SCIENCE AND BUSINESS

Electronic Earful

Cochlear implants sound better all the time

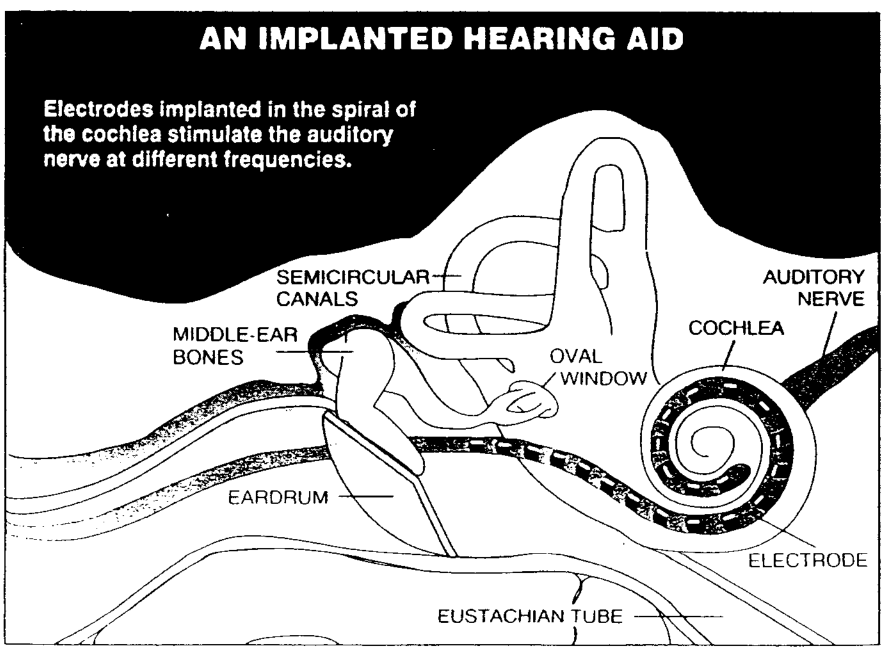
Megawatt light bulb, gradient lenses, molecular computers

Imagine threading a wire through a snail shell a millimeter wide at its widest point. The wire is an electrode, the bony spiral a region of the inner ear known as the cochlea. The reason for traveling this path? To stimulate the nearby auditory nerves electrically so a deaf person can perceive sound. This concept was hyped well before the first cochlear implant was approved for use in adults by the Food and Drug Administration in 1985. One speaker at a meeting of the National Academy of Sciences went so far as to declare, "We are going to clear out the schools for the deaf."

That has not happened and won't. Only people with profound sensorineural hearing loss in both ears who cannot be helped by hearing aids can receive cochlear implants. This type of deafness is caused by damage to the 12,000 sensory hair cells that line the normal cochlea and transform the mechanical vibrations of sound waves into nerve impulses. Implants use electrodes as stand-ins for the cochlear hair cells. So far fewer than 3,000 devices have been implanted, although hearing experts estimate that 250,000 or more patients could derive benefits. But cochlear implants have improved considerably during the past five years and may soon attract more candidates.

The first versions to be approved by the FDA collected sound and transmitted it by electrical induction through the skin to a lone electrode in the inner ear. Such single-channel devices made by 3M Company and others could help just a few patients to comprehend speech, whereas most people got only the marginal benefit of sound awareness. They are no longer sold in the U.S., observes Bruce J. Gantz, director of the Cochlear Implant Research Center at the University of Iowa. "It became pretty obvious that multichannel devices are superior," he says.

One such device, a 22-channel implant made by Cochlear Corporation in Englewood, Colo., earlier this year became the first to win FDA approval for use in children between two and 17 years of age. Previously only adults who lost their hearing after acquiring speech were eligible for implants of any kind.



In Cochlear's device, a battery-powered speech processor worn on the belt or in a shirt pocket selects and encodes a range of sound "features," from the low frequencies of *aah*'s to the peaks of *tsst*. Coded digital signals are then transmitted to the electrodes implanted in the inner ear via radio frequency transmission. President Ronald E. West notes, "We're trying to help with sorting out and processing the frequencies most important to speech comprehension."

Even more electrodes are planned for future models. "The results indicate that more stimulation is better, although it's not a linear relationship," declares Graeme M. Clark, a researcher at the University of Melbourne in Australia. Clark developed the digital speech processor in Cochlear's apparatus and has studied cochlear implants since 1967. He suggests that if a particular frequency is very important, it might help to stimulate not just one but several electrodes in an area.

No matter the number of electrodes, one design consideration stirs endless debate among manufacturers: What is the best way to process sound? One promising strategy has been developed by Blake S. Wilson and co-workers at Research Triangle Institute and Duke University in North Carolina. (The work is supported by the Neural Prosthesis program of the National Institutes of Health.) The approach presents sound as high-speed, nonoverlapping electric pulses. "We used to send signals a maximum of 300 times a second. Now we send them 1,000 times a second," he explains.

Patients are achieving improvements in speech comprehension of 5 to 162 percent when this pulsed strategy is used, Wilson reports. Rapid pulses let patients appreciate the temporal details of speech, crucial to the identification of most consonants, he explains. To perceive the word "pop," for example, a person needs to hear the two silences between the *p*'s on either side of the *aah*. "It's like television, where stationary pictures are sent fast enough to be seen as a whole," Wilson says.

Yet pulsed sound delivery may be more effective for some patients than others. Gantz observes, "It may be that some patients, such as those with poor nerve survival, respond better to analog sound transmission." Analog transmission compresses a wide range of frequencies into a smaller dynamic range. The sound is sent in continuously varying waves. Because it is still not possible to predict preoperatively how a patient will respond to a particular strategy of sound conversion, companies are keeping their options open.

"Since nobody else can come to agreement on how to process sound, we figured we weren't smart enough to do it either," says Joseph H. Schulman, chief scientist at MiniMed Technologies in Sylmar, Calif. So his company is developing a 16-channel implant that can work with digital or analog processors, pulsatile or not, over large or small dynamic ranges. Schulman expects the device to be in clinical trials within a few months.

Smith & Nephew Richards, Inc., as well, is looking at combining both analog and pulsatile approaches in the same device. The Memphis, Tenn., firm has an implant trade named Ineraid in clinical testing. It sends simultaneous stimulation to four of six electrodes.

Where the stimulation occurs in the cochlea may be just as important as the intensity of the stimulation, suggests Margaret W. Skinner, director of the cochlear implant program at Washington University School of Medicine in St. Louis. One of the most desirable goals—and most daunting obstacles—is to assign frequency bands to different electrodes so that signals are sent to the proper place in the cochlea. Low frequencies stimulate regions deepest inside the cochlea; higher ones those in the outer spiral. "Where do the maximum comfort levels sit when all the electrodes are playing—do some need to be eliminated because they're not contributing or are detracting?" Skinner asks.

Researchers are eager to advance the trend toward implanting younger patients so they can take full advantage of the time when speech develops readily. Gantz says, "We're trying to find out if there's a critical window in which the devices work best."

That goal will be particularly challenging in children younger than two years. Clark explains that although everyone's cochlea is adult size at birth, there will be growth in the rest of the cranium. "We need some system of wire lengthening so that the wire can be extended without being bound down by scar tissue or pulled out." It has been done in children older than two years by neatly looping wire in a flat bag. "The technique sounds rather low tech," he says apologetically, then chuckles. "It's about the only aspect of this field that is." —*Deborah Erickson*

Bug-Eyed

Gradient-index lenses bend light to order

In human and insect eyes the light is bent at an ever increasing angle as it moves through tissue. This provides more focal power by shortening the length at which rays are focused.

Unfortunately, the lenses in eyeglasses, cameras and other common optical devices do not usually work so well. That's because the spherical surfaces of these lenses refract light rays at their curved edges more than they do at the center. This spherical aberration creates a fuzzy image that results from diversion of some of the light from its desired focal point. The lens maker can make corrections by painstakingly grinding a lens into an aspherical shape or by adding more lenses, which can introduce new defects of their own.

Since the turn of the century, optical designers have been trying to imitate bug eyes by making lenses from glass in which the refractive index varies as light rays move through the lens. But building such gradient-index properties required sophisticated computers to work out the cumbersome calculations.

Today a handful of companies are producing what are known as GRIN, or gradient-index, lenses. The lenses have a refractive index that varies either from center to edge, a radial gradient, or from front to back, an axial gradient. A lens with a radial gradient focuses light more strongly, allowing it to reach a focal point from an unground flat surface. By contrast, a lens with an axial gradient requires grinding a spherical surface.

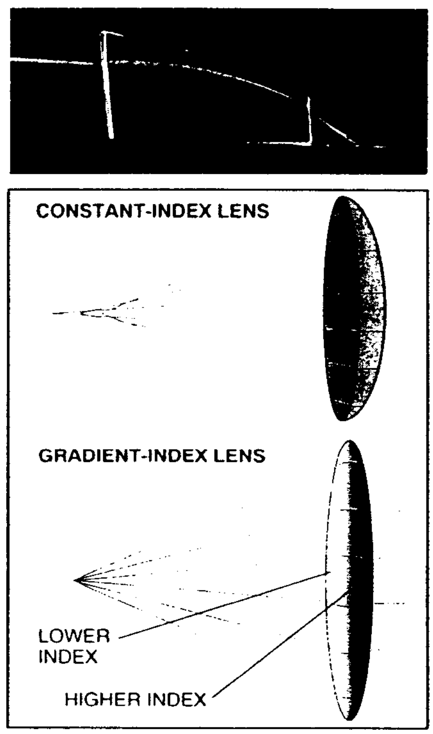
Even with computers, GRIN materials are still tricky to produce. Most are made using an ion-exchange process in which an ion such as potassium from a molten salt bath trades places with another metal in the glass, like thallium. In this case, those areas with more thallium, the heavier element, have a higher refractive index. It can take a month or more for sufficient ions to diffuse into the glass, and the amount of change in refractive index is limited.

Isotec, a Tucson, Ariz., start-up company, claims to have come up with a manufacturing technique that produces a lens blank in a matter of days while doubling the change that can be achieved in the refractive index. The company, which has yet to demonstrate a finished lens, says the process also results in larger blanks and better control of the way light is shaped as it moves through the glass. The process is carried out by fusing together five to 10 layers of lead-silicate glass in a platinum crucible at temperatures of up to 1,500 degrees Celsius. Layers with a greater refractive index contain more lead atoms, which interact strongly with photons.

Isotec got started five years ago, trying to make lenses that could be used to concentrate sunlight onto photovoltaic cells. When early samples of the glass shattered or turned opaque during fabrication, the company brought in Richard Blankenbecler, a particle physicist who is head of the theoretical physics department at the Stanford Linear Accelerator Center.

Blankenbecler suspected that the glass was disintegrating because layers with varying indexes expanded or contracted differently in response to a temperature change. By looking at technical specifications in glass catalogues, he found some glasses whose thermal properties did not change when the index did. If these glasses were used, the different plates could be fused without falling apart.

Now Isotec is talking to potential



GRADIENT-INDEX LENSES can correct for spherical and other optical aberrations by continuously changing the refractive index (bottom). *Light rays hitting a conventional lens, with its single refractive index* (top), *may fail to reach a single focal point. Isotec's gradient-index glasses* (photograph), *which are being developed into lenses, can bend light independent of wavelength or surface curvature.*