Sensory System

LEARNING OBJECTIVES

- Define at least 10 terms relating to the sensory system.
- Describe the function of the sensory system.
- Identify at least 10 sensory system structures and the function of each.
- Identify at least three methods of assessment of the sensory system.
- Describe at least five disorders of the sensory system.

KEY TERMS

- Accommodation (ah-kom-uh-DAY-shun) Focusing of the eye for varied distances
- Auditory (AW-dih-tore-ee) Pertaining to the sense of hearing
- Converge (kon-VERJ) When two eyes move in a coordinated fashion toward fixation on the same near point
- Cutaneous (KYOO-TAY-nees) Pertaining to the skin
- Equilibrium (ee-kwih-LIB-ree-um) State of balance
- Gustatory (GUS-tuh-tore-ee) Pertaining to the sense of taste
- Intraocular (ihn-truh-OK-yoo-lar) Within the eye
- Labyrinth (LAB-ihr-rinth) System of communicating canals in the inner ear
- Olfactory (OL-fee-fak-tore-ee) Pertaining to the sense of smell
- Receptor (ree-SEP-tor) Specific type of cell that responds to a specific stimulus
- Refraction (ree-FRAK-shun) Deviation of light when passing through a medium to another medium of a different density
- Stimulus (STIM-yoo-lus) Any agent that produces a reaction in a receptor
- Vision (VIZ-ee-un) Act or faculty of seeing; sight
**Structure and Function of the Sensory System**

The sensory system consists of receptors in specialized cells and organs that perceive changes (stimuli) in the internal and external environment. The stimuli cause nerve impulses that are sent to the brain for interpretation. Environmental stimuli are perceived with the senses of vision, hearing, touch, taste, position, and balance. Specialized organs of the senses include the eye, ear, tongue, nose, and skin.

**Abbreviations of the Sensory System**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>aq</td>
<td>Aqueous</td>
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<tr>
<td>EENT</td>
<td>Ears, eyes, nose, throat</td>
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<td>o.d.</td>
<td>Right eye</td>
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<tr>
<td>oint</td>
<td>Ointment</td>
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<td>Ophth</td>
<td>Ophthalmology</td>
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<td>o.s.</td>
<td>Left eye</td>
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<td>o.u.</td>
<td>Both eyes</td>
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<td>PERLA</td>
<td>Pupils equally reactive to light</td>
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<td>REM</td>
<td>Rapid eye movement</td>
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<td>RK</td>
<td>Radial keratotomy</td>
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**BRAIN BYTE**

Most people blink every 2 to 10 seconds.

The internal structures of the eye are also shown in Fig. 20-1. The sclera is a tough, white tissue that supports and gives structure to the eye. The sclera is continuous with the transparent cornea that covers the iris and pupil. The cornea focuses light rays on the retina at the back of the eye. The blood supply for the eye originates in the choroid, iris, and ciliary muscles.

**BRAIN BYTE**

Some scientists believe there are nine senses instead of five. They include four internal senses: pain, balance, thirst, and hunger.

The iris and ciliary muscles are the intrinsic muscles of the eye.

The eyeball is not solid but is divided into sections, the anterior and posterior cavities. The anterior cavity is filled with a clear watery fluid called aqueous humor. The posterior cavity is filled with a semifluid gelatin-like substance called vitreous humor. Both the aqueous and vitreous humor help maintain the shape of the eye.

The opening called the pupil is in the choroid layer. The iris is a round, colored muscle that surrounds the pupil. The iris contracts and relaxes to adjust the amount of light entering the eye through the pupil. The lens is a convex, transparent tissue located directly behind the pupil that focuses and directs incoming light on the retina of the eye. The amount of light admitted into the eye is regulated by the movement of the iris.

Vision is similar to the action of a camera, beginning with refraction, the process of the lens bending light rays as they enter the eye to focus on the retina (Fig. 20-2). The eye changes the shape of the lens to focus near and far through the process of accommodation. The pupil constricts to focus the object on the retina and protect it from receiving too much light. The eyes converge on the object so that single binocular vision occurs and only one object is seen.

Specialized cells called rods and cones in the retina absorb the light. The retina of each eye contains 100 million rods and 7 million cones. Rods are sensitive to dim light. Cones react to bright light and allow color distinction through three types of pigments that are
sensitive to different wavelengths of light. The three photopigments recognize the colors: green, red, and blue. The impulses released by the pigments in the rods and cones are transmitted to the brain by the optic nerve.

**Ear**

The auditory or acoustic sense (hearing) is the primary function of the ear. A second function of the ear is to help maintain equilibrium. The ear has three parts, called the external, middle, and inner ear (Fig. 20-3).

The external ear channels the incoming sound waves or vibrations. The auricle or pinna is the flap of tissue on the side of the head that collects and transmits sound waves through the canal to the eardrum (tympanic membrane). Specialized glands in the ear canal produce earwax (cerumen) that protects the middle ear from entry of foreign particles.

The middle ear is an air-filled chamber that begins with the tympanic membrane, which changes sound waves into mechanical movements. Auditory bones (ossicles) transmit the sound vibrations. These three bones are called the **hammer (malleus)**, **anvil (incus)**, and **stirrup (stapes)**. The ossicles amplify and transmit the sound to the inner ear. Two openings into the inner ear are the membrane-covered round window and the oval window, which touches the stapes. Another opening between the middle ear and pharynx is the **eustachian tube**. The eustachian tube has two main functions. It allows the pressure of air in the middle ear to be equalized with the air pressure of the environment. Additionally, fluids and mucus from the middle ear are drained to the nasopharynx. Swallowing and yawning open the eustachian tube for these purposes.

The inner ear contains a series of canals called the **bony labyrinth**, which includes the cochlea, semicircular canals, and vestibule with the membranous labyrinth inside it. The movement of fluid and hair cells lining the cochlea converts the mechanical vibrations from the ossicles to neural impulses. Each ear contains 16,000 hair cells. Each hair cell has 100 stereocilia or bristles that transmit impulses to the auditory cranial nerves. The semicircular canals contain a clear fluid called **endolymph** that gives a sense of balance when the body is in motion. Two chambers called the **scala and utricle of the vestibule** maintain static or resting equilibrium.

Hearing is a result of interpretation of sound waves. Sound waves are described by their amplitude (volume) and pitch (frequency). A sound is perceived when the tympanic membrane is vibrated or the hairs in the cochlea are stimulated. Sound waves may be transmitted through the air, bone, or fluid.

**Tongue**

Taste, or the **gustatory** sense, is perceived by specialized cells located in projections (papillae) on the tongue called **taste buds**. Taste buds are chemoreceptors. The five tastes perceived by the tongue are: **sweet**, **sour**, **bitter**, **salty**, and **umami** (Fig. 20-4). Umami, described as "meatiness," is a response to glutamic acid found in processed meats, cheese, and many Asian foods. Each taste bud has 50 to 300 taste cells. These cells respond to all five types of taste. All areas of the tongue sense all five of the tastes. As more research is completed, new "tastes" may be identified. It is possible that "metallic" is also a primary taste. Before a taste can be sensed, the substance must be dissolved in fluid or saliva. The particular flavor of an item is identified by smell as well as taste.

**Nose**

The olfactory sense, or smell, originates in olfactory receptor cells in the nose that immediately transmit impulses to the brain through the olfactory cranial nerves (Fig. 20-5). The nasal cavity is divided into two sections by the septum. Each side of the nose is further divided into three passageways by bony projections called turbinates. Specialized epithelial tissue near the roof of the nasal cavity contains the olfactory cells. Olfactory receptor neurons are stimulated by chemicals (gases) in the air. When the receptor cells reach a threshold, the olfactory bulb reacts and an impulse is transmitted to the brain. Air that is inhaled also circulates into the paranasal sinuses surrounding the nasal cavity.

The sense of smell is 10,000 times more sensitive than taste. More than 5000 distinct smells can be perceived. However, these smells result from a mixture of only 30 primary or "pure" odors. Some examples of primary odors include floral, putrid, and peppermint. Smells can reduce stress, affect blood pressure, recall memories, and aid in the sense of taste.

**Skin**

The cutaneous senses of the skin perceive touch, pressure, temperature, and pain through five specialized
**Assessment Techniques**

**Sight**

Inner structures of the eye are examined by using an ophthalmoscope (Fig. 20-7). The pupils are usually dilated to allow better visualization.

Visual acuity is assessed with a Snellen chart that shows letters or shapes identified from a distance. Normal vision (emmetropia) is 20/20 vision. This measurement indicates that a character of the designated size can be identified from a distance of 20 feet. A measurement of 20/100 would indicate that a person with normal vision would be able to identify the character at 100 feet, but the person being tested can identify it at 20 feet. A measurement of 20/200 is considered legal blindness. Near vision may be tested with a Jaeger chart. Defective visual acuity can be corrected with eyeglasses or contact lenses.

Pressure of the inner eye, or *intraocular* pressure, is measured by using a tonometer, which can detect glaucoma. It measures the force necessary to indent the cornea with a plunger. The pressure is usually 13 to 19 mm Hg.

A "slit-lamp" is used to view the anterior eye for scratches or deformities. The eye is viewed through a binocular microscope, on which the patient rests the chin to prevent movement of the eyes.

The visual field, or space in which a person can see peripherally, is measured as the patient indicates that flashing pinpoint spots of light in the peripheral field are viewed while concentrating on a central point.

**Hearing**

The instrument used to view the structures of the ear is called an otoscope. Hearing ability can be measured by using an audiometer that emits specific sounds of varied intensity and frequency through the air. Hearing ability may also be assessed by using...
a vibrator on the mastoid process to measure bone conduction of sound waves. Normal hearing is in the range of 10 to 100 dB. Defective hearing can be corrected in some cases with a hearing aid that amplifies the sound (Fig. 20-9). Impedance testing emits sound directly into the ear canal to measure the flexibility of the tympanic membrane. The Rinne test uses a tuning fork to assess transmission of sound through the ear structures. Weber’s test uses a tuning fork to test for unilateral or one-sided hearing loss.

**DISORDERS OF THE Sensory System**

**Anchotomy (ah-KRO-mah-tism), also called color blindness, is a common inherited defect. Monochromatism is complete color blindness in which only grays are seen. Color blindness results from a recessive gene located on the X chromosome. It results when one or more of the three photopigments that assess color is defective. A person affected by monochromatism sees the color but cannot interpret it correctly. Green color blindness is most common; red is the second most common. Red-green color blindness is also possible. Blue color blindness is uncommon. There is no treatment for color blindness, although the person must learn to make adjustments for it. For example, the type of traffic signal at an intersection may be determined by placement of the lights rather than the color.**

**CASE STUDY 20-3** Your friend says that her aunt is color blind but that she has been told that is not possible because only males can be color blind. What should you say?

**Answers to Case Studies are available on the Evolve website: http://evolve.elsevier.com/Geradin**

**Figure 20-10** Cataracts cause blurred or partial vision. (From Patton KT, Thibodeau GA: Anatomy & physiology, ed 7, St. Louis, 2010, Mosby.)

**Aphthous (ah-thoe-OH-peoh-uhl), also called “fairy eye,” is poor vision in one eye often resulting from better vision in the other eye during infancy or early childhood. Exercises, corrective lenses, patching of the eye that has better vision, and surgery to shorten muscles around the eye may be used for treatment in young children. After 6 to 9 years of age, the development of the visual system is complete and the condition cannot be corrected.**

**Anesthesia (ah-an-thes-oh-sis), or hearing loss, can be either perceptual or conductive. Perceptual (a-sem-to-reh-NOH-ral) hearing (perceptive) loss results from damage to neural tissues. Central nervous system tissue does not repair, so this type of hearing loss cannot be corrected. Transmission hearing loss (conductive) may result from otosclerosis (ote- skle-RO-sis). Hearing loss may also result from infection or trauma to ear structures. Treatment of conductive hearing loss may include surgery or use of hearing aids.**

**Agnosia (ah-NOH-zhuh) is a congenital defect of the eyeball that may increase with age. Imperfect curvature of the cornea results in blurred vision. Treatment is use of corrective lenses.**

**Cataract (kat-ar-ahl) is a clouding of the lens that causes blurred or partial vision (Fig. 20-11). The cause is unknown. Cataracts are not contagious and, if treated, do not cause permanent blindness. If untreated, cataracts may cause blindness. Some research indicates that antioxidants taken in food or supplements help to prevent cataracts from occurring.**

**Cataracts can be corrected by surgical replacement of the cloudy lens.**

**Cochlear implant (KOH-ker-ahm PLANT) is a common condition of damaged blood vessels in the retina caused by uncontrolled diabetes mellitus. Visual loss results. According to the American Diabetes Association, diabetes is the leading cause of blindness in people 20 to 74 years of age. The person may not notice the symptoms until the damage is so severe that it causes perceptible loss of vision. Treatment may not be necessary or may include laser surgery. The most important treatment is to control the diabetic condition to prevent damage.**

**Figure 20-11** Cochlear implant. (Courtesy of Stephanie Freese, artist, and American Scientist, The Magazine of Sigma Xi, The Scientific Research Society. In Gould BE, Dyer RI: Pathophysiology for the health professions, ed 4, St. Louis, 2011, Saunders.)
Diplopia (dih-PLO-pee-uh), or double vision, results from muscle imbalance or paralysis of an extracocular muscle. It may also result from a problem with the sixth cranial nerve. Treatment of diplopia is to correct the cause.

Epistaxis (ep-ih-STAK-sis), or nosebleed, may result from disease, trauma, or other conditions such as hypertension, leukemia, or rheumatic fever. Most nosebleeds can be controlled easily with pressure at the base of the nose and application of cold. Application of heat (cautery) may be used to seal bleeding vessels.

Glaucoma (glaw-KO-muh) is a relatively common eye disorder in people older than 35 years of age. Glaucoma results from an increase in the pressure inside the eye, caused by trauma or hereditary factors. The increased intraocular pressure can damage the optic disc and optic nerve and cause “tunnel” vision. A person with glaucoma may feel pain or no symptoms at all until damage occurs. Glaucoma can be controlled with medication that decreases the pressure.

Hyperopia (hi-per-O-pee-uh), or farsightedness, results from a congenital deformity in the eye. The condition is treated with corrective lenses. In some cases, hyperopia may be surgically corrected.

Macular degeneration is the leading cause of blindness in people 65 and older. Macular degeneration results in a slow or sudden painless loss of central vision. The first symptom may be visual distortion from one eye. Recent research indicates that high doses of antioxidant vitamins and zinc may slow vision loss. Treatment may include laser surgery.

Meninge (men-er-EER) disease is a collection of fluid in the labyrinth of the ear leading to dizziness (vertigo), ringing in the ear or tinnitus (thin-ih-tus), pressure, and eventual deafness. The cause is unknown. Treatment includes medication, drainage of the fluid, or surgery.

Myopia (my-O-pee-uh), or nearsightedness, results from a congenital deformity in the eye. Treatment is corrective lenses. Procedures that may be used to correct vision by changing the shape of the eye include radial keratotomy (kare-ih-TOT-o-mee), photoablation keratotomy, and laser (LASK) treatment. It is also possible to implant corrective lenses in the eyes in some cases.

Night blindness, or poor vision in dim light, results from a deficiency in the rods of the retina. This may be caused by insufficient vitamin A, cataracts, a birth defect, or inflammation of the retina. Treatment may include supplementation of the diet with vitamin A.

Otitis media (o-TIE-muh) is a middle ear bacterial or viral infection common in young children (Fig. 20-12). It often appears in conjunction with a throat infection. The person feels pressure or pain in the ear. Otitis media may lead to hearing loss. Treatment includes antibiotics to cure the illness and may include myringotomy (mee-ing-RING-toh-mee), which is the insertion of tubes to relieve pressure and fluid from the middle ear.

Presbyopia (pre-BEE-oh-pee-uh) is a type of farsightedness related to aging. The eye becomes less elastic, and the fluid in the eye decreases. This can usually be treated effectively with corrective lenses. Other changes in the fluid may result in small clumps in the vitreous humor called floaters or flashes of light in the field of vision. These are not usually serious but should be monitored by periodic eye examination.

Retinal detachment (RD) may be due to injury or uncontrolled diabetes mellitus. It may occur gradually, or it may be a medical emergency requiring immediate surgery. The person with a detached retina may experience a sudden appearance of light with eventual loss of visual field. Retinal detachment may be corrected with laser surgery or cryopexy (freezing) that forms scar tissue that holds the retina in place. The most common treatment is scleral buckle. With this treatment, a sponge or band is attached to the sclera to hold the retina in place.

Rhinitis (rih-NITE-sis) is inflammation of the lining of the nose caused by allergic reaction, viral infection, sinusitis, or chemical irritants. Symptoms include drainage of nasal fluids, tears, and sneezing. Treatment depends on the cause and includes medication. Seasonal rhinitis (hay fever) may be caused by pollen in the air.

Ruptured cardiom may result from infection, an explosion, a blow to the head, or a sharp object inserted into the ear. The person experiences a slight pain and discharge from the ear. Healing usually occurs quickly. Scar tissue can form and result in hearing loss if the condition is chronic.

Sinusitis (sih-nus-L-TIS) is a chronic or acute inflammation of the cavities of the cranium. Sinusitis is usually caused by the spread of infection from the nasal passages to the sinuses or by nasal obstructions, which block the normal sinus drainage. The infected person experiences nasal discharge, sneezing, swelling below the eyes, and headache. Treatment may include medications or, in severe chronic cases, may require surgical correction of deformities.

Strabismus (strah-BIZ-mus) is a condition in which both eyes do not focus on the same point or direction. Strabismus may be caused by brain injury, a tumor, or infection, but it is often the result of amblyopia. It may also be an inherited condition in which both eyes cannot be fixed on an object at the same time. Esotropia (es-oh-TRO-pee-uh), or "crossed eyes," is the condition in which the muscles pull the eyes inward. Exotropia (ek-wah-TRO-pee-uh) is the condition in which the muscles pull the eyes outward. Strabismus can be treated with eye exercises, patching, and corrective lenses. Surgery may be performed to correct the extracranial eye muscles.

A sty (stye) is caused by bacterial infection of the sebaceous glands of the eyelid. The sty contains pus and usually drains in 3 or 4 days. The person experiences pain, redness, and swelling. Treatment includes hot compresses, sometimes incision to drain the sty, and antibiotics.

**Issues and Innovations**

**Visual Correction by Surgery**

Radial keratotomy has been a popular microscopic surgery that makes eight incisions into the cornea of the eye. These incisions cause a flattening of the cornea that corrects the refraction error causing myopia, or nearsightedness. The angle and depth of the cuts are calculated by computer and performed by an ophthalmologist. A 10-year study concluded in 1994 by the U.S. National Eye Institute reported that the procedure was successful in two-thirds of cases. However, it also reported that 43% of those who had surgery later developed farsightedness.
Another surgical procedure is called straboplasty. This procedure involves freezing a donor cornea and then cutting it like a contact lens. A prescription correction can be provided with the cornea. The cornea is surgically implanted in the eye. In 4 to 6 months, the eye tissue attaches to the donor cornea, and improved visual acuity results. The procedure has been used successfully to correct myopia, hyperopia, and cataract disorders.

Intacs are intracorneal rings that can be implanted to the cornea to reshape it to repair myopia. This procedure is reversible with removal of the inserts. Intacs are made of the same plastic used in contact lenses. PRELEX is an intraocular lens implant that replaces the lens with a new one. This technique has been used to correct presbyopia, as well as hyperopia and myopia.

In 1995 the Food and Drug Administration approved a computer-controlled laser surgery for vision repair called photorefractive keratectomy. This surgery resheses the cornea by shaving small pieces from the surface. It can be used to correct either nearsightedness or farsightedness. The cornea is reshaped as pieces of the cornea are removed by the laser. The main benefit of this procedure is that it does not weaken the cornea as might occur in radial keratotomy. Other laser surgeries include laser in situ keratomileusis (LASIK) and laser thermal keratoplasty.

Noise Pollution

Noise in the environment can damage the nerve endings and cells in the inner ear. The ossicles of the ear amplify incoming sound 25 times before it reaches the inner ear. Hearing loss in industrial settings with strong noise pollution has been documented and has led to legislation to lower noise levels.

Loud music can also damage the cells in the inner ear. Once damaged, these cells cannot be repaired and the hearing loss is permanent. Environmental studies indicate that protection of the ears is necessary with sound greater than 85 dB. Exposure to 2 hours of noise at 100 dB is known to cause some degree of permanent hearing loss. Even portable stereos with earphones can produce sound as loud as 115 dB.

Most people do not notice hearing loss until they cannot understand normal speech or they develop ringing in the ear (tinnitus). A sensation of fullness or buzzing in the ear after a concert or similar exposure to a loud noise indicates that damage has been done to the hair cells in the inner ear. This is called a “temporary threshold shift.” In some cases, the hair cells may repair, but repeated exposure leads to permanent hearing loss.

The volume of music is too high if it causes a ringing sensation or headache. It is too loud if a normal conversation cannot be heard. Because the ringer is in the earpiece, some cordless telephones have also been found to cause permanent damage to hearing when placed near the ear as it is ringing. Electronic noise-canceling devices are used in head-phones worn by airline pilots and can be purchased by the public. In 2006 Apple Computers developed an iPod software program to limit the maximum volume level because of concern about the damage of the noise while using ear buds. Chapter 34 provides more information regarding the environmental hazards of noise pollution.

Studies have confirmed that even casual use of cellular phones can damage the DNA in sensitive areas of the brain. Dr. Henry Lai of the University of Washington conducted a study that indicates that even low-level exposure to radiofrequency electromagnetic fields and radio frequencies can cause DNA damage to brain cells of rats, resulting in loss of short and long-term memory and slower learning. He also concluded that the damage is cumulative. Research has provided extensive information on biological responses to power-frequency electrical and magnetic fields. A strong link to development of cancer or other health problems due to electromagnetic frequency exposure has not been established. In 2009 the National Cancer Institute reported that research has not consistently linked cell phone use and cancer but suggested further study before drawing conclusions about the effect.

### Summary

- The function of the sensory system is to perceive changes in the internal and external environment with specialized receptors.
- Sensory system structures include the eye, ear, tongue, nose, and skin.

### Review Questions

1. Describe the function of each of the five sensory organs.
2. Describe the location and function of each of the following parts of the sensory system: corpora of Ruffini, optic nerve, cribriform plate, pupillary receptors.
3. Describe three methods of assessment of the sensory system function.
4. Describe the method by which radial keratotomy changes the vision of the eye.
5. Describe how hearing is damaged by noise.
6. Use the following terms in one or more sentences that correctly relate their meaning: accommodation, intraocular, receptor, stimulus, and vision.

### Critical Thinking

1. Investigate and compare the cost of at least three tests used in diagnosing disorders of the sensory system.
2. Investigate the function of at least five common medications used in treatment of sensory system disorders.
3. List at least five occupations involved in the health care of sensory system disorders.
4. Investigate the current surgical techniques for correction of eye disorders with the use of laser technology.
5. Use the Internet to research and describe the styles and cost of hearing aids.

### Explore the Web

**Deaf Culture**

- National Association of the Deaf
  - http://www.nad.org/
- PBS—Sound and Fury
- Alexander Graham Bell Association for the Deaf and Hard of Hearing

**Noise Pollution**

- Noise Pollution Clearinghouse (NPC)
  - http://www.noise.gov/
- Environmental Protection Agency (EPA)
  - http://www.epa.gov/air/noise.html

**Electromagnetic Fields**

- Centers for Disease Control and Prevention
  - http://www.cdc.gov/hota/topics/EMF/
- National Institute of Health—INTERPHONE Study
- National Institutes of Health—National Cancer Institute