



FIGURE 12-5 Diagram of the human ear.

* 12-3 The Ear and Its Response; Loudness

The human ear is a remarkably sensitive detector of sound. Mechanical detectors of sound (microphones) can barely match the ear in detecting low-intensity sounds.

The function of the ear is to transform the vibrational energy of waves into electrical signals which are carried to the brain by way of nerves. A microphone performs a similar task. Sound waves striking the diaphragm of a microphone set it into vibration, and these vibrations are transformed into an electrical signal with the same frequencies, which can then be amplified and sent to a loudspeaker or tape recorder. We shall discuss the operation of microphones when we study electricity and magnetism in later Chapters. Here we shall discuss the structure and response of the ear.

Figure 12-5 is a diagram of the human ear. The ear consists of three main divisions: the outer ear, middle ear, and inner ear. In the outer ear, sound waves from the outside travel down the ear canal to the eardrum (the tympanum), which vibrates in response to the impinging waves. The middle ear consists of three small bones known as the hammer, anvil, and stirrup, which transfer the vibrations of the eardrum to the inner ear at the oval window. This delicate system of levers, coupled with the relatively large area of the eardrum compared to the area of the oval window, results in the pressure being amplified by a factor of about 40. The inner ear consists of the semicircular canals, which are important for controlling balance, and the liquid-filled cochlea where the vibrational energy of sound waves is transformed into electrical energy and sent to the brain.

* The Ear's Response

Sensitivity of the ear

*Loudness
(in "phons")*

The ear is not equally sensitive to all frequencies. To hear the same loudness for sounds of different frequencies requires different intensities. Studies averaged over large numbers of people have produced the curves shown in Fig. 12-6. On this graph, each curve represents sounds that seemed to be equally loud. The number labeling each curve represents the **loudness level** (the units are called *phons*), which is numerically equal to the sound level in dB at 1000 Hz. For example, the curve labeled 40 represents sounds that are heard by an average person to have the same loudness as a 1000-Hz sound with a sound level of 40 dB. From this 40-phon curve, we see that a 100-Hz tone must be at a level of about 62 dB to be perceived as loud as a 1000-Hz tone of only 40 dB.