Objective H To describe the ear in general terms and to elaborate on the structural components of the outer ear and their functions.

The ear is the organ of hearing and equilibrium. It consists of three principal regions: the outer ear, the middle ear, and the inner ear (fig. 12.10). The outer ear is open to the external environment, the middle ear is open to the pharynx through the auditory (eustachian) tube, and the inner ear communicates with the brain through sensory nerves. Incoming sound waves pass in sequence through a gaseous medium (external ear), solid medium (middle ear), and fluid medium (inner ear).

The outer ear directs sound waves to the middle ear. Structures of the outer ear include the auricle (pinna), external auditory canal, and the tympanic membrane (“eardrum”). The funnel-shaped auricle directs the sound waves to the external auditory canal, a 2.5-cm (1-in.) fleshy tube that fits into the bony external acoustic meatus (see fig. 6.11). Ceruminous glands (problem 5.28) deep within the external auditory canal secrete protective cerumen (ear wax). The thin tympanic membrane conducts sound waves to the middle ear.

Figure 12.10 The ear.

A ruptured tympanic membrane (“broken eardrum”) may occur as the result of infections or trauma. A middle-ear infection (acute purulent otitis media) in children is common following a cold or tonsillitis. The pathogens gain entry into the middle ear through the auditory tube. An intense earache is a common symptom of a middle-ear infection. The pressure from the inflammation may eventually rupture the tympanic membrane permitting drainage of pus. Spontaneous perforation of the tympanic membrane from an infection or a loud noise usually heals rapidly, but scar tissue may form and lessen sensitivity to sound vibrations.
12.17 What are the common physical parameters used to describe a sound wave?

There are two: amplitude and frequency (fig. 12.11). The amplitude is the “height” of the wave; the power or intensity of the wave is proportional to the square of its amplitude. Intensity translates psychologically into loudness, and is measured (on a logarithmic scale) in decibels (dB).

Frequency is the number of oscillations (“back-and-forth,” in the case of sound) the wave makes in a unit of time. Frequency translates into pitch, and is measured in hertz (Hz), where 1 Hz = 1 cycle per second.

![Figure 12.11 Profiles of sound-wave amplitude and frequency.](image)

**Auditory (eustachian) tube.** The auditory tube connects the middle-ear cavity to the pharynx. With this connection, the air pressure is equalized on both sides of the tympanic membrane. The auditory tube also permits moisture to drain from the middle-ear cavity.

**Objective I**  To describe the structural components of the middle ear and their functions.

The middle-ear cavity, or tympanic cavity, is the air-filled space medial to the tympanic membrane (see fig. 12.10). Its structures and their functions are as follows:

**Auditory ossicles.** The three auditory ossicles (see problem 6.23 and fig. 6.15) are the malleus (“hammer”), attached to the tympanic membrane; the incus (“anvil”), located between the other two; and the stapes (“stirrup”), attached to the vestibular (oval) window. The vestibular window is a membrane-covered opening into the inner ear. These small bones (the smallest in the body) articulate and move as levers to amplify the sound waves about 20 times as they are transmitted through the middle-ear cavity.
Objective J  To describe the structural components of the inner ear and their functions.

The inner ear contains not only the organs of hearing, but also those of equilibrium and balance. Its structures and their functions are as follows:

Bony labyrinth. This is a network of cavities in the petrous part of the temporal bone (see fig. 6.15). The cavities consist of three bony semicircular canals (see figs. 12.10 and 12.12), each of which swells into a globular ampulla, a central vestibule, and a snail-shaped cochlea.

Membranous labyrinth. This intercommunicating system of membranous ducts is seated in the bony labyrinth, and its parts are named with those of the bony labyrinth (fig. 12.13). Thus we have the membranous semicircular canals and their ampullae, which possess receptors sensitive to rotary motions of the head. The vestibule consists of a connecting utricle and saccule, which possess receptors sensitive to gravity and linear motions of the head. Extending through the center of the cochlea is the membranous cochlear duct, and within the cochlear duct is found the spiral organ (organ of Corti) (see fig. 12.14). The spiral organ is a “transducer” that converts sound (mechanical) impulses into nerve (electrical) impulses. The membranous labyrinth is filled with a fluid called endolymph, and to the outside of the membranous labyrinth is a fluid called perilymph.

The vestibular window (oval window) is located at the footplate of the stapes, where it transfers sound waves from the solid medium of the auditory ossicles to the fluid medium of the cochlea. The cochlear window (round window) is positioned directly below the vestibular window, where it reverberates in response to loud sounds.

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**Figure 12.12** The bony labyrinth of the inner ear.

**Figure 12.13** The membranous labyrinth of the inner ear.
12.18 Describe the cochlea in detail.

The cochlea has three chambers: an upper scala tympani, a lower scala vestibuli, and a middle cochlear duct (fig. 12.14). The scala tympani is continuous with the scala vestibuli, and both contain perilymph. The cochlear duct is bordered by the vestibular membrane and the basilar membrane. It contains endolymph. It also contains the hair cells that are embedded in the basilar membrane and that contact the tectorial membrane. The cochlear duct and the structures it contains constitute the spiral organ (organ of Corti). The spiral organ is considered the functional unit of hearing because it is here that the fluid vibrations of the mechanical sound waves stimulate the hair cells (dendritic endings of neurons) causing nerve impulses (sound sensations) to be conveyed through the cochlear nerve to the brain for perception.

High-frequency sound waves activate hair cells closer to the vestibular window at the base of the cochlea. Low-frequency sound waves activate hair cells farther away from the vestibular window, toward the top of the cochlea.

![Figure 12.14 The cochlea is shaped like a snail shell. (a) The three chambers of the cochlea (in bold) and (b) the spiral organ.](image)

2.20 Explain how changes in body motion (that involve the head) are monitored by hair cell receptors within the vestibular organs (the three semicircular canals, the utricle, and the saccule).

Whenever the head is moved—or, more precisely, accelerated—in a certain direction, the hair cells of the vestibular organs move with the head. However, because of inertia, the endolymph within the vestibular organs tends to keep its original position in space; thus, it pushes in the opposite direction, against the hair-cell receptors, thereby stimulating them. The information generated by the receptors, in the form of nerve impulses, is transmitted to the CNS, where it helps to regulate postural reflexes and equilibrium.

Receptors in the roughly spherical utricle and saccule detect linear acceleration in any given direction. Receptors in the semicircular canals detect rotational acceleration—also in any direction, since the semicircular canals are disposed in perpendicular planes.