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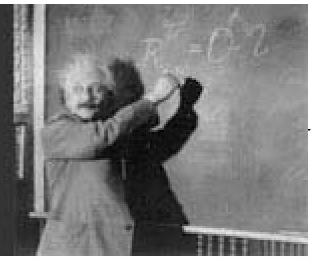

Wiretapping the insect world

By Chris Clarke

OTTAWA — In the H.H.J. Nesbitt Building at Carleton University hangs a display of 40 moths, eerily life like. Each looks ready to fly at the slightest provocation.

Biologist Dr. Jayne Yack works down the hall from the gallery. She's an animal behaviourist with a penchant for butterflies, sounds and bitter chocolate.

“I’ve always been fascinated with the sensory world of animals,” Yack says. “Any way that an insect can evolve to hear a sound, I want to find out.”

Yack has devoted the last 15 years to studying the hearing of the insect order *Lepidoptera*, which includes 160,000 different species of moths, butterflies and skippers. Six years ago she started listening to butterflies solely. This devotion has led to some radical and influential insights and theories on butterfly evolution.

Dr. Jayne Yack recently recieved $285,000 in grants to buy equipment needed to continue her research.

She works in a crowded office. Countless reports, manila folders, printouts, notes, and journal articles are stacked on her desk. Over it, pinned to a bulletin board, are pictures of her family, highly magnified butterfly ears, printouts of sound wave patterns from caterpillars, and a simple insect classification table. She doesn’t need the table but it’s a useful tool to help explain the difference between a butterfly and a moth to people who can't tell them apart.

Yack is in the midst of ordering new equipment for the laboratory. The $285,000 grant awarded to her last year by the Canada Foundation for Innovation, with matching funds from the Ontario Innovation Trust, has finally come in. She is buying the equipment she desperately needs: a portable laser vibrometer, an electrophysiology rig, a soundproof room and high-speed video equipment top the list.

These instruments are necessary for Yack’s research into bioacoustics and the neuroethology of insect hearing. Neuroethology is the junction of neural sciences, animal behaviourism and animal biology.

Using nature as a design template

...."There are millions of years of research that can help us, in nature."

Biomimetics, or bionics, is the application of models found in nature to technology. The reason: humans are unlikely to improve on eons of evolution.

Examples include:

Velcro - A Swiss engineer picking the burrs from his dog's fur inspired the clinging tabs.

'Smart' clothing - made of fabric that opens in heat and closes in cold. Based on pinecones which need the heat of forest fires to open so it can scatter its seed

Morphing airplane wings - inspired by birds with differently shaped wings for flying at different speeds. In order to change the shape and structure of the airplane wings, the overlaying skin must also be able to change, so engineers rebuilt the wings with fish-inspired scales that could slide over each other.

Source: Wikipedia

"It's an attempt to understand the neural mechanisms behind behaviour and the evolution of behaviour," she explains.

Before the grant, Yack traveled to university labs in Toronto and New York to conduct her studies. In the summer of 2004, Yack and Sarah Brown, a first-year Carleton University masters student, hauled plastic containers filled with potted plants halfway across campus to the university's only soundproof room. In the room, the pair painstakingly recorded the clickings from *Antherea polyphemus* caterpillars that lived off the plants.

The recordings are part of a project designed to show how some caterpillars communicate with each other and establish territory. It's one of three ongoing experiments exploring caterpillar communication and its effect on the insect's social organization and behaviour.

Around the corner from her office at Yack's lab, Brown goes through this data. She measures and counts the spikes in the audio wavelength printouts. She is trying to show how the sounds correspond to different situations. She is compiling evidence to support her theories behind the clicking sounds made by caterpillars. Three years ago, Brown never imagined she would enjoy listening to the cries of a caterpillar.

Chalk it up to Yack's intense passion for butterfly hearing.

Her students describe her enthusiasm as contagious. It's so infectious that most of Yack's researchers are former students of her third-year animal behaviour class. Brown changed her field of study after she took the course.

Fourth-year biology student Tiffany Timbers, another undergraduate researcher, credits the biologist for changing her attitude towards insects. Once disgusted, she is now lured by the intricacies of the bugs.

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"You miss the details in everyday life but once you look at them [insects], you see the complexities and it goes from being scary or intimidating to beautiful," Timbers says. "I'm not enjoying just the organism but enjoying what its complexities are ultimately going to tell you about it."

Her research is getting more and more popular. Yack will be gaining an four or five more student researchers for the summer in addition to the seven she already has working in her lab. And it's only her first year with student researchers.

Perhaps it's the work she's done – providing insight into the evolution of butterflies – that attracts students.

In 2000, a paper published by Yack and Dr. James Fullard, a University of Toronto biologist, in the science journal *Nature*, concluded that bats created modern-day butterflies.

Evolutionary war games

Research suggests at some point, over 50 million years ago, moths and butterflies both flew during the night. But something happened and butterflies started flying during the day. Around the same time, bats

Adapting to an adaptation

Although moths evolved ears capable of hearing the sonar calls of bats, Dr. James Fullard of University of Toronto, may have found a new evolutionary link.

His studies into the Northern long-eared bat show an unusually high number of moths in its diet. What Dr. Fullard and his team found was the bat had adapted its sonar detection to trick moth ears.

Dr. Fullard writes: 'As a bat closes onto its flying prey, it changes its echolocation calls from relatively long, intense and slowly repeated "search" pulses to a shorter, fainter and more rapidly repeated train of pulses called the terminal "buzz".'

This change in frequency makes the bat sound farther away. The terminal buzz effectively "cloaks' the bat for about a second because moths haven't evolved a way to hear it yet. This counteracts a moth's natural evasive manoeuvres when a bat's call reaches a certain distance. The bat feasts with its new adaptation.

Source: Dr. James Fullard summer work Web page evolved the ability to use echolocation, a sonar radar system where bats emit high frequency sounds that bounce off objects and back to the bat. Bats became incredibly lethal hunters of flying insects.

Echolocation proved devastating on moths and butterflies and it had important consequences for the two species. Moths stayed nocturnal and developed ears to detect the ultrasonic squeaks of bats; butterflies abandoned the night and the predator altogether.

Enter a unique species of butterfly native to Panama known as hedylids. Hedylids are a nocturnal butterfly with moth-like ear structures on their wings. The ears resemble little rabbit ears and are basically a thin membrane, like a drum skin, stretched over an air sac. This organ, called a tympanal organ, is very sensitive to vibrations.

Yack videotaped a few hedylids as she played ultrasound that mimicked bats. The hedylids went into evasive action, spiraling, dive bombing and flying in upward and downward loops to avoid the virtual "bat." She removed the hearing organs, performed the same experiment and found the butterflies didn't react at all.

Hedylid butterflies most likely evolved ears to escape bats and are considered living ancestors to modern butterflies.

While not a direct evolutionary link, Yack believes these night butterflies are more of an ecological link between moths and butterflies. Hedylids are more like living ancestors to modern butterflies.

However, the insect world is hardly ever simple. Some butterfly ears act to detect predators. Some butterflies communicate to each other through their ears. A species of the Hamadryas butterfly will group together and fly in spirals clicking at each other.

To complicate the matter, there are many theories about the hearing structures' actual function. One theory suggests butterfly ears may act as a barometer, detecting changes in pressure, and not as a form of hearing. Yack says this hypothesis shows how little research has been done on the insect. She intends to prove the hearing hypothesis through collecting more evidence with her new lab equipment.

"What are these structures designed to pick up those signals important to a species' survival?" she asks.

It's a common question. One asked by Dr. Andrew Mason, a University of Toronto professor and biologist. Mason doesn't have a focal insect like Yack; instead, he is drawn to a number of bugs, publishing papers on jumping spiders, katydids and flies.

Like Yack, his interest in communication and sounds fostered a curiosity into how the nervous system is designed to interpret brain waves produced by sounds.

He studies insects because it is more practical to look at simpler structures to find basic principles of hearing, and the effects on thinking and behaviour. Once you find these basics, you are more likely to find the same principles elsewhere.

"Insects are easier to experiment with so you can look at general questions not easily explored with vertebrates," Mason says.

Hearing aid evolution

'Insects are easier to experiment with so you can look at general questions not easily explored with vertebrates.'

Mason's research has yielded some surprising applications. His work with Cornell's Dr. Ron Hoy and Dr. Ron Miles, chair of mechanical engineering at Binghamton University, into the remarkable hearing of the parasite fly, *Ormia ochracea*, will probably revolutionize hearing aids.

"When this fly came along, it was especially interesting because it was doing something different," Mason says. "There was some novel principle at work and this principle had applications."

Ormia uses its incredible hearing to find singing crickets in the night without visual cues. The fly needs to find a cricket so it can lay its eggs in it. Later, the unlucky cricket will feel the squirming larva burst from its stomach.

But how the *Ormia* fly found crickets baffled researchers because the fly's ears were too close together. The hearing organs, located behind the head and only two millimeters apart, violated two principles that guide almost every animals' hearing, including humans.

The first, interaural time difference, is the difference in time it takes for sound to reach your ears. For instance, if a noise happens to the left of a person, the sound will reach the left ear slightly before the right. The brain interprets the signal as coming more from the left and the person will look that way.

The second principle, interaural level difference, concerns the difference in sound intensity. If a noise happens to the left, it will sound louder in the left ear than the right.

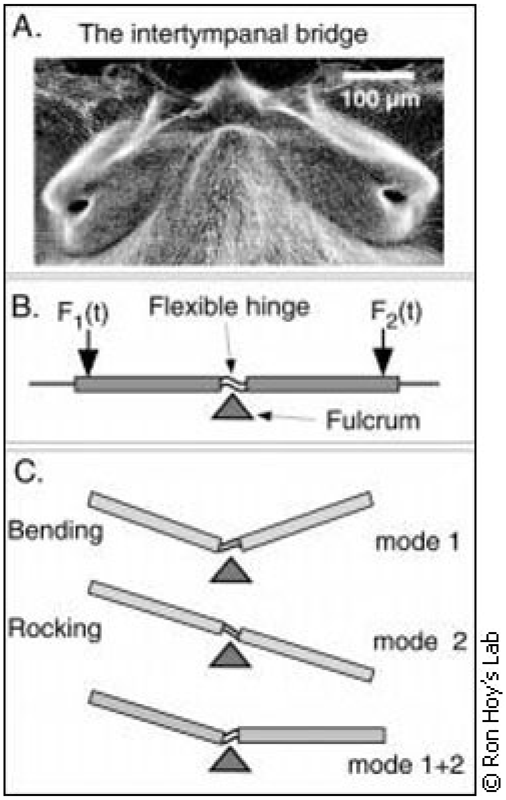
The *Ormia* fly's ears are so close together, however, it would be impossible to distinguish sounds from the left and the right because there is no time delay or noise difference. The fly would hear only a cacophony of noise.

What researchers found was a link between the fly's ears.

Like butterflies, *Ormia* ears are like simple drum skins but the two hearing organs are linked by a bridge. This hinged bridge rocks up and down, back and forth, like a seesaw.

When sound vibrations hit the bridge, the rocking hinges deflect and amplify the vibrations, creating a measurable difference in both time and level of sound.

The nervous system can then easily figure out which side the noise comes from.



Ormia's tympanal bridge may lead to a a working directional mic model and revolutionize hearings aids.

This bridge is believed to be unique in the animal kingdom. This uniqueness may pay out massive dividends by paving the way for a new model of hearing aid.

The problem with the modern hearing aid is its amplification of all sounds — it cannot filter unnecessary noise.

Consider, for example, two people are dining at a patio restaurant. In order to hear each other speak, their ears block the noise of traffic, other conversations, and the other beeps and hums of modern day life. However, when someone turns up their hearing aid to hear a conversation better, it increases all the surrounding noise as well.

This problem is not new. Advances in digital signal processing have vastly improved hearing aids, but the same problem persists. Miles says hearing aid developers have spent the past decade searching for a workable model using directional microphones.

Directional mics would focus noise coming from the front of a person, where most conversation occurs. But a practical, easy-to-reproduce model kept slipping through the fingers of researchers.

Instead, the answer comes from bioacoustic research into how a parasitic fly finds its gruesome nest.

"*Ormia* provides a significantly different way of creating directional mics that have a chance of working better than other approaches," says Miles.

Once development is complete, "ormiaphones" will most likely be cheaper to produce than current hearing aids, he adds.

Although Miles says the project is ahead of schedule, there are still a slew of tiny details to discover, adjust and solve.

"It's harder than making a car or an airplane because they've been made for decades. We're making something never made before," Miles said.

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Curiosity vs practical applications

making something never made before.'

Although this work will have significant implications for humans, Mason is not worried about whether his research will have any real world applications.

“It’s not really practical to go prospecting for a bug doing something strange that can be applied to real life or put into some formula,” he says. “If you want to discover things you don’t know, you have to be generally curious. It’s basic curiosity that leads to potentially useful facts.”

Nevertheless, Mason finds himself making more friends in the engineering department. He says he is more aware of the overlap of his studies with engineering problems.

“I’m not changing my studies but I am changing who I talk to.”

Likewise, Yack doesn’t worry about searching for immediate applications either. She’s worried more about collecting sound data. Each day she spends on her passion, new insights are made into the butterfly world.

“I’m trying to provide good biology, good knowledge so people can do whatever they want with it.”

She too is making some surprise collaborations through her work with caterpillar communication.

Caterpillars talk using vibrations. Groups in England and Venezuela are figuring out a way to measure these vibrations so they can calculate how many caterpillars of a given species are in a forest. This may lead to better pest control.

Although she has made advances into some areas of butterfly hearing, Yack is not afraid to look at her work with a critical eye. Considering the nuances of butterfly hearing, she finds it is necessary to question her own work.

“The structure is like nothing else…. you always have to be asking: what else can it be?” she says.

Related Links

- Yack's Laboratory
- Ormia Fly Hearing
- Wikipedia: Butterfly

Catalyst A publication by the science reporting students at the School of Journalism and Communication