Chapter 40 Sense Organs

Chapter Outline

40.1 Chemical Senses

A. **Chemoreceptors** are responsible for taste and smell by being sensitive to chemicals in food, liquids, and air.
   1. Chemoreception is found universally in animals; it is thought to be the most primitive sense.
   2. Chemoreceptors are present all over a planarian but concentrated in the auricles at the side of the head.
   3. Insects, such as houseflies, taste with their feet.
   4. Crustacea have chemoreceptors on their antennae and appendages.
   5. In amphibians, chemoreceptors are located in the nose, mouth, and all over the skin.
   6. In mammals, receptors for taste are in the mouth, and receptors for smell are in the nose.

B. Sense of Taste
   1. Human **taste buds** are located primarily on the tongue.
   2. Many lie along the walls of **papillae**, the small elevations on surface of the tongue.
   3. Isolated ones are present on the surfaces of the hard palate, pharynx, and epiglottis.
   4. Taste buds are embedded in tongue epithelium and open at a taste pore.
   5. Taste buds have supporting cells and elongated taste cells that end in **microvilli**.
   6. Microvilli bear **receptor proteins** for certain chemicals.
      a. Molecules bind to receptor proteins and impulses are generated in associated sensory nerves
      b. Nerve impulses go to the brain cortical areas which interpret them as tastes.
   7. Humans have four primary types of taste buds.
      a. Taste buds for each are concentrated in particular regions.
         1) Sweet receptors are most plentiful near the tip of the tongue.
         2) Sour receptors occur primarily along the margins of the tongue.
         3) Salty receptors are most common on the tip and upper front portion.
         4) Bitter receptors are located near the back of the tongue.
      b. The brain appears to take an overall weighted average of taste messages as the perceived taste.

C. Sense of Smell
   1. The sense of smell depends on **olfactory cells** located in olfactory epithelium high in the roof of the nasal cavity.
   2. Olfactory cells are modified neurons.
   3. Each cell has a tuft of five olfactory cilia that bear receptor proteins for an odor molecule.
      a. There are around 1,000 different types of odor receptors; many olfactory cells carry the same type.
      b. Nerve fibers from like olfactory cells lead to the same neuron in the olfactory bulb.
      b. An odor activates a characteristic combination of cells; this information is pooled in the olfactory bulb.
      c. Interneurons communicate this information via the olfactory tract to areas of cerebral cortex.
   4. Olfactory bulbs are directly connected with the limbic system; smells associate with emotions and memory.
   5. Taste and smell supplement each other.
      a. "Smelling" food also involves the taste receptors.
      b. Losing taste when you have a cold is usually due to a loss of smell.

40.2 Sense of Vision

A. Animals lacking **photoreceptors** depend on their senses of hearing and smell rather than sight.

B. Photoreceptors vary in complexity.
   1. In its simplest form, a **photoreceptor** indicates only the presence of light and its intensity.
   2. "Eyespots" of planaria allow flatworms to determine direction of light.
   3. Image-forming **eyes** occur in four invertebrate groups: cnidaria, annelids, molluscs, and arthropods.
   4. Arthropods have **compound eyes** composed of many independent visual units (**ommatidia**), each possessing all of the elements needed for light reception.
      a. The cornea and crystalline cone of each visual unit focus rays toward the photoreceptors.
      b. Photoreceptors generate nerve impulses, which pass to the brain by way of optic nerve fibers.

c. The image resulting from all stimulated visual units is crude; the small size of compound eyes limits the number of visual units.
d. Insects have color vision but utilize a narrower range of the electromagnetic spectrum and can see some ultraviolet.

5. Some fishes, reptiles, and most birds are believed to have color vision, but among mammals, only humans and other primates have color vision; this is adaptive for day activity.
6. Vertebrates and certain molluscs (e.g., the squid and the octopus) have a **camera-type eye**.
   a. Molluscs and vertebrates are not closely related; therefore this is convergent evolution.
   b. A single lens focuses an image of the visual field on closely packed photoreceptors.
   c. In vertebrates the lens changes shape to aid in focusing; in molluscs the lens move back and forth.
   d. The human eye is considerably more complex than a camera.

C. The Human Eye
1. The human eye is an elongated sphere 2.5 cm in diameter with three layers.
2. The **sclera** is the outer, white fibrous layer that covers most of the eye; it protects and supports the eyeball.
3. The **cornea** is a transparent part of the sclera at the front of the eye; it is the window of the eye.
4. The middle, thin, dark-brown layer is the **choroid** containing many blood vessels and pigments absorbing stray light rays.
5. To the front of the eye, the choroid thickens and forms a ring-shaped **ciliary body** and finally becomes the **iris** that regulates the size of the opening called a pupil.
6. **The lens** divides the cavity into two portions: **aqueous humor** fills the anterior cavity and **vitreous humor** fills the posterior.
7. Retina
   a. The inner layer is the **retina** that contains photoreceptors called **rod cells** and **cone cells**.
   b. The **fovea centralis** is a small area of retina that contain only cones; this area produces acute color vision in daylight.
   c. Cone cells are not very sensitive in low intensity light; at night, the rods are still active.

D. Focusing of the Eye
1. Light rays enter the eye through the pupil and are focused on the retina.
2. Focusing involves light passing through the cornea, the lens, and the humors.
3. Because of refraction, the image on the retina is inverted 180º from actual but is perceived righted in the brain.
4. Shape of the lens is controlled by the ciliary muscle.
5. The lens is flatter when the ciliary muscle is relaxed when we are viewing distant objects.
6. The lens is naturally elastic and becomes rounder for viewing near objects where light rays must bend to a greater degree.
7. This change is called visual accommodation.
8. An aging lens loses its ability to accommodate for near objects and we may need reading glasses by middle age.
9. The lens is also subject to **cataracts**, or becoming opaque; surgery is the only current treatment.
   a. A surgeon opens the eye near the rim of the cornea.
   b. The enzyme zonulysin digests away the ligaments holding a lens in place.
   c. A cryoprobe freezes the lens for easy removal.
   d. An intraocular lens attached to the iris is implanted to avoid the need for thick glasses or contact lenses.
10. Persons who can see well close up but not far away are **nearsighted**.
   a. They often have an elongated eyeball that focuses a distant image in front of the retina.
   b. They can wear corrective concave lenses to refocus the image on the retina.
   c. **Radial keratotomy** is a new treatment that surgically cuts and flattens the cornea.

11. Persons who can see far away but not up close are **farsighted**.
    a. They often have a shortened eyeball that focuses near images behind retina.
    b. They can wear corrective convex lenses to refocus the image on retina.
12. When the cornea or lens is uneven, the image is fuzzy; this is **astigmatism** corrected by an unevenly ground lens to compensate for unevenness.

E. Photoreceptors of the Eye
1. Vision begins when light has been focused on photoreceptors in the retina.
2. Rods and cones have an outer segment joined to an inner segment by a stalk.
3. The outer segment contains stacks of membranous disks (lamellae) with many molecules of **rhodopsin**.
4. The rhodopsin molecules contain a protein **opsin** and the pigment molecule **retinal** derived from Vitamin A.
5. When a rod absorbs light, rhodopsin splits into opsin and retinal, leading to a cascade of reactions and the closure of ion channels in the rod cell plasma membrane.
6. This stops the release of inhibitory molecules from the rod's synaptic vesicles and starts signals that result in impulses to brain.
7. The rods are stimulated by low light and provide night vision.
8. Because rods are distributed throughout the retina, rods detect our peripheral vision and motion but not color or detail.
9. Cones located primarily in the **fovea centralis** are activated by bright light and detect detail and color.
10. The three kinds of cones contain either blue, green, or red pigment.
11. Each pigment is composed of retinal and opsin, but the structure of opsin varies among the three.
12. Combinations of cones are stimulated by intermediate colors; the combined nerve impulses are interpreted in the brain as one of 17,000 hues.

F. Integration of Visual Signals in the Retina
1. The retina has three layers of neurons.
    a. The rods and cones are nearest the choroid.
    b. Bipolar cells form the middle layer.
    c. Ganglion cells, whose fibers become the optic nerve, form the innermost layer.
2. Since only rod and cone cells are sensitive to light, light must penetrate through the ganglion cells.
3. Rods and cones synapse with **bipolar cells** which pass the impulse to **ganglionic cells**.
4. There are more rods and cones than nerve fibers leaving ganglionic cells.
5. Up to 100 rods synapse with a ganglion cell; this results in indistinct vision.
6. Each cone synapses with one ganglionic cell; this accounts for the detailed images of cones, mostly found in the fovea.
7. Integration occurs as signals pass from the bipolar to the ganglion cells.
    a. If all rod cells in a receptive field are stimulated, the ganglion cell is weakly stimulated or neutral.
    b. If only the center is lit, it is stimulated; if only the edge is lit, it is inhibited.
    c. Therefore considerable processing occurs in the retina before an impulse is sent to the brain.
8. The **blind spot** is an area where the optic nerve passes through the retina; it lacks rods and cones.

40.3 Sense of Hearing and Balance

A. Anatomy of the Ear
1. The human ear has three divisions: an outer, middle, and inner ear.
2. The **outer ear** consists of the **pinna** (external flap) and the **auditory canal**.
    a. The **auditory canal** opening is lined by fine hairs that filter air.
    b. Modified sweat glands in the auditory canal secrete earwax to guard against foreign matter.
3. The **middle ear** begins at the **tympanic membrane** and ends at a bony wall with membrane-covered openings (the **oval window** and **round window**).
    a. It contains small bones called **ossicles**: malleus (hammer), incus (anvil), and stapes (stirrup).
    b. The malleus adheres to the tympanum; the stapes touches the oval window.
    c. The **auditory (eustachian) tube** extends from the middle ear to the pharynx to equalize the inside and outside air.
4. The **inner ear** has three regions: the semicircular canals, vestibule, and cochlea.
5. The **cochlea** resembles a snail shell because it spirals.

B. Process of Hearing
   1. The process of hearing begins when sound waves enter the auditory canal, causing the ossicles to vibrate.
   2. Sound is amplified about 20 times by the size difference between the tympanic membrane and the oval window.
   3. The stapes strikes the membrane of the oval window, passing pressure waves to the fluid in the cochlea.
   4. Three canals are located within cochlea: **vestibular canal**, **cochlear canal**, and **tympanic canal**.
   5. The vestibular canal connects with the tympanic canal, which leads to the oval window membrane.
   6. Along the basilar membrane are hair cells whose stereocilia are embedded in a tectorial membrane.
   7. The hair cells of the spiral organ (**organ of Corti**) synapse with nerve fibers of the cochlear (auditory) nerve.
   8. When the stapes strikes the membrane of the oval window, pressure waves move from the vestibular canal to the tympanic canal and across the basilar membrane, and the round window bulges.
   9. The basilar membrane vibrates up and down bending the stereocilia of hair cells embedded in the tectorial membrane.
   10. This generates nerve impulses in the cochlear nerve that travel to the brain stem.
   11. When they reach the auditory areas of the cerebral cortex, this is interpreted as sound.
   12. The spiral organ is narrow at its base and widens at its tip; each part is sensitive to different pitches.
   13. Nerve fibers from each region (high pitch base or low pitch tip) lead to slightly different regions of the brain, producing the sensation of pitch.
   14. Sound volume is caused by more vibration; the increased stimulation is interpreted as louder sound intensity.
   15. Tone is an interpretation by the brain based on the distribution of the hair cells stimulated.

C. Sense of Balance
   1. The sense of balance is divided into:
      a. **rotational equilibrium** (angular or rotational movement of the head), and
      b. **gravitational equilibrium** (vertical or horizontal movement).
   2. Rotational equilibrium utilizes the semicircular canals.
      a. The **semicircular canals** are oriented at right angles to one another in three different planes.
      b. The enlarged base of each semicircular canal is called an **ampulla**.
      c. Fluid flowing over and displacing a cupula causes the stereocilia of the hair cells to bend; the pattern of impulses carried by the vestibular nerve to the brain changes.
      d. Continuous movement of the fluid in the semicircular canals causes **vertigo** motion sickness.
      e. By spinning and stopping, we see a room still spin; this indicates that vision is also involved in balance.
   3. Static equilibrium utilizes the utricle and saccule.
      a. A **vestibule** or space between the semicircular canals and the cochlea contains the **utricle** and the **saccule**.
      b. The **utricle** and **saccule** are small membranous sacs, each of which contains hair cells.
      c. Hair cell stereocilia are embedded within a gelatinous material called the otolithic membrane.
      d. Calcium carbonate granules (**otoliths**) rest on this membrane.
      e. The utricle is sensitive to horizontal movements; the saccule responds best to up-down movements.
      f. When a body is still, otoliths in the utricle and saccule rest on the otolithic membrane above the hair cells.
      g. As the head bends or the body moves, otoliths are displaced and the otolithic membrane sags, bending the larger stereocilia (kinocillium) of hair cells beneath; this tells brain the direction of movement.

D. Sensory Receptors in Other Animals
   1. The lateral line system of fish and amphibians detects water currents and pressure waves.
   2. Primitive fishes have the system on surface; advanced fishes enclose it in a canal on the side.
   3. The lateral line receptor is a collection of hair cells with cilia embedded in a mass of gelatinous material (cupula).

4. Static equilibrium organs called statocysts are found in cnidaria, molluscs, and crustacea.
5. A small particle called a statolith stimulates cilia that generate impulses, indicating the position of the head.