The Special Senses Outline

PART 1 THE EYE AND VISION (pp. 545–565; Figs. 15.1–15.19)

15.1 The eye has three layers, a lens, and humors and is surrounded by accessory structures (pp. 549–557; Figs. 15.1–15.9)

A. Vision is our dominant sense; 70% of our body's sensory receptors are found in the eye. (p. 549)

B. Accessory Structures of the Eye (pp. 549–552; 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.
    a. Several glands are associated with the eyelid: the lacrimal caruncle, tarsal glands and ciliary glands that produce oily secretions.
3. The conjunctiva is a transparent mucous membrane that produces a lubricating mucus that prevents the eye from drying out.
    a. The palpebral conjunctiva lines the eyelids, and the bulbar conjunctiva covers the anterior surface of the eyeball.
4. The lacrimal apparatus consists of the lacrimal gland, which secretes a dilute saline solution (tears), and small ducts that drain excess fluid into the nasolacrimal duct.
    a. Lacrimal fluid contains mucus, antibodies, and lysozyme to cleanse, moisten, and protect the eyes.
5. The movement of each eyeball is controlled by six extrinsic eye muscles that are innervated by the abducens and trochlear nerves.
    a. Four rectus muscles, superior, inferior, lateral, and medial, originate at the back of the orbit and run straight to their insertion on the eyeball.
    b. Two oblique muscles, superior and inferior, run along the side of the eyeball and insert on the eyeball at an angle.
    c. The action of the oblique muscles offsets the action of the superior and inferior rectus, allowing the eyeball to be directly elevated or depressed.

C. Structure of the Eyeball (pp. 552–557; Figs. 15.4–15.9)

1. The wall of the eyeball is composed of three layers: the fibrous, vascular, and inner layers, which enclose an internal cavity filled with fluids, called humors, that help maintain shape.
2. The fibrous layer has two different regions: the sclera and cornea.
    a. The sclera is opaque white, while the cornea is clear, and allows light to enter the eye.
3. The vascular layer forms the middle layer, and has three regions: choroids, ciliary body, and iris.
    a. The choroid is vascular tissue that nourishes eye layers, the ciliary body consists of smooth muscle that encircles the lens, determining its shape, and the iris surrounds the pupil, acting reflexively to control pupil size and the amount of light that enters the eye.
4. The inner layer is the retina, which contains photoreceptors: rods and cones, as well as bipolar cells, ganglion cells, and glia.

a. The neural layer possesses an optic disc (blind spot), where the optic nerve exits the eye, and lacks photoreceptors.
b. Lateral to the blind spot is the macula lutea, which has a pit in its center called the fovea centralis, and has the highest density of cones, producing the most detailed color vision.

5. Internal chambers, the anterior and posterior segments, are separated by the lens, and contain fluid.
   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.
6. The lens is an avascular, biconvex, transparent, flexible structure that can change shape to allow precise focusing of light on the retina.

15.2 The cornea and lens focus light on the retina (pp. 557–561; Figs. 15.10–15.14)

A. Overview: Light and Optics (pp. 558–560; Figs. 15.10–15.14)
1. Electromagnetic radiation includes all energy waves from long waves to short waves and includes the visible light that our eyes see as color.
2. Refraction, or bending, of a light ray occurs when it meets the surface of a different medium at an oblique angle rather than a right angle.
3. A convex lens bends light so that it converges at a focal point, forming an image, called a real image, which projects upside down and reversed from left to right.
4. Focusing of Light on the Retina
   a. Light is bent three times: as it enters the cornea, upon entering the lens, and upon leaving the lens.
   b. The far point of vision is that distance beyond which no change in lens shape (accommodation) is required and, in a normal eye, is at a distance of about 6 meters, or 20 feet.
   c. During distant vision, the ciliary muscles are completely relaxed, causing a maximal flattening of the lens.
   d. Focusing for close vision demands that the eye make three adjustments: accommodation of the lens, causing it to thicken and increase light refraction, constriction of the pupils, which better directs light to the lens, and convergence of the eyeballs, allowing the object to remain focused on the foveae.
   e. The near point of vision occurs at the point of maximal thickening of the lens, and is 10 cm, or 4 inches, from the eye.
   f. 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.
   g. Hyperopia, or farsightedness, occurs when objects are focused behind the retina and results in seeing distant objects clearly but close objects are blurred.
   h. Astigmatism results from an uneven curvature of the cornea or lens, which produces blurred images.

15.3 Phototransduction begins when light activates visual pigments in retinal photoreceptors (pp. 561–567; Figs. 15.15–15.18; Table 15.1)

A. Functional Anatomy of the Photoreceptors (pp. 562–563; Fig. 15.15)

1. Photoreception is the process by which light energy produces graded receptor potentials.
   a. Photoreceptors are modified neurons that have their photoreceptive ends inserted into the pigmented layer of the retina.
   b. Photoreceptors contain visual pigments that change as they absorb light.

B. Comparing Rod and Cone Vision (p. 563; Table 15.1)

1. Rods are highly sensitive and are best suited to night vision.
2. Cones are less sensitive to light and are best adapted to bright light and color vision.

C. Visual Pigments (pp. 563–566; Figs. 15.16–15.18)

1. Within photoreceptors is a light-absorbing molecule, retinal, that combines with opsin proteins to form one of four types of visual pigments.
2. Cone opsins absorb light within a given range of wavelengths, giving them their names, blue, green, and red.

D. Information Processing in the Retina (p. 567)

1. Exposure of the photoreceptors to light causes pigment breakdown, which hyperpola-rizes the receptors inhibiting the release of neurotransmitter conveying the information.

E. Light and Dark Adaptation (p. 567)

1. 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.
2. 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.

15.4 Visual information from the retina passes through relay nuclei to the visual cortex (pp. 567–569; Fig. 15.19)

A. The Visual Pathway to the Brain (pp. 567–568; Fig. 15.19)

   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, which project to the primary visual cortex in the occipital lobes.

B. Depth Perception (p. 569)

1. Depth perception is created when the visual fields of each eye, which differ slightly, overlap.

C. Visual Processing (p. 569)

1. 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.

PART 2 THE CHEMICAL SENSES: SMELL AND TASTE

15.5 Airborne chemicals are detected by olfactory receptors in the nose (pp. 569–572; Figs. 15.20–15.21)

A. Location and Structure of Olfactory Receptors. The receptors for smell and taste are chemoreceptors, which means that they respond to chemicals in a solution. (pp. 569–570; Fig. 15.20)

B. Specificity of Olfactory Receptors (pp. 570–571; Fig. 15.21)

1. The olfactory epithelium is the organ of smell located in the roof of the nasal cavity.
2. The olfactory sensory neurons are bipolar neurons with a thin apical dendrite that terminates in a knob with several olfactory cilia.

C. Physiology of Smell (p. 571)

1. 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.

D. The Olfactory Pathway (pp. 571–572)

1. In olfactory transduction, an odorant binds to the olfactory receptor, a G protein, and the secondary messenger of cyclic AMP.
2. Axons of the olfactory sensory neurons synapse in the olfactory bulbs, sending impulses down the olfactory tracts to the thalamus, hypothalamus, amygdaloid body, and other members of the limbic system.

15.6 Dissolved chemicals are detected by receptor cells in taste buds (pp. 572–574; Figs. 15.22–15.23)

A. Location and Structure of Taste Buds (p. 572; Fig. 15.22)

1. Taste buds, the sensory receptor organs for taste, are located in the oral cavity, with the majority located within the papillae of the tongue.

B. Basic Taste Sensations (pp. 572–573)

1. Taste sensations can be grouped into one of five basic qualities: sweet, sour, bitter, salty, and umami.

C. Physiology of Taste (p. 573)

1. For a chemical to be tasted, it must be dissolved in saliva, move into the taste pore, and contact a gustatory hair, producing graded potentials that release neurotransmitters to sensory dendrites.
2. Each taste sensation appears to have its own special mechanism for transduction: salty taste is due to Na^+ influx, sour taste is due to H^+, bitter, sweet, and umami tastes are triggered through G-protein-triggered Ca^{++} release.

D. The Gustatory Pathway (pp. 573–574; Fig. 15.23)

1. Afferent fibers carrying taste information from the tongue are found primarily in the facial nerve and glossopharyngeal cranial nerves.
2. Taste impulses from the few taste buds found on the epiglottis and the lower pharynx are conveyed via the vagus nerve.

E. Influence of Other Sensations on Taste (p. 574)

1. Taste is strongly influenced by smell and stimulation of thermoreceptors, mechanoreceptors, and nociceptors.

PART 3 THE EAR: HEARING AND BALANCE

15.7 The ear has three major areas (pp. 574–579; Figs. 15.24–15.27; Table 15.2)

A. External Ear (p. 576; Fig. 15.24; Table 15.2)

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 tympanic membrane, or eardrum, is a thin connective tissue membrane that serves as the boundary between the outer and middle ear and transfers sound energy to the auditory ossicles.

B. Middle Ear (pp. 576–577; Figs. 15.24–15.25)
1. The middle ear, or tympanic cavity, is a small, air-filled, mucosa-lined cavity in the petrous portion of the temporal bone, spanned by the auditory ossicles.
   a. The pharyngotympanic tube links the middle ear with the nasopharynx, which allows pressure to be equalized between the middle ear and external ear pressure.

C. Inner Ear (pp. 577–579; Figs. 15.24, 15.26–15.27; Table 15.2)
1. 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 and is filled with perilymph.
   b. The membranous labyrinth, consisting of the saccule and the utricle, is suspended in the perilymph within the bony labyrinth and is filled with endolymph.
   c. Three semicircular canals project from the posterior aspect of the vestibule, with a semicircular duct through the center of each that bears a nodular swelling at one end, the ampulla, containing an equilibrium receptor, the crista ampullaris.
   d. The spiral, snail-shaped cochlea extends from the anterior part of the vestibule and contains the cochlear duct, which houses the spiral organ, the receptor organ for hearing.
   e. The cavity of the bony cochlea is divided into three chambers: the scala vestibuli, scala media, and scala tympani.
   f. The floor of the cochlear duct is composed of the osseous spiral lamina and the basilar membrane, which is important to sound reception.

15.8 Sound is a pressure wave that stimulates mechanosensitive cochlear hair cells (pp. 579–583; Figs. 15.28–15.32)

A. Properties of Sound (pp. 579–581; Figs. 15.28–15.29)
1. Sound is produced by a vibrating object and propagated by the molecules of the medium.
2. Frequency is the number of waves that pass a given point in a given time, and is measured in hertz (Hz).
3. Amplitude, or height, of the wave reveals a sound's intensity (loudness), and is measured in decibels (dB).

B. Transmission of Sound to the Internal Ear (p. 581; Fig. 15.30)
1. Airborne sound entering the external acoustic meatus strikes the tympanic membrane and sets it vibrating.
2. Vibrations are transmitted along the auditory ossicles to the oval window on the vestibule, producing a pressure wave within the perilymph.
3. Sounds with frequencies high enough to hear create pressure waves that vibrate the basilar membrane.

C. The resonance of the basilar membrane is tuned to specific frequencies: The fibers near the ovak window are short and stiff and respond to high-frequency pressure waves, while the longer fibers near the apex resonate with lower-frequency sound. (p. 582; Fig. 15.31)
D. Sound transduction occurs after the trapped stereocilia of the hair cells are deflected by localized movements of the basilar membrane. (pp. 582–583; Fig. 15.32)

15.9 Sound information is processed and relayed through brain stem and thalamic nuclei to the auditory cortex (pp. 583–584; Fig. 15.33)

A. The auditory pathway transmits impulses from the cochlea through the spinal ganglia 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. (pp. 583–584; Fig. 15.33)
B. Auditory processing involves perception of pitch, detection of loudness, and localization of sound. (p. 584)

15.10 Hair cells in the maculae and cristae ampullares monitor head position and movement (pp. 584–588; Figs. 15.34–15.36)

A. The equilibrium sense responds to head movements, visual information, and information from stretch receptors in muscles and tendons, in order to initiate reflexes that maintain position, and coordinate complex movements. (p. 584)
B. The maculae monitor position of the head in space, and respond to linear acceleration. (pp. 584–585; Fig. 15.34)
C. The cristae ampullares, located in the semicircular canals, detect rotational acceleration. (pp. 585–587; Fig. 15.35)
D. The equilibrium pathway to the brain involves impulses sent to the vestibular nuclei or cerebellum, which send commands to motor centers that control reflexive movements in extrinsic eye muscles, and neck, limb, and trunk muscles. (pp. 587–588; Fig. 15.36)

15.11 Ear abnormalities can affect hearing, equilibrium, or both (pp. 588–589; Fig. 15.37)

A. Conduction deafness occurs when something hampers sound conduction to the fluids of the inner ear: Sensioneural deafness results from damage to neural structures at any point from cochlear hair cells through auditory cortical cells. (p. 588; Fig. 15.37)
B. Tinnitus is a ringing or clicking sound in the ears in the absence of auditory stimuli. (p. 588)
C. Ménière's syndrome is a labyrinth disorder that causes a person to suffer repeated attacks of vertigo, nausea, and vomiting: Hearing may be impaired, or lost completely. (p. 588)

Developmental Aspects of the Special Senses (pp. 589–590)

A. Taste and Smell (p. 589)
   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. 589)
   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 (p. 589)
1. The ear begins to develop in the embryo at 3 weeks.
2. Newborn infants can hear and respond reflexively, but 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.