The human world of sound begins with the vibration of a tiny membrane within an organ no bigger than a fingertip.
Basham is one of eight patients working with Michael Dorman, an ASU professor of speech and hearing science. Each of these hearing-impaired patients received a cochlear implant about 10 years ago.

The cochlea is a tiny spiral-shaped chamber within the inner ear. It is the essential organ for hearing in humans. Millions of nerve endings within the cochlear spiral connect directly to the auditory nerve. Implants electrically stimulate these cochlear nerves.

Within the past two years, Dorman has refitted each patient with a new, improved processor. The new processors improve function of the implants.

"Implants have been around since the 1970s," Dorman explains. "What’s interesting from the technology viewpoint is that we’re getting better at making them. As technology improves our patients do better. We want to know how much better they’re doing, and why they’re doing better."

Several times a year, the eight individuals visit Dorman at his ASU laboratory. He uses a variety of hearing tests in a search for answers.

Dorman tests each person’s ability to recognize everything from single vowels and consonants to complete sentences. The results describe, quantitatively, how much better the patients hear with the new processor. The patients, however, describe the difference in a more qualitative sense.

“This one’s much more clear,” says Basham, describing her new device. “The processor can reproduce sound in a much more normal manner. Also, the microphone is so much better that I can hear things from a greater distance.”

Basham can also hear a wider range of sound. “What I do hear is much easier to sort out from the rest of the environment,” she adds.

“What really excites me about this new device is that I can use the telephone more efficiently,” says Bobby Hise, a minister from Lubbock, Texas. “I could ... I anticipated some part of the answer.” Using the new device, “I can get phone calls from anybody and talk about anything.”

An Austrian company called Med El manufactures the new, improved cochlear implants that Dorman is testing. A group at the Research Triangle Institute in North Carolina developed the underlying technology. Dorman collaborates with the group. Their work is supported by the National Institutes of Health.

Dorman tests the new device as part of a project aimed at getting approval from the Food and Drug Administration to market it in the United States. Without the new implant, Dorman’s patients would be stuck with 1970s technology. The original manufacturer of cochlear implants no longer supports the product.

“It’s a story about corporate greed,” Dorman explains. During the early 1970s, implant technology had gotten to a point where companies began to take an interest in manufacturing the devices for commercial use.

About 200 people received an implant devised and tested as part of a clinical trial for FDA approval. But the product was never approved.

“The principals in that particular company really thought that they would hold the company for a short time, and then sell it. They never put money into research and development,” Dorman says. While waiting for FDA approval, they sold the product to another medical company. Unable to get the hearing implant approved, the second company sold it to yet another company.

“But they too, literally had only money to lose, unless they could get FDA approval,” Dorman continues. They didn’t.

“There are 300 to 400 ‘orphan’ patients wandering around with a device that nobody wants to work on because they can’t make any money off of it. We decided to help ourselves and those patients by giving them a new implant as a ‘research only’ device.”

The original 200 patients are ideal for Dorman’s research because of the nature of their first implants. Most cochlear implant systems are
subcutaneous, meaning that the device's receiver is implanted completely under the skin. On the outside, a radio frequency transmitter is held against the implant with a magnet. The transmitter is connected by a thin cable to a processor that looks something like a Walkman™ radio.

Today, Dorman's patients all use a percutaneous device. The connector to the implanted electrodes actually protrudes through the skin just above and behind the ear. All of the electronics for signal processing are housed outside of the body. The processing unit connects to the implant by "picking in" to the connector known as a pedestal, that protrudes through the skin.

To update a subcutaneous device, a doctor would have to surgically implant a new receiver. But updating the percutaneous device is easy—Dorman simply plugs in the new processor into the existing pedestal.

Ironically, the pedestal that makes Dorman's work possible may be the reason the original device never received FDA approval. Although nobody knows the exact reason the device was turned down, Dorman suspects that the FDA saw the pedestal as an infection hazard because it protrudes through the skin. If the new processor is approved, it will be marketed as a subcutaneous device.

"Companies have decided that it's more cosmetically sellable to have nothing sticking through the skin," says Dorman, noting that the skin around the pedestal can become red and irritated. "The skin can look a little messy."

Based on the results of Dorman's research, however, the FDA recently allowed patients fitted with the original implant to use the new processor with their existing pedestals. This will allow all of the original implant patients to benefit from findings made by Dorman's research group.

"The new implant has really allowed me to live an independent life," says Kay Howell-Ellis, a former nurse from Indian Hills, Colo. About two years before she received her implant, her husband was diagnosed with terminal brain cancer.

"Before he died I was aware that I was going to be living alone," Howell-Ellis explains. "I didn’t have the cochlear implant at that time. I wondered how I was going to function. We decided to go ahead and have my implant while he was still alive. I think it was something of a boon to my late husband to know that I wasn’t going to become a total hermit."

Today, Howell-Ellis enjoys the freedom that her hearing allows. "I still have my own home. I still do my own gardening. I can shop. I can make my own appointments," she says. The new implant technology has added even more independence to Howell-Ellis’ life.

"I can talk on the phone now," she says. "I can hear and understand people talking beside me or behind me most of the time. With the original implant, I pretty much had to stop what I was doing. I had to look at the speaker and use lip-reading a lot more than I do now."

Dorman attributes the improvements in cochlear implant technology to a pair of factors. First, the new implants use more electrodes. These electrodes are implanted inside the cochlea deep within the inner ear itself. They create an electric signal in response to the vibrations of a sound. This impulse is carried along nerve fibers directly to the brain.

Each electrode is mapped to a certain range of frequencies. Original implant devices had six electrodes, but used only four. New devices take advantage of all six electrodes, allowing for reception of a greater range of frequencies.

"It turns out you only need about six or eight electrodes to reproduce speech perfectly well," he says. "In fact, a person can understand sentences with only four electrodes. Part of what I do is an attempt to figure out why a person can do that at all. It doesn’t seem enough."

Another benefit of the newer technology is the processor design. With older implants, the electrodes received signals simultaneously, causing interference between the currents.

New implant devices stagger the impulses so that no two electrodes are receiving signals at the same time. This method significantly reduces the interaction between the different current fields, according to Dorman.

"It’s a lot easier to recognize sounds as parts of speech because a range of short bursts of sound over a narrow range of frequencies (pitches)—sometimes hard to tell apart."

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Hise never takes hearing for granted now. More difficult is encouraging his students to appreciate this ability. When he is asked to talk to kids about what it was like to regain his hearing, he has a ready response.

“You never will understand what I found unless you know what I lost,” he says.

To demonstrate how many sounds we take for granted, Hise assigns an exercise to the kids. As fast as you can, he tells them, write down every sound you have heard since waking up this morning.

“They’ll say they heard the alarm, they water running, dogs barking, friends talking, cars going by on the street,” he says.

Then he tells them, “You take all that, and you can put a hundred things between each of them. You say you heard the alarm. Did you roll over in bed? Did you hear the sheets ruffle? Did you hear your feet hit the floor?”

Usually, Hise says that eight out of every 10 sounds listed are environmental sounds—not people talking. He says that the loss of those sounds is what disconnects you from the world.

“I can have a relationship with my family and not hear them,” says Hise, who is an expert lip-reader. “But I can’t have a relationship with my world.”

Research to improve cochlear implants is supported by the National Institutes of Health and the Austrian firm, Med El. For more information, contact Michael F. Dorman, Ph.D., Department of Speech and Hearing Science, 602.965.3345. Send E-mail to: aomfd@asuvm.inre.asu.edu

—Diane Boureau

The human brain can recognize a vibration in the air as a whispered voice, a song on the radio, a buzzing mosquito, or as a train whistling in the distance. But how exactly does it do that? Simple, sort of. The brain has its own personal translator—the amazing human ear.

A healthy ear picks up vibrations in the air and passes them along to the brain for specific interpretation. First, however, the ear must translate these vibrations into a language that the brain can understand. That language relies on the nuances of electrical energy.

When something vibrates, sound waves are created. The scoop-shaped outer ear catches these waves and funnels them through the ear canal to the eardrum, causing the eardrum to vibrate. These vibrations continue through the intricate bones of the middle ear and across a tiny membrane to special fluids contained inside the tiny spiral chamber of the inner ear. This spiral chamber is called the cochlea.

The movement of this fluid, in turn, moves the basilar membrane, which lines the entire cochlea. Each section of the basilar membrane is “tuned” to a different frequency, or pitch. Therefore, different pitches are received in different sections of the cochlea.

Movement of the basilar membrane vibrates a set of cells that sit on top of the membrane. These cells are called hair cells because they have hairlike protein rods protruding from their tops. The motions of these “hairs” create an electric signal that is passed along a nerve cell to the brain. The brain then interprets the electric signal as a sound.

ASU researcher Michael Dorman’s patients are like strangers in a foreign land. Their ears receive sounds well enough. But they can’t localize these sounds or talk with other people. Their ears receive sounds well enough. But they can’t translate those sounds into electric signals because the hair cells inside their cochlea are damaged. Sounds are collected and transmitted, but their brains never register the sounds at all.

Fortunately, says Dorman, “The brain doesn’t care how the charge gets started.” Dead people can have electrodes surgically implanted within the cochlea. These electrodes mimic the action of the hair cells.

Outside the body, a microphone receives sound waves and directs them into a processor. The processor converts the vibrations into electric currents that are sent to the electrodes. Each electrode is mapped to a range of frequencies based on the area of the cochlea in which it is implanted.

The electrode passes its currents along to the appropriate nerve cell, which in turn carries its message to the brain. Then—voila—translation is completed and the brain “hears” the sound. —Diane Boureau

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