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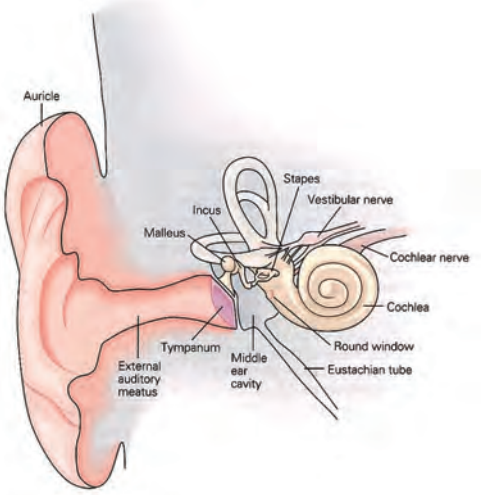

Figure 30.1 **The structure of the human ear.** The external ear, especially the prominent auricle, focuses sound into the external auditory meatus. Alternating increases and decreases in air pressure vibrate the tympanum. These vibrations are conveyed across the air-filled middle ear by three tiny, linked bones: the malleus, the incus, and the stapes. Vibration of the stapes stimulates the cochlea, the hearing organ of the inner ear. (Adapted from Noback1967.)

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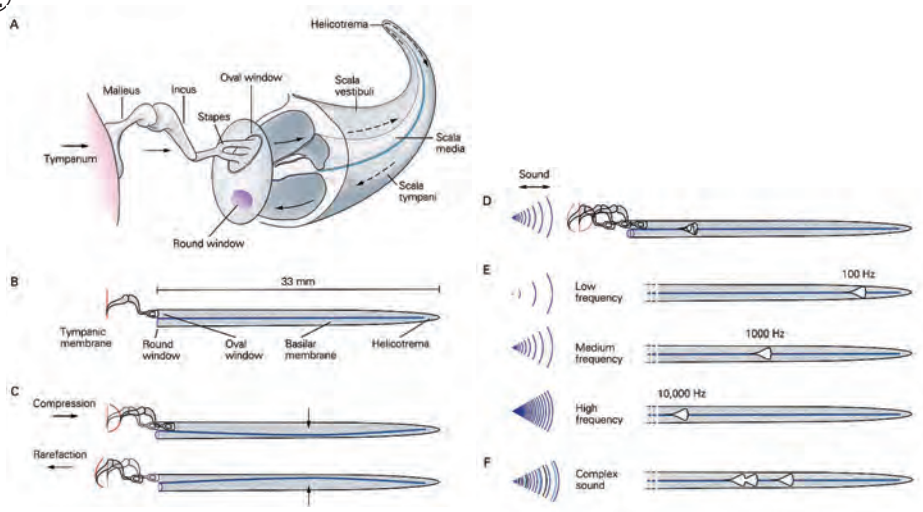

Figure 30-3 **Motion of the basilar membrane**.
A. A conceptual drawing of an uncoiled cochlea displays the flow of stimulus energy. Sound vibrates the tympanum, which sets the three ossicles of the middle ear in motion. The stapes, a piston-like bone set in the elastic oval window, produces oscillatory pressure differences that rapidly propagate along the scala vestibuli and scala tympani. Low-frequency pressure differences are shunted through the helicotrema.
B. A further simplification of the cochlea converts the spiral organ into a linear structure and reduces the three fluid-filled compartments to two, separated by the elastic basilar membrane.
C. If the basilar membrane had uniform mechanical properties along its full extent, a compression would drive the tympanum and ossicles inward, increasing the pressure in the scala vestibuli and forcing the basilar membrane downward (top). Note that the increased pressure in the scala tympani is relieved by outward bowing of the round-window membrane. Under similar circumstances, opposite movements would occur during a rarefaction (bottom). Movement of the ossicles is greatly exaggerated here and in D.
D. Because the basilar membrane's mechanical properties in fact vary continuously along its length, oscillatory stimulation by sound causes a traveling wave on the basilar membrane. Such a wave is shown, along with the envelope of maximal displacement over an entire cycle. The magnitude of movement is grossly exaggerated in the vertical direction; the loudest tolerable sounds move the basilar membrane by only ±150 nm, a scaled distance less than one hundredth the width of the lines representing the basilar membrane in these figures.
E. Each frequency of stimulation excites maximal motion at a particular position along the basilar membrane. Low-frequency sounds, such as a 100 Hz stimulus, excite basilar-membrane motion near the apex where the membrane is relatively broad and flaccid (top). Mid-frequency sounds excite the membrane in its middle (middle). The highest frequencies that we can hear excite the basilar membrane at its base (bottom). The mapping of sound frequency onto the basilar membrane is approximately logarithmic.
F. The basilar membrane performs spectral analysis of complex sounds. In this example a sound with three prominent frequencies (such as the three dominant components of human speech) excites basilar-membrane motion in three regions, each of which represents a particular frequency. Hair cells in the corresponding positions transduce the basilar-membrane oscillations into receptor potentials, which in turn excite the nerve fibers that innervate these particular regions.

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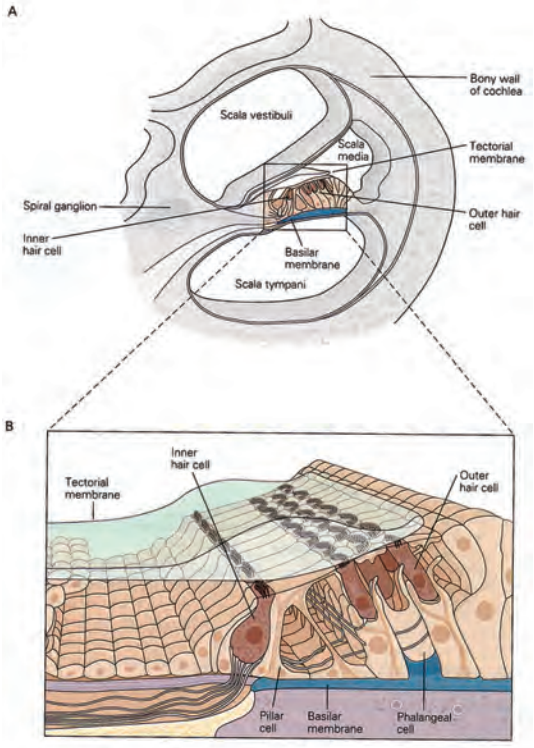

Figure 30-4 **Cellular architecture of the organ of Corti in the human cochlea. Although there are differences among species, the basic plan is similar for all mammals**.
A. The inner ear's receptor organ is the organ of Corti, an epithelial strip that surmounts the elastic basilar membrane along its 33 mm spiraling course. The organ contains some 16,000 hair cells arrayed in four rows: a single row of inner hair cells and three of outer hair cells. The mechanically sensitive hair bundles of these receptor cells protrude into endolymph, the fluid contents of the scala media. The hair bundles of outer hair cells are attached at their tops to the lower surface of the tectorial membrane, a gelatinous shelf that extends the full length of the basilar membrane.
B. Detailed structure of the organ of Corti. The hair bundle of each Inner cell is a linear arrangement of the cell's stereocilla, while the hair bundle of each outer hair cell is a more elaborate, V-shaped palisade of stereocilia. The hair cells are separated and supported by phalangeal and pillar cells (see Figure 30-5A). One hair cell has been removed from the middle row of outer hair cells so that three-dimensional aspects of the relationship between supporting cells and hair cells can be seen. The diameter of an outer hair cell is approximately 7 µm. Empty spaces at the bases of outer hair cells are occupied by efferent nerve endings that have been omitted from the drawing.

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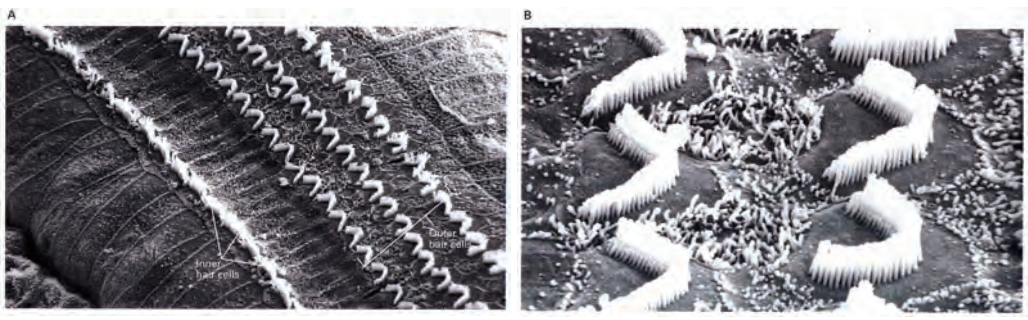

Figure 30-5 **Scanning electron micrographs of the organ of Corti after removal of the tectorial membrane**.
A. In the single row of inner hair cells the stereocilia of the cells are arranged linearly. In contrast, in the three rows of outer hair cells the stereocilia of each cell are arranged in a V configuration. The surfaces of a number of other cells are visible: the inner spiral sulcus cells, the heads of the inner pillar cells, the phalangeal processes of Deiters' cells, and the surfaces of Hensen's cells.
B. The V-shaped configuration of the stereocilia of the outer hair cells is shown at higher magnification. The apical surfaces of the hair cells surrounding the stereocilia appear smooth, whereas the surfaces of supporting cells are endowed with microvilli.