WIRED FOR SOUND

A new implant bypasses the damaged ear, reproducing sound for the totally deaf


DON GRAYSTON

Bioengineer Donald Eddington, surrounded by computers, holding inner ear implant

The young man—call him David—was in the barber's chair when it finally happened. As the talkative barber circled to David's right side, the chattering voice seemed to fade. Ever since a bad attack of nausea and dizziness months before, David had been having trouble hearing with his right ear. Now the hearing was completely gone. Six months later, after another attack, he woke to a world of total silence. His wife seemed to be talking frantically, but without making a sound. The hearing in his left ear had deserted him too.

At 27, David was a victim of Ménière's syndrome, a disease that can destroy the thousands of fragile hair cells (so called because of their shape) lining the inner ear. Like nearly 2 million other Americans whose hair cells have been destroyed, he was totally and permanently deaf. Neither surgery nor a hearing aid would help; the hair cells, which convert sound waves into nerve impulses intelligible to the brain, cannot be replaced.

Nearly two decades later, David is still immersed in silence. But it is no longer impenetrable. In a computer-filled room at the artificial hearing laboratory of the University of Utah in Salt Lake City, he can hook a slender cable to the dime-sized plug protruding from behind his left ear and listen to a fuzzy but mostly understandable form of speech. The voice that he usually hears is that of Donald Eddington, a leading ear bioengineer, who heads the Utah lab and has brought the world of sound back to David. For three years David has been a volunteer in Eddington's project, doing his part to create an artificial inner ear that could end the isolation of the deaf.

In normal hearing, sound waves travel through the eardrum and bones to a hard, snail-like structure called the cochlea. There the vibrations jostle 24,000 microscopic hair cells arranged, like piano strings, in order of pitch from high to low. The hair cells, in turn, send electrical signals through the auditory nerve to the brain.

In most of the totally deaf, the hair cells are dead. Eddington's cure is to run tiny wires—six in David's case—to pinhead-sized platinum electrodes implanted at selected points along the cochlea's scale, thus tapping into the auditory nerve. The wires run through the plug behind David's ear and into the cable, which is connected to a complex electronic system and to a microphone that picks up a speaker's voice. "The implant actually bypasses the damaged ear interior," Eddington explains. "Our electrodes simply stimulate the nerves directly, not with vibrations but with minute electrical shocks. The system mimics the electrical patterns perceived by the brain as speech."

When Eddington started out five years ago, his rudimentary system could reproduce only crude sounds—like those of slamming doors, ringing bells, and city traffic—but not speech. Then he began to unravel the ear's mysterious code. Sending electrical impulses into six electrodes, one at a time, he got his patients to recognize simple tunes like *Twinkle, Twinkle Little Star* and *Mary Had a Little Lamb*.

In the next, crucial step, he stimulated the electrodes in concert, creating the patterns associated with speech. By questioning his patients, he began to learn just how each sensation sounded to them. "Determining whether a sound is pure or fuzzy, reedy or brassy, is no trivial task," says Eddington. "We had to know how the stimulus changed the perception of sound. Is the sound loud or soft? Is the pitch high or low? What is the sound's texture and quality?"

With the help of a computer, Eddington soon learned how to modify speech signals before they reach the ear. Now, after years of trial and error, he is at last refining an electronic language for the deaf. While facing away from the speaker (to prevent lip-reading), patients can understand about 75 per cent of words read from lists that include sounds as similar as "bit," "bat," "bite," and "boat." They can also often understand simple sentences like "How was your plane

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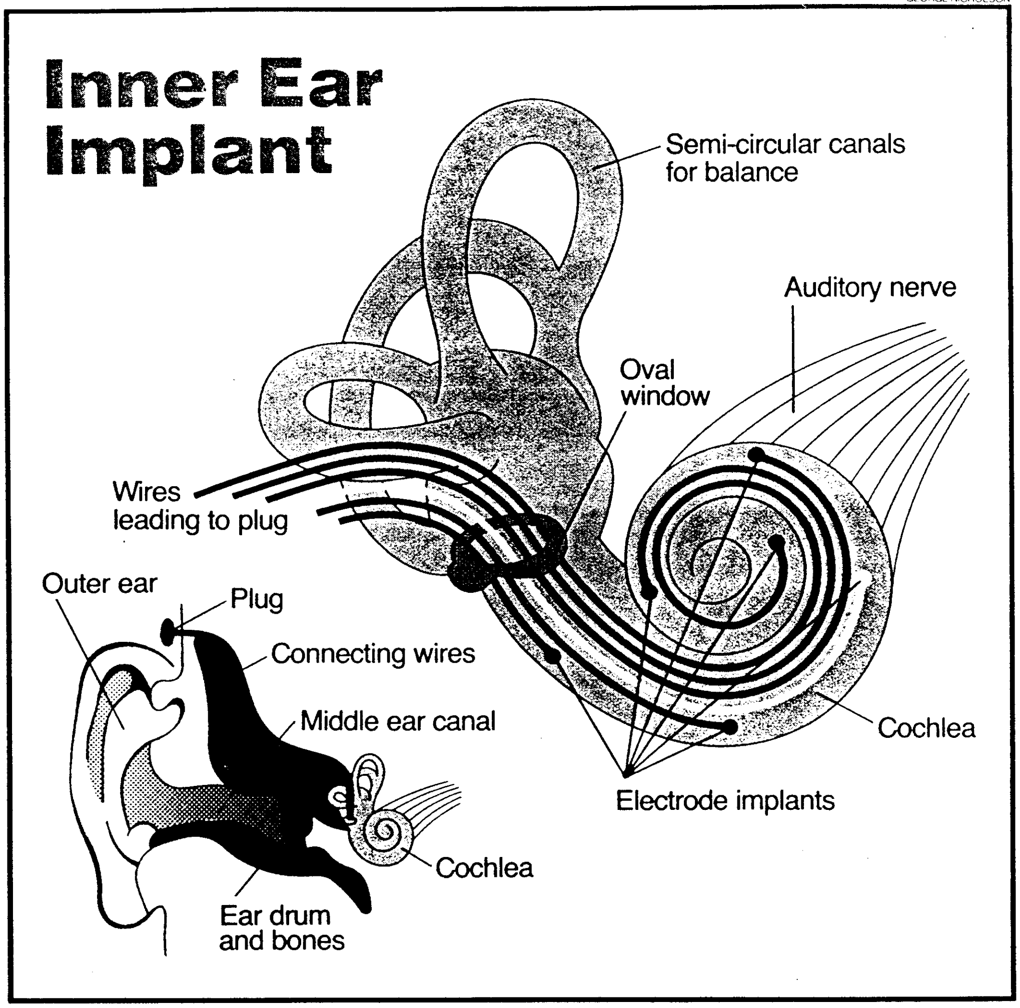


flight?" Next year Eddington hopes to have an 18-electrode implant that will dramatically increase intelligibility.

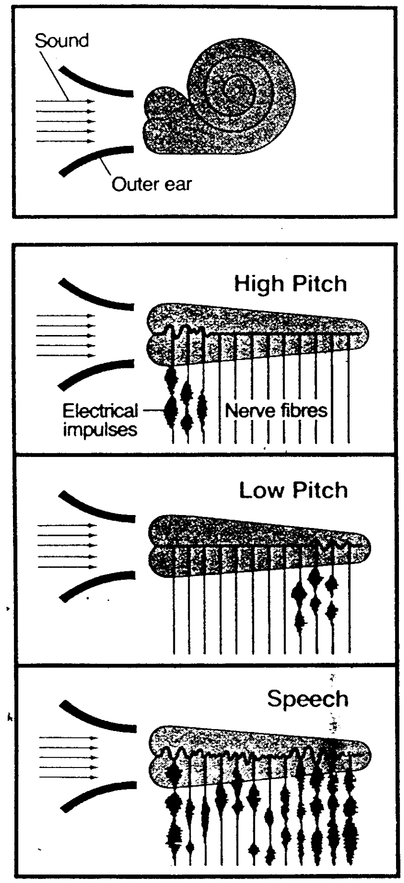
But, as he points out, "speech is a complex signal intricately encoded on the auditory nerve," and it will require a lot more work to produce artificial implants that function as well as real ears. David still has trouble judging just how loud some sounds are; he cannot recognize certain kinds of sounds, especially unusual words spoken out of context. Nonetheless, he is elated. Says he: "I never expected to hear so well so quickly."

For now, the tiny electrodes are hooked to hulking laboratory computers. But Eddington is confident that once he perfects his system he can reduce it with existing technology to a unit the size of a cigarette case. Indeed, scientists at the Ear Research Institute in Los Angeles have miniaturized more than 100 single-electrode versions of the inner ear implant. Patients wear these units for as long as 14 hours a day, and recognize a limited range of sound but little speech. Engineers at Stanford University are devising sophisticated implants with the same minuscule microcircuits—chips—used in computers. Robbin Michaelson, a researcher at the University of California at San Francisco, who is developing a system much like Eddington's, predicts that a unit enabling those with inner ear deafness to understand speech could be on the market in a couple of years.

Such an implant, says Eddington, might help not only adults with inner ear deafness, but also infants born deaf because of defective hair cells. For those who have been deaf for a lifetime, he admits, learning the spoken language from scratch would be difficult unless the device worked as well as a real ear. But that too may be possible. Bioengineers are dreaming of an electronic ear with as many as 5,000 electrodes, based on even greater knowledge of the labyrinthine ear structure and human speech. It could be implanted in deaf babies at birth. And people who had been afflicted later in life could once more enjoy talking to friends and listening to Beethoven's Fifth.

—Pamela Weintraub

Cochlea



Sound waves entering the ear travel through spiraled cochlea, where they stimulate nerve fibers that signal the brain. The fibers running from the thick end of the spiral (shown unrolled above) transmit high-pitched sounds; fibers at the other end transmit low-pitched sounds. Speech is heard when a mix of high-, medium-, and low-pitched sounds reaches the nerves. To mimic this, scientists stimulate inner ear nerves with electrodes (upper left)