chapter 13

Sensory System

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Key Terms

chemoreceptors (p. 231)
cochlea (p. 250)
cornea (p. 241)
equilibrium (p. 236)
eustachian tube (p. 249)
mechanoreceptors (p. 231)
olfactory receptors (p. 236)
optic chiasm (p. 247)
ossicles (p. 248)
pain receptors (p. 231)
photoreceptors (p. 231)
proprioception (p. 236)
referred pain (p. 234)
refraction (p. 245)
retina (p. 241)
sclera (p. 241)
thermoreceptors (p. 231)
vestibule (p. 251)

Objectives

1. State the functions of the sensory system.
2. Define the five types of sensory receptors.
3. Describe the four components involved in the perception of a sensation and two important characteristics of sensation.
4. Describe the five general senses.
5. Describe the special senses of smell and taste.
6. Describe the sense of sight, including:
   - Describe the structure of the eye.
   - Explain the movement of the eyes.
   - Describe how the size of the pupils changes.
7. Describe the sense of hearing, including:
   - Describe the three divisions of the ear.
   - Describe the functions of the parts of the ear involved in hearing.
   - Explain the role of the ear in maintaining the body's equilibrium.

The sensory system allows us to experience the world. Senses let you see the trees, hear the voices of your friends and family, feel the heat of the sun, and taste your favorite foods. When the external environment becomes threatening, the sensory system also acts as a warning system. For example, if you place your hand on a hot surface, the sensory system experiences the episode as pain. The pain is a danger signal indicating that the body must make an adjustment to remove the harmful stimulus.

In addition to sensing outside information, the sensory system also allows us to keep track of what is happening within our bodies. For example, when the stomach fills with food, sensory information is carried to the central nervous system (CNS). In response to this information, the stomach is told to digest the food.

RECEPTORS AND SENSATION

CELLS THAT DETECT STIMULI

Sensory neurons transmit information to the CNS (Table 13-1). A receptor is a specialized area of a sensory neuron that detects a specific stimulus. For example, the receptors in the eye respond to light, whereas the receptors on the tongue respond to chemicals in food. The five types of sensory receptors are as follows:

- **Chemoreceptors** (kee-moh-ree-SEP-tors): Receptors stimulated by changes in the chemicals such as hydrogen ion (H^+), calcium, and food
- **Pain receptors**, or nociceptors (noh-see-SEP-tors): Receptors stimulated by tissue damage or distention
- **Thermoreceptors**: Receptors stimulated by changes in temperature
- **Mechanoreceptors**: Receptors stimulated by changes in pressure or movements of body fluids
- **Photoreceptors**: Receptors stimulated by light

WHAT SENSATION IS

A sensation is the conscious awareness of incoming sensory information. Yelling "Ouch," for example, indicates that you have become aware of a painful stimulus.

EXPERIENCING A SENSATION

FOUR COMPONENTS

Four components are involved in the perception of a sensation. Using the sense of sight as an example, these

Table 13-1 Types of Sensory Receptors

RECEPTOR	STIMULUS	EXAMPLE
Chemoreceptors	Changes in chemical concentrations of substances	Taste and smell
Pain receptors (nociceptors)	Tissue damage	Pain
Thermoreceptors	Changes in temperature	Heat and cold
Mechanoreceptors	Changes in pressure or movement of fluids	Hearing and equilibrium
Photoreceptors	Light energy	Sight

four components are illustrated in Figure 13-1 and described as follows:

- *Stimulus:* Light is the stimulus for the sense of sight. In the absence of light, you cannot see.
- *Receptor:* Light waves stimulate the photoreceptors in the eye, producing a nerve impulse.
- *Sensory nerve:* The nerve impulse is conducted by a sensory nerve (optic nerve) to the occipital lobe of the brain.
- *Special area of the brain:* The sensory information is interpreted as sight in the occipital lobe of the brain. This is an important point; the sensation is experienced by the brain and not by the sensory receptor. For example, you see an object, hear a voice, or feel pain because the sensory information has stimulated a part of the brain.

As you study each sensation, identify the stimulus, type of receptor, name of the sensory nerve, and specific area of the brain that interprets the sensation.

TWO CHARACTERISTICS OF SENSATION

Two important characteristics of sensation are projection and adaptation. Projection describes the process whereby the brain, after receiving a sensation, refers that sensation back to its source. You see with your eyes, hear with your ears, and feel pain in your injured finger because the cortex of your brain receives the sensation and projects it back to its source. Projection answers the question, "If pain is experienced by the brain, why does my injured finger hurt?" (Figure 13-2, *A*).

The experience of "phantom limb pain" is another example of projection. If a leg is amputated, the person may still feel pain in the amputated leg (see Figure 13-2, *B*). The missing leg often throbs with pain. What is the cause of phantom limb sensation? The severed nerve endings of the amputated leg continue to send sensory information to the parietal lobe of the brain. The brain interprets the information as pain and

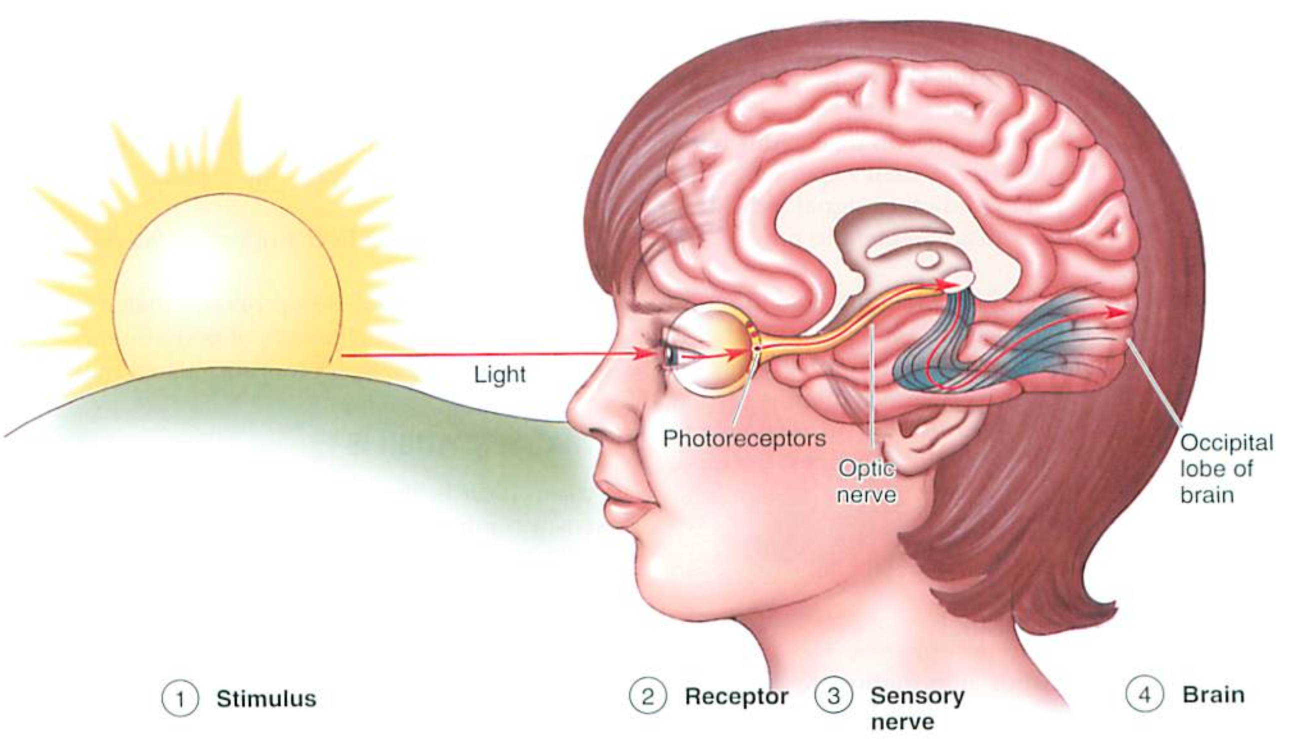


FIGURE 13-1 Four components of sensation.

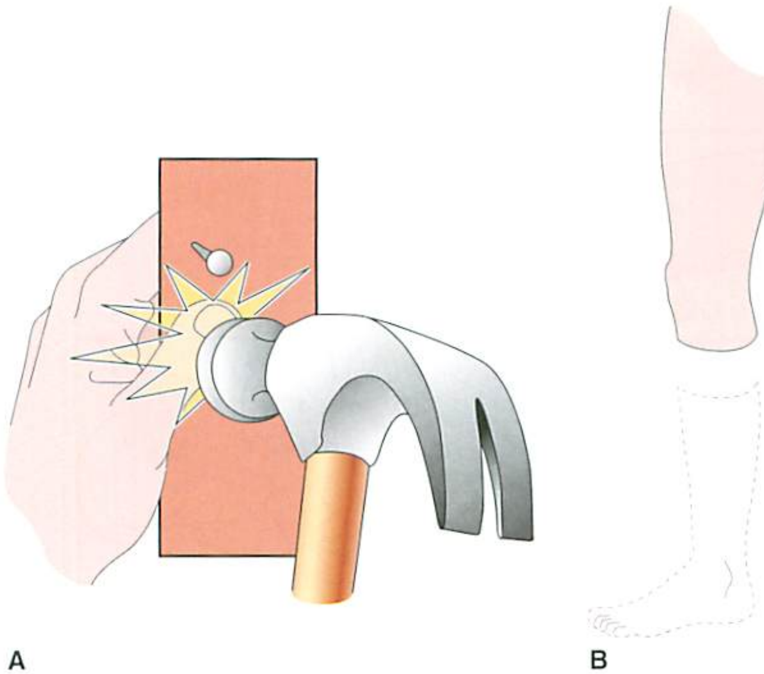


FIGURE 13-2 **A,** Projection . . . ouch! **B,** Phantom limb. The *dashed line* represents the amputated part.

projects the feeling back to the leg area. For most amputees, the phantom limb pain diminishes as the severed nerves heal, but the person often experiences a phantom limb presence. The amputated leg still feels as though it is attached. There is some good news about phantom limb sensation—the sensation often "locates" the amputated limb and helps a patient learn to use an artificial limb.

Sensory adaptation is another characteristic of sensation; it is illustrated by the sense of smell. When you enter a room with a strong odor, the odor at first seems overwhelming. After a short time, however, the odor becomes less noticeable. The sensory receptors in the nose have adapted. When continuously stimulated, these receptors send fewer signals to the area of the brain that interprets sensory information as smell.

Receptors vary in their ability to adapt. Pain receptors do not adapt, whereas the receptors for the smell adapt rapidly. Generally, receptors that regulate homeostatic mechanisms adapt very slowly or not at all.

There are two groups of senses: general and special senses. General senses are called *general,* or *somatic,* because their receptors are widely distributed throughout the body. The special senses are localized within a particular organ in the head. The special senses include taste, smell, sight, hearing, and balance.

? Re-Think

1. Predict what would happen to the sense of sight if the optic nerve were severed (cut)?
2. Define *projection* and *adaptation*.

THE GENERAL SENSES

General senses include pain, touch, pressure, temperature, and proprioception (Figure 13-3). Receptors for the general senses are widely distributed and are found in the skin, muscles, joints, and viscera.

PAIN

The receptors for pain, called *nociceptors,* consist of free nerve endings that are stimulated by tissue damage. Pain receptors do not adapt and may continue to send signals after the stimulus is removed. Pain receptors are widely distributed throughout the skin, the visceral organs, and other internal tissues. Oddly enough, the nervous tissue of the brain lacks pain receptors; there is no pain in the brain. Tissues surrounding the brain, like the meninges and the blood vessels, however, do contain pain receptors. You can feel a headache.

Pain serves a protective function. Being unpleasant, pain motivates the person to remove its cause. The failure of the pain receptors to adapt is also protective. For example, if a person complains of right lower quadrant (RLQ) abdominal pain, the pain is used as a valuable clue about what is wrong. In this example, the pain is indicative of acute appendicitis, requiring an appendectomy (surgical removal of the appendix). Once the diagnosis is made, the pain is treated. If the physician merely relieved the pain, surgical intervention might have been delayed, resulting in a ruptured appendix and life-threatening peritonitis. Although unpleasant and undesirable, pain serves the body well.

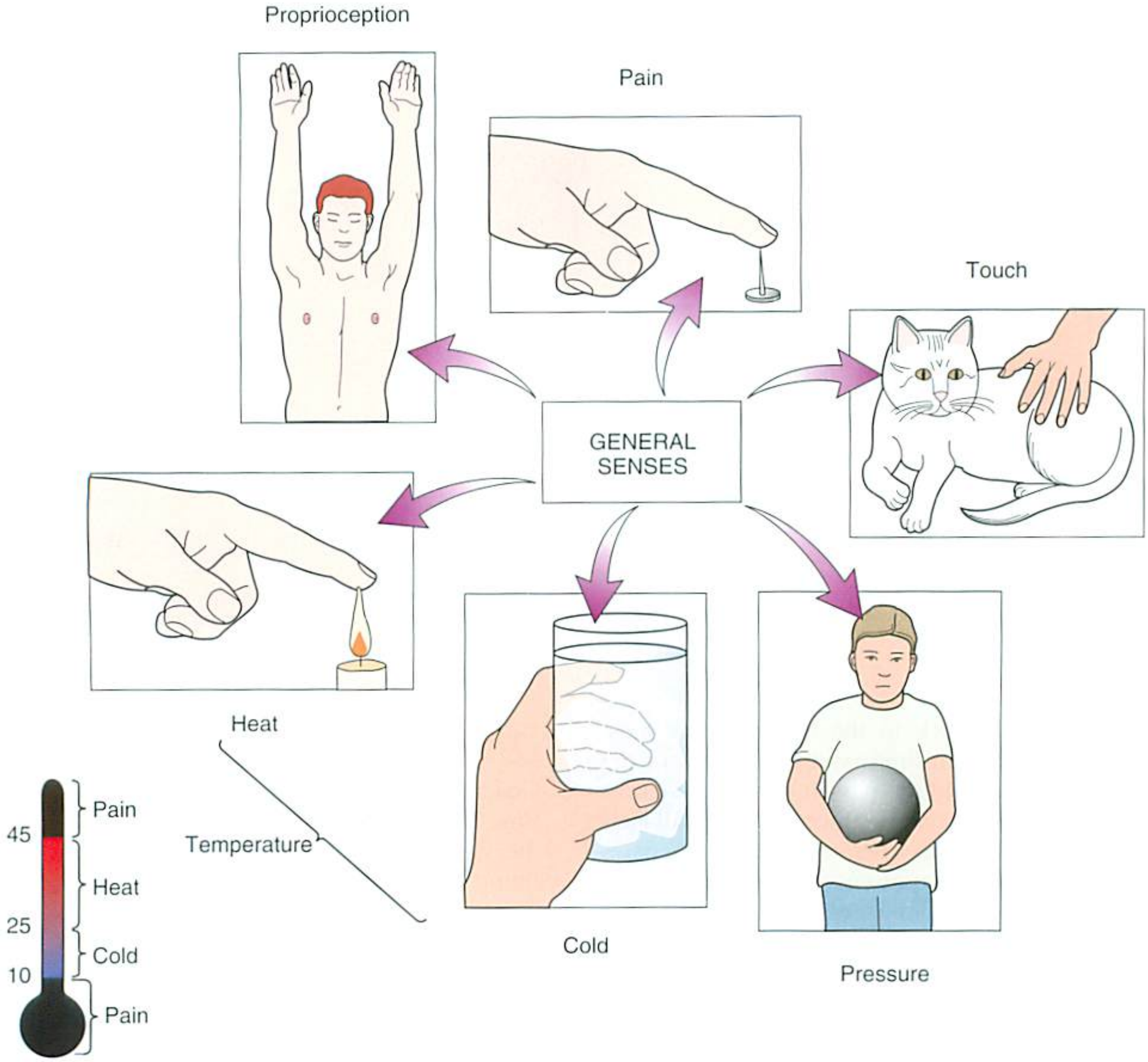


FIGURE 13-3 General senses.

Some patients are at risk because of a diminishment or alteration in the sensation of pain. Patients with diabetes mellitus, for example, often develop nerve damage in their legs and feet; the nerve damage is called *diabetic neuropathy*. Because they cannot feel the pain, persons with neuropathy may develop blisters on their feet because of poorly fitting shoes. The blistered site continues to expand and eventually becomes infected and gangrenous, requiring amputation. This is a common experience among diabetic persons and is the reason for meticulous attention to their foot care.

What stimulates nociceptors? The specific signals that stimulate pain are not well understood. Three pain triggers have been identified. First, tissue injury promotes the release of chemicals that stimulate pain receptors. Second, a deficiency of oxygen stimulates pain receptors. For example, if the blood supply to an internal organ is diminished, a condition called *ischemia,* the tissue is deprived of oxygen and the person experiences pain. The pain of a heart attack is caused in part by the oxygen deprivation experienced by the cardiac muscle. The administration of oxygen helps relieve pain. Third, pain may be experienced when tissues are stretched or deformed. The stimulus is mechanical (distention, distortion) rather than chemical. For example, if the intestine becomes distended, the person will often experience a severe cramping pain.

Why is pain originating in the heart often experienced in the shoulder and left arm? When pain feels as if it is coming from an area other than the site where it originates, it is called **referred pain** (Figure 13-4). Patients with heart disease often complain of pain or an aching sensation that starts in the shoulder region and moves down the left arm into the fourth and fifth fingers. In other words, stimulation of pain receptors in the heart causes pain that is experienced as being away from the heart.

What is the explanation for referred pain? The occurrence of referred pain is the result of shared sensory nerve pathways. The nerve pathways that

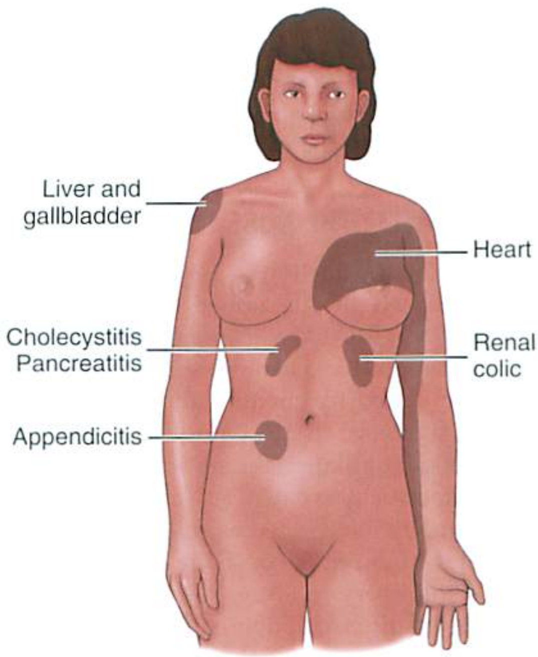
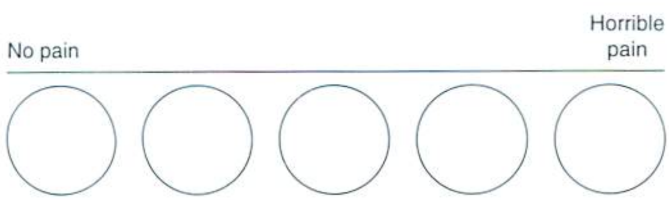


FIGURE 13-4 Sites of referred pain.

carry information from the heart are the same pathways that carry information from the shoulder and left arm. As a result, the brain interprets heart pain as shoulder and arm pain.

Once the pain receptors are stimulated, where does the information go? Pain impulses for most of the body travel up the spinal cord in a sensory nerve tract called the *spinothalamic tract*. The information is then transmitted to the thalamus, where the person first becomes aware of the pain, and then to the parietal lobe. The parietal lobe can identify the source of the pain and judge its intensity and other characteristics.

You will spend much time assessing pain. You will determine the location of the pain, its duration, and what the pain "feels like"—sharp, dull, deep, superficial, burning, throbbing, cramping, aching, gnawing, stabbing, and a host of other descriptive terms. You will also use a pain scale that will help you evaluate the intensity of pain. For example, you may ask your patient to rate his or her pain from 1 (pain-free) to 5 (horrible pain). Create your own pain scale (1 to 5) using the following "smiley face" approach.



Relief of pain is achieved in many ways, such as rest, change of position, meditation techniques, surgical intervention, the administration of oxygen, and the use of drugs. Drugs called *analgesics*, including aspirin, acetaminophen, ibuprofen, and opioids (morphine), relieve pain. Pain management is a huge clinical problem!

? Re-Think

1. List five words used to describe pain.
2. Provide an example of referred pain.

TOUCH AND PRESSURE

The receptors for touch and pressure are mechanoreceptors; they respond to forces that press, move, or deform tissue. Touch receptors are also called *tactile receptors* and are found mostly in the skin; they allow us to feel a cat's soft fur (see Figure 13-3). They are particularly numerous in the lips and tips of the fingers, toes, tongue, penis, and clitoris. Fingers have the highest concentration of touch receptors. Receptors for heavy pressure are located in the skin, subcutaneous tissue, and the deep tissue. Pressure receptors are stimulated by the heavy ball in the boy's arms in Figure 13-3.

Touch is the first sensory system to develop in the fetus and is essential to its growth and development. The importance of touch extends throughout the lifespan. If an infant is not touched, it does not thrive and will likely die (failure-to-thrive syndrome). An appreciation of touch in the health of a preterm infant forms the basis of "kangaroo care"; the tiny, diaper-clad infant is placed in the blouse or shirt of its parent. The warmth and physical contact with the parent causes many neurobiological changes that calm the infant, stabilize its temperature, and improve feeding. Sadly, you will often encounter infants or "warehoused" older persons who have been diagnosed with failure to thrive. They are generally the untouched and ignored. Touch is life-sustaining!

TEMPERATURE

The receptors for temperature are called *thermoreceptors*. The two types of thermoreceptors are heat and cold receptors. Thermoreceptors are found in free nerve endings, as well as in other specialized sensory cells beneath the skin, and are scattered widely throughout the body. Note the temperature scale in Figure 13-3. The cold receptors are stimulated at between 50° and 76° F (10° and 25° C). Heat receptors are stimulated between 76° and 112° F (25° and 45° C). At both ends (extremes) of the temperature scale, pain receptors are stimulated, producing a freezing or burning sensation. Both heat and cold thermoreceptors display adaptation so that the sensation of heat or cold fades rapidly. Immerse your hand in warm water and note how quickly the feeling of warmth disappears, even though the temperature of the water has not decreased. Your heat receptors have adapted.

Remember that pain receptors do not adapt. If you place your hand in boiling water, you will feel intense continuous pain. Sensory information regarding temperature is sent to the parietal lobe. What about the cooling effects of menthol? Menthol anesthetizes the heat receptors. Thus, the only thermoreceptors that can be activated are the cold receptors.

PROPRIOCEPTION

Proprioception (proh-pree-oh-SEP-shun) is the sense of orientation, or position. This sense allows you to locate a body part without looking at it. In other words, if you close your eyes, you can still locate your arm in space; you do not have to see your arm to know that it is raised over your head (see Figure 13-3). Proprioception plays an important role in maintaining posture and coordinating body movements.

The receptors for proprioception, called *proprioceptors,* are located in muscles, tendons, and joints. Proprioceptors are also found in the inner ear, where they function in **equilibrium**. The cerebellum, which plays a major role in coordinating skeletal muscle activity, receives sensory information from these receptors. Sensory information regarding movement and position is also sent to the parietal lobe of the cerebrum. Think how busy the proprioceptors are in the midst of a basketball game!

? Re-Think

1. What receptors are stimulated when you immerse your hand in boiling water?
2. Name three triggers that activate nociceptors.

2+2 Sum It Up!

The sensory system is designed to detect information from within and outside the body and to convey that information to the CNS for interpretation. Receptors located on sensory neurons respond to specific stimuli. There are five types of receptors: chemoreceptors, nociceptors, thermoreceptors, mechanoreceptors, and photoreceptors. There are four components necessary for experiencing a sensation: stimulus, receptor, sensory nerve, and special area of the brain. Two characteristics of a sensation are adaptation and projection. Senses are classified as general or special. The general senses include pain, touch, pressure, temperature, and proprioception.

THE SPECIAL SENSES

The five special senses are smell, taste, sight, hearing, and balance (Table 13-2). The receptors for the special senses are located in the head.

SENSE OF SMELL: THE NOSE

The sense of smell, olfaction, is associated with sensory structures located in the upper nose (Figure 13-5). These **olfactory** (ol-FAK-tor-ee) **receptors** are very sensitive and classified as chemoreceptors, meaning that they are stimulated by chemicals that dissolve in the moisture of the nasal tissue. Once the olfactory receptors have been stimulated, the sensory impulses travel along the olfactory nerve (CN I). The sensory information is eventually interpreted as smell within the olfactory area of the temporal lobe. Faint odor? Sniff harder, because the olfactory receptors are located high in the nose where the air circulation is poor.

WHAT A SMELL CAN TELL

Think of the many pleasant "smell experiences" you have each day: food, flowers, home, fragrant candles, your child, a pet—the list goes on, as do the functions served by the sense of smell. Food odors can stimulate the digestive tract secretions, literally causing you to drool and ingest necessary nutrients. The sense of smell can function as a protective warning, telling you of spoiled food and threatening environments, such as a room filled with leaking gas. Other familiar odors pack an emotional punch, often eliciting memories (pleasant and not-so pleasant). Aromatherapy uses the sense of smell for its healing and calming effects on the body. And, of course, Mr. and Ms. Rover, in the heat of the moment, illustrate well the role of pheromones (sex odors) in mating and reproduction. By the way, each person has a unique odor as distinctive as fingerprints.

Some odors are harsh and unpleasant. For example, ammonia fumes activate both the olfactory receptors and the trigeminal nociceptors. Thus, "smelling salts" quickly and uncomfortably revive a semiconscious person. Unpleasant odors can trigger distressing

Table 13-2 Special Senses

TYPE OF SENSE	ORGAN	SPECIFIC RECEPTOR	STIMULUS	RECEPTOR
Smell	Nose	Olfactory cell	Changes in chemical concentrations of substances	Chemoreceptor
Taste	Tongue	Gustatory cell	Changes in chemical concentrations of substances	Chemoreceptor
Sight	Eye	Rods and cones	Light energy	Photoreceptor
Hearing	Inner ear: cochlea	Organ of Corti (hair cells)	Movement of fluids	Mechanoreceptor
Balance	Inner ear, vestibular apparatus	Hair cells	Movement of fluids	Mechanoreceptor

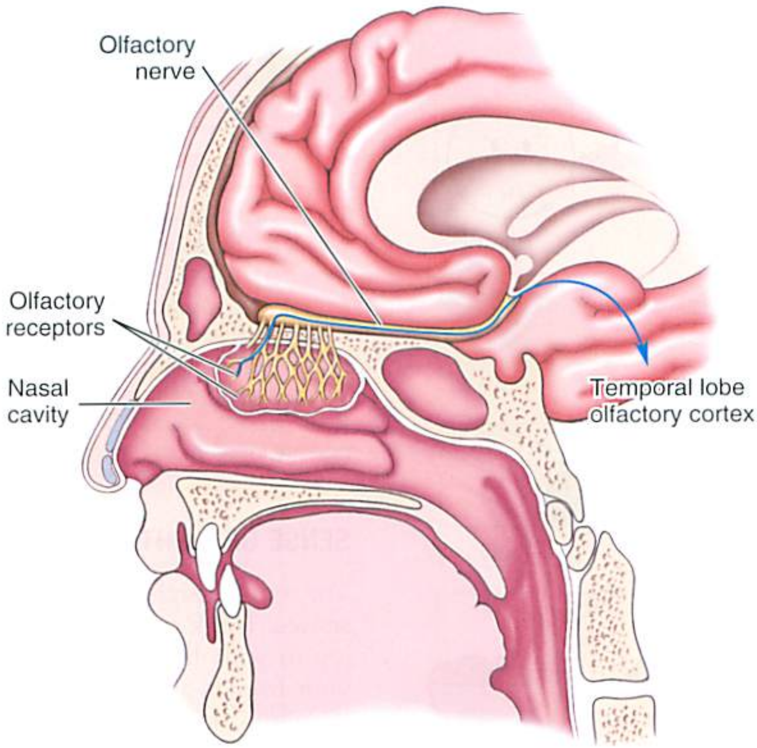


FIGURE 13-5 Sense of smell: olfactory receptors, olfactory nerve, and the olfactory cortex (temporal lobe).

visceral responses. For example, putrid odors can stimulate the emetic center, causing the person to vomit in response to the noxious stimulus.

Some persons experience an olfactory aura, meaning that they smell an odor that is not present. Olfactory auras most often occur prior to seizure activity or before the onset of a migraine headache. The person may "smell" chicken soup, bleach, rotting flesh, or worse. Sometimes, the aura is a distortion of an odor. For example, a person may experience body odor as a smell of beer. These strange smell events are called *olfactory hallucinations*.

Your sense of smell is also a valuable diagnostic tool. You can smell the acetone breath of a person in diabetic ketoacidosis, the putrid odor of an infected wound, and the odor of alcohol on the breath of an intoxicated person. Think that's good? Rover can smell the presence of melanoma and his ears perk right up when he smells the breath of a person with pulmonary tuberculosis. Cranial nerve (CN I) assessment? Have the person identify various odors such as vanilla; an intact olfactory nerve identifies the vanilla odor. Clearly, the olfactory receptors that hang out in the nose are very busy and do much more than just smell perfume.

SENSE OF TASTE: THE TONGUE

The sense of taste is often called the social sense, as in "let's do lunch"; it is also called the *gustatory* (GUS-tah-tor-ee) *sense* or *gustation*. Taste buds are the special organs of taste. The taste receptors are located primarily on the tongue and are classified as chemoreceptors, meaning that they are activated by the chemicals in our food. A small number of taste buds are also located on the palate, tonsils, and throat. Rover, of course, has many taste buds in his throat. So not to worry when he gulps his treat; he is tasting and thoroughly enjoying it despite its rapid disappearance. The four basic taste sensations are salty, sweet, sour, and bitter. Each sensation is concentrated on a particular area of the tongue, as illustrated in Figure 13-6. The tip of the tongue is most sensitive to sweet and salty substances. Sour sensations are found primarily on the sides of the tongue, and bitter substances are most strongly tasted on the back part of the tongue.

When the taste receptors are stimulated, the taste impulses travel along three cranial nerves (facial, glossopharyngeal, and vagus nerves) to various parts of the brain, eventually arriving in the parietal and temporal lobes of the cerebral cortex. Note that because the taste sensation is carried by three cranial nerves, when assessing cranial nerve function, you will be asking the patient to detect specific tastes and stimulating only parts of the tongue. For example, a person with damage to the facial nerve may experience loss of taste only on the anterior two thirds of the left side of the tongue.

SOME TASTEFUL COMMENTS

- The salty receptors can trigger a "salt craving." For example, as her blood volume expands during pregnancy, the woman's taste buds may sense a decrease

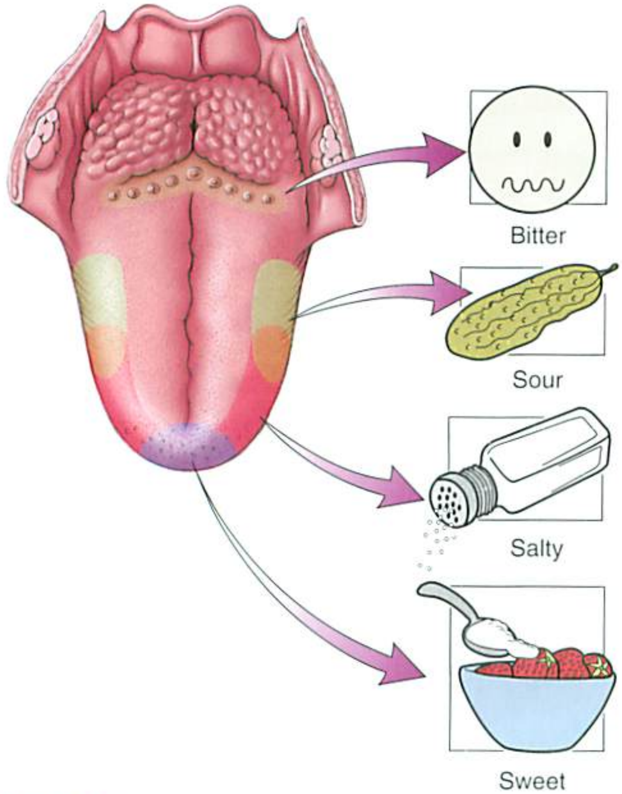


FIGURE 13-6 Sense of taste. The four taste sensations are bitter, sour, salty, and sweet.

of salt in her blood, causing her to increase her intake of salt. Because salt plays a crucial role in blood volume regulation, the salt craving has an important survival role. Ever notice the gathering of deer around a salt lick?

- Taste receptors seem especially sensitive to bitter-tasting substances. This sensitivity serves a protective role because the poisonous substances in plants are often bitter.
- Food often tastes differently when you have a cold. The senses of taste and smell are closely related. When interpreted in the cerebral cortex, information from both senses may combine to produce a different taste sensation. Therefore, food often tastes different when you have a cold or stuffy nose.
- The sense of taste can be lost or altered. Drugs and radiation used in the treatment of cancer often change or destroy the sensation of taste. Obviously, the loss of taste affects appetite and nutrition.
- Two other tastes have been suggested. A metallic taste has been attributed to the effects of certain drugs. A second taste has been described by a Japanese word, *umami*, which means yummy or delicious and refers to a meaty flavor.
- There is also some evidence that the tongue can taste the texture and shape of food.

? Re-Think

1. Locate and classify olfactory receptors.
2. Why does food taste different when you have a cold?

2+2 Sum It Up!

The special senses include smell, taste, sight, hearing, and balance. The nose houses the receptors for smell, the olfactory receptors. CN I (olfactory nerve) carries information from the nose to the temporal lobe of the cerebrum. Distortions in the sense of smell are common and include anosmia and olfactory auras/hallucinations. The sense of taste is called the *gustatory sense*. Sensory information from the taste buds is carried by three cranial nerves (CN VII, IX, and X) to the temporal and parietal lobes of the cerebrum.

SENSE OF SIGHT: THE EYE

The sense of sight (vision) is one of our most cherished senses. Think of all that you see that brings so much joy to your life—the smiles of children, the faces of your friends and pets, and the beautiful colors of the trees and flowers. The eyes are the organs of vision; they contain the visual receptors. Assisting the eyes in their function and protecting them from injury are the visual accessory organs. The study of the eye is called *ophthalmology*.

VISUAL ACCESSORY ORGANS

The visual accessory organs include the eyebrows, eyelids, conjunctiva, eyelashes, lacrimal apparatus, and extrinsic eye muscles (Figure 13-7).

Eyebrows

The eyebrows, patches of hair located above the eyes, perform a protective role. They keep perspiration out of the eyes and shade the eyes from glaring sunlight. Eyebrows also participate in your facial expression, as in the "raised eyebrow" look.

Eyelids

The eyelids, or palpebrae, protect the eyes. They prevent the entrance of foreign objects and wash tears over the surface of the eye. The upper and lower eyelids meet at the corners of the eyes. The corners are called the *medial (inner) canthus* and *lateral (outer) canthus*. The eyelids are composed of four layers: skin, skeletal muscle (orbicularis oculi), connective tissue, and an inner lining called the *conjunctiva*. The margin of the eyelids contains tarsal or meibomian glands, special types of sebaceous glands that secrete an oil that coats the surface of the eye and reduces evaporation of the tears. Skeletal muscles open and close the eyelids. The levator palpebrae superioris muscle (*levator* means "to raise," like an elevator) is attached to the eyelid and the upper bony orbit; contraction of this muscle opens the eye. Contraction of the orbicularis oculi muscle closes it.

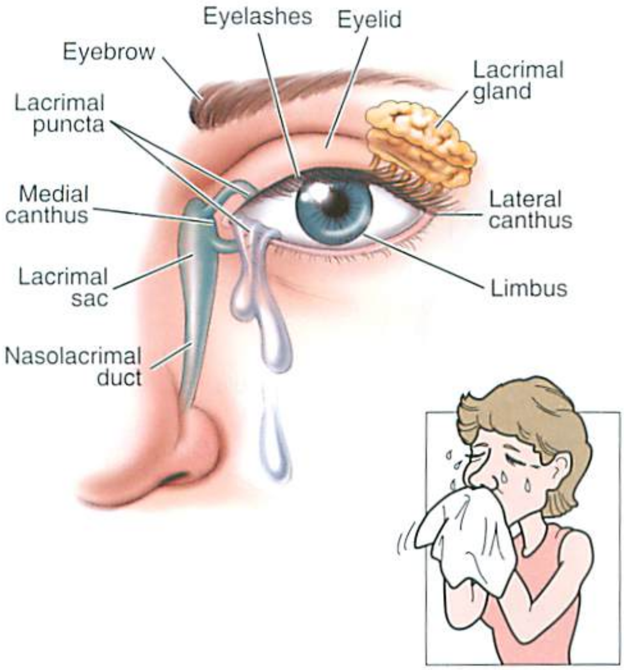


FIGURE 13-7 Visual accessory organs and lacrimal apparatus.

Look in the mirror. Lid levels matter. Your eyelid normally covers a small part of the upper iris (colored part of your eye); it should not cover the pupil (hole). Sometimes, a patient cannot lift the eyelid completely and the person has a sleepy look. This condition is called *ptosis of the eyelid*. The upper eyelid of a person with an overactive thyroid may appear to be pulled up too high, thereby exposing the white sclera above the iris. This is called "lid lag." Thus, the eyelids often provide diagnostic clues about underlying diseases or disorders. While you are looking in the mirror, pull down your lower lid and note its inner lining; it forms a sac (the conjunctival sac). Eyedrops are temporarily held in this sac until the blinking eyelids wash the medication over the surface of the eye.

Occasionally, a hair follicle at the edge of the lid becomes infected, usually by *Staphylococcus*. This infection is called a *stye*, or *hordeolum*; it is red, swollen, and painful.

Conjunctiva

The conjunctiva (kon-junk-TIE-vah) is a thin mucous membrane that lines the inner surface of the eyelids. The conjunctiva also folds back to cover a portion of the sclera on the anterior surface of the eyeball; this part of the sclera is called *the white of the eye*. The conjunctiva does not cover the cornea; it secretes a thin mucous film that moistens the surface of the eye. The anterior surface of the eye must be kept moist; otherwise, it will ulcerate and scar. Figure 13-7 identifies the limbus, the meeting place of the white of the eye with the cornea that overlies the colored iris.

The conjunctiva is very vascular, meaning that it has many blood vessels. Evidence of its rich vascularity is its bloodshot appearance when the blood vessels are dilated. Eyedrops that claim to "get the red out" cause the blood vessels of the conjunctiva to constrict, thereby decreasing the amount of blood. Pink eye, also associated with dilated blood vessels, is a highly contagious bacterial or viral conjunctivitis. It is commonly seen in groups of children in whom it is difficult to maintain good hygienic conditions. Conjunctivitis can also be caused by irritation and allergies.

Eyelashes

Eyelashes line the edges of the eyelid and help trap dust. Touching the eyelashes stimulates blinking—a mascara challenge! Interestingly, the camel has three eyelids and two layers of eyelashes to deal with its sandy environment. Imagine how long it would take to get out of the house with so many lids and lashes to paint!

Lacrimal Apparatus: It's Tearing Me Up!

The lacrimal (LAK-ri-mal) apparatus is concerned with the secretion, distribution, and drainage of tears. It is composed of the lacrimal gland and a series of ducts called *tear ducts* (see Figure 13-7). The lacrimal gland is located in the upper lateral part of the orbit. The lacrimal gland secretes tears, which flow across the surface of the eye toward the nose. The tears drain through small openings called *lacrimal puncta* and then into the lacrimal sac and nasolacrimal ducts. The nasolacrimal ducts eventually empty into the nasal cavity. Normally, tears flow to the back of the throat and are swallowed. If the secretion of tears increases, as in crying, the nose begins to run. The excess tears may overwhelm the drainage system and spill onto the cheeks. Similarly, the nasolacrimal ducts can become swollen and close when a person has a cold. The tears cannot drain and thus spill out onto the cheeks.

Tears perform several important functions. They moisten, lubricate, and cleanse the surface of the eye. Tears also contain an enzyme called *lysozyme*, which helps destroy pathogens and prevents infection. Blinking stimulates lacrimation and helps spread the tears over the surface of the eye. Routine use of eyewashes may do more harm than good by washing away natural antibacterial secretions.

Extrinsic Eye Muscles

Extrinsic eye muscles also function as visual accessory organs (see "Muscles of the Eye" later in this chapter).

? Re-Think

1. List the visual accessory organs.
2. Trace the flow of tears from their origin to their destination.

THE EYEBALL

The eyeball has a spherical shape and is approximately ¾ to 1 inch (2 to 3 cm) in diameter (Figure 13-8, *A*). Most of the eyeball sits within the bony orbital cavity

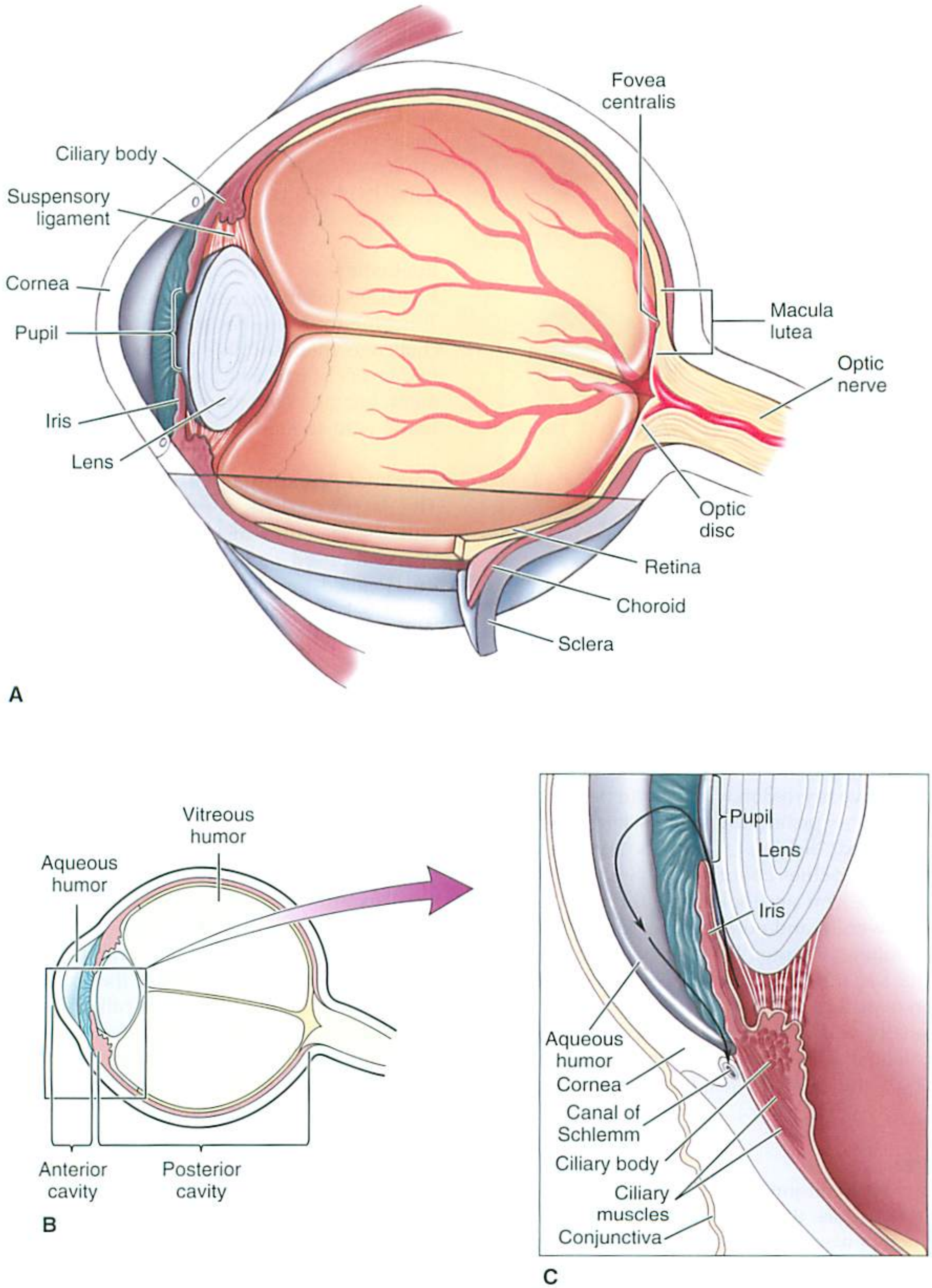


FIGURE 13-8 **A,** Structure of the eyeball. **B,** Cavities and fluids. **C,** Flow of aqueous humor from the ciliary body to the canal of Schlemm *(arrow)*.

of the skull, partially surrounded by a layer of orbital fat. Thus, the eyeball is recessed and well protected. Interestingly, our eyes are the same size from infancy to adulthood. Think about it: the large eyeballs in young animals are what make them so stinkin' cute!

The eyeball is composed of three layers: the sclera, the choroid, and the retina. Identify the structures in Figure 13-8 as they are described in the following text.

Layers of the Eyeball

Sclera. The outermost layer is called the **sclera** (SKLEH-rah). The sclera is a tough fibrous connective tissue that covers most of the eyeball. The sclera helps contain the contents of the eye; it also shapes the eye and is the site of attachment for the extrinsic eye muscles. The sclera extends toward the front of the eye. The anterior sclera is covered by conjunctiva and, as indicated earlier, is called *the white of the eye*. A transparent extension of the sclera is called the **cornea** (KOR-nee-ah). The cornea covers the area over the iris (the colored portion of the eye).

The cornea is avascular (contains no blood vessels) and transparent, meaning that light rays can go through this structure. Because light enters the eye first through the cornea, it is called *the window of the eye*. The cornea has a rich supply of sensory nerve fibers and is therefore sensitive to touch. If the surface of the cornea is touched lightly, the eye tears and blinks to remove the source of irritation. This response is called the *corneal reflex* and serves a protective function. The corneal reflex involves two cranial nerves. A branch of the trigeminal nerve (CN V) provides sensory fibers to the surface of the cornea; the facial nerve (CN VII) provides motor fibers that result in tearing and blinking. Think of how your eye responds to a piece of dust—through pain, tearing, and blinking.

Choroid. The middle layer of the eye is the choroid (KOH-royd). The choroid layer is highly vascular and is attached to the innermost layer, the retina. The choroid performs two functions: (1) it provides the retina with a rich supply of blood, and (2) dark pigments located in the choroid absorb any excess light to prevent glare.

The choroid extends toward the front of the eyeball to form the ciliary body and the iris. Collectively, the middle layer (choroid, ciliary muscle, and iris) is called the *uvea*. The ciliary body secretes a fluid called *aqueous humor* and gives rise to a set of intrinsic eye muscles called the *ciliary muscles*. The most anterior portion of the choroid is the iris, the colored portion of the anterior eye. The song "Beautiful Brown Eyes" is a serenade to the iris.

The opening, or hole, in the middle of the iris is called the *pupil*. The size of the pupil is determined by two sets of intrinsic eye muscles located in the iris. The iris regulates the amount of light entering the eye.

Do You Know...

Why the "Beautiful Lady" Can't See?

A group of drugs, including atropine and scopolamine (muscarinic receptor antagonists), belongs to a drug classification called *belladonna*, or "beautiful lady." Why beautiful? When belladonna is placed in the eyes of the young lady, the pupils dilate, becoming wide, dark, and very seductive. Dilated pupils may indeed be beautiful, but they do not promote acute vision. "Beautiful lady" may be beautiful, but she needs an escort because she certainly cannot see.

Today, belladonna drugs are still used, primarily for their mydriatic and cycloplegic effects in eye examinations and surgical procedures. Interestingly, atropine is still used by photographers to create pictures of "beautiful ladies."

Retina. The innermost layer of the eyeball is the **retina** (RET-i-nah). It lines the posterior two thirds of the eyeball. The retina is the nervous layer containing the visual receptors, which are sensitive to light and are therefore called *photoreceptors*. The two types of photoreceptors are rods and cones. The rods are scattered throughout the retina but are more abundant along its periphery. The rods are sensitive to dim light and provide us with black-and-white vision. The cones are most abundant in the central portion of the retina and provide us with color vision. The area of the retina that contains the highest concentration of cones is called the *fovea centralis,* an area in the center of a yellow spot called the *macula lutea* (see Figure 13-8, *A*). Because the fovea centralis contains so many cones, it is considered the area of most acute vision.

A second small circular area of the retina is in the back of the eye. The neurons of the retina converge there to form the optic nerve; it contains no rods or cones. This area is called the *optic disc*. Because there are no photoreceptors on the optic disc, images that focus on this area are not seen. The optic disc is therefore called the *blind spot*. You can locate your own blind spot. Draw a rectangle with a small X on the left side and a dot on the right. Using only one eye (cover the second eye), look at the X as you move it closer to your eye. At some point, you will not be able to see the dot on the right when it focuses on your blind spot.

Here's another interesting fact about the optic disc. A head-injured person may develop increased intracranial pressure. This increased pressure pushes the optic disc forward. The bulging optic disc seen on ophthalmic examination is described as a choked disc or papilledema. The eyes can provide a wealth of information about a patient with a head injury.

? Re-Think

1. List the three layers of the eyeball.
2. Name the anterior extensions of the choroid and the sclera.
3. Why might a detached retina cause retinal death and blindness?

Cavities and Fluids

There are two cavities in the eyeball: the posterior and anterior cavities (see Figure 13-8, *B*). The posterior cavity is larger and is located between the lens and the retina. The posterior cavity is filled with a gel-like substance called the *vitreous humor*. The vitreous humor gently pushes the retina against the choroid layer, thereby ensuring that the retina receives a good supply of oxygenated blood. For the forensic sleuths: Immediately after death, the concentration of potassium ion (K^+) in the vitreous humor increases slowly and consistently. Thus, its measurement is used to determine time of death and is considered more accurate than the onset of rigor mortis.

Do You Know...

Why We Sometimes See Spots in Front of Our Eyes?

The spots are called *floaters* or *muscae volitantes*, meaning "flying flies." They are either particles or red blood cells that have escaped from the capillaries in the eye. These substances float through the vitreous humor, occasionally getting in our line of vision. The presence of these substances is usually considered normal and harmless. However, the sudden appearance of floaters or an increase in the number of floaters may indicate that a hole has formed in the retina. The development of a retinal tear often precedes retinal detachment and demands immediate professional attention.

The anterior cavity is located between the lens and the cornea. The anterior cavity is filled with a watery fluid called *aqueous humor*. Aqueous humor is produced by the ciliary body and circulates through the pupil into the space behind the cornea (see Figure 13-8, *B*). The aqueous humor performs two functions: (1) it maintains the shape of the anterior portion of the eye, and (2) it provides nourishment for the cornea. The aqueous humor leaves the anterior cavity by way of tiny canals located at the junction of the sclera and the cornea. These outlet canals are called *venous sinuses* or the *canals of Schlemm* (see Figure 13-8, *C*).

Drainage of aqueous humor through the canals of Schlemm may become impaired. Consequently, aqueous humor accumulates in the eye and elevates the pressure in the eye. An elevated intraocular pressure is called *glaucoma*. Glaucoma is serious because the elevated pressure compresses the choroid, chokes off the blood supply to the retina, and damages the optic nerve. Glaucoma is a leading cause of retinal damage and blindness. Treatment of glaucoma is aimed at decreasing the formation of aqueous humor and improving the drainage of aqueous humor through the canal of Schlemm.

? Re-Think

Trace the origin, path, and drainage of aqueous humor.

2+2 Sum It Up!

The eyeball has three layers: sclera, choroid, and retina. The sclera extends anteriorly as the cornea. The choroid extends anteriorly as the ciliary body and iris. (The middle layer and its extensions are called the *uvea*.) The inner retinal layer contains the photoreceptors, the rods and cones. There are two cavities: the posterior cavity that contains vitreous humor, and the anterior cavity that contains aqueous humor. Aqueous humor is secreted by the ciliary body, flows anteriorly through the pupil, and is drained through the canal of Schlemm. Impaired drainage of aqueous humor increases intraocular pressure (glaucoma), leading to blindness.

MUSCLES OF THE EYE

The two groups of muscles associated with the eye are the extrinsic and intrinsic eye muscles. The extrinsic eye muscles move the eyeball in its bony orbit. The intrinsic eye muscles move structures within the eyeball.

Extrinsic Eye Muscles

How do you move your eyes? The extrinsic eye muscles are skeletal muscles located outside the eye (Figure 13-9, *A*). Six extrinsic eye muscles attach to the bone of the eye orbit and the sclera, the tough outer connective tissue layer of the eyeball. There are four rectus muscles and two oblique muscles:

- Superior rectus
- Inferior rectus
- Medial rectus
- Lateral rectus
- Superior oblique
- Inferior oblique

The extrinsic eye muscles move the eyeball in various directions. You can move your eyes up, down, and sideways because of the rectus muscles. You can also roll your eyes because of the oblique muscles. The extrinsic eye muscles are innervated by three cranial nerves, with the most important being the oculomotor nerve (CN III). Then there is LR_6SO_4, which sounds like a nasty chemical formula. However, it helps you remember that the lateral rectus (LR) muscle is innervated by the abducens nerve (CN VI) whereas the superior oblique (SO) muscle is innervated by the trochlear nerve (CN IV). Cranial nerve assessment of CN III, IV, and VI: observe movement of the eyeballs up, down, medial, lateral, and around.

Back to the mirror. Note that both eyes move together in a coordinated way; when one eye moves, the other eye moves. Both eyes focus on the same object. In the event of a traumatic injury to an eye, you may need to immobilize the injured eye, usually by applying a loose covering over it. However, because both eyes move in a coordinated way, if you want to immobilize the injured eye, you must cover both eyes. Then it is off to the ophthalmologist for treatment.

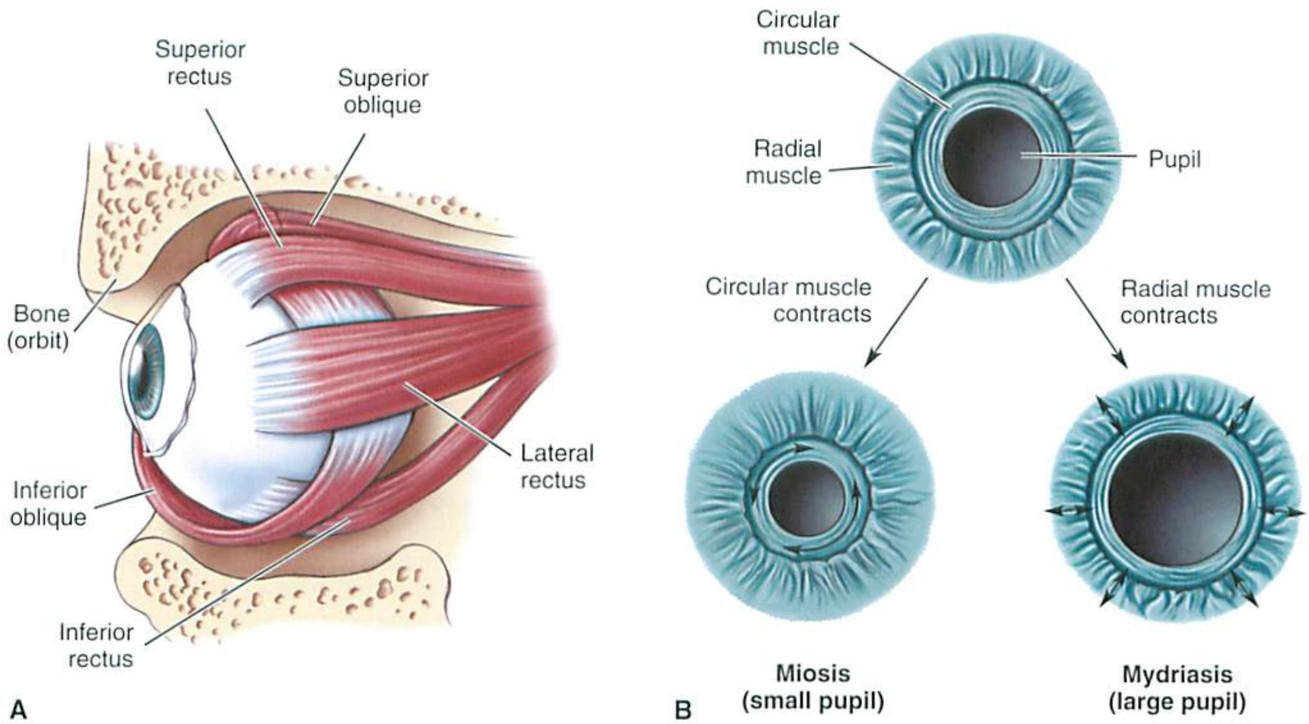


FIGURE 13-9 A, Extrinsic muscles: four rectus muscles and two oblique muscles (only five are shown). **B,** Intrinsic eye muscles: iris (circular and radial muscles).

Occasionally, the eyeballs are not aligned and do not focus on a desired point. This condition is called *strabismus* (Figure 13-10). If the eye deviates medially toward the nasal side, the eyes look crossed; hence, the term *cross-eyed*. If uncorrected, strabismus not only presents a serious cosmetic problem, but can also lead to loss of vision.

Do You Know...

About Lazy Eye?

Normally, both eyes work together and focus on one object; in response, the brain forms a single image. Sometimes, both eyes do not focus on the same object, usually because the muscles of one eye are weak (lazy) and therefore unable to move the affected eye into position. The occipital lobe is then presented with different information from each eye. The occipital lobe, however, can't process both signals; it receives information from one eye and suppresses information from the lazy eye. If uncorrected, the "lazy" eye will become nonfunctional (blind). Loss of vision resulting from lazy eye is called *suppression amblyopia*. It is common and preventable; treatment, however, must begin early.

Intrinsic Eye Muscles

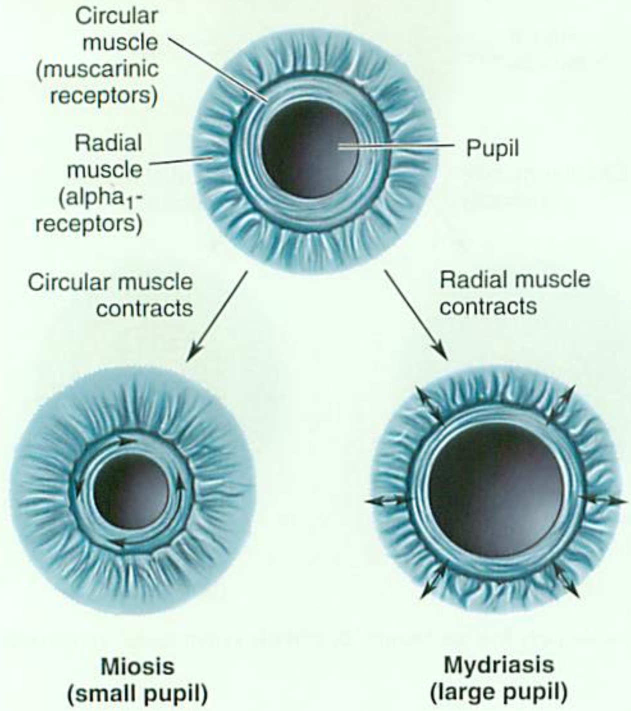
The intrinsic muscles are smooth muscles located in the eyeball, specifically in the iris and the ciliary body. There are three intrinsic eye muscles, as described in the following text.

Muscles of the Iris. The iris is composed of two eye muscles: the radial muscle and the circular muscle (see Figure 13-9, *B*). These muscles control the size of the pupil and therefore regulate the amount of light that enters the eye. The muscle fibers of the radial muscle are arranged like the spokes of a wheel. Just as the spokes radiate from the center of the wheel, the radial muscle fibers radiate from the area of the pupil. Contraction of the radial muscle causes the pupil to dilate, thereby increasing the amount of light entering the eye. Sympathetic nerve fibers supply the radial muscles. Thus, sympathetic nerve stimulation causes pupillary dilation, or mydriasis (mi-DRY-ah-sys). Drugs that dilate the pupil are called *mydriatic agents*.

The second muscle located in the iris is the circular muscle. Contraction of the circular muscles causes the pupil to constrict, thereby decreasing the amount of light entering the eye. The circular muscle is supplied by parasympathetic nerve fibers in the oculomotor nerve (CN III). Parasympathetic nerve stimulation causes pupillary constriction, or miosis (see Figure 13-9, *B*). Drugs that constrict the pupils are called *miotic agents*. Some drugs, such as opioids (narcotics), constrict the pupils so intensely that the pupils are described as pinpoint. (An easy way to remember the difference between mydriasis and miosis is that the words *dilate* and *mydriasis* both contain the letter *d*.)

Ramp It Up!

Pupil Size and Drugs that Affect the Autonomic Receptors on the Iris



Many drugs affect pupillary size, and you must understand these effects so that you can make sound clinical judgments. The effects of drugs on pupil size are described in terms of autonomic receptor terminology. (You may need to review cholinergic and adrenergic receptors in Chapter 12.)

The radial muscle of the iris is innervated by sympathetic fibers and contains alpha$_1$-adrenergic receptors. Activation of the alpha$_1$ receptor by norepinephrine (NE) causes pupillary dilation or mydriasis. The circular muscle of the iris is innervated by parasympathetic fibers and contains muscarinic receptors. Activation of the muscarinic receptors causes pupillary constriction or miosis. There are several clinical important implications.

1. An ophthalmologist may want to examine the interior of the eye; dilation of the pupils and paralysis of the muscles of accommodation (ciliary muscles) facilitates the exam. Eyedrops containing an antimuscarinic drug (e.g., atropine, other drugs included in the belladonna drug class) achieve mydriasis and cycloplegia (paralysis of the muscles of accommodation). Remember that muscarinic activation causes pupillary constriction, so muscarinic blockade causes pupillary dilation, or mydriasis.
2. Patients with glaucoma (increased intraocular pressure) are advised to avoid taking drugs that cause mydriasis because mydriasis diminishes the drainage of aqueous humor and further elevates intraocular pressure. Patients often take a number of drugs. Many commonly used drugs, such as antidepressants, have antimuscarinic effects. Therefore, while treating the primary problem of depression, you must also consider other secondary clinical conditions, such as glaucoma. Otherwise, the depression may improve in response to the antidepressant drug, but the glaucoma may worsen because of its antimuscarinic effect on the eye.
3. A neurological assessment includes the response of the photopupillary reflex. Drugs that activate or block the receptors on the iris affect the pupillary response and interfere with the neurological assessment.

Pupillary size is also affected by drugs that do not affect the autonomic receptors. For example, opioids, such as morphine, cause miosis; the pupils may be described as pinpoint pupils. The eyes reveal much about the patient.

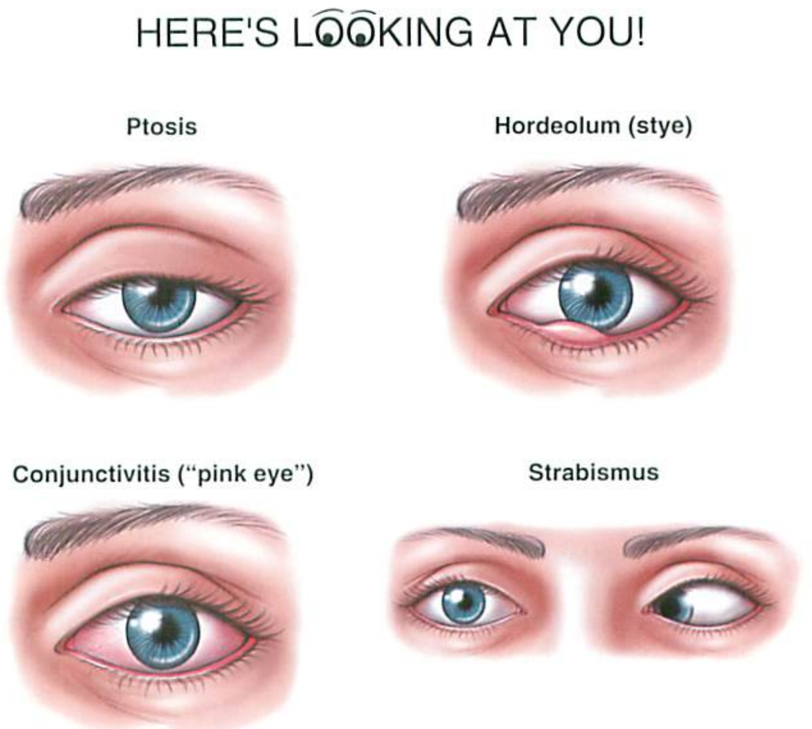


FIGURE 13-10 Conditions of the eye.

Photopupillary Reflex. When one eye is exposed to light, the pupil immediately constricts, thereby restricting the amount of light entering the eye. This response is called the *photopupillary reflex*. The pupil of the other eye also constricts even if no light is directed at it. The second eye is said to constrict consensually; it consents to constrict when the photopupillary reflex is stimulated in the opposite eye. Both of these effects are assessed when an eye exam is performed.

Who is PERRLA? Pupillary function is evaluated by noting the size, shape, and reactivity to light. PERRLA is an assessment term for pupillary function: *P*upils *E*qual, *R*ound, *R*eact to *L*ight, and *A*ccommodation.

Ciliary Muscle. The third intrinsic eye muscle is the ciliary muscle. Locate the ciliary muscles in Figure 13-8, *C*. The ciliary muscles arise from the ciliary body. The ciliary muscles attach to the suspensory ligaments, which, in turn, tug on the lens, causing the lens to change its shape. Why tug? Read on.

? Re-Think

1. List the extrinsic eye muscles and state their function.
2. List the intrinsic eye muscles and state their functions.
3. Describe the effect of the photopupillary reflex on pupillary size.

REFRACTION AND ACCOMMODATION

For us to see, the light waves must enter the eye and bend to focus on the retina. The bending of light waves is called **refraction**. Let's see how this happens. Although the cornea and aqueous humor are all capable of refracting light, the lens can change its shape and its refracting power. The need for refraction by the lens is illustrated in Figure 13-11, *A*. The light waves are shown traveling in a straight line toward the retina. Unless light waves 1 and 3 are bent, they will not focus on point X.

How does the lens bend light waves (see Figure 13-11, *B*)? The bottom part of light wave 1 hits the lens first and is slowed before penetrating it. The top of the light wave continues to travel until it hits the lens. For a split second, the top of the light wave travels faster than the bottom. The light wave therefore bends. This illustrates how the lens bends several light waves. For sharp vision, light waves must be refracted to focus on one particular area of the retina.

Why and how does the lens change its shape? The lens can change its shape, becoming fatter or thinner. The lens is an elastic structure held in place by the suspensory ligaments attached to ciliary muscles (see Figure 13-8, *A*). When the ciliary muscles contract and relax, the tension on the lens causes the changes in the shape of the lens. The lens either thins out or becomes fatter. The change in shape affects how much the light is bent. For example, if the lens becomes fatter, the light wave is bent at a sharper angle. If the lens thins, the degree of refraction lessens and the light wave is not bent as much.

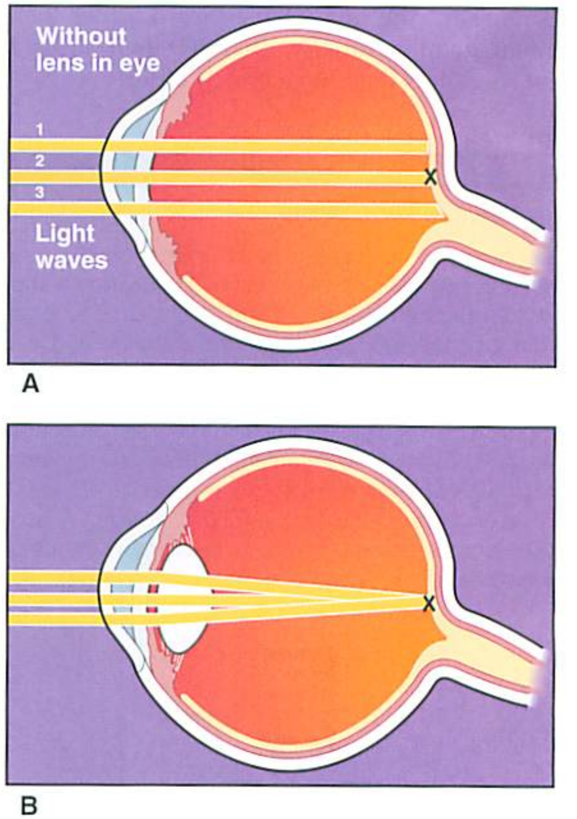


FIGURE 13-11 Refraction. **A,** Path that the light waves travel (without lens). **B,** Refraction of the first and third light waves (with lens).

The ability of the lens to change its shape allows the eye to focus objects close up or at a distance. For example, if you hold a pencil 6 inches in front of your eyes, you will be able to see it clearly. The focusing of the close-up object (pencil) on the retina is caused primarily by the lens. The lens becomes fatter and bends the light waves more acutely so as to focus them on the retina. This ability of the lens to change its shape to focus on a close object is called *accommodation*. A professional who assesses the ability of the eyes to refract light is called an *optometrist*. Optometrists prescribe lenses to correct the errors of refraction. (Do not confuse ophthalmologist with optometrist.)

Accommodation is accompanied by pupillary constriction and by convergence, the movement of the eyes medially toward the nose. Accommodation, pupillary constriction, and convergence all work together to focus both eyes on one object.

Emmetropia (em-eh-TROHP-ee-ah) refers to the ability of the eye to refract light without the assistance of a corrective lens. With advancing age, the lens loses some of its ability to change shape, thereby diminishing the ability to accommodate for close objects. This condition, which is often evident after age 40, is called *presbyopia* (pres-bee-OH-pee-ah) (*presbyter* means "an old man"). Persons with presbyopia have difficulty adjusting to close objects. Presbyopia accounts for the tendency of older persons to hold the newspaper at arm's length. You may have heard older persons comment good naturedly on how their arms have gotten shorter as they have gotten older!

Do You Know...

What Is Meant by 20/20 Vision?

The ability of the eye to focus an image on the retina is assessed by use of the Snellen chart. This chart is composed of lines of letters arranged in decreasing size. The person is placed at a distance 20 feet away from the chart and is asked to cover one eye and read a line of letters. A score of 20/20 means that the person can see at 20 feet what a person with normal eye function can see. Thus, 20/20 vision is considered normal. A score of 20/40 means that a person can see at 20 feet what a person with normal vision can see at 40 feet. Thus, 20/40 vision is less perfect than 20/20 vision. A score of 20/200 indicates severely impaired vision, and the person is considered legally blind.

Re-Think

1. Define refraction and explain how the lens refracts light.
2. With regard to refraction, why does a person with presbyopia move his or her arms to see a newspaper more clearly?

Sum It Up!

There are two groups of muscles associated with the eyeball: extrinsic eye muscles and intrinsic eye muscles. The extrinsic eye muscles move the eyeball and are innervated by CN III, IV, and VI. The intrinsic eye muscles control pupillary size and the shape of the lens. By changing pupillary size, the iris regulates the amount of light that enters the posterior cavity. By changing the curvature of the lens, the muscles enable the lens to refract light.

STIMULATION OF THE PHOTORECEPTORS

Once the light penetrates the various eye structures, it must stimulate the photoreceptors (rods and cones). Why do you see black and white at night and color during daylight?

Night Vision

The rods are widely scattered throughout the retina but are more abundant in the periphery. In low light conditions the pupil dilates, thereby allowing more light to enter the eye. The dilated pupil allows the light rays to scatter along the periphery of the retina, thereby stimulating the rods. Rods provide us with black-and-white vision. The image produced by the stimulation of rods is somewhat fuzzy. Because rods respond to dim light, stimulation of rods is often called *night vision*.

Do You Know...

What Night Blindness Is?

Stimulation of the rods (night vision photoreceptors) by light waves causes the breakdown of a chemical substance called *rhodopsin*. This breakdown, in turn, stimulates nerve impulses. As nerve impulses are formed, the amount of rhodopsin is used up and must be replaced. The synthesis of additional rhodopsin requires vitamin A. Because night vision depends on an adequate supply of rhodopsin, a deficiency of vitamin A can cause night blindness.

Color Vision

Cones are the photoreceptors for color vision. Cones are most abundant in the central portion of the retina, especially in the macula lutea. When in a well-lit environment the pupil is constricted and directs the light toward the central cone-rich part of the retina. The image produced by the stimulation of cones is colored and sharp. Why colored? There are three types of cones, each with a different visual pigment (a light-sensitive chemical). One type of cone produces a green color, another produces blue, and a third produces red. Stimulation of combinations of these cones produces the many different colors and shades of colors that we enjoy.

INFORMING THE BRAIN: THE VISUAL PATHWAY

Nerve impulses that arise from the photoreceptors leave the eye (retina) by way of the optic nerve (CN II). The nerve impulses travel along the fibers of the optic nerve to the occipital lobe of the brain. This pathway from the retina to the brain is called the *visual pathway*.

Figure 13-12 illustrates the pathways of the optic nerves as each leaves the eye. Note that half of the fibers from the left eye cross over and travel to the right side of the brain, and half of the fibers from the right eye cross over and travel to the left side of the brain. The crossing over of the fibers allows the occipital lobe

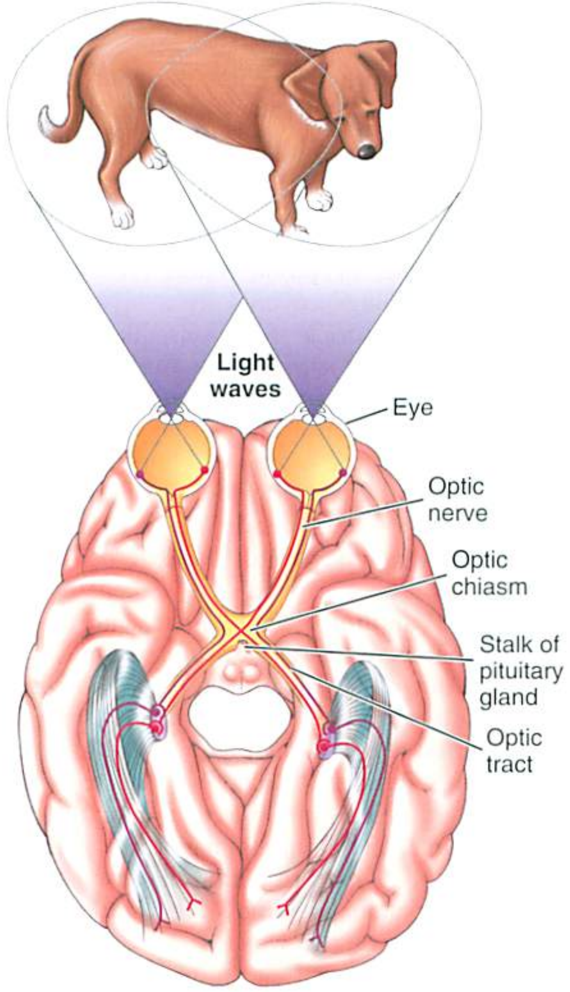


FIGURE 13-12 Visual pathway. Note the optic chiasm and the pituitary gland (behind the optic chiasm).

to integrate the information from both eyes and produce only one image. The point at which the fibers from the left and right eyes crisscross is called the **optic chiasm** (KYE-ass-im). The optic chiasm is located directly in front of the pituitary gland. An enlargement of the pituitary gland can therefore cause visual disturbances as the tumor presses on the optic chiasm and interferes with the transmission of the nerve impulse to the occipital lobe.

SEEING HAPPENS WHEN...

When all the parts of the eye, visual pathway, and brain are working correctly, you can see. Light waves enter your eye, are refracted, and are focused on the photoreceptors of the retina. The photoreceptors translate the light signal to a nerve impulse, which is then transmitted from the retina, along the optic nerve, and finally to the occipital lobe of the brain, where you experience vision.

SEEING DOESN'T HAPPEN WHEN...

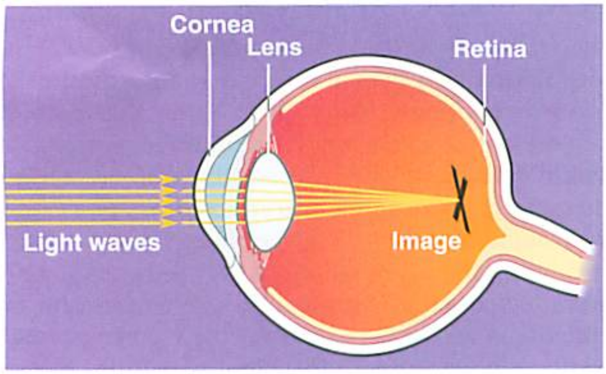
When the parts of the eye and visual pathway do not work normally, a person may experience diminished vision or blindness. Any defect along this pathway from the cornea to the brain can interfere with vision. Certain conditions may prevent the entrance of light into the eye. For example, a scarred cornea or a cloudy lens (cataract) may block the entrance of light, thereby preventing the stimulation of the rods and cones. Errors of refraction such as nearsightedness and farsightedness can adversely affect the focusing of light on the retina (Figure 13-13). Light waves are focused either in front of the retina (nearsightedness) or beyond the retina (farsightedness). Although these conditions can diminish vision, they are generally treatable. The more serious and often untreatable conditions affect the retina in the following ways:

- Increased intraocular pressure (glaucoma) may squeeze the blood vessels of the choroid, depriving the retina of an adequate blood supply. The cells of the retina then die and blindness results.
- The photoreceptors of the macula lutea can degenerate, causing macular degeneration and a loss of vision.
- A person with diabetes often experiences severe damage of the retinal blood vessels. The blood vessels develop microaneurysms. The aneurysms rupture, causing bleeding and scar formation throughout the retina. Retinal photoreceptor cells are replaced with scar tissue. This is called *diabetic retinopathy*.
- Another type of retinal damage includes a detached retina (the retina falls away from the choroid, its blood supply). Activities that cause jarring movements of the head, such as boxing and basketball, increase the risk of retinal detachment.
- Certain conditions or injuries can destroy the optic nerve. For example, a tumor on the optic nerve or at the optic chiasm can interfere with the transmission of the nerve impulse along the nerve to the brain.
- Finally, tumors, blood clots, or trauma can damage the primary visual cortex of the occipital lobe of the brain, causing cortical blindness.

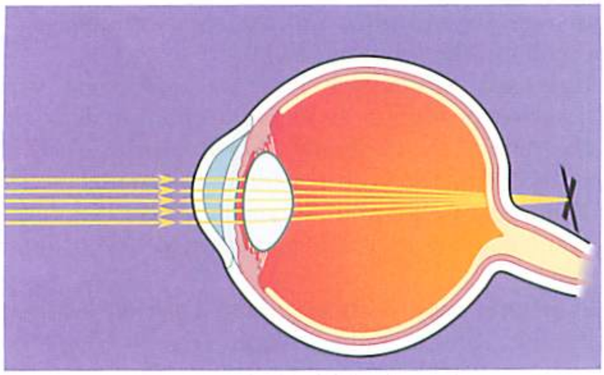
Do You Know...

About High Concentrations of Oxygen and Blindness?

The administration of oxygen is generally beneficial and often lifesaving. Oxygen (O_2) therapy, however, must be delivered with care, particularly in preterm infants. In "preemies" younger than 32 weeks' gestation, the administration of very high concentrations of oxygen can cause blindness. The oxygen is usually administered to a severely hypoxemic infant. While relieving the hypoxemia, the high concentration of O_2 also causes constriction of the developing blood vessels of the retina. Deprived of its blood supply, the retina dies and is replaced by a retrolental membrane of fibrous tissue. The O_2-induced blindness is called *retrolental fibroplasia* or the *retinopathy of prematurity*.



Myopia (nearsightedness)



Hyperopia (farsightedness)

FIGURE 13-13 Errors of refraction: myopia and hyperopia.

? Re-Think

1. Describe the pathway of light to the retina.
2. Describe the path of the nerve impulses (action potentials) generated in the photoreceptors to the primary visual cortex in the occipital lobe.

2+2 Sum It Up!

Light stimulates the photoreceptors, rods (black and white) and cones (color), generating nerve impulses or electrical signals (action potentials) that are carried by the optic nerve (CN II) and visual pathway to the primary visual cortex of the occipital lobe. By tracing these pathways of light and action potentials, you can understand the sequence of events in seeing.

SENSE OF HEARING: THE EAR

Listen to the sounds around you. Perhaps some of it is background noise that you mostly ignore. Other sounds provide you with information. Most importantly, you can hear sounds that you enjoy, such as the voices of friends and sounds of music. The ear is the organ of the sense of hearing.

Refer to Figure 13-14 to identify the structures described as follows.

STRUCTURE OF THE EAR

The ear is divided into three parts: the external ear, the middle ear, and the inner ear.

External Ear

The external ear is the part of the ear you can see. It is composed of the auricle and the external auditory canal. The auricle, or pinna (Latin for "wing"), is composed of cartilage covered by a layer of loose-fitting skin. The auricle functions like a satellite dish gathering sound waves. The auricle opens into the external auditory canal, a passageway for sound waves to enter the ear. The external auditory canal is hollowed out of the temporal bone. It is about 1 inch long (2.5 cm) and ½ inch (1.25 cm) wide and extends to the tympanic membrane, or eardrum. The tympanic membrane separates the external ear from the middle ear.

The external auditory canal is lined with tiny hairs and glands that secrete cerumen, a yellowish waxy substance also known as earwax. The hairs and cerumen help prevent dust and other foreign objects from entering the external ear. Cerumen tends to be a victim of our cleanliness fetish; we insert hairpins, toothpicks, and other sharp objects into the canal in an attempt to dig out the wax. These objects may damage the tympanic membrane. Cotton-tipped applicators, although appearing safer, actually remove very little wax and can push any accumulated wax up against the eardrum and impair hearing. It is best not to insert *any* objects into the ear canal. This practice is more common than you think. A young child may insert an object such as a bean into the external canal; over time, the bean accumulates moisture and swells, making it difficult to remove. Off to the ear doctor for bean removal!

Middle Ear

The middle ear is a small, air-filled chamber located between the tympanic membrane at one end and a bony wall at the other end. The middle ear contains several structures: the tympanic membrane, three tiny bones, several small muscles, and the eustachian tube (also called the *pharyngotympanic tube*).

The tympanic membrane is composed primarily of connective tissue and has a rich supply of nerves and blood vessels. The tympanic membrane vibrates in response to sound waves entering the ear through the external auditory canal. The vibration of the tympanic membrane is passed on to the tiny bones in the middle ear.

The middle ear contains three tiny bones, or **ossicles**, which are the tiniest bones in the body—the malleus (hammer), incus (anvil), and stapes (stirrup). The ossicles transmit vibration from the tympanic membrane to the oval window, a membranous structure that separates the middle ear from the inner ear.

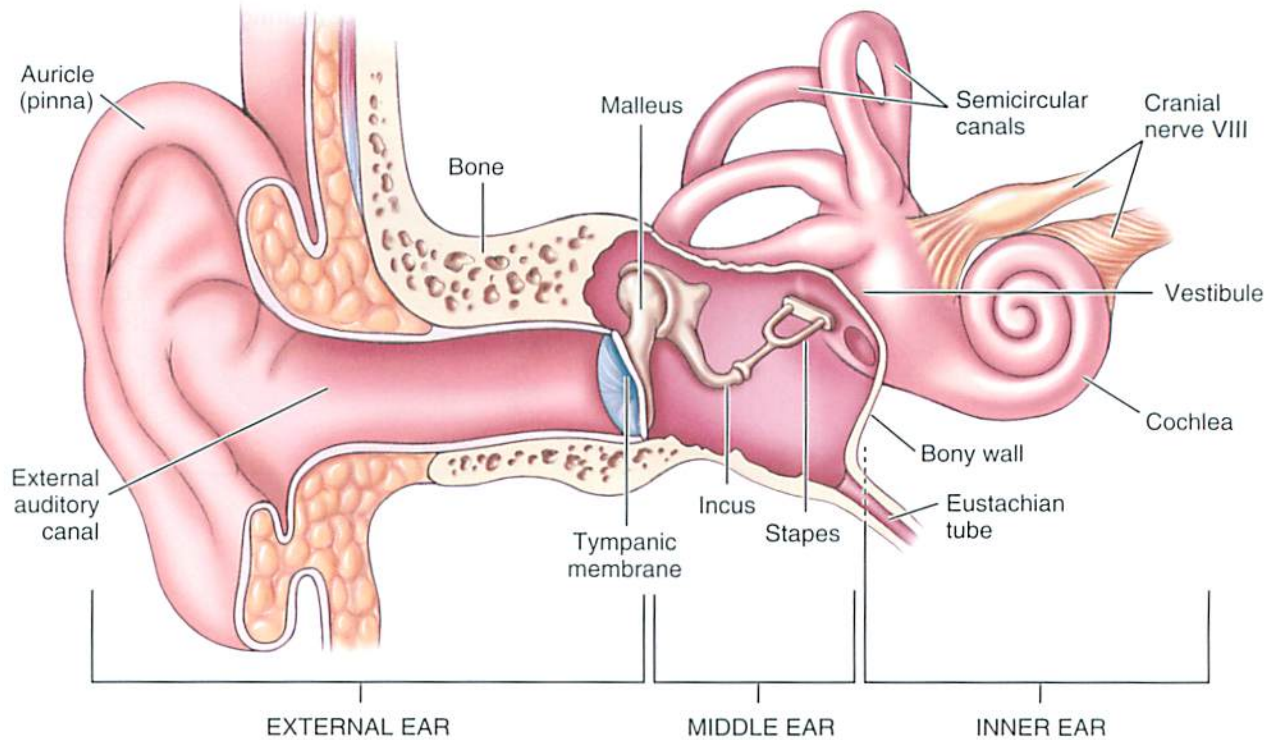


FIGURE 13-14 Three divisions as well as structures of the ear.

The middle ear has a passageway connecting it to the pharynx, or throat. This passageway is called the *auditory tube,* or the **eustachian tube**. The purpose of the eustachian tube is to equalize the pressure on both sides of the tympanic membrane by permitting air to pass from the pharynx into the middle ear. If the pressures across the membrane become unequal, the tympanic membrane bulges. As the tympanic membrane is stretched, pain receptors are stimulated. Pain caused by stretched tympanic membranes is why your ears sometimes hurt when you take off and land in an airplane. Hints to prevent a pressure difference across the tympanic membrane include chewing gum, drinking water through a straw, yawning, and swallowing. Babies can suck on a nipple or pacifier.

Inner Ear

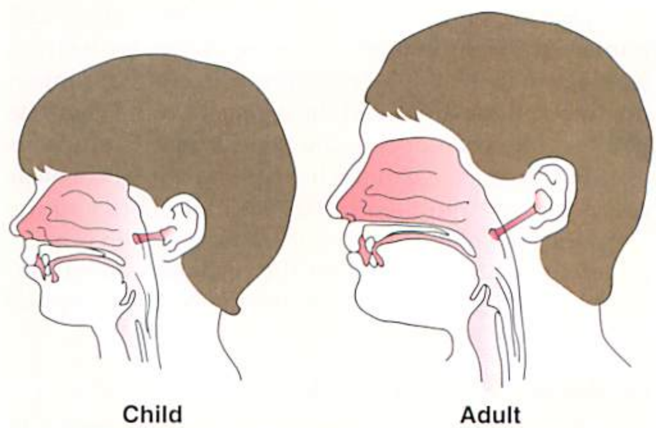
The inner ear consists of an intricate system of tubes, or passageways, hollowed out of the temporal bone. This coiled network of tubes is called a *bony labyrinth* (Figure 13-15). Inside the bony labyrinth is a similarly shaped *membranous labyrinth*. The bony labyrinth is filled with a fluid called *perilymph*. The membranous labyrinth is surrounded by perilymph and is itself filled with a thick fluid called *endolymph*. (For our purposes, the endolymph is the more important fluid.) The inner ear has three parts: the vestibule, the semicircular canals, and the cochlea. The cochlea is concerned with hearing. The vestibule and semicircular canals are concerned with balance.

Do You Know...

Why Children Tend to Outgrow Ear Infections?

The size and position of the eustachian tube in a child are different than in an adult. The eustachian tube of a child is shorter and lies in a more horizontal position than the adult eustachian tube. The child who develops a cold will often sniffle, thereby forcing the nasal drainage from the throat region into the eustachian tubes and middle ear. This drainage results in a middle ear infection called *otitis media*.

As the child grows, the eustachian tube grows longer and becomes more vertical. There is less chance for bacteria to enter the middle ear from the throat. In this sense, children are said to outgrow ear infections.



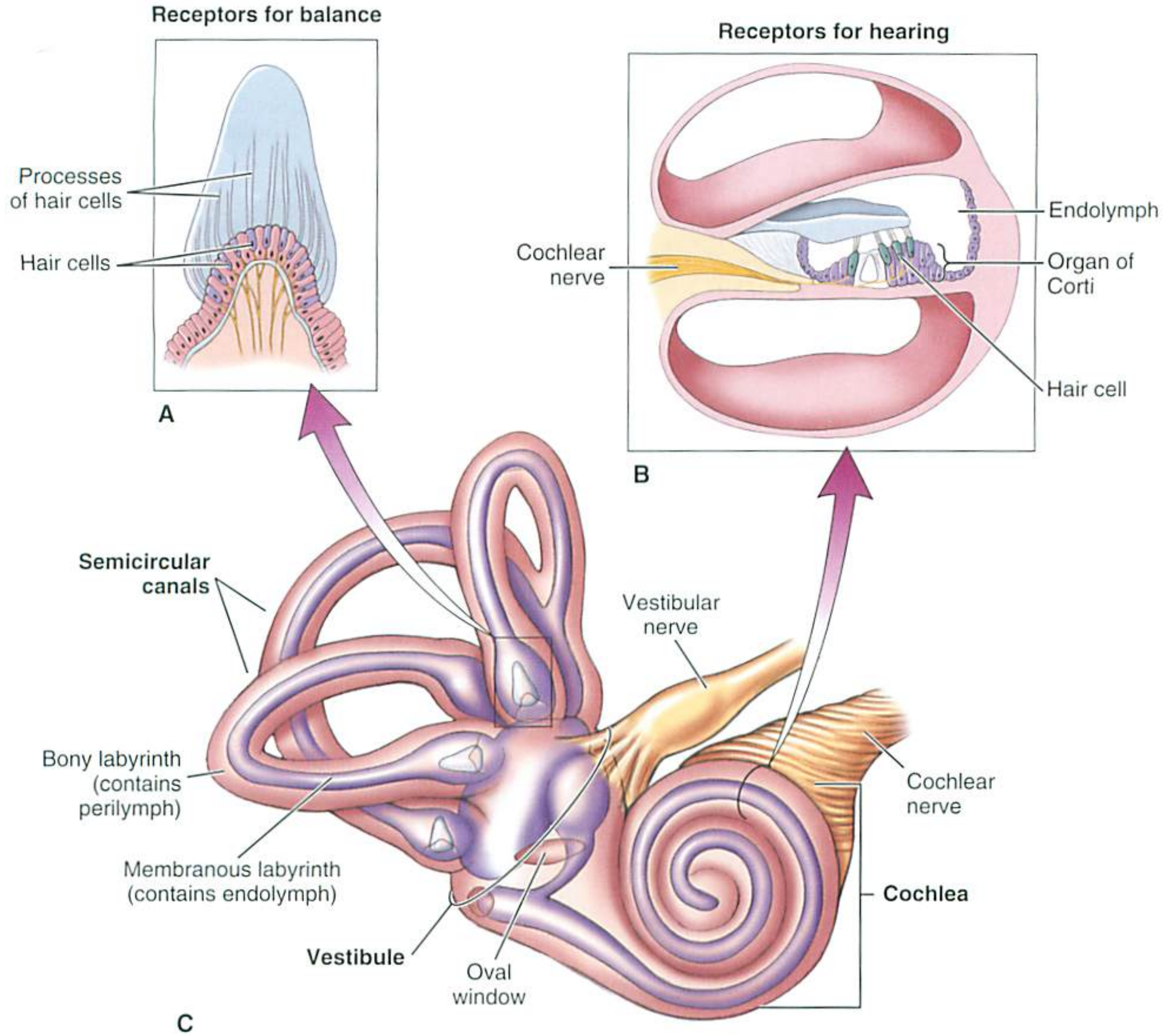


FIGURE 13-15 Inner ear. **A,** The receptors for balance. **B,** The receptors for hearing (organ of Corti). **C,** Structures of the inner ear.

The **cochlea** is a snail-shaped part of the bony labyrinth. Sitting on a membrane within the cochlea and immersed in endolymph are the receptors for hearing (see Figure 13-15, *B*). The receptors are cells that contain tiny hairs; these are called the *organ of Corti*. When the hairs on the receptor cells are bent, a nerve impulse is sent by the cochlear branch of the vestibulocochlear nerve (CN VIII) to the primary auditory cortex of the temporal lobe of the brain, where the sensation is interpreted as hearing. Note that the receptors are stimulated by the bending of the hairs; hence, the receptors are classified as mechanoreceptors.

HEARING HAPPENS WHEN...

How do we hear the sounds of music? As Figure 13-16 illustrates, the vibrating guitar strings disturb the air, causing sound waves. The sound waves are gathered by the auricle, travel through the external auditory canal, and hit the tympanic membrane, causing the tympanic membrane to vibrate. This vibration, in turn, causes the middle ear bones (malleus, incus, and stapes) to vibrate. The stapes, sitting within the oval window, then causes the fluid in the inner ear to move. Because the hairs (organ of Corti) are sitting within the endolymph, movement of the fluid causes the hairs to bend. The bending of the hairs triggers a nerve impulse carried by the cochlear branch of the vestibulocochlear nerve (CN VIII) to the primary auditory cortex of the temporal lobe, where it is interpreted as sound.

HEARING DOESN'T HAPPEN WHEN...

What happens when the parts do not work? Following the steps listed in Figure 13-16, consider the number

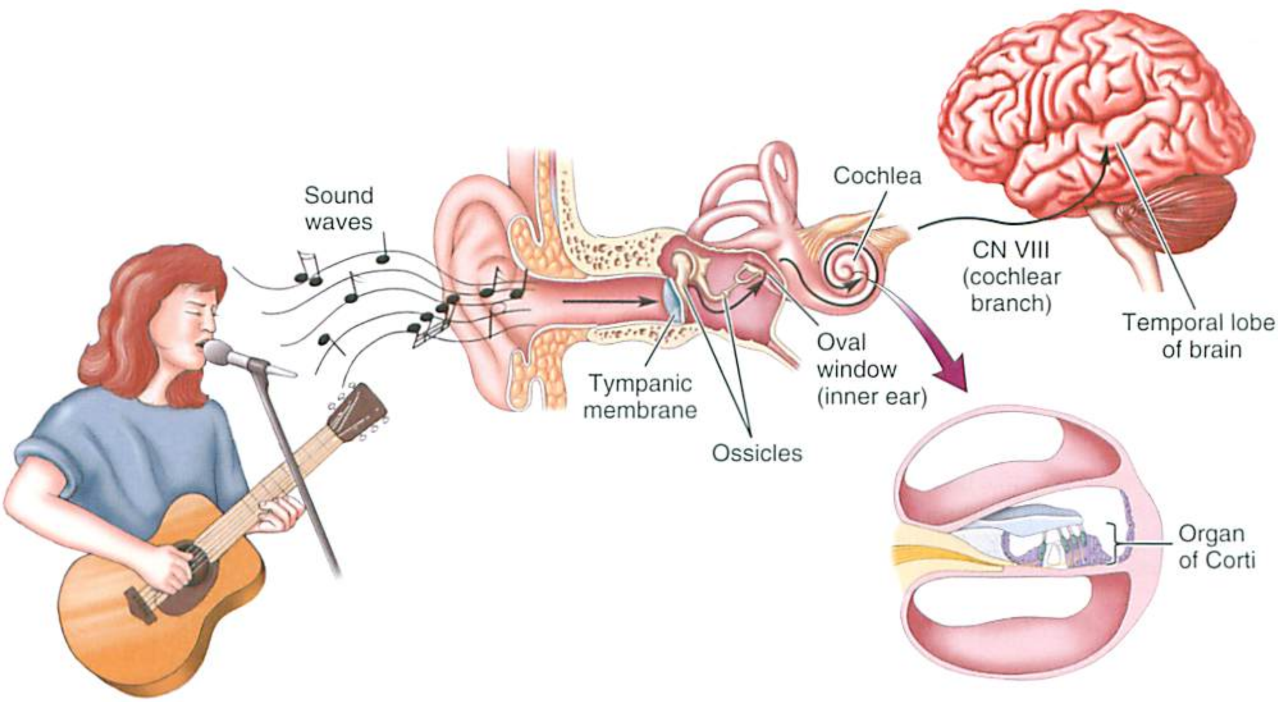


FIGURE 13-16 Steps in hearing.

of ways our hearing may become impaired. For example, the vibration of the tympanic membrane may become blunted if a plug of cerumen (earwax) becomes lodged against the tympanic membrane. The sound waves may then be unable to vibrate the eardrum. The tiny ossicles may also become fused to one another. This condition diminishes the ability of the bones to transmit vibration from the tympanic membrane to the oval window. This problem often develops in children who have experienced repeated middle ear infections.

Another problem is that the stapes may become glued, or fixed, to the oval window. This condition diminishes the transmission of vibration to the inner ear. Deafness resulting from impaired function of the ossicles is called *bone conduction deafness*. The cochlear branch of CN VIII in the inner ear may also be damaged. The damaged nerve cannot conduct nerve impulses from the ear to the brain. This condition develops in persons exposed to prolonged periods of loud noise. For example, "rock and roll deafness" is hearing loss associated with loud music. Nerve damage also occurs in response to certain drugs, especially antibiotics. Drugs that cause damage to the vestibulocochlear nerve are called *ototoxic agents*. Nerve conduction deafness is commonly experienced by older persons. Finally, the primary auditory cortex of the temporal lobe may be damaged. The person will then experience a cortical deafness.

? Re-Think

1. List the three parts of the ear.
2. Describe the pathway of hearing from the collection of sound waves in the external ear to the primary auditory cortex in the temporal lobe of the cerebrum.

SENSE OF BALANCE: THE EAR

We all appreciate our ears as organs of hearing, but we may not realize that our ears play an important role in equilibrium or balance. Damage to the inner ear, for example, may make it impossible for us to stand without losing balance.

The receptors for balance are mechanoreceptors. These cells contain hairlike projections immersed in a gel-like fluid within the vestibule and semicircular canals of the inner ear (see Figure 13-15). The **vestibule** contains the receptors that provide information about the position of the head at rest. The receptors in the semicircular canals provide information about the position of the body as it moves about. These receptors sense the changing positions of the head. When the positions change, the hairs are bent, and the receptor cells send nerve impulses through the vestibular branch of the vestibulocochlear nerve (CN VIII) to several parts of the brain, including the cerebellum, midbrain, and temporal lobe. The brain dispatches signals to the various muscles to restore balance.

Because the vestibulocochlear nerve carries sensory information concerning both hearing and balance, someone with an ear infection may complain of feeling dizzy. The person should be assured that as the ear infection resolves, the dizzy feeling will also disappear.

Do You Know...

Why Rocks in Your Head Keep You Balanced?

Tiny hairs on the inner ear cells concerned with balance (vestibule and the semicircular canals) bend in response to movement of the head. The tiny hair receptors contain little stones called *otoliths*. The stones make the hairs much more sensitive to a change in head position. So otoliths, the rocks in your head, keep you balanced. Notably, sharks have elaborate otoliths. Ask any Great White about his otoliths and he will quickly tell you that the rocks in his head keep him balanced, coordinated, and fine-tuned for Xtreme fishing. He would quickly starve without his array of otoliths.

2+2 Sum It Up!

The ear is the organ of hearing. There are three parts of the ear: external, middle, and inner ear. Sound waves enter the external ear, vibrate the tympanic membrane, which, in turn vibrates the middle ear ossicles (malleus, incus, stapes). The stapes, sitting in the oval window, vibrates the endolymph in the inner ear. Movement of the endolymph activates the hearing mechanoreceptors, the organ of Corti, forming nerve impulses. The nerve impulses travel along the cochlear branch of CN VIII to the primary auditory cortex in the temporal lobe. The ear is also the organ that contains the sense receptors for balance. The mechanoreceptors are located within the inner ear and specifically within the semicircular canals and vestibule. Activation of the receptors causes nerve impulses that are carried by the vestibular branch of CN VIII to various parts of the brain (cerebellum, midbrain, and temporal lobe).

As You Age

1. The general senses diminish with age. A decrease in the number and sensitivity of sensory receptors, dermatomes, and neurons results in dulling of pain, touch, and tactile sensation.
2. A gradual loss in taste and smell begins around the age of 50 years.
3. Cumulative damage to hair cells in the organ of Corti occurs after the age of 60. Older adults can lose the ability to hear high-pitched sounds and the consonants *ch, f, g, s, sh, t, th,* and *z*. Also, 25% of older adults are hearing impaired.
4. Vision diminishes by the age of 70, primarily because of a decrease in the amount of light that reaches the retina and impaired focusing of the light on the retina.
5. The muscles of the iris become less efficient, so the pupils usually remain somewhat constricted.
6. The lacrimal glands become less active, and the eyes become dry and more susceptible to bacterial infection and irritation.

MEDICAL TERMINOLOGY AND DISORDERS Disorders of the Senses: Eyes and Ears

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
Eye			
aphakia	a-	without	**Aphakia** refers to *the absence of the lens when the cataract is extracted.* **Pseudoaphakia (pseudo = false or fake)** refers to *an eye that has an artificial lens.*
	-phak/o-	lens	
	-ia	condition of	
blepharitis	blephar/o-	eyelid	**Blepharitis** is *an inflammation of the eyelid.*
	-itis	inflammation	
cataracts		From a Latin word meaning "waterfall or broken water"	*Clouding of the lens, thereby diminishing the amount of light that enters the posterior eye.*
lacrimal	lacrim/o-	tear	The **lacrimal** gland secretes tears that wash over the cornea and drain through the lacrimal ducts.
	-al	pertaining to	
ocular	ocul/o-	eye	**Ocular** is a word that *refers to the eye,* as in an ocular disease such as glaucoma.
	-ar	pertaining to	

MEDICAL TERMINOLOGY AND DISORDERS Disorders of the Senses: Eyes and Ears—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
ophthalmoscope	ophthalm/o-	eye	An **ophthalmoscope** is *an instrument used to examine the eye.*
	-scope	instrument used for examination	
photophobia	phot/o-	light	A patient with a corneal abrasion may be described as being **photophobic,** or having *a fear of pain-inducing exposure to light.*
	-phob/o-	fear of	
	-ia	pertaining to	
Disorders			
conjunctivitis	conjunctiv/o-	conjunctiva	Refers to *inflammation or infection of the conjunctiva; it is usually viral, bacterial, or allergenic in origin.*
	-itis	inflammation	
errors of refraction	*refringere*	From a Latin word meaning "to break up" (referring to light)	Refers to *distorted vision resulting from improper refraction of light as it enters the eye.* **Emmetropia** (emmetros = well-proportioned/relaxed; -opia = condition of vision) refers to *normal refractive condition of the eye.* Errors of refraction are described in the text.
glaucoma	From the Greek word *glaukos*	Name given to any condition in which gray or green replaces the black color of the pupil	Also called the "silent thief of sight," glaucoma is the second most common cause of blindness in the United States. **Glaucoma** is *a group of eye conditions that cause damage to the optic nerve (CN II) and blindness.* The damage is due to increased intraocular pressure (IOP). There are four major types of glaucoma: open-angle glaucoma, angle-closure glaucoma, congenital glaucoma, and secondary glaucoma. Secondary glaucoma is due to drugs (corticosteroids), eye infections/trauma, or systemic diseases such as diabetes mellitus.
keratitis	kerat/o-	cornea	*Refers to inflammation of the cornea.* **Keratitis** is most often caused by pathogens associated with the use of contact lenses. **Exposure keratitis** is caused by drying and ulceration of the cornea in response to incomplete closure of the eyelids (as occurs with **exophthalmos,** protrusion of the eyeball). **Photokeratitis** is due to excess UV radiation (snow blindness or welder's arc eye). Healing may cause scarring and necessitate a corneal transplant, or keratoplasty (-plasty = surgical repair of).
	-itis	inflammation	
macular degeneration		From a Latin word *macula* meaning "spot"	Called **age-related macular degeneration (AMD)** and *results from damage of the macular cells of the retina with loss of vision in the center of the visual field (like a hole punched in the center of a picture).* **Dry AMD** is due is atrophy of the retina and loss of photoreceptors. **Wet AMD,** or **exudative AMD,** is due to neovascularization (new blood vessel growth), which causes blood or fluid to leak below the macula.
nystagmus		From a Latin word meaning "a nodding" or drowsiness	*Involuntary and rapid oscillating movements of the eyeball.* The movement may be side-to side **(horizontal nystagmus),** up and down **(vertical nystagmus),** or rotary **(rotary or torsional nystagmus).**

Continued

MEDICAL TERMINOLOGY AND DISORDERS Disorders of the Senses: Eyes and Ears—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
retinopathy	retin/o-	retina	*Refers to permanent damage of the retina.* Retinopathy is often characterized by microvascular retinal changes and angiogenesis (formation of new blood vessels). The new blood vessels are fragile and leak fluid or blood into the eye; this causes retinal scarring and severe loss of vision or blindness. There are many causes of retinopathy, the most common being **diabetic retinopathy**.
	-pathy	disease	
strabismus		From a Greek word *strabismos* meaning "to squint"	Also called "crossed eyes." *A disorder in which two eyes do not align in the same direction and therefore do not focus on the same point.* There is **convergent strabismus,** whereby the eye(s) deviates medially, and **divergent strabismus,** whereby the eye(s) deviates laterally.
uveitis	uvea-	From a Latin word meaning "grape"	*Inflammation of the uvea, the middle layer of the eye.* **Anterior uveitis** affects the front part of the eye, usually the iris, causing **iritis. Posterior uveitis** affects the choroid, the layer that supplies most of the blood to the retina. Posterior uveitis is most apt to cause loss of vision.
	-itis	inflammation	
Ear			
myringotomy	myring/o-	eardrum	A **myringotomy** is *an incision into the eardrum usually in an attempt to insert a plastic tube for the purpose of preventing the accumulation of fluid within the middle ear* as occurs in **otitis media.** Also called a *tympanoplasty* (tympan/o- = eardrum).
	-otomy	incision into	
otoscope	ot/o-	ear	An **otoscope** is *an instrument used to visualize the external auditory canal and the tympanic membrane (eardrum).*
	-scope	instrument for examination	
otosclerosis	ot/o-	ear	*Refers to an abnormal bone growth in the middle ear causing a gradual loss of hearing; causes bone conduction deafness.*
	-scler/o-	hard	
	-osis	condition of	
ototoxic	ot/o-	ear	Many drugs are considered to be ototoxic, harmful to the ear and causing a loss of hearing.
	-toxo-	poison	
	-ic	pertaining to	
presbycusis	presby/o-	old age	**Presbycusis** refers to *impaired hearing that develops with advancing age.*
	-acous/os	hearing condition	
Disorders			
Ménière's disease		Named after the French physician Ménière, who first described the disorder	*A disorder of the inner ear thought to be caused by a buildup of inner ear fluid (endolymph).* There are four main symptoms: hearing loss, a feeling of pressure in the ear, tinnitus or a roaring sound, and vertigo. The vertigo is most distressing, causing the person to experience a spinning sensation that, in turn, causes severe nausea, vomiting, and sweating.
kinetosis	kinesi/o-	From a Greek word *kinein,* meaning "to put in motion"	Also called **motion sickness** and **travel sickness** (car, plane, boat). Motion sickness occurs in response to excessive stimulation of the equilibrium receptors in the inner ear. The Greek word for *nausea* means "ship," a reference to seasickness.
	-osis	condition of	

MEDICAL TERMINOLOGY AND DISORDERS Disorders of the Senses: Eyes and Ears—cont'd

Medical Term	Word Parts	Word Part Meaning or Derivation	Description
otitis	ot/o-	ear	*A general term for inflammation or infection of the ear and causes* otalgia *or* otodynia, *an earache.* It is classified as otitis externa, otitis media, and otitis interna. **Otitis externa** is *an outer ear infection, most commonly "swimmer's ear."* **Otitis media** is *a middle ear infection with fluid or pus accumulation behind the tympanic membrane (eardrum).* The drum may burst, causing scarring of the tympanic membrane. Offending pathogens enter the middle ear from the pharynx (throat) via the eustachian tube. **Aerotitis media** is *inflammation of the middle ear caused by changes in atmospheric pressure, as in air travel.* **Otitis interna** *(inner ear inflammation/infection)* affects the sensory cells for both hearing and balance; vertigo is a common symptom.
	-itis	inflammation	

Get Ready for Exams!

Summary Outline

The sensory system allows us to experience the world through a variety of sensations: touch, pressure, pain, proprioception, temperature, taste, smell, vision, hearing, and equilibrium.

I. Receptors and Sensation

A. Receptor
1. A receptor is a specialized area of a sensory neuron that detects a specific stimulus.
2. The five types of receptors are chemoreceptors, pain receptors (nociceptors), thermoreceptors, mechanoreceptors, and photoreceptors.

B. Sensation
1. A sensation is a conscious awareness of incoming sensory information.
2. There are four components of a sensation.
3. Two characteristics of sensation are projection and adaptation.

II. General Senses

A. Pain
1. Pain receptors (nociceptors) are free nerve endings.
2. The stimuli for pain are tissue damage, lack of oxygen, and stretching or distortion of tissue.

B. Touch and pressure
1. Receptors are mechanoreceptors that respond to forces that press, move, or deform tissue.
2. The receptors for pressure are located in the skin, subcutaneous tissue, and deep tissue.

C. Temperature
1. There are thermoreceptors for heat and cold.
2. Thermoreceptors are found in free nerve endings and in other specialized sensory cells beneath the skin.

D. Proprioception
1. Proprioceptors are located primarily in the muscles, tendons, and joints.
2. Proprioceptors sense orientation or position.

III. Special Senses

A. Sense of smell: The nose
1. Olfactory receptors are chemoreceptors.
2. Sensory information travels along the olfactory nerve to the temporal lobe.

B. Sense of taste: The tongue
1. Taste buds contain chemoreceptors for taste.
2. There are four basic taste sensations: sweet, salty, sour, and bitter.
3. Sensory information travels along the facial, glossopharyngeal, and vagus nerves to the gustatory cortex in the parietal lobe.

C. Sense of sight: The eye
1. The visual accessory organs include the eyebrows, eyelids, eyelashes, lacrimal apparatus, and extrinsic eye muscles.
2. The eyeball has three layers: the sclera, choroid, and retina (contains the photoreceptors, rods, and cones).
3. The eyeball has two cavities. One is a posterior cavity filled with vitreous humor; the other is an anterior cavity filled with aqueous humor.
4. There are two sets of eye muscles: extrinsic and intrinsic eye muscles.
5. The extrinsic eye muscles move the eyeball.
6. The intrinsic eye muscles control the size of the pupil and shape of the lens for refraction.

7. Light stimulates the photoreceptors.
8. The electrical signal is carried to the occipital lobe via the optic nerve and visual pathway.

D. Sense of hearing: The ear
1. There are three parts of the ear: the external ear, middle ear, and inner ear.
2. The middle ear contains the ossicles.
3. The inner ear structure concerned with hearing is the cochlea. It contains the hearing receptors, or the organ of Corti (mechanoreceptors).
4. Hearing information is carried by the cochlear (CN VIII) to the temporal lobe.
5. Steps in hearing are summarized in Figure 13-16.

E. Sense of balance: The ear
1. The receptors are mechanoreceptors located in the vestibule and semicircular canals of the inner ear.
2. The receptors are activated when the head changes position.
3. Balance information travels along the vestibular nerve (CN VIII) to many areas of the brain (cerebellum, midbrain, and temporal lobe).

Review Your Knowledge

Matching: Senses

Directions: Match the following words with their descriptions below. Some words may be used more than once.

a. sight
b. taste
c. smell
d. hearing
e. balance

1. ___ Involves rods and cones, the retina, and CN II
2. ___ Involves the organ of Corti and CN VIII
3. ___ Is the olfactory sense; uses chemoreceptors
4. ___ Uses mechanoreceptors; sensory information transmitted by the vestibular branch of CN VIII
5. ___ Gustatory sensation
6. ___ From photoreceptors to the occipital lobe
7. ___ From receptors to the auditory cortex

Matching: Structures of the Eye

Directions: Match the following words with their descriptions below. Some words may be used more than once.

a. choroid
b. vitreous humor
c. lens
d. cornea
e. iris
f. aqueous humor
g. conjunctiva
h. retina

1. ___ The layer of the eyeball that contains the photoreceptors
2. ___ The colored muscle portion of the eye that determines the size of the pupil
3. ___ The shape of this structure determined by the ciliary muscles; refracts light
4. ___ Layer of the eyeball that provides the blood supply for the retina
5. ___ Secreted by the ciliary body and drained by the canal of Schlemm
6. ___ Gel-like substance in the posterior cavity; maintains the shape of the eye and helps hold the retina in place
7. ___ Contains the radial and circular muscles; mydriasis and miosis
8. ___ The window of the eye; an avascular structure
9. ___ Includes the macula lutea
10. ___ Inner lining of the lids; "pink eye"

Matching: Structures of the Ear

Directions: Match the following words with their descriptions below. Some words may be used more than once.

a. external ear
b. middle ear
c. inner ear

1. ___ Contains the malleus, incus, and stapes
2. ___ Connected to the pharynx by the eustachian tube
3. ___ Home of cerumen
4. ___ Location of the organ of Corti and CN VIII
5. ___ Cochlea, semicircular canals, and vestibule
6. ___ Endolymph and perilymph; mechanoreceptors
7. ___ Separated from the middle ear by the tympanic membrane
8. ___ Separated from the inner ear by the oval window
9. ___ Bone conduction deafness
10. ___ Nerve conduction deafness

Multiple Choice

1. The retina
  a. refracts light.
  b. contains rods and cones.
  c. covers the optic disc, the area of most acute vision.
  d. secretes vitreous humor.

2. What is the consequence of diminished blood flow to the choroid?
  a. Aqueous humor cannot be formed and the intraocular pressure increases.
  b. Light cannot be refracted.
  c. The retina dies.
  d. The pupil constricts.

3. A drug or effect that is described as mydriatic
  a. decreases intraocular pressure.
  b. dilates the pupil.
  c. increases the secretion of aqueous humor.
  d. increases the numbers of cones.

4. Which of the following does not describe the middle ear?
  a. It contains the malleus, incus, and stapes.
  b. It connects with the pharynx by the eustachian tube.
  c. It is the location of the organ of Corti.
  d. It is concerned with bone conduction.

5. The organ of Corti
  a. is the receptor for hearing.
  b. refers to the ossicles within the middle ear.
  c. leans up against the tympanic membrane and "feels" its vibration.
  d. activates CN II.

6. Touch, pressure, pain, and temperature are
   a. mediated through mechanoreceptors.
   b. classified as general senses.
   c. interpreted in the precentral gyrus.
   d. general senses that are interpreted in the occipital lobe.
7. Cranial nerves III, IV, and VI
   a. carry sensory information from the retina to the occipital lobe.
   b. carry sensory information from the organ of Corti to the primary auditory cortex.
   c. innervate the extrinsic eye muscles.
   d. are the motor nerves involved in the corneal reflex.
8. Which of the following is not a sense?
   a. Gustation
   b. Lacrimation
   c. Olfaction
   d. Proprioception
9. Which of the following best describes these structures: superior oblique, inferior oblique, superior rectus, inferior rectus, medial rectus, and lateral rectus?
   a. Cranial nerves that stimulate the extrinsic eye muscles
   b. Muscles that form the iris
   c. Middle ear structures
   d. Extrinsic eye muscles
10. Which of the following is least related to the eyelids?
   a. Levator palpebrae superioris
   b. CN III
   c. Ptosis, causing a "sleepy" appearance
   d. Optic nerve

Go Figure

1. **According to Figures 13-1 and 13-3 and Table 13-1**
   a. The general senses include touch, pressure, smell, temperature, and proprioception.
   b. Pain receptors are stimulated on either extreme of the thermoreceptors.
   c. Figure 13-3 identifies the four components of a sensation that are specific to the special senses.
   d. All the receptors in Table 13-1 are represented in Figure 13-3.
2. **According to Figures 13-5 and 13-6, and Table 13-1**
   a. Olfactory receptors are mechanoreceptors.
   b. Activation of chemoreceptors in the nasal membrane elicits the sensation of smell in the olfactory cortex of the temporal lobe.
   c. The tip of the tongue is responsible for differentiating among bitter, sour, salty, and sweet tastes.
   d. The gustatory sense (taste) is mediated by a nociceptor.
3. **According to Figure 13-7**
   a. The lacrimal gland is located medially and secretes aqueous humor.
   b. Tears are drained through openings in both the medial and lateral canthi.
   c. The lacrimal sac is located laterally and inferior to the lacrimal gland.
   d. The lacrimal puncta are part of the drainage system for tears.
4. **According to Figure 13-8**
   a. Vitreous humor fills the anterior cavity and gives shape to the cornea.
   b. Aqueous humor fills the posterior cavity and gently presses the retina against the choroid.
   c. The retina lies against the choroid in the posterior portion of the eyeball.
   d. The optic nerve receives sensory information from all structures within the eye, particularly the lens.
5. **According to Figure 13-8**
   a. Aqueous humor drains from the anterior cavity by way of the canal of Schlemm.
   b. Vitreous humor drains from the posterior cavity by way of the optic disc.
   c. The macula lutea and fovea centralis are areas of the choroid.
   d. All of the above are true.
6. **According to Figure 13-8**
   a. The retina, choroid, and sclera are layers of the posterior eyeball.
   b. Suspensory ligaments attach the lens to the cornea.
   c. The macula lutea and fovea centralis are intrinsic eye muscles.
   d. The iris is located posterior to the lens.
7. **According to Figures 13-8 and 13-9**
   a. The ciliary muscles are extrinsic eye muscles.
   b. The iris is composed of circular and radial muscles.
   c. The intrinsic eye muscles include the ciliary muscles and the superior and inferior oblique muscles.
   d. Mydriasis occurs in response to the constriction of the circular muscles of the iris.
8. **According to Figures 13-11 and 13-13**
   a. Refraction is accomplished by the contractile activity of the extrinsic eye muscles.
   b. Hyperopia and myopia are called *errors of refraction*.
   c. Refraction is accomplished by the contraction and relaxation of the iris.
   d. The lens focuses the light rays on the optic disc.
9. **According to Figure 13-12**
   a. The optic chiasm is located in the primary visual cortex.
   b. All fibers from the right eye cross at the optic chiasm and travel to the left side of the brain.
   c. All fibers from the left eye cross at the optic chiasm and travel to the right side of the brain.
   d. Some fibers from both the left and right eyes cross at the optic chiasm and travel to opposite sides of the brain.

10. According to Figures 13-14 and 13-15

a. Bone conduction is an inner ear event.
b. Nerve conduction is a middle ear event.
c. The external ear is separated from the middle ear *by the oval window.*
d. CN VIII receives input from receptors for both hearing and balance.

11. According to Figures 13-14, 13-15, and 13-16

a. Vibration of the tympanic membrane is caused by fluid movement in the inner ear.
b. The eustachian tube connects the middle ear with the semicircular canals.
c. The semicircular canals and vestibule house the organ of Corti.
d. The cochlear branch of CN VIII carries information to the temporal lobe.