Hearing aid

A device that amplifies sound for someone with a hearing loss. A typical aid consists of a microphone, an electronic amplifier, an earphone (called a receiver), and a battery. The sound is coupled to the ear with an earmold. The great majority of earmolds are cast from impressions of the individual patient's ear canal, but over-the-counter and mail-order hearing aids use prefabricated earmolds, commonly offered in several sizes. In the case of in-the-ear hearing aids, all components are small enough to be contained in an earmold shell that fits within the ear canal and concha, or even within the canal alone (Fig. 1). See AMPLIFIER; EAR (VERTEBRATE); EARPHONES; MICROPHONE.

Development. Pre-electric ear trumpets provided acoustic gain as early as the late eighteenth century. By the early 1920s, hearing aids containing miniature vacuum tubes could provide an amount of amplification limited only by the quality of the seal between the earmold and the ear (to prevent whistling caused by feedback). By 1962 the transistor plus subminiature microphones and earphones had made the components small enough to produce all-in-the-ear hearing aids. See TRANSISTOR.

By 1989, hearing-aid designers had come to understand that they needed to take the transmission characteristics of the ear into account to create normal frequency response at the eardrum, and that hearing loss is typically accompanied by hearing distortions that need to be compensated by electronic processing of the signal. This understanding, combined with integrated circuits, high-quality miniature microphones and receivers, zinc-air batteries, and high-efficiency class D amplifiers, made it practical to produce hearing aids with a fidelity (exclusive of the processing) equal to the best home stereo systems. See BATTERY; INTEGRATED CIRCUITS.

Types of hearing loss. Hearing loss caused by abnormalities in the mechanical parts of the ear is called conductive; that created by loss of hair cells of the cochlea is called cochlear or sensorineural; and that created by pathology of the eighth nerve (much less common) is called neural. Conductive hearing loss is effectively overcome with surgery or hearing aids, while the latter two types of loss present a greater challenge for hearing aids.

In the normal inner ear, approximately 15,000 outer hair cells provide some 30–50 dB of mechanical amplification for quiet sounds, while approximately 5000 inner hair cells convert sound-induced mechanical energy into nerve impulses that go to the brain (Fig. 2). A major cause of damage to these hair cells is excessive exposure to loud noise and music. A loud ringing in the ear after such an exposure is an indication of likely death of some of the cells. The loss of hair cells causes two symptoms: a loss of hearing sensitivity to quiet sounds, and a loss of ability to understand speech in noise. The two symptoms can occur in various ratios. When loss of sensitivity is the dominant symptom, hearing aids can restore nearly normal hearing by amplifying these quiet sounds without overamplifying louder sounds, and by providing extra gain for those high-frequency sounds made inaudible by the typical high-frequency hearing loss. A signal-processing system called wide-dynamic-range compression (WDRC) does all of that. Although this system was widely criticized when it was introduced, it is now used in almost all analog and digital hearing aids. See SIGNAL PROCESSING.

Unfortunately, a loss of speech cues available to the brain often accompanies a loss of inner (as opposed to outer) hair cells, and the loss of redundant
cues makes it difficult for the listener to understand speech in noise. This difficulty can be helped by increasing the signal-to-noise ratio in several ways: using directional-microphone hearing aids, leaning closer to the talker, using a microphone held close to the talker, or using a system of microphones worn by each of several talkers (a development that can improve the signal-to-noise ratio by a factor of 10). See HEARING (HUMAN); HEARING IMPAIRMENT.

**User satisfaction.** Surveys show that a nearly constant 60% of hearing-aid users are satisfied overall, with no increase of satisfaction from analog to digital aids. The dissatisfied 40% include those whose hearing aids are not properly fitted or are inappropriate to the loss; those whose earmold fit does not prevent feedback or prevent their own voices from sounding hollow (the latter effect is called occlusion); those—a small percentage—for whom wearing a hearing aid is disturbing under any circumstances; and most important, those who are unable, even with the hearing aids, to understand speech in the presence of noise or competing speech. For the last group, both analog and digital aids may fail equally by providing audibility but not the ability to separate speech from interference. The surveys show no difference in overall satisfaction between inexpensive analog hearing aids and expensive digital hearing aids, although both analog and digital aids with directional microphones produce higher satisfaction. (As noted above, an even greater improvement in signal-to-noise ratio can be obtained using a microphone held close to the talker or using a system of microphones worn by each of several talkers.)

While many of the claims of the superiority of digital over analog hearing aids have been exaggerated, digital circuits do have potential advantages deriving from their flexibility, and the better ones provide sophisticated feedback reduction that does not simultaneously reduce audibility or intelligibility. From the standpoint of convenience, a digital circuit can analyze a listening environment and adjust the hearing aid to the processing the manufacturer has chosen for that environment (directional versus omni mode, for example), so that the user does not have to readjust the controls. Although many digital hearing aids have not achieved the sound quality of the best analog aids, digital aids have neither an inherent advantage or disadvantage in sound quality compared to analog aids.

**Binaural hearing aids.** Some years ago the use of binaural hearing aids (an aid in each ear) was looked on with some suspicion, as a way to get people to buy a second aid that offered no advantage. The Federal Trade Commission strictly limited advertising claims for the advantages of binaural hearing aids. It is now recognized that an aid in each ear offers three real advantages: (1) Binaural release from masking: because of the directional cues created by binaural listening, the ability to separate speech from interference is improved by several decibels. (2) Binaural loudness
summation: a sound heard by two ears is louder than the same sound heard by one ear. This means that less amplification is required of each hearing aid of a binaural pair, and for the same loudness the physical level of sound going into each ear is less. The danger of feedback, and the danger of distortion created by overload of the mechanical parts of the ear, are thereby reduced. (3) The loss of intelligibility in the unaided ear that often occurs over time from the auditory deprivation is avoided. See MASKING OF SOUND.