

CHAPTER 17

LECTURE OUTLINE

I. INTRODUCTION

- A. Receptors for the special senses - smell, taste, vision, hearing, and equilibrium - are housed in complex sensory organs.
- B. Ophthalmology is the science that deals with the eye and its disorders.
- C. Otorhinolaryngology is the science that deals with disorders of the ear, nose and throat.

II. OLFACTION: SENSE OF SMELL

- A. Both smell and taste are chemical senses.

B. Anatomy of olfactory receptors

- 1. The receptors for olfaction, which are bipolar neurons, are in the nasal epithelium in the superior portion of the nasal cavity (Figure 17.1).
 - a. They are first-order neurons of the olfactory pathway.
 - b. olfactory hairs are the parts that respond to the olfactory stimulus
- 2. Supporting cells are epithelial cells of the mucous membrane lining the nose.
- 3. Basal stem cells produce new olfactory receptors.

C. Physiology of Olfaction

- 1. Genetic evidence suggests there are hundreds of primary scents.
- 2. In olfactory reception, a generator potential develops and, through a transduction process, triggers one or more nerve impulses (Figure 17.2)

D. Odor Thresholds and Adaptation

- 1. Adaptation to odors occurs quickly, and the threshold of smell is low: only a few molecules of certain substances need be present in air to be smelled.

E. The Olfactory Pathway

- 1. Olfactory receptors convey nerve impulses to olfactory nerves, olfactory bulbs, olfactory tracts, and the cerebral cortex and limbic system.
- 2. **Clinical Connection:** Hyposmia, a reduced ability to smell, affects half of those over age 65 and 75% of those over 80. It can be caused by neurological changes, drugs, or the effects of smoking

III. GUSTATION: SENSE OF TASTE

- A. Taste is a chemical sense.

1. To be detected, molecules must be dissolved.
2. Taste stimuli classes include sour, sweet, bitter meaty, and salty.
3. Other “tastes” are a combination of the five primary taste sensations plus olfaction,

B. Anatomy of Taste Buds and Papillae

1. The receptors for gustation, the gustatory receptor cells, are located in taste buds (Figure 17.3).
2. Taste buds consist of supporting cells, gustatory receptor cells, and basal cells .
3. Taste buds are found on the margins of papillae.
4. The papillae include circumvallate, fungiform, and foliate papillae.
 - a. Filiform papilla cover the tongue but act as tactile receptors instead of taste receptors

C. Physiology of Gustation

1. When a tastant is dissolved in saliva it can make contact with the plasma membrane of gustatory receptor cells.
2. Receptor potentials developed in gustatory hairs cause the release of neurotransmitter that gives rise to nerve impulses.
 - a. Receptor potentials develop in response to chemicals in the food (ie sodium or hydrogen)

D. Taste Thresholds and Adaptation

1. Taste thresholds vary for each of the primary tastes with the threshold for bitter being the lowest, then sour, and finally the other primary tastes.
2. Adaptation to taste occurs quickly.

E. The Gustatory Pathway

1. Gustatory receptor cells convey nerve impulses to cranial nerves V, VII, IX, and S, the medulla, the thalamus, and the parietal lobe of the cerebral cortex (Figure 17.3).
2. **Clinical Connection:** Taste aversion causes individuals to avoid foods which upset their digestive system. Because cancer treatments cause nausea, cancer patients may lose their appetites because they develop taste aversion for most food.

IV. VISION

A. Introduction

1. More than half the sensory receptors in the human body are located in the eyes.
2. A large part of the cerebral cortex is devoted to processing visual information.

B. Electromagnetic Radiation

1. Visible light (wavelengths between 400 and 700 nm) is the only part of the spectrum of electromagnetic radiation that can be detected by the eyes (Figure 17.4)

C. Accessory Structures of the Eyes

1. Eyelids
 - a. The eyelids shade the eyes during sleep, protect the eyes from excessive light and foreign objects, and spread lubricating secretions over the eyeballs (Figure 17.5).
 - b. From superficial to deep, each eyelid consists of epidermis, dermis, subcutaneous tissue, fibers of the orbicularis oculi muscle, a tarsal plate, tarsal glands, and conjunctiva (Figure 17.5).
 - 1) The tarsal plate gives form and support to the eyelids.
 - i. The tarsal glands secrete a fluid to keep the eye lids from adhering to each other.
 - c. The conjunctiva is a thin mucous membrane that lines the inner aspect of the eyelids and is reflected onto the anterior surface of the eyeball.
2. Eyelashes and Eyebrows
 - a. Eyelashes and eyebrows help protect the eyeballs from foreign objects, perspiration, and the direct rays of the sun (Figure 17.6)
3. The lacrimal Apparatus
 - a. The lacrimal apparatus consists of structures that produce and drain tears (Figure 17.6b).
4. Extrinsic Eye Muscles
 - a. The six extrinsic eye muscles move the eyeballs laterally, medially, superiorly, and inferiorly (Figures 17.6a and 17.7).

D. Anatomy of the Eyeball

1. The eye is constructed of three layers (Figure 17.7).
 - a. The fibrous tunic is the outer coat of the eyeball. It can be divided into two regions: the posterior sclera and the anterior cornea. At the junction of the sclera and cornea is an opening known as the scleral venous sinus or canal of Schlemm (Figure 17.7).
 - 1) The sclera, the “white” of the eye, is a white coat of dense fibrous tissue that covers all the eyeball, except the most anterior portion, the iris; the sclera gives shape to the eyeball and protects its inner parts. Its posterior surface is pierced by the optic nerve.

- 2) The cornea is a nonvascular, transparent, fibrous coat through which the iris can be seen; the cornea acts in refraction of light.
- b. The vascular tunic is the middle layer of the eyeball and is composed of three portions: choroid, ciliary body, and iris (Figure 17.7).
 - 1) The choroid absorbs light rays so that they are not reflected and scattered within the eyeball; it also provides nutrients to the posterior surface of the retina.
 - 2) The ciliary body consists of the ciliary processes and ciliary muscle.
 - i. The ciliary processes consist of protrusions or folds on the internal surface of the ciliary body where epithelial lining cells secrete aqueous humor.
 - ii. The ciliary muscle is a smooth muscle that alters the shape of the lens for near or far vision.
 - 3) The iris is the colored portion seen through the cornea and consists of circular iris and radial iris smooth muscle fibers (cells) arranged to form a doughnut-shaped structure.
 - i. The black hole in the center of the iris is the pupil, the area through which light enters the eyeball.
 - ii. A principal function of the iris is to regulate the amount of light entering the posterior cavity of the eyeball (figure 17.8)
- c. The third and inner coat of the eye, the retina (nervous tunic), lines the posterior three-quarters of the eyeball and is the beginning of the visual pathway (Figure 17.7).
 - 1) The surface of the retina is the only place in the body where blood vessels can be viewed directly and examined for pathological changes (Figure 17.9).
 - 2) The optic disc is the site where the optic nerve enters the eyeball.
 - 3) The vessels of the retina are the central retinal artery and vein. They are bundled together with the optic nerve with branches across the retinal surface.
 - 4) The retina consists of a pigment epithelium (nonvisual portion) and a neural portion (visual portion).
 - i. The pigment epithelium aids the choroid in absorbing stray light rays.

- ii. The neural portion contains three zones of neurons that are named in the order in which they conduct nerve impulses: photoreceptor neurons, bipolar neurons, and ganglion neurons (Figure 17.10).
- 5) The photoreceptor neurons are called rods or cones because of the differing shapes of their outer segments.
 - i. Rods are specialized for black-and-white vision in dim light; they also allow us to discriminate between different shades of dark and light and permit us to see shapes and movement.
 - ii. Cones are specialized for color vision and sharpness of vision (high visual acuity) in bright light; cones are most densely concentrated in the central fovea, a small depression in the center of the macula lutea.
 - a) The macula lutea is in the exact center of the posterior portion of the retina, corresponding to the visual axis of the eye.
 - iii. The fovea is the area of sharpest vision because of the high concentration of cones.
 - iv. Rods are absent from the fovea and macula and increase in density toward the periphery of the retina.
 - v. **Clinical Connection:** A detached retina may result in visual distortions or blindness
 - vi. **Clinical Connection:** Age related macular disease is a degenerative disorder of the retina and the pigmented layer in persons 50 years of age or older
- 2. The eyeball contains the nonvascular lens, just behind the pupil and iris. The lens fine tunes the focusing of light rays for clear vision (Figure 17.7).
- 3. The interior of the eyeball is a large space divided into two cavities by the lens: the anterior cavity and the vitreous chamber (Figure 17.11).
 - a. The anterior cavity is subdivided into the anterior chamber (which lies behind the cornea and in front of the iris) and the posterior chamber (which lies behind the iris and in front of the suspensory ligaments and lens).

- 1) The anterior cavity is filled with a watery fluid called the aqueous humor that is continually secreted by the ciliary processes behind the iris.
- 2) The aqueous humor flows forward from the posterior chamber through the pupil into the anterior chamber and drains into the scleral venous sinus (canal of Schlemm) and then into the blood.
- 3) The pressure in the eye, called intraocular pressure, is produced mainly by the aqueous humor. The intraocular pressure, along with the vitreous body, maintains the shape of the eyeball and keeps the retina smoothly applied to the choroid so the retina will form clear images.
- 4) Excessive intraocular pressure, called glaucoma, results in degeneration of the retina and blindness.

b. The second, and larger, cavity of the eyeball is the vitreous chamber (posterior cavity). It lies between the lens and the retina and contains a gel called the vitreous body. It is formed during embryonic life and is not replaced thereafter.

c. Table 17.1 summarizes the structures associated with the eyeball.

E. Image formation on the retina involves refraction of light rays by the cornea and lens, accommodation of the lens, and constriction of the pupil.

1. The bending of light rays at the interface of two different media is called refraction; the anterior and posterior surfaces of the cornea and of the lens refract entering light rays so they come into exact focus on the retina (Figure 17.12).
2. Images are focused upside-down (inverted) on the retina and also undergo mirror reversal (Figure 17.12); these inverted images are rearranged by the brain to produce perception of images in their actual orientation.
3. The lens fine tunes image focus and changes the focus for near or distant objects.
4. **Clinical Connection:** Age-related Macular Disease. A disease of the retina in persons 50 years of age and older.

F. Accommodation and Near Point of Vision

1. Accommodation is an increase in the curvature of the lens, initiated by ciliary muscle contraction, which allows the lens to focus on near objects (figure 17.12). To focus on far objects, the ciliary muscle relaxes and the lens flattens.

2. The near point of vision is the minimum distance from the eye that an object can be clearly focused with maximum effort.
3. **Clinical Connection:** With aging the lens loses elasticity and its ability to accommodate resulting in a condition known as presbyopia.

G. Refraction Abnormalities (Figure 17.13)

1. Myopia is nearsightedness.
2. Hyperopia is farsightedness .
3. Astigmatism is a refraction abnormality due to an irregular curvature of either the cornea or lens.
4. **Clinical Connection:** LASIK surgery can be utilized to correct the above conditions.

H. Constriction of the Pupil

1. Constriction of the pupil means narrowing the diameter of the hole through which light enters the eye; this occurs simultaneously with accommodation of the lens and functions to prevent light rays from entering the eye through the periphery of the lens.

I. Convergence

1. In convergence, the eyeballs move medially so they are both directed toward an object being viewed; the coordinated action of the extrinsic eye muscles bring about convergence.

V. Physiology of Vision

A. The first step in vision transduction is the absorption of light by photopigments (visual pigments) in rods and cones (photoreceptors) (Figure 17.14).

1. Photopigments are colored proteins that undergo structural changes upon light absorption.
 - a. The single type of photopigment in rods is called rhodopsin. A cone contains one of three different kinds of photopigments so there are three types of cones.
 - b. All photopigments involved in vision contain a glycoprotein called opsin and a derivative of vitamin A called retinal.
 - 1) Retinal is the light absorbing part of all visual photopigments.
 - c. There are four different opsins, one for each cone photopigment and another for rhodopsin.
 - d. Figure 17.15 shows how photopigments are activated and restored.

- e. Bleaching and regeneration of the photopigments accounts for much but not all of the sensitivity change during light and dark adaptation.
2. Once receptor potentials develop in rods and cones, they release neurotransmitters that induce graded potentials in bipolar cells (Figure 17.16).

B. Light and Dark Adaptation

1. light adaptation —your visual system adjusts in seconds to the brighter environment by decreasing its sensitivity.
2. dark adaptation— sensitivity increases slowly over many minutes.
3. **Clinical Connection:** Most forms of colorblindness (inability to distinguish certain colors) result from an inherited absence of or deficiency in one of the three cone photopigments and are more common in males. A deficiency in rhodopsin may cause night blindness (nyctalopia).

C. Release of Neurotransmitter by Photoreceptors

1. Figure 17.16a. Light striking cis retinal induces a conformational change that in turn activate enzymes which breakdown cGMP causing the cGMP gated channels to close
2. The closing of cGMP gated channels causes the cell to hyperpolarize and reduce the amount of neurotransmitter released.
3. **Clinical Connection:** Color blindness and Night blindness.

D. The Visual Pathway

1. Bipolar cells transmit excitatory signals to ganglion cells, which depolarize and initiate nerve impulses
2. Impulses from ganglion cells are conveyed through the retina to the optic nerve, the optic chiasma, the optic tract, the thalamus, and the occipital lobes of the cortex (Figure 17.17).

E. Brain pathway and Visual Fields

1. Axons of the optic nerve pass through the optic chiasm where some crossover to to the other side, while some remain on the same side, before continuing to the thalamus.
2. The visual field, defined as the area which the eyes can see, have a central half and a peripheral half. (Figure 17.17)

VI. HEARING AND EQUILIBRIUM

A. Anatomy of the Ear

1. The ear consists of three anatomical subdivisions.

2. External (Outer) Ear

- a. The external (outer) ear collects sound waves and passes them inwards; it consists of the auricle (pinna), external auditory canal (meatus), and tympanic membrane (eardrum) (Figure 17.18)
- b. Ceruminous glands in the external auditory canal secrete cerumen (earwax) to help prevent dust and foreign objects from entering the ear.
- c. Excess cerumen may become impacted, causing temporary partial hearing loss before it is removed.

3. Middle Ear

- a. The middle ear (tympanic cavity) is a small, air-filled cavity in the temporal bone that is lined by epithelium. It contains the auditory (Eustachian) tube, auditory ossicles (middle ear bones, the malleus, incus, and stapes), the oval window, and the round window (Figure 17.19).

4. Internal (inner) Ear

- a. The internal (inner) ear is also called the labyrinth because of its complicated series of canals (Figure 17.20). Structurally it consists of two main divisions: an outer bony labyrinth that encloses an inner membranous labyrinth.
- b. The bony labyrinth is a series of cavities in the petrous portion of the temporal bone.
 - 1) It can be divided into three areas named on the basis of shape: the semicircular canals and vestibule, both of which contain receptors for equilibrium, and the cochlea, which contains receptors for hearing.
 - 2) The bony labyrinth is lined with periosteum and contains a fluid called perilymph. This fluid, chemically similar to cerebrospinal fluid, surrounds the membranous labyrinth.
 - 3) The membranous labyrinth is a series of sacs and tubes lying inside and having the same general form as the bony labyrinth.
 - i. The membranous labyrinth is lined with epithelium.
 - ii. It contains a fluid called endolymph, chemically similar to intracellular fluid.
- c. The vestibule constitutes the oval central portion of the bony labyrinth. The membranous labyrinth in the vestibule consists of two sacs called the utricle and saccule.

- d. Projecting upward and posteriorly from the vestibule are the three bony semicircular canals. Each is arranged at approximately right angles to the other two.
 - 1) The anterior and posterior semicircular canals are oriented vertically; the lateral semicircular canal is oriented horizontally.
 - 2) One end of each canal enlarges into a swelling called the ampulla.
- e. The portions of the membranous labyrinth that lie inside the semicircular canals are called the semicircular ducts (membranous semicircular canals).
- f. The vestibular branch of the vestibulocochlear nerve consists of ampullary, utricular, and saccular nerves.
- g. Anterior to the vestibule is the cochlea, which consists of a bony spiral canal that makes almost three turns around a central bony core called the modiolus (Figure 17.21).

B. Cross sections through the cochlea show that it is divided into three channels by partitions that together have the shape of the letter Y

- 1. The channel above the bony partition is the scala vestibuli, which ends at the oval window.
- 2. The channel below is the scala tympani, which ends at the round window. The scala vestibuli and scala tympani both contain perilymph and are completely separated except at an opening at the apex of the cochlea called the helicotrema.
- 3. The third channel (between the wings of the Y) is the cochlear duct (scala media). The vestibular membrane separates the cochlear duct from the scala vestibuli, and the basilar membrane separates the cochlear duct from the scala tympani.
- 4. Resting on the basilar membrane is the spiral organ (organ of Corti), the organ of hearing (Figure 17.21, c,d).
 - a. Projecting over and in contact with the hair cells of the spiral organ is the tectorial membrane, a delicate and flexible gelatinous membrane.

C. The Nature of Sound Waves

- 1. Sound waves result from the alternate compression and decompression of air molecules.
 - a. The sounds heard most acutely by human ears are from sources that vibrate at frequencies between 1000 and 4000 Hertz (Hz; cycles per minute).

- 1) The frequency of a sound vibration is its pitch; the greater the intensity (size) of the vibration, the louder the sound (as measured in decibels, dB).
- b. **Clinical Connection:** Exposure to loud sounds can damage hair cells of the cochlea and possibly lead to deafness.

VII. Physiology of Hearing

- A. The events involved in hearing are seen in Figure 17.22).
 1. The auricle directs sound waves into the external auditory canal.
 2. Sound waves strike the tympanic membrane, causing it to vibrate back and forth.
 3. The vibration conducts from the tympanic membrane through the ossicles (through the malleus to the incus and then to the stapes).
 4. The stapes moves back and forth, pushing the membrane of the oval window in and out.
 5. The movement of the oval window sets up fluid pressure waves in the perilymph of the cochlea (scala vestibuli).
 6. Pressure waves in the scala vestibuli are transmitted to the scala tympani and eventually to the round window, causing it to bulge outward into the middle ear.
 7. As the pressure waves deform the walls of the scala vestibuli and scala tympani, they push the vestibular membrane back and forth and increase and decrease the pressure of the endolymph inside the cochlear duct.
 8. The pressure fluctuations of the endolymph move the basilar membrane slightly, moving the hair cells of the spiral organ against the tectorial membrane; the bending of the hairs produces receptor potentials that lead to the generation of nerve impulses in cochlear nerve fibers.
 9. Pressure changes in the scala tympani cause the round window to bulge outward into the middle ear.
- B. Differences in pitch are related to differences in the width and stiffness of the basilar membrane and sound waves of various frequencies that cause specific regions of the basilar membrane to vibrate more intensely than others.
 1. High-frequency or high-pitched sounds cause the basilar membrane to vibrate near the base of the cochlea.
 2. Low-frequency or low-pitched sounds cause the basilar membrane to vibrate near the apex of the cochlea.

- C. Hair cells convert a mechanical force (stimulus) into an electrical signal (receptor potential); hair cells release neurotransmitter, which initiates nerve impulses.
- D. The cochlea can produce sounds called otoacoustic emissions. They are caused by vibrations of the outer hair cells that occur in response to sound waves and to signals from motor neurons.

VIII. Auditory Pathway

- A. Nerve impulses from the cochlear branch of the vestibulocochlear nerve (Figure 17.23) pass to the cochlear nuclei in the medulla. Here, most impulses cross to the opposite side and then travel to the midbrain, to the thalamus, and finally to the auditory area of the temporal lobe of the cerebral cortex.
 - 1. **Clinical Connection:** Cochlear implants are devices that translate sounds into electronic signals that can be interpreted by the brain.

IX. Physiology of Equilibrium

A. There are two kinds of equilibrium.

- 1. Static equilibrium refers to the maintenance of the position of the body (mainly the head) relative to the force of gravity.
- 2. Dynamic equilibrium is the maintenance of body position (mainly the head) in response to sudden movements, such as rotation, acceleration, and deceleration.

B. Otolithic Organs: Saccule and Utricle

- 1. The maculae of the utricle and saccule are the sense organs of static equilibrium; they also contribute to some aspects of dynamic equilibrium (Figure 17.24).
- 2. The maculae consist of hair cells, which are sensory receptors, and supporting cells.

C. Membranous Semicircular Ducts

- 1. The three semicircular ducts, along with the saccule and utricle maintain dynamic equilibrium (Figure 17.25).
- 2. The cristae in the semicircular ducts are the primary sense organs of dynamic equilibrium.

D. Equilibrium Pathways

- 1. Most vestibular branch fibers of the vestibulocochlear nerve enter the brain stem and terminate in the medulla; the remaining fibers enter the cerebellum (Figure 17.26)
- 2. Various pathways between the vestibular nuclei, cerebellum, and cerebrum enable the cerebellum to play a key role in maintaining static and dynamic equilibrium.

3. **Clinical Connection:** Motion Sickness
4. Table 17.2 summarizes the structures related to hearing and equilibrium.

X. DEVELOPMENT OF THE EYES AND EARS

A. Eyes

1. Eyes begin to develop when the ectoderm of the lateral walls of the prosencephalon bulges to form a pair of optic grooves (Figure 17.27)
2. As the neural tube closes the optic grooves enlarge and move toward the surface of the ectoderm and are known as optic vesicles.
3. When the optic vesicles reach the surface, the surface ectoderm thickens to form the lens placodes and the distal portions of the optic vesicles invaginate to form the optic cups.
4. The optic cups remain attached to the prosencephalon by the optic stalks.

B. Ears

1. Inner ear develops from a thickening of surface ectoderm called the otic placode (Figure 17.28).
2. Otic placodes invaginate to form otic pits.
3. Otic pits pinch off from the surface ectoderm to form otic vesicles
4. Otic vesicles will form structures associated with the membranous labyrinth of the inner ear.
5. Middle ear develops from the first pharyngeal (branchial) pouch.

XI. AGING AND THE SPECIAL SENSES

- A. Changes in vision, that occur with age include: loss of lens elasticity; loss of transparency of lens; discoloration of the sclera; weakening of the extrinsic muscles; less responsive irises; lowered tear production; and, lessening of color vision.
- B. Changes in hearing, that occur with age include; hearing loss of high pitched sounds; loss of hair cells; degeneration of the auditory pathway and an increase in tinnitus.

XII. DISORDERS: HOMEOSTATIC IMBALANCES

- A. A cataract is a loss of transparency of the lens that can lead to blindness.
- B. Glaucoma is abnormally high intraocular pressure, due to a buildup of aqueous humor inside the eyeball, which destroys neurons of the retina. It is the second most common cause of blindness (after cataracts), especially in the elderly.

- C. Deafness is significant or total hearing loss. It is classified as sensorineural (caused by impairment of the cochlear or cochlear branch of the vestibulocochlear nerve) or conduction (caused by impairment of the external and middle ear mechanisms for transmitting sounds to the cochlea).
- D. Meniere's syndrome is a malfunction of the inner ear that may cause deafness and loss of equilibrium.
- E. Otitis media is an acute infection of the middle ear, primarily by bacteria. It is characterized by pain, malaise, fever, and reddening and outward bulging of the eardrum, which may rupture unless prompt treatment is given. Children are more susceptible than adults.

XIII. MEDICAL TERMINOLOGY - Alert students to the medical terminology associated with the special senses.