ON THE FLY

a warm southern night, a cricket chirps and attracts not the mate it was seeking but the deadly attention of the parasitoid fly, *Ormia ochracea*.

The fly's reproductive cycle demands that it deposit its larvae on or near a live cricket, and evolution has afforded the night-flying *Ormia* specialized equipment to home in on the hapless host insect by sound alone. Unlike most flies, which rely on sensor hairs on their legs and can "hear" only low frequencies, *Ormia* has ears on its chest that have actual eardrums. The ears are connected by a tiny mechanical structure that uses two resonant modes of vibration to provide the insect with directional, high-frequency hearing.

Flying through the darkness with uncanny accuracy, *Ormia* lands on the cricket and deposits her larvae. The larvae burrow into the host and begin devouring it from the inside out. Later, the larvae abandon the cricket's desiccated exoskeleton to pupate.

THE JUXTAPOSITION OF THE *ORMIA OCHRACEA* FLY ON THE BACK OF A CRICKET AMID SEVERAL HEARING AIDS GIVES A SENSE OF SCALE TO ENGINEER RONALD MILES' RESEARCH. MILES IS ATTEMPTING TO MIMIC THE MECHANICAL STRUCTURE OF THE FLY'S AUDITORY SYSTEM IN HIS DESIGN OF WHAT WILL BE THE WORLD'S SMALLEST DIRECTIONAL MICROPHONE. THE MICROPHONE WILL BE USED IN A HEARING AID THAT CAN BE WORN INSIDE THE EAR AND ALLOW USERS TO DETERMINE THE DIRECTION OF SOUND.

Binghamton University Professor Ronald Miles is hoping a tiny mechanical structure that allows the parasitoid fly *Ormia ochracea* to locate its victims with unerring and deadly accuracy may soon prove equally beneficial to the millions of Americans who suffer from hearing loss.

Miles and associate researchers from Cornell University are developing a directional microphone for hearing aids that is smaller and more effective than anything currently available. With support from a $1.1 million grant, the team is basing its design on the unique structure found in the auditory system of a fly that is native to the southern United States and Central America.

The structure, known as the intertympanal bridge, makes it possible for the fly to localize sounds even though its ears are very close together. Localizing sounds is a special challenge for small animals like *Ormia*, which is the size of the common housefly. To be able to localize sounds, small animals must be able to discern and process minute differences in signals that arrive almost simultaneously in ears that are of necessity very close together.

The challenge might be easiest to appreciate by thinking about how humans tell where sounds are coming from. When there is a question about the source of a sound, most people have a tendency to cock or turn their heads in an attempt to exaggerate and weigh the difference in signals reaching one ear over the other. Even aided by this behavioral adaptation, higher vertebrates rely on sophisticated neural processing to determine the origins of sounds.

For *Ormia*, whose eardrums are located less than 100 microns apart on its chest, turning its head to discern minute differ-

Fly ears provide model for better hearing aid

ences in signals would be non-productive. And sophisticated neural processing is out of the question. Instead, such discernment is made possible by the intertympanal bridge, which links the insects' ears and provides a sort of mechanical pre-processing that reduces the processing requirements on the central nervous system.

The horizontal bridge is designed so that it can rock back and forth across a pivot like a teeter-totter or, like a hinged teeter-totter, simultaneously rock back and forth and independently flap up and down on either side of the pivot in response to vibrations excited from a sound wave on the fly's eardrums.

These uncoupled resonant modes make it possible for the combined movements to "add" on one side and "cancel" on the other. This causes the two ears to have significantly different responses to sound, helping the fly to recognize where sounds are coming from.

The responses of the uncoupled resonant modes are analogous to an electronic circuit for recording stereophonic sound. This type of circuit allows two non-directional microphones—in this case the tympanic membranes or eardrums of the fly—to construct a small directional receiver.

The intertympanal bridge was recently discovered and studied by Miles, Ronald Hoy of Cornell University's Department of Neurobiology and Behavior and biologist Daniel Robert of the University of Zurich, who collaborated on a three-year project funded by a $340,000 grant from the National Science Foundation to explore *Ormia's* auditory system.

Although scientists had been aware of *Ormia's* ability to localize sound since the 1960s, Robert didn't discover until 1992 where *Ormia's* ears are, and the NSF project then answered a basic scientific question about how *Ormia's* auditory system can determine the direction of sound.

The new $1.1 million grant from the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health will allow Miles and a new team to take that basic science and put it to practical use in a way that will improve the quality of life for many. For this project, Miles is working with Cornell University, Sandia National Laboratories and a private sector enterprise—JVD Inc.

More than 28 million Americans or about 10 percent of the population are afflicted with hearing loss. As baby-boomers head into their senior years, the Better Hearing Institute in Washington D.C. predicts that the number of people with hearing and speech impairments will increase at a faster rate than the total U.S. population through the year 2050.

One of the biggest complaints most people have about hearing aids is that they typically do nothing to help the user distinguish speech, which generally comes from in front of the user, from the ambient noise coming from everywhere around the user, Miles said.

The new microphone will be sensitive to speech range frequencies from 400 hertz to 4 kilohertz and allow a 20-decibel attenuation of sounds that come from behind the wearer, which should make a "substantial" improvement in speech intelligibility, Miles said.

A 20-decibel difference is approximately the difference between a whisper and a normal speaking voice.

The smallest directional microphone now available is about the size of a pencil eraser. While that might seem small, it is too large to allow the use of directional microphones in the cosmetically preferable in-the-ear hearing aids, Miles said. Instead, users must wear bulky behind-the-ear hearing aids if they need directional microphones.

The new microphone, which is expected to be about one-third that size—or only about 2 millimeters across—ought to fit easily in an in-the-ear package, he added.

Miles and his team expect to design and develop a prototype microphone over the next three years. With Miles providing the design work, the prototypes will be produced at the School of Electrical Engineering at Cornell using microelectromechanical technology (MEMS). Sandia National Laboratories, home of the world's most extensive MEMS fabrication facility, will ready the product for commercial production in what promises to be a ground-breaking hearing aid.

In less than five years, in-the-ear hearing aids with directional capabilities should be commonly available, Miles said.

As a vibrations specialist, Miles said he is intrigued by basic research questions. But, ultimately, as an engineer, he is compelled to look for practical ways to use the findings of basic science. By working on consecutive projects to study *Ormia's* auditory system and then to put that knowledge to practical use, Miles said he's enjoying the best of both worlds.

WHAT ARE THE DIFFERENT DEGREES OF HEARING LOSS?

With mild hearing loss, in the 26-45 decibel (dB) range, one-on-one conversations are audible if the listener can see the speaker's face and is standing at close range.

With a moderate hearing loss, in the 45-65 dB range, detecting conversational levels of speech through background noise is extremely difficult. Hearing and understanding conversational levels is difficult even in quiet backgrounds.

With a severe hearing loss, in the 66-85 dB range, hearing is difficult in all situations. Those with profound hearing loss, beyond 85 dB, may not register even the loudest speech or environmental noises.

WHAT IS A DECIBEL?

A decibel is a logarithmic expression used to express power ratios and is an important unit of measurement for indicating power level and pulse compression. A decibel is one-tenth of a *bel*. It is equal to the smallest degree of difference of loudness ordinarily detectable by the human ear.

HOW LOUD ARE THESE SOUNDS?

Movie theater: 87 dB
Living room band practice: 116 dB
Jackhammer: 130 dB
Gunshot: 140 dB
Jet takeoff: 150 dB