

15: The Special Senses

Objectives

The Eye and Vision

1. Describe the structure and function of accessory eye structures, eye layers, the lens, and humors of the eye.
2. Outline the causes and consequences of cataracts and glaucoma.
3. Trace the pathway of light through the eye to the retina, and explain how light is focused for distant and close vision.
4. Outline the causes and consequences of astigmatism, myopia, hyperopia, and presbyopia.
5. Describe the events involved in the stimulation of photoreceptors by light, and compare and contrast the roles of rods and cones in vision.
6. Compare and contrast light and dark adaptation.
7. Trace the visual pathway to the visual cortex, and briefly describe the steps in visual processing.

The Chemical Senses: Taste and Smell

8. Describe the location, structure, and afferent pathways of taste and smell receptors, and explain how these receptors are activated.

The Ear: Hearing and Balance

9. Describe the structure and general function of the outer, middle, and internal ears.
10. Describe the sound conduction pathway to the fluids of the internal ear, and follow the auditory pathway from the spiral organ (of Corti) to the temporal cortex.
11. Explain how one is able to differentiate pitch and loudness, and localize the source of sounds.
12. List possible causes and symptoms of otitis media, deafness, and Ménière's syndrome.
13. Explain how the balance organs of the semicircular canals and the vestibule help maintain dynamic and static equilibrium.

Developmental Aspects of the Special Senses

14. List changes that occur in the special sense organs with aging.

Chapter Outline

I. The Eye and Vision (pp. 548–569; Figs. 15.1–15.20)

- A. Vision is our dominant sense; 70% of our body's sensory receptors are found in the eye (p. 548).
- B. Accessory Structures of the Eye (pp. 548–551; Figs. 15.1–15.3)
 1. Eyebrows are short, coarse hairs overlying the supraorbital margins of the eye that shade the eyes and keep perspiration out.

2. Eyelids (palpebrae), eyelashes, and their associated glands help to protect the eye from physical danger as well as from drying out.
 3. Conjunctiva is a transparent mucous membrane that lines the eyelids and the whites of the eyes. It produces a lubricating mucus that prevents the eye from drying out.
 4. The lacrimal apparatus consists of the lacrimal gland, which secretes a dilute saline solution that cleanses and protects the eye as it moistens it, and ducts that drain excess fluid into the nasolacrimal duct.
 5. The movement of each eyeball is controlled by six extrinsic eye muscles that are innervated by the abducens and trochlear nerves.
- C. Structure of the Eyeball (pp. 551–556; Figs. 15.4–15.9)
1. Three layers form the wall of the eyeball.
 - a. The fibrous tunic is the outermost coat of the eye and is made of a dense avascular connective tissue with two regions: the sclera and the cornea.
 - b. The vascular tunic (uvea) is the middle layer and has three regions: the choroid, the ciliary body, and the iris.
 - c. The inner layer (retina) is the innermost layer made up of two layers: the outer pigmented layer absorbs light; the inner neural layer contains millions of photoreceptors (rods and cones) that transduce light energy.
 2. Internal Chambers and Fluids
 - a. The posterior segment (cavity) is filled with a clear gel called vitreous humor that transmits light, supports the posterior surface of the lens, holds the retina firmly against the pigmented layer, and contributes to intraocular pressure.
 - b. The anterior segment (cavity) is filled with aqueous humor that supplies nutrients and oxygen to the lens and cornea while carrying away wastes.
 3. The lens is an avascular, biconcave, transparent, flexible structure that can change shape to allow precise focusing of light on the retina.
- D. Physiology of Vision (pp. 556–569; Figs. 15.10–15.20)
1. Overview: Light and Optics
 - a. Electromagnetic radiation includes all energy waves from long waves to short waves, and includes the visible light that our eyes see as color.
 - b. Refraction of a light ray occurs when it meets the surface of a different medium at an oblique angle rather than a right angle.
 2. Focusing of Light on the Retina
 - a. Light is bent three times: as it enters the cornea and on entering and leaving the lens.
 - b. The far point of vision is that distance beyond which no change in lens shape is required (about 6 meters or 20 feet).
 - c. Focusing for close vision demands that the eye make three adjustments: accommodation of the lens, constriction of the pupils, and convergence of the eyeballs.
 - d. Myopia, or nearsightedness, occurs when objects focus in front of the retina and results in seeing close objects without a problem but distant objects are blurred.
 - e. Hyperopia, or farsightedness, occurs when objects are focused behind the retina and results in seeing distant objects clearly but close objects are blurred.
 3. Photoreception is the process by which the eye detects light energy.
 - a. Photoreceptors are modified neurons that structurally resemble tall epithelial cells.

- b. Rods are highly sensitive and are best suited to night vision. Cones are less sensitive to light and are best adapted to bright light and color vision.
- c. Photoreceptors contain a light-absorbing molecule called retinal.
- 4. Stimulation of the Photoreceptors
 - a. The visual pigment of rods is rhodopsin and is formed and broken down within the rods.
 - b. The breakdown and regeneration of the visual pigments of the cones is essentially the same as for rhodopsin.
- 5. Exposure of the photoreceptors to light causes pigment breakdown, which hyperpolarizes the receptors inhibiting the release of neurotransmitter conveying the information.
- 6. Light adaptation occurs when we move from darkness into bright light. Retinal sensitivity decreases dramatically and the retinal neurons switch from the rod to the cone system.
- 7. Dark adaptation occurs when we go from a well-lit area into a dark one. The cones stop functioning and the rhodopsin starts to accumulate in the rods, increasing retinal sensitivity.
- 8. Visual Pathway to the Brain
 - a. The retinal ganglion cells merge in the back of the eyeball to become the optic nerve, which crosses at the optic chiasma to become the optic tracts.
 - b. The optic tracts send their axons to neurons within the lateral geniculate body of the thalamus.
 - c. Axons from the thalamus project through the internal capsule to form the optic radiation of fibers in the cerebral white matter. These fibers project to the primary visual cortex in the occipital lobes.
- 9. Visual processing occurs when the action of light on photoreceptors hyperpolarizes them, which causes the bipolar neurons from both the rods and cones to ultimately send signals to their ganglion cells.

II. The Chemical Senses: Taste and Smell (pp. 569–574; Figs. 15.21–15.24)

- A. The receptors for taste and smell are chemoreceptors that respond to chemicals in solution (p. 569).
- B. The Olfactory Epithelium and the Sense of Smell (pp. 569–571; Figs. 15.21–15.22)
 - 1. The olfactory epithelium is the organ of smell located in the roof of the nasal cavity.
 - 2. The olfactory receptors are bipolar neurons with a thin apical dendrite that terminates in a knob with several olfactory cilia.
 - 3. To smell a particular odorant, it must be volatile and it must be dissolved in the fluid coating the olfactory epithelium that stimulates the olfactory receptors.
 - 4. In olfactory transduction, an odorant binds to the olfactory receptor, a G protein, and the secondary messenger of cyclic AMP.
 - 5. Axons of the olfactory receptor cells synapse in the olfactory bulbs, sending impulses down the olfactory tracts to the thalamus, hypothalamus, amygdala, and other members of the limbic system.
- C. Taste Buds and the Sense of Taste (pp. 571–573; Figs. 15.23–15.24)
 - 1. Taste buds, the sensory receptor organs for taste, are located in the oral cavity, with the majority located on the tongue.

2. Taste sensations can be grouped into one of five basic qualities: sweet, sour, bitter, salty, and umami.
 3. Physiology of taste
 - a. For a chemical to be tasted it must be dissolved in saliva, move into the taste pore, and contact a gustatory hair.
 - b. Each taste sensation appears to have its own special mechanism for transduction.
 4. Afferent fibers carrying taste information from the tongue are found primarily in the facial nerve and glossopharyngeal cranial nerves.
 5. Taste impulses from the few taste buds found on the epiglottis and the lower pharynx are conveyed via the vagus nerve.
 6. Taste is strongly influenced by smell and stimulation of thermoreceptors, mechanoreceptors, and nociceptors.
- D. Homeostatic Imbalances of the Chemical Senses (p. 573)
1. Anosmias are olfactory disorders resulting from head injuries that tear the olfactory nerves, nasal cavity inflammation, or aging.
 2. Uncinate fits are olfactory hallucinations.
 3. Taste disorders are less common but may be caused by respiratory tract infections, head injuries, chemicals, medications, or head and neck radiation.

III. The Ear: Hearing and Balance (pp. 574–588; Figs. 15.25–15.38)

- A. Structure of the Ear (pp. 574–577; Figs. 15.25–15.28)
1. The external ear consists of the auricle (pinna) and the external acoustic meatus, which is lined with skin bearing hairs, sebaceous glands, and ceruminous glands.
 2. The middle ear, or tympanic cavity, is a small, air-filled, mucosa-lined cavity in the petrous portion of the temporal bone. It is spanned by the auditory ossicles.
 3. The internal ear has two major divisions: the bony labyrinth and the membranous labyrinth.
 - a. The vestibule is the central cavity of the bony labyrinth with two membranous sacs suspended in the perilymph, the saccule and the utricle.
 - b. The semicircular canals project from the posterior aspect of the vestibule, each containing an equilibrium receptor region called a crista ampullaris.
 - c. The spiral, snail-shaped cochlea extends from the anterior part of the vestibule and contains the cochlear duct, which houses the spiral organ (of Corti), the receptors for hearing.
- B. Physiology of Hearing (pp. 577–583; Figs. 15.29–15.33)
1. Properties of Sound
 - a. Sound is a pressure disturbance produced by a vibrating object and propagated by the molecules of the medium.
 - b. Frequency is the number of waves that pass a given point in a given time.
 - c. Amplitude, or height, of the wave reveals a sound's intensity (loudness).
 2. Airborne sound entering the external acoustic meatus strikes the tympanic membrane and sets it vibrating.
 3. The resonance of the basilar membrane processes sound signals mechanically before they ever reach the receptors.
 4. Transduction of sound stimuli occurs after the trapped stereocilia of the hair cells are deflected by localized movements of the basilar membrane.

5. Impulses generated in the cochlea pass through the spiral ganglion, along the afferent fibers of the cochlear nerve to the cochlear nuclei of the medulla, to the superior olivary nucleus, to the inferior colliculus, and finally to the auditory cortex.
 6. Auditory processing involves perception of pitch, detection of loudness, and localization of sound.
- C. Homeostatic Imbalances of Hearing (p. 583)
1. Deafness is any hearing loss, no matter how slight.
 2. Tinnitus is a ringing or clicking sound in the ears in the absence of auditory stimuli.
 3. Ménière's syndrome is a labyrinth disorder that causes a person to suffer repeated attacks of vertigo, nausea, and vomiting.
- D. Equilibrium and Orientation (pp. 584–587; Figs. 15.34–15.37)
1. The equilibrium sense responds to various head movements and depends on input from the internal ear, vision, and information from stretch receptors of muscles and tendons.
 2. The sensory receptors for static equilibrium are the maculae.
 3. The receptor for dynamic equilibrium is the crista ampullaris, found in the ampulla of the semicircular canals and activated by head movement.
 4. Information from the balance receptors goes directly to reflex centers in the brain stem, rather than to the cerebral cortex.

IV. Developmental Aspects of the Special Senses (pp. 588–589)

- A. Taste and Smell (p. 588)
1. Smell and taste are highly developed at birth.
 2. Women generally have a more acute sense of taste and smell than men.
 3. Beginning in the fourth decade of life, the ability to taste and smell declines as receptors are replaced more slowly than in younger people.
- B. Vision (p. 588)
1. By the fourth week of development, eyes begin to develop and—even before photoreceptors develop—CNS connections are made.
 2. Vision is the only sense not fully developed at birth. Newborn infants see only in gray tones, exhibit uncoordinated eye movements, and often use only one eye at a time.
 3. By 5 months, vision has improved, and by 5 years, vision is well developed.
 4. With age, the lens loses clarity and the pupil stays partly constricted, decreasing visual acuity in people over 70.
- C. Hearing and Balance (pp. 588–589)
1. The ear begins to develop in the embryo at 3 weeks.
 2. Newborn infants can hear, but respond reflexively. By the fourth month of life, hearing includes recognition.
 3. With age, the ability to hear high-pitched sounds declines, and hearing loss is exacerbated by exposure to loud noises.

Laboratory Correlations

1. Marieb, E. N., and S. J. Mitchell. *Human Anatomy & Physiology Laboratory Manual: Main Version*. Eighth Edition Update. Benjamin Cummings, 2009.
 - Exercise 24: Special Senses: Vision
 - Exercise 25: Special Senses: Hearing and Equilibrium
 - Exercise 26: Special Senses: Olfaction and Taste

Online Resources for Students

myA&P[™]

www.myaandp.com

The following shows the organization of the Chapter Guide page in myA&P[™]. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 15 in one convenient location, with e-book links to each section of the textbook. Students can also access A&P Flix animations, MP3 Tutor Sessions, Interactive Physiology[®] 10-System Suite, Practice Anatomy Lab[™] 2.0, PhysioEx[™] 8.0, and much more.

Objectives

Section 15.1 The Eye and Vision (pp. 548–569)

MP3 Tutor Session: The Visual Pathway

Art Labeling: The Eye and Associated Accessory Structures (Fig. 15.1b, p. 548)

Art Labeling: Internal Structures of the Eye (Fig. 15.4a, p. 552)

Case Study: Special Senses: Vision

Section 15.2 The Chemical Senses: Taste and Smell (pp. 569–574)

Memory Game: Eyesight Factors and the Art of Smelling

Section 15.3 The Ear: Hearing and Balance (pp. 574–588)

Art Labeling: Structure of the Ear (Fig. 15.25a–b, p. 575)

Section 15.4 Developmental Aspects of the Special Senses (pp. 588–589)

Chapter Summary

Memory Game: Sensory Organs

Crossword Puzzle 15.1

Crossword Puzzle 15.2

Crossword Puzzle 15.3

Crossword Puzzle 15.4

Crossword Puzzle 15.5

Web Links

Chapter Quizzes

Art Labeling Quiz

Matching Quiz

Multiple-Choice Quiz

True-False Quiz

Chapter Practice Test

Study Tools

Histology Atlas
myeBook
Flashcards
Glossary

CourseCompass™

Resources in the myA&P™ Chapter Guide are also available in the Chapter Contents section of the CourseCompass™. Students can also access A&P Flix animations, MP3 Tutor Sessions, Interactive Physiology® 10-System Suite, Practice Anatomy Lab™ 2.0, PhysioEx™ 8.0, and much more.

Answers to End-of-Chapter Questions

Multiple-Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

30. The nasolacrimal duct empties into the nasal cavity. (p. 549)
31. Rods are dim-light visual receptors, while cones are for bright-light and high-acuity color vision. (p. 553)
32. The fovea lies lateral to the optic disc. It contains only cones and provides detailed color vision for critical vision. (p. 553)
33. Retinal changes to the all-*trans* form; the retinal-opsin combination breaks down, separating retinal and opsin (bleaching). The net effect is to “turn off” sodium entry into the cell, effectively hyperpolarizing the rod. (p. 562)
34. Each cone responds maximally to one of these colors of light, but there is overlap in their absorption spectra that accounts for the other hues. (p. 562)
35. The receptors are located in the roof of the nasal cavity. They are poorly located, because air must make a hairpin turn upward to reach them. (p. 570)
36. False. Each olfactory receptor has a single type of receptor protein, but it may bind several different types of odorant molecules. (p. 570)
37. The five basic tastes are sweet, sour, salty, bitter, and umami. Taste is served by cranial nerves VII (facial), IX (glossopharyngeal), and X (vagus). (pp. 571–572)
38. With age, the lens enlarges, loses its crystal clarity and becomes discolored, and the dilator muscles of the iris become less efficient. Atrophy of the organ of Corti reduces hearing acuity, especially for high-pitched sounds. The sense of smell and taste diminish due to a gradual loss of receptors, thus appetite is diminished. (pp. 588–589)

Critical Thinking and Clinical Application Questions

1. Papilledema – a nipple-like protrusion of the optic disc into the eyeball, which is caused by conditions that increase intracranial pressure. A rise in cerebrospinal fluid pressure caused by an intracranial tumor will compress the walls of the central vein resulting in its congestion and bulging of the optic disc. (p. 589)
2. Pathogenic microorganisms spread from the nasopharynx through the pharyngotympanic tube into the tympanic cavity. They may then spread posteriorly into the mastoid air cells via the mastoid antrum resulting in mastoiditis, and medially to the internal ear, causing

secondary labyrinthitis. If unchecked, the infection may spread to the meninges, causing meningitis and possibly an abscess in the temporal lobe of the brain or in the cerebellum. They may also invade the blood, causing septicemia. The cause of her dizziness and loss of balance is a disruption of the equilibrium apparatus due to the labyrinthitis. (p. 574)

3. Conjunctivitis. The foreign object probably would be found in the conjunctival sac near the orifice of the lacrimal canals. (p. 549)
4. This is known as a detached retina. The condition is serious, but the retina can be reattached surgically using lasers before permanent damage occurs. (p. 553)
5. The inability to hear high-pitched sounds is called presbycusis, a type of sensorineural deafness. It is caused by the gradual loss of hearing receptors throughout life, but is accelerated if one is exposed to loud rock music for extended periods. (p. 589)
6. Blindness, because visual impulses will be blocked from reaching the optic disc. (p. 566)
7. Albinism involves a hereditary inability for melanocytes to synthesize tyrosinase, an enzyme that is needed for the production of melanin, a light-absorbing pigment that is normally present in the choroid and the pigmented layer of the retina. A lack of melanin allows light scattering and reflection within the eye, which causes visual confusion. (p. 559)
8. Jan had tinnitus. (p. 583)
9. This condition might be retinal detachment. (p. 553)
10. In addition to nausea and fatigue, the chemotherapy could affect his sense of taste. (p. 573)