Left half of visual field perceived by right cerebral cortex, and vice versa.
Visual field defects
print this out and follow from the fields to the visual cortex using 4 colors
remember: fields are reversed and upside down

1. Optic nerve
   *ipsilateral (same side) blind eye*

2. Chiasmatic (pituitary tumors classically)
   *lateral half of both eyes gone*

3. Optic tract
   *opposite half of visual field gone*

4. & 5. Distal to geniculate ganglion of thalamus:
   *homonymous superior field (4) or homonymous inferior field (5) defect*
Visual Pathways to Other Parts of the Brain

- Some axons from the optic tracts
  - Branch to midbrain
    - Superior colliculi
    - Pretectal nuclei
- Other branches from the optic tracts
  - Branch to the suprachiasmatic nucleus
Normal Ophthalmoscopic View of Eye
Retina
Photoreceptors and neurons in the retina process the stimulus from incoming light.

Optic nerve
Axons of retinal ganglion cells form optic nerves and exit the eye.

Optic chiasm
Optic nerves cross at the optic chiasm.

Superior colliculus
Some optic tract fibers project to the superior colliculus.

Lateral geniculate nucleus of thalamus
The majority of the optic tract fibers project to the lateral geniculate nucleus in the thalamus.

Occipital lobe (visual cortex)
Receives processed information from the thalamus.
• Double vision: *diplopia* (what the patient experiences)
  – Eyes do not look at the same point in the visual field
• Misalignment: *strabismus* (what is observed when shine a light: not reflected in the same place on both eyes) – can be a cause of diplopia
  – Cross eyed
  – Gaze & movements not conjugate (together)
  – Medial or lateral, fixed or not
  – Many causes
    • Weakness or paralysis of extrinsic muscle of eye
      – *Surgical correction necessary*
    • Oculomotor nerve problem, other problems
• Lazy eye: *amblyopia*
  – Cover/uncover test at 5 yo
  – If don’t patch good eye by 6, brain ignores lazy eye and visual pathway degenerates: eye functionally blind

*NOTE: some neurological development and connections have a window of time - need stimuli to develop, or ability lost*
One of the Ishihara charts for color blindness

Commonly X-linked recessive: 8% males and 0.4% females
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
Disorders of the Eye and Vision: Macular Degeneration

- Age-related macular degeneration (AMD)
  - Involves the buildup of visual pigments in the retina.

Dry

Wet
Cataract (opaque lens)
Hearing and Equilibrium
Terminology, remember...

- Optic – refers to the eye
- Otic – refers to the ear

- Getting eyedrops and ear drops mixed up is probably not a good idea.
Hearing and Equilibrium

- The external ear is located mostly on the outside of the body, and the middle and inner areas are housed within the petrous portion of the temporal bone.
- Movements of the inner ear fluid result in the sensations of hearing and equilibrium, or balance.
The Outer (External) Ear

- Composed of:
  - The 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

- Contains an air-filled tympanic cavity.
- Medially, a bony wall that houses the oval window and round window separates the middle ear from the inner ear.
The Middle Ear

- Tympanic cavity maintains an open connection with the atmosphere through the auditory tube (pharyngotympanic tube or Eustachian tube).
  - opens into the nasopharynx (upper throat) from the middle ear
  - has a normally closed, slitlike opening at its connection to the nasopharynx
  - air movement through this tube (as a result of chewing, yawning, and swallowing) allows the pressure to equalize on both sides of the tympanic membrane
- Tympanic cavity of the middle ear houses the auditory ossicles.
  - malleus (hammer), the incus (anvil), and the stapes (stirrup)
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
The Inner (Internal) Ear

- Inner ear – also called the labyrinth
- Lies within the petrous portion of the temporal bone
- Bony labyrinth – a cavity consisting of three parts
  - Semicircular canals
  - Vestibule
  - Cochlea
The Inner Ear

- Located within the petrous portion of the temporal bone, where there are spaces or cavities called the bony labyrinth.
  - the vestibule and semicircular canals = the vestibular complex
    - contains two saclike, membranous labyrinth parts—the utricle and the saccule - interconnected through a narrow passageway
  - semicircular canals of the vestibular complex, the membranous labyrinth is called the semicircular ducts
  - cochlea houses a membranous labyrinth called the cochlear duct
- Within the bony labyrinth are membrane-lined, fluid-filled tubes and spaces, called the membranous labyrinth.
  - receptors for equilibrium and hearing
Figure 16.17b

- Entrance to mastoid antrum in the epitympanic recess
- Semicircular canals
- Vestibule
- Vestibular nerve
- Cochlear nerve
- Cochlea
- Pharyngotympanic (auditory) tube
- External acoustic meatus
- Tympanic membrane
- Oval window (deep to stapes)
- Internal jugular vein
- Round window

Ossicles:
- Malleus (hammer)
- Incus (anvil)
- Stapes (stirrup)
The Inner (Internal) Ear

- 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
The Inner (Internal) Ear

- Membranous labyrinth (continued)
  - Filled with a clear fluid – endolymph
    - Confined to the membranous labyrinth
  - Bony labyrinth is filled with perilymph
    - Continuous with cerebrospinal fluid
The Membranous Labyrinth

Figure 16.20
The Vestibule

- The central part of the bony labyrinth
- Lies medial to the middle ear
  - Utricle and saccule – suspended in perilymph
    - Two egg-shaped parts of the membranous labyrinth
    - House the **macula** – a spot of sensory epithelium
The Vestibule

- Macula – contains receptor cells
  - Monitor the position of the head when the head is still
  - Contains columnar supporting cells
  - Receptor cells – called hair cells
    - Synapse with the vestibular nerve
The Semicircular Canals

Figure 16.20
Equilibrium

- Rotation of the head causes **endolymph** within the semicircular canal to push against the **cupula** covering the hair cells, resulting in bending of their **stereocilia** and the initiation of a nerve impulse.
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
  - The basilar membrane – the floor of the cochlear duct
Structures for Hearing

- Housed within the **cochlea** in both inner ears.
  - snail-shaped spinal chambers in the bone of the inner ear
  - has a spongy bone axis called the **modiolus**
- Membranous labyrinth houses the **spiral organ** (organ of **Corti**) which is responsible for hearing.
The Role of the Cochlea in Hearing

Figure 16.24
Vestibular membrane
Spiral lamina
Spiral ganglion
Scala vestibuli (vestibular duct)
Scala media (cochlear duct)
Scala tympani (tympanic duct)
Cochlear nerve, division of the vestibulocochlear nerve (CN VIII)

(a) Cochlea section
Equilibrium and Auditory Pathways

• The equilibrium pathway
  – Transmits information on the position and movement of the head
  – Most information goes to lower brain centers (reflex centers)

• The ascending auditory pathway
  – Transmits information from cochlear receptors to the cerebral cortex
(b) Close-up of cochlea
Auditory Pathway from the Organ of Corti

**Figure 16.25**

- Medial geniculate body of thalamus
- Primary auditory cortex in temporal lobe
- Inferior colliculus
- Lateral lemniscus
- Superior olivary nucleus (pons-medulla junction)
- Cochlear nuclei
- Midbrain
- Medulla
- Vestibulocochlear nerve
- Spiral ganglion of cochlear nerve
- Spiral organ of Corti
Disorders of Equilibrium and Hearing: Meniere’s Syndrome

• Meniere’s syndrome – equilibrium is greatly disturbed
  – Excessive amounts of endolymph in the membranous labyrinth

![Normal](image1.png) ![Meniere's](image2.png)
Disorders of Equilibrium and Hearing: Conduction Deafness

• Deafness
  – Conduction deafness
    • Sound vibrations cannot be conducted to the inner ear
      – Ruptured tympanic membrane, otitis media, otosclerosis

Normal tympanic membrane

Ruptured tympanic membrane

Otitis media
REFERENCES


Supplementary Physiology II Textbooks:
8. Rhodes and Bell, Medical Physiology: Principles for Clinical Medicine, 3rd Ed. 2009, Lippincott Williams & Wilkins.
   ➢E-Book: ISBN 9781609139339
REFERENCES

MONOGRAPHS


The End...... ☺