Cochlear Implants

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“Bi-on-ics

Etymology: from bi (as in “life”) + onics (as in “electronics”); the study of mechanical systems that function like living organisms or parts of living organisms” (Fischman)

OVERVIEW

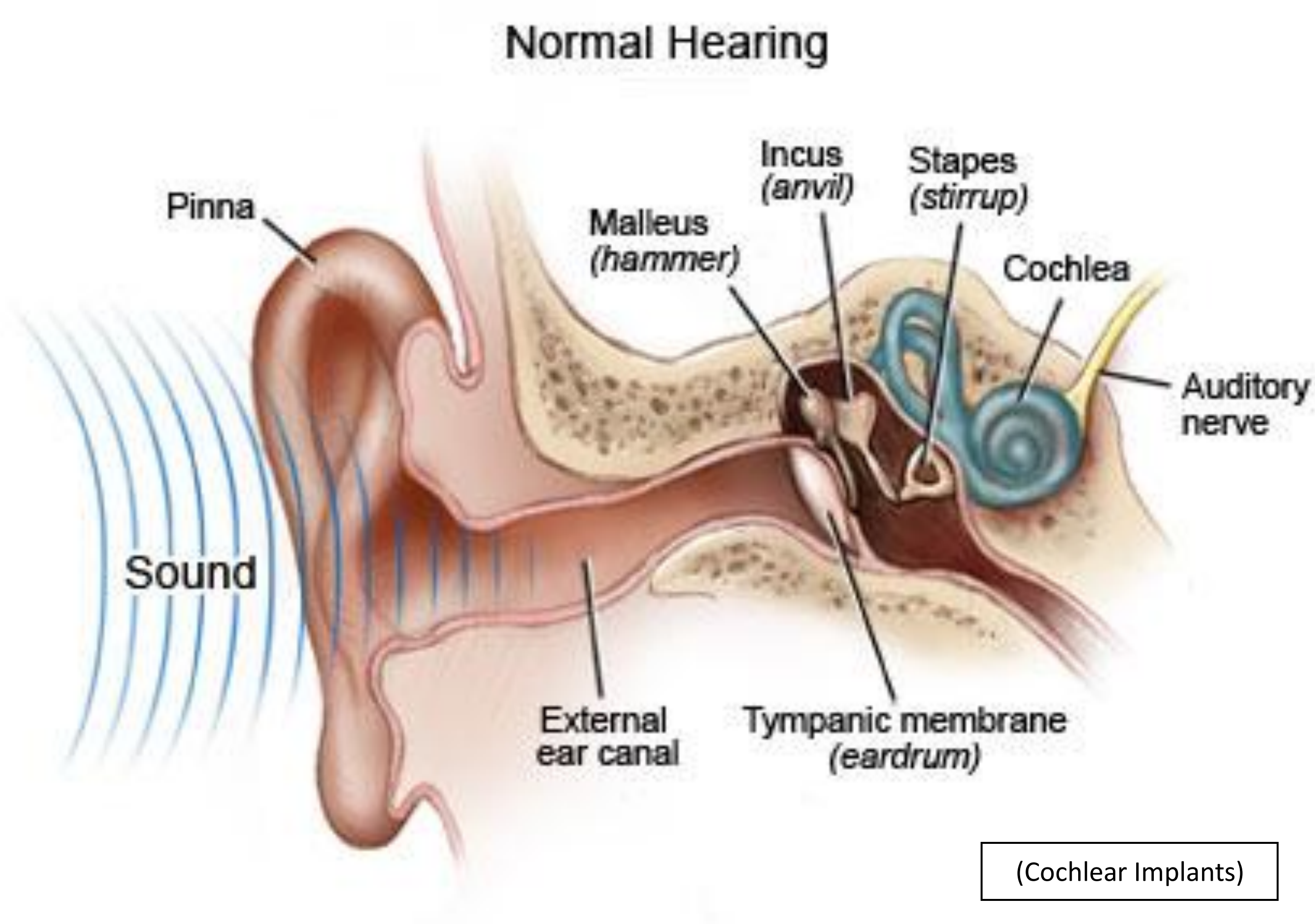
The cochlea is a snail-shell shaped structure located in the inner ear. This organ detects the pressure impulses of sound waves and delivers electrical impulses to the brain via the auditory nerve. Cochlear implants, developed by Dr. Bill House in the 1960s, are designed to function in a similar manner in people with sensorineural deafness.

Cochlear implantation is an outpatient procedure. Candidates must be generally healthy, have severe to profound hearing loss in both ears, and receive little or no benefit from traditional hearing aids. The surgery lasts 2-4 hours (Cochlear) under general anesthesia. The surgeon cuts back a flap of skin behind the ear, and drills a recessed bed in the skull with a specialized drill. The drilled away bone allows for the secure placement of the receiver.

Once this has been done, the surgeon continues to drill, this time using magnification to locate the middle ear and to drill a tiny hole into the cochlea itself. An electrode array is inserted into the cochlea so that it winds around the snail-shell shape.

The attached receiver is placed in the mastoid bone. All of the drill holes are sealed with tissue, and the flap is sutured closed.

One month is allowed to pass after surgery before the implant is activated so that the wounds may heal. After the waiting period is over, the deaf experience sound often for the first time through electric stimulation of the auditory nerve.

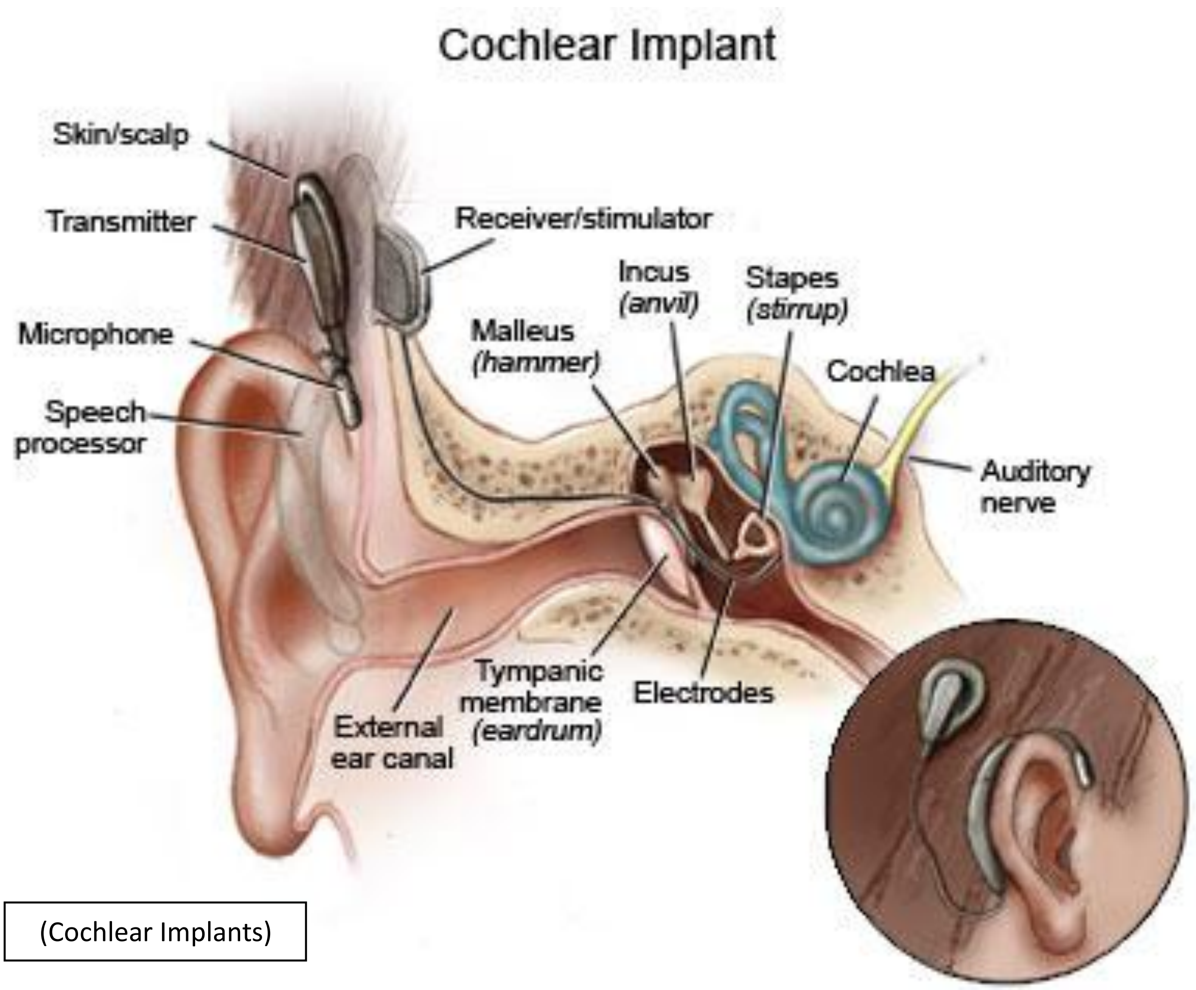


(Cochlear Implants)

In people with normal hearing, the ear functions as the medium between vibrations picked up from the environment and the auditory nerve.

Sound vibrations are first picked up by the outer ear, the part visible from the outside. These vibrations are directed through the ear canal and to the middle ear where they cause the tympanic membrane, or eardrum to vibrate. The vibration is then transferred to the three tiny bones of the middle ear, the stapes, the anvil, and the hammer.

In turn, this motion causes vibrations in the fluid filled cochlea. The inner membrane of the cochlea is covered in tiny, long, thin cells appropriately named hair cells. These move in the fluid and send signals to the auditory nerve that are interpreted by the brain as components of speech such as pitch and frequency.



(Cochlear Implants)

In people with sensorineural deafness, the hair cells inside the cochlea are underdeveloped, misformed, or damaged. Causes can be genetic, or diseases such as meningitis or rubella. Regardless of the underlying cause, when the hair cells fail to respond correctly to the vibrations transmitted to the cochlea, the auditory nerve is not correctly stimulated, and the sensation of sound never reaches the brain.

From the outside, a cochlear implant basically consists of a microphone, a speech processor and a transmitter

MICROPHONE

The microphone generally is above the ear and connected to the behind the ear unit. This serves well for users who are utilizing speech reading to supplement the sound they receive through the cochlear implant. A user can face the speaker while the microphone picks up sounds.

SPEECH PROCESSOR

The speech processor looks much like a traditional hearing aid. Its function, however, is intrinsically different. Whereas traditional hearing aids attempt to help the inner ear function by amplifying sound, the speech processor actually performs the job of the inner ear. It takes the sound input from the microphone and breaks it down into the pattern of frequencies that make up the sound.

TRANSMITTER

The transmitter is held onto the scalp just behind the ear by a magnet under the skin. The earliest cochlear implants did not utilize this magnet system. Instead the outer and inner portions were connected directly by a sort of socket running through the skin – leading to frequent infection.

In more modern devices, radio transmission and the use of magnets allow for communication between the two pieces, but with no open wound.

Other forms of communication were considered in the early history of cochlear implants. Infrared light shone through the eardrum, and ultrasonic vibrations to the scalp (Clark) were both among the proposed and abandoned methods.

IMPLANTED PORTION OF COCHLEAR IMPLANT

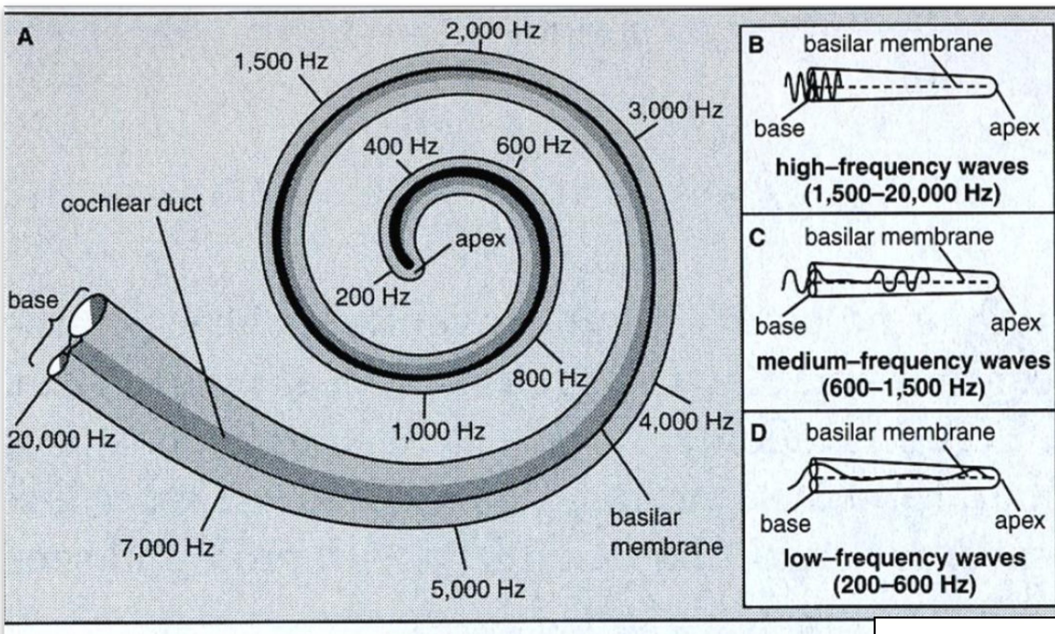
The implanted portion of a cochlear implant consists of a receiver embedded firmly within the mastoid bone of the skull. The receiver picks up coded pulse signals from the transmitter via radio wave (Clark) and sends electrical signals through a wire that ends in the spiral of the cochlea. This wire consists of an electrode array that functions to stimulate the auditory nerve much like the hair cells normally would. In this way sound bypasses much of the inner ear, including the nonfunctioning cochlea.

The most interesting part of the cochlear implant is certainly the 17 millimeters of wire that are actually coiled around inside the cochlea itself. This is the electrode array that delivers electrical impulses to different areas of the cochlea, ultimately stimulating the auditory nerve and giving the deaf perception of sound.

CHALLENGES FOR ELECTRODE ARRAY

Sounds in spoken language fall over an incredibly wide range of frequencies. On the lower end is the frequency of a male speaking voice, 125,000 Hertz. In English the upper bound is the frequency of the "s" sound which can be as high as 7,000 Hertz (Waltzman 317).

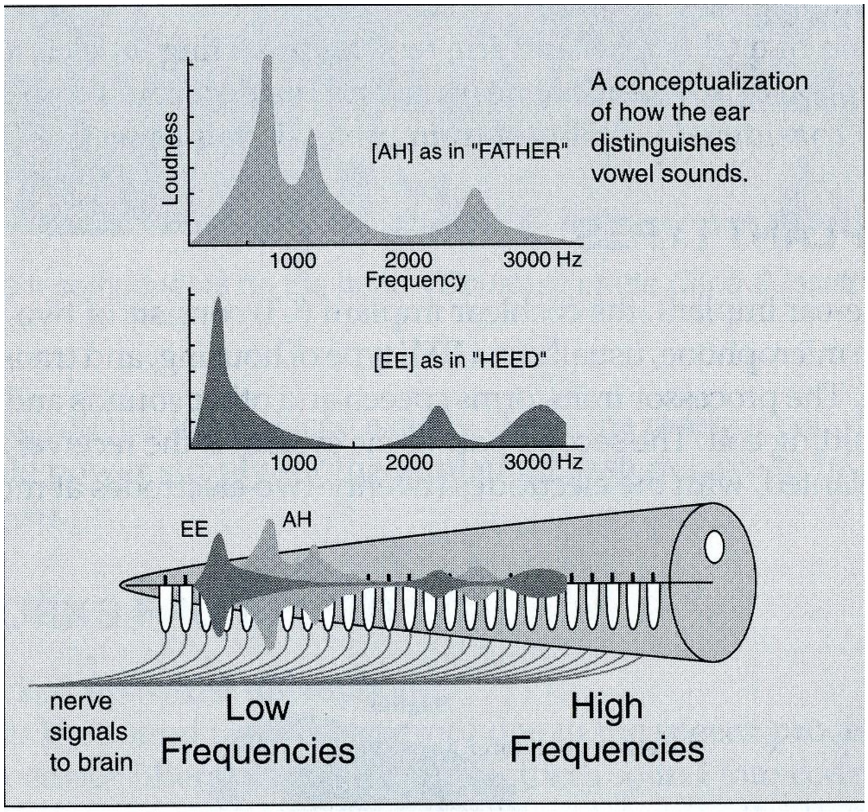
This range of frequency is mapped below in a normal cochlea.



(Vonlanthen 275)

High frequency sounds stimulate the auditory nerves nearest the beginning of the spiral. Lower frequency sounds travel further through the coil and stimulate the auditory nerves there. The brain interprets the location of the signal in relation to the cochlea as an important determination of sound.

Any particular language sound is a mixture of different frequencies at different intensities, as shown on the following page.



(Vonlanthen 275)

In cochlear implants, as the speech processor distinguishes different frequencies in speech input the "location of the stimulated electrode [changes to mimic] the normal change in location of spectral peaks along the [cochlear] membrane" (Waltzman 319). So when the external microphone picks up the 'ah' sound, the stimulation of the auditory nerve by the electrode array is very similar to the stimulation of the auditory nerve by the vibration through the hair cells of the cochlea in a person with normal hearing.

Modern cochlear implants can consist of 22-electrode array. Each electrode is a platinum ring that wraps around an insulated wire. The rings are spaced out along the tip of the wire that winds through the cochlea spiral. During surgery, surgeons often encounter difficulty in inserting the array fully due to obstructions such as ossification. To solve this potential problem, the electrodes are not assigned a specific frequency until after the surgery is complete, and the surgeon can tell exactly where each electrode lies.

Many different mappings are in common use for cochlear implants. A mapping is the particular way in which electrodes are stimulated given a particular input sound or set of input frequencies. A new cochlear implant user will go through several mappings with their audiologist in order to find the one that works best.

Another problem with cochlear implants is possible damage to the ear from the device. The consistent use of electric stimulation could potentially be detrimental to the components of the ear. Insertion of the electrode array into the cochlea can and generally does destroy any residual hearing in the ear. This is why some choose to implant only one ear, saving the other for the possibility of improved future technology.

Devices exist that call for only partial insertion of the electrode array tip into the cochlea. This compromises quality of perception, but also preserves a portion of the cochlea for the application of some novel device.

Much research has gone into the development of safe conventions for the use of a cochlear implant. In general, electric pulses sent through the array are bounded by an upper frequency of 4000 Hertz (Vonlenthan). Usage below these levels has been determined to cause "no loss of auditory ganglion cells" (Clark).

CONTROVERSY

In the United States, children are now eligible for implants at only 12 months of age. Earlier cases are rare, but they do occur. Cochlear implants allow young children access to language. Children with cochlear implants learn to speak the same way that hearing children do. They hear.

Opposition to the use of cochlear implants in general and specifically in children exists within the Deaf community. (Deaf refers to anyone who uses sign language to communicate, whereas deaf refers to people who cannot hear.) Because the Deaf are connected by a bond so strong as common language they have developed their own culture, and often do not consider deafness a disability.

Most often the decision to implant a young deaf child falls to the hearing parents. The Deaf community sees this as a direct conflict of interest. Many people also see the use of cochlear implants as a way of disowning Deaf culture in order to join the hearing community.

Opinions, however, are changing with time; Gallaudet University, the only deaf university in the United States, is now "encouraging open discussion of cochlear implants and their place in education and the deaf community" (Christiansen 262).

CONCLUSION

The first cochlear implants used only a single electrode, and so could only stimulate the auditory nerve at one location along the cochlea. Frequencies were maxed out at 1,000 Hertz. Patients could only distinguish vowel sounds; consonant sounds were not transmitted at all.

Only forty years later, the most advanced cochlear implants today use 22-electrode arrays; new technologies are still being developed.

Right now over 20,000 cochlear implants are in use worldwide. That means that there are 20,000 deaf people hearing right now. Dr. House's ingenuity and modern technology have been combined to form a mechanical system that is not only capable of functioning as the ear, but also able to function in conjunction with the human brain. Cochlear implants are justifiably dubbed the bionic ear.

Bibliography

Campbell, Macaulay. “Wired for sound: How cochlear implants work.” *Seattle Post-Intelligencer*. September 28, 2000. <http://www.seattlepi.com/lifestyle/wired28.shtml>

Christiansen, John B., and Irene Leigh. *Cochlear Implants in Children: Ethics and Choices*. Washington, D.C.: Gallaudet UP, 2002.

Clark, Graeme M. “The Multiple-Channel Cochlear Implant: The Interface between Sound and the Central Nervous System for Hearing, Speech, and Language in Deaf People: A Personal Perspective.” *Philosophical Transactions: Biological Sciences*, Vol. 361, No. 1469, pp. 791-810

“Cochlear Implants.” *Kids Heath from Nemours*. <http://kidshealth.org/parent/general/eyes/cochlear.html>

Fischman, Josh. “Bionics”. *National Geographic.* January 2010. pp 35-37, 40

House, William. "Interview with William F. House M.D., Physician, Dentist, Father of Neurotology." by Douglas L. Beck. *Audiology Online*. February 23, 2004 http://www.audiologyonline.com/interview/interview_detail.asp?interview_id=255

Waltzman, Susan B., and Noel L. Cohen. *Cochlear Implants*. New York: Thieme, 2000

Vonlanthen, A., and Horst Arndt. *Hearing Instrument Technology for the Hearing Healthcare Professional*. Clifton Park, NY: Thomson Delmar Learning, 2007.