The mighty impact of insects

How studying a bug's life is helping ASU researchers address environmental and societal challenges

By Meghan Finnerty, ASU News
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Arizona State University has a lot of insects — and for good reason. A colony of researchers is studying how social insects can be used as tools to answer fundamental questions.

The Social Insect Research Group, or SIRG, in the School of Life Sciences has been studying the evolution, organization and function of insects for over 20 years. Today, the group includes 18 faculty members, with more than a dozen undergraduate and graduate student researchers.

“SIRG has no equivalent anywhere in the world,” said Professor Gro Amdam, a SIRG member.

Social insects like ants, bees and termites (in contrast to solitary insects like locusts and fruit flies) are broadly defined by their ability to engage in social interactions beyond mating, but there are varying levels of sociality.

Insect colonies function like a brain, explained researcher Stephen Pratt, who is also associate director of graduate programs for the School of Life Sciences. Colonies act as a form of collective intelligence, like how cells work together to produce cognition or make developmental pathways.

They also have a significant impact on various ecosystems.

“Ants are dominant scavengers, herbivores, granivores, etc., and honey bees are dominant pollinators,” Associate Professor Timothy Linksvayer said.

But how do social insects function and adapt, and how can insect research inform new technologies and build more sustainable futures?

“I always try to impress upon people how critical it is to just wonder,” said Rick Overson, research scientist in the Global Locust Initiative. “Even just something like bugs on a sidewalk that we walk by like 100 times a day, there are so many fascinating, unknown things.”

This Earth Month, learn more about how SIRG members are answering questions about robots, aging, agriculture and more through research on ants, bees and locusts.

Ants lead the way

SIRG has a strong roster of ant experts.

“I can't think of any place that has this many people studying ants. I think it is pretty unique,” Pratt said.

There are about 15,000 species of ants, and at any given time, there are more than 30 species inside Interdisciplinary Science and Technology Building 1.

“I think that people underestimate the effect ants have on the ecosystem,” said Jessie Ebie, an associate teaching professor. “When I talk to most people, their first question to me is, ‘I have ants in my kitchen; how do I kill them?’ And my response is: 'I spend all of my time trying to keep them alive in the lab.'”

According to Pratt, profound biological problems can be addressed by investigating ants. Faculty and student researchers are running experiments, growing colonies and connecting what they learn to climate, agriculture, communication, social structures and even robots.

Robots and engineering

In cartoons, you may have seen ants working together to carry something large. According to Pratt, some species of ants really excel at carrying objects.

“We've been trying to figure out how. What are they doing? What are the rules?” he said. “They push when they need to, they pull when they need to and lift when they need to. Somehow, they do all that without any kind of leadership.”

If researchers can find answers to these questions, the insights could be applied to advancing technology like robotics. Imagine robots moving large objects on the ocean floor, in outer space or after an earthquake.

But the potential applications of insects go far beyond moving heavy things.

Associate Professor Ted Pavlic is the director of the BEET (Bringing Ecology and Engineering Together) Lab. His research focuses on the intersection of ecological principles and engineering problem-solving — where animals have provided vast inspiration.

“For example, studying how individual ants contribute to the balanced nutrient intake of a whole colony, we have designed decentralized systems for meeting the dynamic lighting and heating demands of smart buildings without having to rely on a central management system,” said Pavlic, who is also an associate professor in the School of Computing and Augmented Intelligence.

The lab aims to highlight deep connections between these disciplines to push the limits of our imaginations.

“We imagine applications in nanomedicine where nanobots that are similarly very limited individually can collectively implement treatment such as the targeted application of therapies for cancer and other diseases,” Pavlic said.

Communication and collective behavior

Working with Temnothorax ants, Pratt spends hours at a time painting each ant in the colony to study their behavior. These ants form small societies, and entire colonies can be found inside an acorn on the forest floor.

“They do interesting things like make collective decisions about where to live,” Pratt said. “(But) if no single ant has a global view of all of the potential nests, how do they decide? That's our question.

Pratt says ant colonies approach decision-making differently than humans or governmental systems.

“Humans are very hierarchical, and we have all of these mechanisms of centralizing information and having well-informed leaders make decisions and then issue commands,” he explained. “(Ants) don’t do that. There's nobody in charge, but the group as a whole is still able to make these rational collective actions.”

Chemicals and crops

Associate Professor Jürgen Liebig and PhD student Beth Ponn work alongside Ebie to study weaver ants, an aggressive and bright green species found in Australia. Their nests are shaped like balls and woven together with leaves and silk and span tree tops. It’s a species Ebie describes as "brutal."

"They can take down lizards and insects. They don’t sting, but instead they bite and spray formic acid,” she said. “One of the cool things about these ants is that they actually serve as a really effective biological pest control for fruit trees.

"The downside is that when someone gets too close to pick the fruit, they swarm," she added, "which makes harvesting pretty unpleasant. We also don’t yet have a way to guide the ants to the specific trees we’d like them to protect.”

These ant colonies can contain about a half million workers distributed over many leaf nests in trees. One of these nests contains the queen, the mother of all the workers who care for her and raise their mother’s offspring.

“I'm interested in how the workers distributed across these multiple nests know that the queen is present in the colony. When the queen dies, the workers begin producing their own male offspring, but they don’t do this while she’s alive,” Ebie said.

Discovering how the colony detects the location of the queen could be the key to potentially using weaver ants for crop protection. These researchers believe the queen is releasing a chemical signal.

“??What we'd like to do is develop a synthetic mimic of the queen pheromone. You could imagine placing it in a container near a fruit tree that has ants on it, attracting many of them off the tree when it’s time to harvest. Then you could simply release them back onto the tree afterward. You could also direct colonies to trees of interest,” Ebie explained.

Genetics and aging

Among social insects, those who reproduce live significantly longer than those who don’t — often over 10 times longer — and gene expression might be the answer to understanding why that is.

“We share genes with insects that might not exactly have the same function, but they have the same origin,” said Liebig. “If you identify genes that are essential or that are associated with this change in aging, what would these genes do in humans? Do they potentially also have a function in aging?”

Queen ants, who are responsible for reproduction, are living longer. According to Linksvayer, there is normally a trade-off between reproduction and survival in animals.

“My research has always been focused on how genes in one individual can affect the traits of a second individual,” he said. “For example, genes expressed in a worker might affect the lifespan of a queen. There is increasing evidence that workers are actually transmitting proteins and other compounds directly to the queen and those compounds might be impacting their lifespans.”

In addition to studying these functional questions, he compares the DNA of ant species that vary in queen lifespan and colony size to identify genetic changes that may enable queens to live longer and colonies to fight off diseases.

“If we can figure out genetically what is going on, maybe that can lead to applied results in human lifespans and disease control,” Linksvayer said.

Hope for the honey bee

“Honey bees have been a research model for many fields of science, including ecology, behavior, physiology, genetics and omics, basically every branch of biology,” said Research Professor Hong Lei. “Their evolutionary success deserves our attention in its own right if we want to sustain the ecosystem that we rely upon.”

Lei and two other SIRG faculty members, professors Brian Smith and Jon Harrison, have proposed a new research project to investigate how bees develop resilience to cope with climate stress.

“(The Apis mellifera species) has achieved the highest level of social living, and it is well known as a producer of honey, wax and pollination services of great economic value,” said Amdam.

However, honey bees are having a harder time surviving.

ASU's beekeeper Cahit Ozturk says it's vital to figure out why. Otherwise, the loss of honey bees would have a massive impact on agriculture.

For example, to pollinate California's 1.5 million acres of almond orchards, which account for 80% of the world's almonds, it relies on 3 million bee colonies. That's about 100 billion honey bees.

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"Our work makes it possible to breed honey bees that are more resilient to diseases, the workload of commercial pollination and changes in global climate. This should allow bee colonies to survive better in the future," Amdam said.

Innovating locust mitigation

While some insects like ants and bees are helpful to agriculture — others can be detrimental.

There are thousands of species of grasshoppers found around the world, but a handful of species, called locusts, can lay ruin to agricultural systems.

The locust can be a solitary insect like a typical grasshopper, but they can also respond to their environment and change into a completely different form.

"Their color, their brain chemistry, their behavior — it all starts to change. In some species, the solitary form is a green color and it just camouflages and nobody really pays attention to it. But when the environment changes, they turn into this gregarious form and they go down this different developmental path that causes them to become a gregarious and swarming locust," said Rick Overson, a research scientist in the Global Locust Initiative.

Locusts are known for causing devastating harm on farmland and communities. Once locusts become gregarious, they become attracted to one another and begin socializing to form large groupings. These groupings turn into large swarms that can fly for over hundreds of kilometers and then land and eat everything in their path.

The Global Locust Initiative at ASU houses three to five species of locusts at a time. Presently, the lab is studying the desert and migratory locusts, some of the most important economic pests in the world.

Their team is investigating their behavioral ecology and nutritional physiology. The goal is not to seek the extinction of locusts, but to find ways to coexist more sustainably with these insects.

In West Africa, the ASU team is working with partners to manipulate nutrients in the soil to make its plants less appealing for locusts, and in Latin America they are working with stakeholders to understand locust biology and to design baits that are more attractive to locusts and have less environmental damage than pesticide sprays.

“Locusts at certain stages of their life really prefer carbohydrate-rich foods, and that's what happens when humans overgraze land or they under-fertilize, which is really common because of the costs associated with fertilizer and the pressure on our ranchlands globally,” Overson said.

“Even though I'm a biologist by training, it has been very rewarding to collaborate for many years with a diverse group of people like land managers, government officials, farmers groups and social scientists to tackle the challenge of improving grasshopper and locust management," he said.

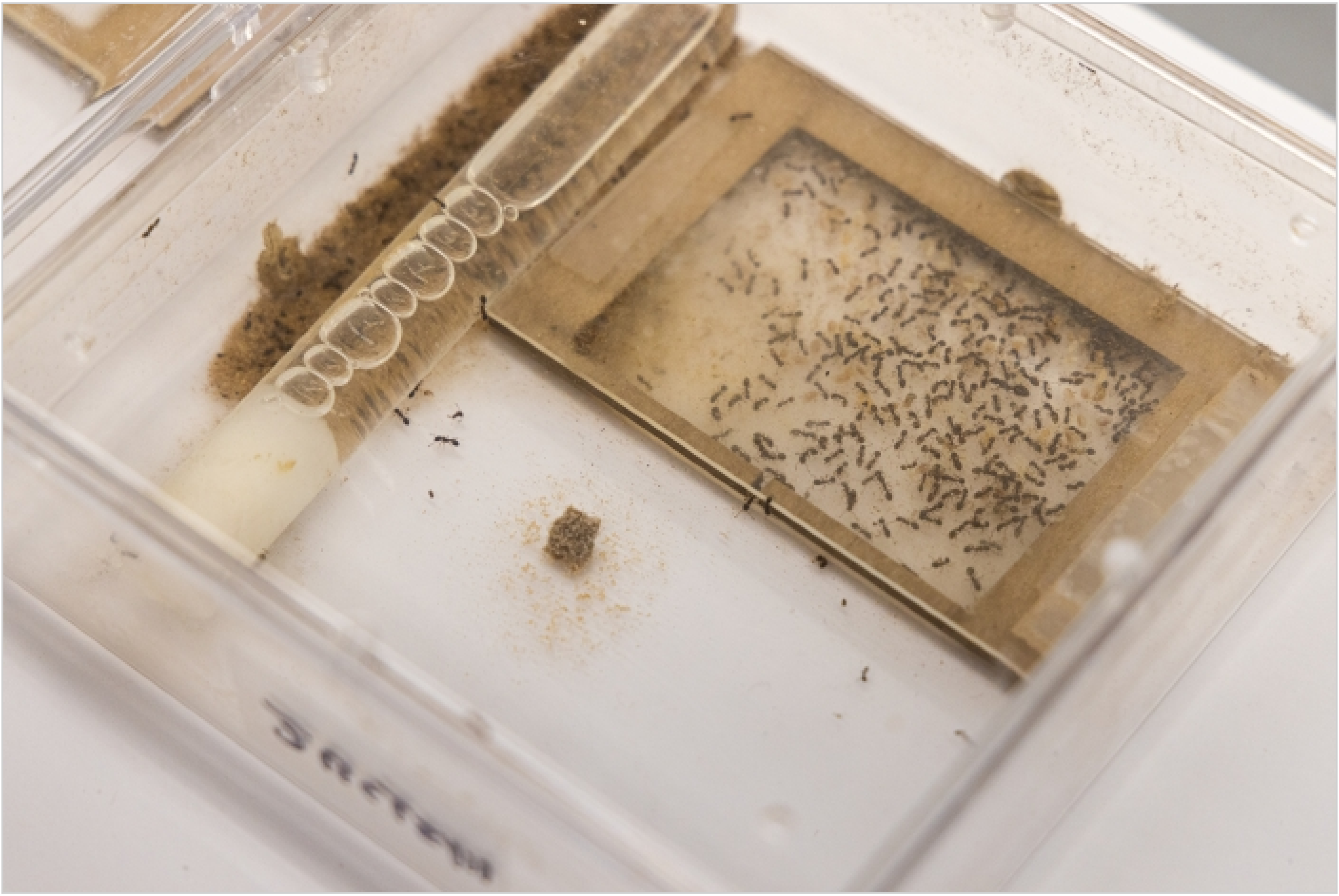
This story originally appeared on ASU News.

Main image

Oecophylla ants — also known as "weaver ants" — make a vertical bridge in the trees. Photo by Ted Palvic/ASU

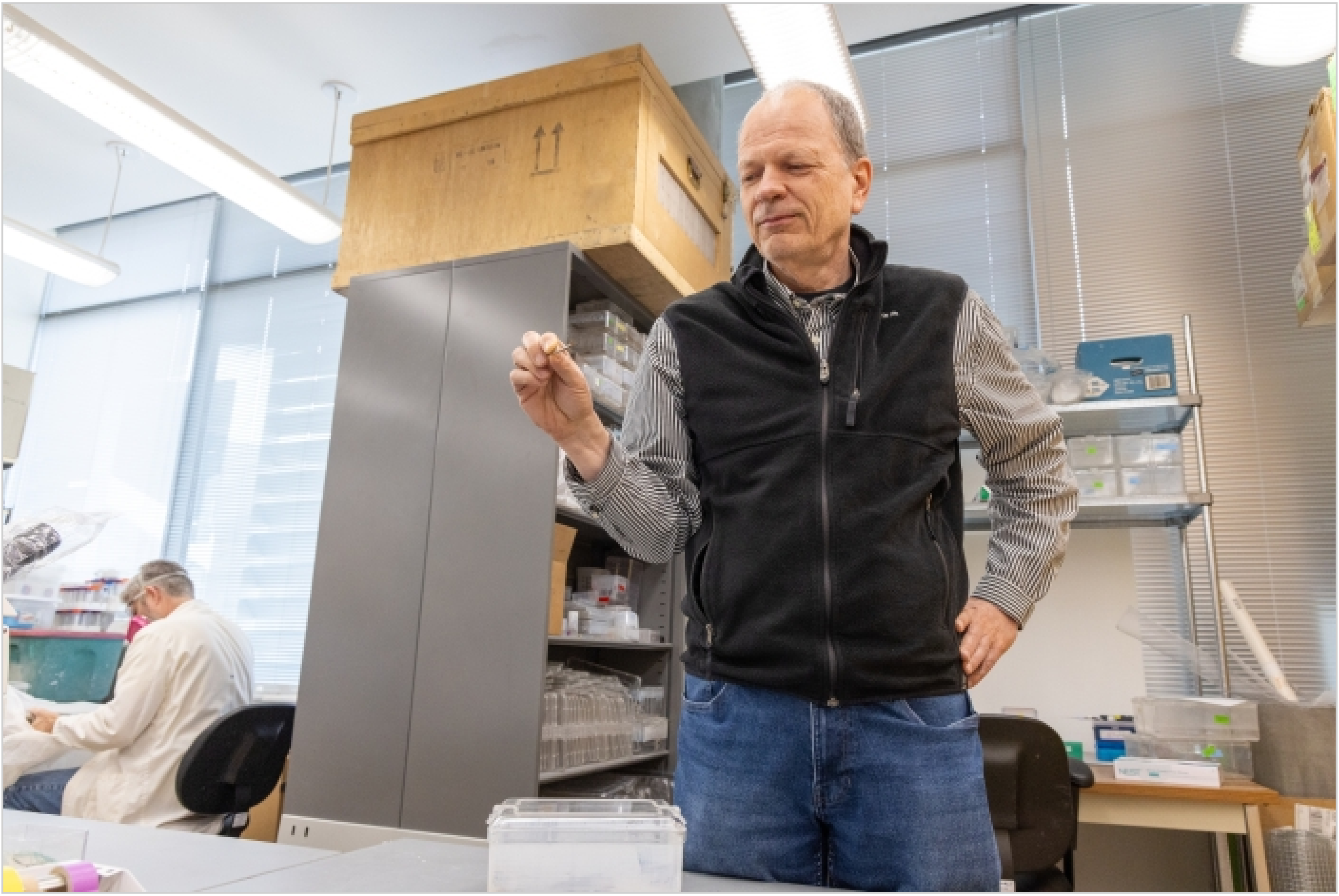
Text image(s)

The BEET Lab is applying insights from insects to Thymio robots, an open-source programmable robot. Photo courtesy of Ted Pavlic/ASU



Entire colonies of Temnothorax ants can fit inside of an acorn. Photo by Meghan Finnerty/ASU

Jessie Ebie, Beth Ponn and Jason Fleming collect, keep, maintain and research weaver ants (Oecophylla). Photo by Meghan Finnerty



Associate Professor Jürgen Liebig holds up a Harpegnathos worker ant. Photo by Meghan Finnerty

Cahit Ozturk, ASU's beekeeper checks on the hives at the Bee Lab Annex. Photo by Meghan Finnerty

During an outbreak in Argentina, gregarious-phase juvenile South American locusts (*Schistocerca cancellata*) gather on a fence post. Photo by Rick Overson/ASU

Gallery

Camponotus ocreatus, or major worker ant.

At the Bee Annex, ASU faculty maintain healthy colonies for SIRG research.

Weaver ants are typically found in Australia and build silk nests.

Different phases of the Central American locust (Schistocerca piceifrons) during a recent outbreak in Yucatán, Mexico.

Camponotus planatus, also known as the compact carpenter ant.

The solitary (left) and gregarious (right) phase of the Central American locust (Schistocerca piceifrons).