The Garden's Secret

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IF YOU THINK the din of daily life is becoming unbearable — with blaring televisions, jangling cell phones and passing cars that spew window-thumping music — you don't know the half of it. All around you, all the time, thousands of organisms are busy chatting away.

Much of that communication is happening in ways that human ears can't hear, much less understand. Just take a stroll in your backyard. You might not know it, but you're missing most of what's going on. The second you step out the door, your insect neighbors are probably spreading the word to their bug buddies that the big guys are back, invading their world.

At the same time, plants in your garden could be sending out chemical signals to warn nearby plants about insect predators. "Batten down the hatches," they're saying. "Get ready to churn out toxic chemicals that can stop that stink bug in its tracks." Your fruit trees might be having a chemical conversation with insect-hunting birds, telling them the leaves are loaded with bugs that would make a dandy meal for hard-working warblers.

Are your ears burning yet?

In laboratories scattered across campus, MU scientists are studying the different ways that plants, insects and animals talk to each other. They use different techniques to study how treehoppers and tree frogs, katydids and even an undistinguished-looking little plant called *Arabidopsis* use communication to compete successfully in the natural world.

What they're discovering in the lab could one day help researchers breed hardier plants or develop new ways to protect food crops from insect attack. Their research could even provide clues about how the human brain processes language.

"There's a very large world of organisms that communicate with each other using things other than sounds, and insects and plants are among them," says Jack Schultz, a plant scientist and director of Mizzou's Christopher S. Bond Life Sciences Center.

More than two decades ago, Schultz was one of a handful of researchers who discovered the airborne chemical signals that plants use to communicate. Scientists stumbled onto this "odor language" when they studied the ways plants defend themselves against insect attacks. "Plants respond to attacks from insects by changing their internal chemistry," Schultz says. "We and a few other investigators discovered that nearby plants were responding to attacks against their neighbors, and we wondered how that might happen."

They found that airborne signals from insect-damaged plants were being picked up by nearby undamaged plants. Those neighbor plants then began to undergo molecular and biochemical changes to beef up their defenses against attackers.

Schultz's research team, which includes

colleague and spouse Heidi Appel, works with *Arabidopsis thaliana*, a model plant in the Brassicaceae family that is related to mustard and cabbage. When insects attack, *Arabidopsis* produces defensive chemicals called glucosinolates, "which are what make mustard spicy and provide the health benefits in broccoli," Appel says. "Different plant families are known to make different kinds of defensive chemistry, and we as humans take advantage of that defensive chemistry when we use the plants as herbs and spices."

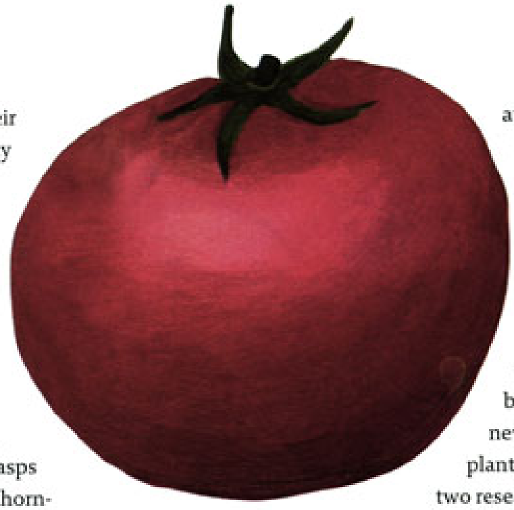
Some of the most familiar of these defensive chemicals are called "green leaf volatiles" — the compounds that give new-mown grass its distinctive odor. "Which means when you mow your lawn, those are all plants crying in agony," Schultz says. "Plants are wonderful chemical factories. Well over half the prescription drugs that humans use started out as plant chemicals."

Chemical conversation

How do scientists know that plants use their internal chemistry to communicate? Schultz and his colleagues use a sensitive instrument called a gas chromatograph mass spectrometer, a file cabinet-sized device that can identify individual molecules in a sample of air. First, they wound a test plant by cutting it, or they infest it with insects. Then they put the plant in an airtight container, concentrate the air and filter it to extract whatever chemicals the plant has produced. The chromatograph analyzes what chemicals are present.

Scientists are discovering that a complex conversation is going on out there. In addition to warning other plants about insect attacks, some plants can even use chemical odors to enlist the aid of beneficial bugs.

Sooner or later, just about everyone who grows tomatoes comes across a large, green, leaf-chomping caterpillar called a tomato hornworm. Hornworms can strip a tomato plant of its leaves in a single afternoon, but they do have a natural enemy that can stop them in their tracks: a tiny parasitic wasp that lays its eggs on the caterpillar's body. When the eggs hatch, the baby wasps devour the hornworm from the inside out. This wasp species can lay its eggs only on a tomato hornworm.



"That tiny mother wasp has to find a caterpillar somewhere out there in the great wide world," Schultz says. "The question becomes, how does she find a tomato hornworm when there are so few caterpillars and so many plants to search?"

When a hornworm chews on a tomato plant, that plant emits a chemical signal, another odor, to call in the parasitic wasp, he says. "Recent evidence suggests that which odor the tomato emits depends on which kind of insect has attacked it.

"If the wasp flies near a tomato plant with hornworm, the odor will say, 'Tomato hornworm is here on this plant, come get it.' If some other caterpillar is eating the plant, the wasp will not recognize the odor. It will fly right on by," Schultz says. "So the plant is, in effect, speaking specifically to the wasp. It's saying, 'Your one and only host is here.' "

But plants don't always have the upper hand in this conversation between predator and prey. "If you think about it for a minute, it would also be advantageous to the attacker if it could avoid being recognized by the host," Schultz says.

"What we find are examples of attacking organisms — insects or microbes — that provide a host with a signal that says 'I'm not here' or 'Don't bother to defend yourself' or, in the case of some insects, 'Why don't you make me a home?' The plant is trying to detect the attacking organism, and the attacker is providing a false signal, like a wolf in sheep's clothing."

Sending a good vibration

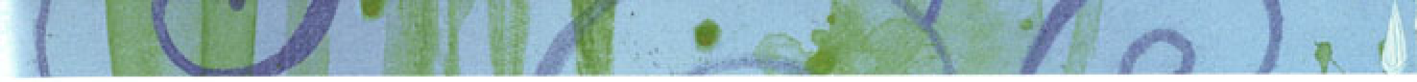
Plant scientist Appel has just started working with Mizzou biologist Rex Cocroft on a new approach to studying plant communication. The two researchers want to find out if plants can detect their insect enemies by listening to the noise they make.

To do that, they use a laser to measure the minute vibrations that caterpillars generate as they chew on plant leaves. Cocroft uses that technology in his research on a group of sap-eating insects called treehoppers that communicate with each other by sending vibrations through the stems of their host plant.

In the laboratory, Cocroft and Appel plan to measure the vibrations that an insect makes as it munches on a plant leaf and then see if the plant responds by changing its chemistry to ward off the attacker.

Treehoppers aren't the only animals that use vibrations to communicate. Scientists have found that elephants produce low-pitched rumbles that can travel through the ground to other elephants miles away. Some spiders can tell from vibrations on their webs that they've captured insect prey. Many species of rodents talk to each other by drumming their feet on the ground. A subterranean species, the golden mole, communicates by butting its head against the side of its burrow.

Cocroft uses treehoppers for his experiments because it's easier to reproduce their natural habitat in the lab, although he and his students also set up treehopper habitats in screened tents and study their research subjects in the field. This group of insects with about 3,000 species has a diversity of social behavior, Cocroft says. "They are very easy to work with, very



diverse, and they have a lot of ways in which communication is involved in their lives."

Cracking the code

What may explain that diversity is the intimate relationship treehoppers have with their host plant. "They are parasites of plants in the same way that mosquitoes are parasites of us. Many of them are very specific to a given plant, and they will spend their entire life on that plant. For them, the plant is their whole world. It turns out that communication is one of the ways they adapt to live on the plant," he says.

Treehoppers are sap-feeding insects. They have a flexible mouth part that looks like a little hypodermic syringe they insert through the plant stem to suck nutrients. The best feeding place on a plant is usually the fastest growing shoot, which has the best nutrition, Cocroft says.

When some group-living treehoppers need to find a new place to feed, a few individuals will leave the group and go out and explore the plant. When those scouts find a new feeding site, they send out vibrations — Cocroft, who records those signals, describes them as "a very cow-like moo." Other treehoppers home in on that signal and follow it like a beacon to the new feeding site.

Some mother treehoppers also use communication to help watch over their newly hatched young, who cluster near the mother on a plant stem. If a predator appears, the baby insects vibrate a warning message to Mom. The baby closest to the predator starts the signal, and it quickly spreads throughout the group. "It's like a wave at a football game," Cocroft says. "It's very quick; it's over in a fraction of a second." The mother then rushes up and tries to chase away the attacker by kicking at it with her hind legs.

Cocroft and his students record the different vibrational signals and measure their pitch and frequency. "There's a kind of code-breaking aspect that is the first step in studying the communication system of insects," he says.

Scientists can do that by observing what situations insects are in when they produce certain signals — like when baby treehoppers send signals if a predator appears. "That suggests it has something to do with defense against predators, but we don't know exactly what," Cocroft says. "Once you make those observations, they suggest some hypotheses about how these signals function and then you can test those hypotheses. To see if you have interpreted the code correctly, you can play back the signals and see if the receiver responds appropriately — for example, if a mother treehopper rushes up to defend her young when she detects their coordinated vibrations."

Putting science to work

This research might seem arcane to nonscientists, but understanding how communication works in other species could provide important clues to human language.

Schultz, the plant scientist, points out ways that his research on plant communication could be put to use outside the laboratory. "People are already taking some of these volatile odor signals from plants and spraying them in greenhouses to turn on the plant defenses," he says.

"Or, if you know what the signal is and where the signaling genes are, you can breed a plant to be more sensitive and to respond faster to attack. If we can figure out how to detect plant signals in the air outdoors, then you could go through a soybean field and find infested plants even if you can't see anything. You could treat only the infested plant and have huge economic savings and a much reduced environmental impact." Someday, fruit and vegetable producers might even use odor sensors to gauge the ripeness of their products.

Conducting basic science research is "like casting seeds on the ground," Cocroft says. "You never know when basic research is going to yield practical results."