Insect research gives humans six legs up

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A leafcutter ant slices through a leaf. Scientists are interested in ants for more than just their role in the ecosystem. Ants and other social insects have evolved capabilities that we humans would like to use for ourselves. Photo from B. Hölldobler and E.O. Wilson, The Superorganism, W.W. Norton, N.Y., 2008

(PhysOrg.com) -- You could say that Bert Hölldobler's career began during a childhood walk in the Bavarian woods with his father. The elder Holldobler turned over a rock out in the forest, exposing a colony of carpenter ants underneath.

“I still have this picture burned into my brain of these beautiful shiny chestnut-brown ants moving around getting their larvae to safety,” Hölldobler says. “This whole colony disappearing like water into the ground was so impressive for me.”

Ants have always fascinated humans. Who hasn’t, at some point in life, gotten down on hands and knees to study an ant superhighway traversing a sidewalk? Science fiction writers rely time and again on bizarre, ant-like aliens to hold audiences in thrall. Ants look about as unlike a human being as anything could. And yet they have a social life that is in many ways similar to our own. This contradiction makes them endlessly intriguing.

It's easy to understand Hölldobler's interest in watching ants, and how it propelled him into his career. But fascination alone doesn't win research grants or publish papers.

"If the ants would not have turned out to be of such scientific significance, I may have worked with something else," says Hölldobler, who is now a Foundation Professor in ASU's School of Life Sciences, part of the College of Liberal Arts and Sciences. Hölldobler won a Pulitzer Prize for "The Ants," a book he co-wrote with his friend and former Harvard University colleague E. O. Wilson.

How are ants — the bane of every picknicker, the victim of every 9-year-old's magnifying glass — scientifically important?

Why has ASU created an entire Social Insect Research Group devoted to studying creatures such as ants, bees and termites? What can observing insects possibly do to benefit human beings?

First of all, Hölldobler points out, social insects are extremely ecologically important. Bees pollinate crops. Termites decompose cellulose from wood and bring the nutrients back into the soil. Ants also are decomposers. In addition, they turn soils, distribute seeds and provide natural pest control.

"From a purely ecological point of view, we only understand the impact of ants in our ecosystem by knowing them," says Hölldobler. "And

Arizona has one of the richest ant faunas in the United States."

Life imitates nature

Scientists are interested in ants for more than just their role in the ecosystem, however. Ants and other social insects have evolved capabilities that we humans would like to use for ourselves.

"They've been exposed to millions of years of evolution," says Stephen Pratt, an ant researcher and professor in ASU's School of Life Sciences. "We have pretty good reason to expect that evolution has been a very stringent designer to make these things work well, to make them maximize fitness. We want to take advantage of the power of natural selection to find really effective solutions to problems."

Imitating nature to solve human problems is called biomimicry, and it is a growing field of study. Scientists are increasingly looking to natural systems as models for accomplishing tasks in a sustainable, eco-friendly way. Biomimicry is being used in fields ranging from architecture to medicine to alternative energy.

This year, ASU became a member of the Biomimicry Affiliate Program of the Montana-based Biomimicry Institute. Last February, ASU conducted a conference on "Social Biomimicry: Insect Societies and Human Design." Presenters included researchers from 11 universities throughout the United States and Europe, and also industry representatives from Icosystem Corporation, the architectural firm HOK, Southwest Airlines and the exhibit design and special effects company, Work as Play. The symposium was entirely organized by School of Life Sciences graduate students.

"The symposium was, to my knowledge, the first where people from architecture, from design, even work processes, came together to discuss biomimicry," Hölldobler said. "I'm amazed that they model some of their systems according to ant trails."

Ants have developed some pretty remarkable capabilities. Millions of years before people began plowing the earth, ants were farming fungus. Other ants have learned to domesticate animals, herding aphids and feeding on the sugary honeydew they secrete.

"They have everything that we call civilization except culture," says Hölldobler, whose upcoming book to be published this fall "Leafcutter Ants: Civilization by Instinct" also was co-written with E.O. Wilson.

Fungus gardens created by leafcutter ants are vulnerable to bacteria and parasitic fungi. But the ants have evolved ways to deal with this problem. They have developed glands in their bodies that produce antibiotics and fungicides. They also culture antifungal bacteria on their bodies.

Many of the human diseases we struggle with today are becoming resistant to the drugs we use to fight them. As a result, scientists are interested in finding new ways to kill germs. The substances produced by ants could offer novel approaches for humans.

Leafcutter ants have another neat trick up their metaphorical sleeves. They use their sharp mandibles to cut through leaves, but how exactly do they do it? If you hold up a sheet of paper and try to cut it in the air with a knife, you can see exactly how difficult the ants' task is. The paper will simply bend under the knife's pressure.

Hölldobler's colleague, Flavio Roces, discovered that the ants' mandibles vibrate while they cut leaves. Vibrations smooth out the force fluctuations that would normally cause the leaf to bend. You can see how this works when you cut bread with a serrated knife (which causes vibrations) or use an electric carver on your Thanksgiving turkey.

The discovery was published in the journal *Science*. A group of engineers from the Technical University in Ilmenau, Germany, read the article and were inspired to create new vibrating microsurgical instruments.

“We did not search around and ask, ‘Who wants to pick up on this discovery?” notes Hölldobler. “But if other researchers approach us, we are very open.”

Lots of living things can offer biological solutions to human problems. What’s particularly intriguing about social insects, however, is that they are social. Even our closest relatives — the primates — don’t form societies that can match the scale and complexity of the insect world. As a result, we can learn a lot about social interactions from these strange societies.

Rational ignorance

Imagine an ant colony that lives in a rock crevice. One day, a bulldozer comes and knocks the crevice wide open to make room for a new highway. The ants need to find a new home, and they need to do it quickly.

A dozen or more ants scurry out to scout for a new home. Somehow these ants must evaluate potential sites, communicate the possibilities to the group, and form a consensus — preferably before the queen gets squashed under somebody’s sandal.

“The key thing that makes that interesting, I think, is that they do it without any sort of leadership. Nobody’s in charge. And for the most part there’s no single ant who has seen all the options," Pratt says.

The ants do form a consensus, and generally it's a good one. Pratt studies how they do this, and how it compares to human decision-making. He wants to know what behavioral rules and communication pathways ants use to find consensus in a group with no leader.

When selecting a new nest, an ant will evaluate a potential site. The ant then decides if the site is good enough to be a new home for the colony.

"She comes to her own individual decision," Pratt says. "And the better she likes it, the more likely she is to rapidly go off and tell somebody else about it. And then that ant comes and sees it. And she makes her own independent choice. And then she too may begin to advertise it. And that advertising will grow and snowball more rapidly for a better nest than for a worse nest."

Anyone who uses the Internet regularly is familiar with this kind of positive feedback loop. Google ranks websites in part based on how many other sites link to them. Many websites play up their "most popular" content, leading even more viewers to look at it. Facebook's "like" button and "share this" options also play into these kinds of loops.

But what's popular on the Internet isn't always the content with the highest quality or accuracy. Pratt is interested in how ants consistently make rational choices using this method, while humans fall prey to cabbage soup diets and email hoaxes.

"A fad or a market bubble is basically just enthusiasm building on enthusiasm, without any underlying reason to be enthusiastic. So they can be really malicious, these positive feedback cycles," Pratt says. "The interesting thing about ants is they seem to have tamed these things, and they use it in a way that generally works out very well for them."

He has discovered that part of the reason ants make more rational decisions than humans is, ironically, their ignorance.

"Most of the ants who actually participate in the decision just get to see one nest. They basically give it a rating based on some internal idea of what a good nest is, and then they advertise it based on how good they think it is," he explains.

In other words, they don't make comparisons between options the way humans often do. Multiple studies have shown that people make irrational decisions when comparisons come into play. Pratt uses an example of shopping for a camera. Two cameras are similar in quality, but camera A is less expensive while camera B has more memory. People will choose one camera or the other based on whether they value savings or memory more.

But if you throw in a third camera — one that is clearly worse than either A or B — people's decisions suddenly make much less sense. If camera C is much worse than camera B, but not too much worse than camera A, people become more likely to select camera B.

"It's comparative. People evaluate things not by their underlying value, but by comparing them with what else happens to be there," says Pratt.

Left to their own decision-making devices, ant colonies will not fall prey to "decoy" options similar to camera C. But when Pratt forced individual ants to consider all three options, they made the same irrational decisions that humans make.

Pratt says that studying ant decision-making helps us "open up the black box" to understand what the mechanisms behind decision-making are. The goal is to make better decisions, and businesses are already taking advantage of what ants know to improve speed and productivity.

For example, Southwest Airlines is using ant-based algorithms at Phoenix Sky Harbor Airport to get planes to available gates faster. The program was so successful that Southwest is now applying ant algorithms to the ticketing and check-in process.

A wide variety of industries, from trucking to computer networking, are using insect algorithms to solve problems such as scheduling, web server allocation and delivery routing.

Invasion of the ant robots

Now Pratt is applying his knowledge of ants to robotics. He got involved in robot research when he was trying to solve a problem he had in his own lab.

Some of Pratt's experiments require him to track the behaviors of multiple ants in a group. He and his colleagues painstakingly mark each ant with paint using a "brush" made from a single hair. They take videos of the ants in action, and then go through the recordings to analyze what each ant is doing.

Analyzing all that data is extremely time-consuming. Pratt has been working with engineers at the Georgia Institute of Technology to automate the process. They are developing programs that can automatically infer what the ants are doing in certain situations. This could include where the ants go, with whom they are interacting, and whether they are exchanging information by "antennating."

"There might be hundreds or thousands of interactions like that over the course of a few hours," Pratt says.

The Georgia Tech engineers want to use similar technology to track groups of robots. Robot teams can be used to do work, especially in places that humans can't, such as under the sea or in a minefield.

"There are a lot of things about social insects that really appeal to engineers, like the fact that they don't require a leader and the fact that they're robust to disturbances. If a few ants get lost from a colony, the colony can rapidly adapt and continue to function normally. Also they don't require really high-quality continuous communications from one ant to another," says Pratt.

Pratt is also working with engineers at the University of Pennsylvania to help robots solve a problem that a group of ants has already mastered—collective transport.

Aphaenogaster cockerelli are the cowardly lions of the ant world. These desert ants are big and scary looking, but they can be intimidated easily by their much smaller competition. When the A. cockerelli and their smaller counterparts find the same piece of food, the former don't stick around to fight it out. Instead, they hoist their treasure and run away with it.

What's amazing about these ants is how well they carry their cargo together. If you've ever tried to move a couch with another person you know just how hard it is to coordinate this kind of motion. A. cockerelli carry things in much bigger groups, and they do it quickly and smoothly. They rotate around obstacles and maneuver over uneven ground, even though they can't yell, "Hey, slow down!" or "Stop pushing so hard!"

Pratt and his colleagues are trying to figure out how the ants work together so well. They have devised a fake "fig" that is really a force sensor. Each arm of the sensor can detect the amount and direction of pressure placed on it. By coating the sensor with fig juice, the researchers entice the ants into picking it up and carrying it back to the nest.

“They’re really very dogged. If it smells good they really, really want it,” he says, adding that he rewards them for their hard work after the experiment with a piece of real fig.

The work will help robots work better together. If the idea of robot squadrons sounds too much like science fiction, consider that British Petroleum has been using a fleet of robotic submarines to do work 1,500 meters under water in an attempt stop the flow of oil from the exploded rig in the Gulf of Mexico this year. And NASA has placed robotic rovers on the surface of Mars to help us learn about the Red Planet.

From antibiotics to decision-making to robotics, social insect research has many practical applications that can benefit humans. But Hölldobler cautions that we shouldn’t dismiss the value of basic research.

“I’m often asked, when I give talks to the public, ‘What is this good for?’ But this is the wrong question to ask. I usually give the example of the double helix: DNA. Watson and Crick were totally uninterested in how to cure cancer, or anything like that. They were simply driven to understand the alphabet of life,” he explains.

“I could easily say why social insects are important,” he says. “But what motivates me and many of the other researchers is, first of all, understanding this complex social life that evolved over more than 100 million years.”

For Hölldobler, Pratt and their fellow entomologists, every day at work is the turning over of another rock to watch the beautiful creatures that hide underneath. We don’t yet know how insects developed their complex social lives, but we do know that our own society — with its computers, airplanes and advanced medical care — was built upon curiosity and the drive to understand.

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