



The Secret Language of Plants

By Kat McGowan



Growing evidence suggests that certain plants like maple trees, when under attack, send airborne signals warning their neighbors of impending danger.

Up in the northern Sierra Nevada, the ecologist [Richard Karban](#) is trying to learn an alien language. The sagebrush plants that dot these slopes speak to one another, using words no human knows. Karban, who teaches at the University of California, Davis, is listening in, and he's beginning to understand what they say.

The evidence for plant communication is only a few decades old, but in that short time it has leapfrogged from electrifying discovery to decisive debunking to resurrection. Two studies published in 1983 demonstrated that willow trees, poplars and sugar maples can warn each other about insect attacks: Intact, undamaged trees near ones that are infested with hungry bugs begin pumping out bug-repelling chemicals to ward off attack. They somehow know what their neighbors are experiencing, and react to it. The mind-bending implication was that brainless trees could send, receive and interpret messages.



Richard Karban, an ecologist at the University of California, Davis, studies how sagebrush communicate.

The first few “talking tree” papers quickly were shot down as statistically flawed or too artificial, irrelevant to the real-world war between plants and bugs. Research ground to a halt. But the science of plant communication is now staging a comeback. Rigorous, carefully controlled experiments are overcoming those early criticisms with repeated testing in labs, forests and fields. It’s now well established that when bugs chew leaves, plants respond by releasing volatile organic compounds into the air. By Karban’s [last count](#), 40 out of 48 studies of plant communication confirm that other plants detect these airborne signals and ramp up their production of chemical weapons or other defense mechanisms in response. “The evidence that plants release volatiles when damaged by herbivores is as sure as something in science can be,” said [Martin Heil](#), an ecologist at the Mexican research institute Cinvestav Irapuato. “The evidence that plants can somehow perceive these volatiles and respond with a defense response is also very good.”

Plant communication may still be a tiny field, but the people who study it are no longer seen as a lunatic fringe. “It used to be that people wouldn’t even talk to you: ‘Why are you wasting my time with something we’ve already debunked?’” said Karban. “That’s now better for sure.” The debate is no longer whether plants can sense one another’s biochemical messages — they can — but about why and how they do it. Most studies have taken place under controlled lab conditions, so one of the major open questions is to what extent plants use these signals in the wild. The answer could have big implications: Farmers might be able to adapt this chatter, tweaking food plants or agricultural practices so that crops defend themselves better against herbivores. More broadly, the possibility that plants share information raises intriguing questions about what counts as behavior and communication — and why organisms that compete with one another might also see fit to network their knowledge.

Scientists are also exploring how the messages from these signals might spread. Just a few months ago, the plant signaling pioneer [Ted Farmer](#) of the University of Lausanne discovered an almost entirely unrecognized way that plants transmit information — with electrical pulses and a system of voltage-based signaling that is eerily reminiscent of the animal nervous system. “It’s pretty spectacular what plants do,” said Farmer. “The more I work on them, the more I’m amazed.”

Farmer's study doesn't mean that plants have neurons, or brains, or anything like the systems that animals use to communicate. We don't do justice to them when we try to put their fascinating, alien biology into human terms, he said. But we may have dramatically underestimated their capabilities. As researchers begin to learn the language of plants, they are starting to get a whole new view of the leafy green world we live in.

Secret Lives

Karban started off as a cicada researcher, studying how trees cope with the plague of sap-sucking bugs that descends upon them every 17 years. Back then, the assumption was that plants survived by being tenacious, adapting their physiology to hunker down and suffer through droughts, infestations and other abuse. But in the early 1980s, the University of Washington zoologist David Rhoades was finding evidence that plants actively defend themselves against insects. Masters of synthetic biochemistry, they manufacture and deploy chemical and other weapons that make their foliage less palatable or nutritious, so that hungry bugs go elsewhere. For Karban, this idea was a thrilling surprise — a clue that plants were capable of much more than passive endurance.

Electric Signals

How does one leaf know it's being eaten, and how does it tell other parts of the plant to start manufacturing defensive chemicals? To prove that electrical signals are at work, [Ted Farmer's team](#) placed microelectrodes on the leaves and leaf stalks of *Arabidopsis thaliana* (a model organism, the plant physiologist's equivalent of a lab rat) and allowed Egyptian cotton leafworms to feast away. Within seconds, voltage changes in the tissue radiated out from the site of damage toward the stem and beyond. As the waves surged outward, the defensive compound jasmonic acid accumulated, even far from the site of damage. The genes involved in transmitting the electrical signal produce channels in a membrane just inside the plant's cell walls; the channels maintain electrical potential by regulating the passage of charged ions. These genes are evolutionary analogues to the ion-regulating receptors that animals use to relay sensory signals through the body. "They obviously come from a common ancestor, and are deeply rooted," Farmer said. "There are lots of interesting parallels. There are far more parallels than differences."

What Rhoades found next was even more surprising — and controversial. He was looking at how the Sitka willow altered the nutritional quality of its leaves in response to infestation by tent caterpillars and webworms. In the lab, when he fed the insects leaves from infested trees, the worms grew more slowly. But their growth was also stunted when he fed them leaves from undamaged willows that lived near the trees being eaten. The same biochemical change seemed to be happening in both groups of trees, and Rhoades' conclusion, [published in 1983](#), was that the untouched willows were getting a message from those under attack. That same year, [Ian Baldwin](#) and Jack Schultz from Dartmouth University [found that](#) seedlings of poplar and sugar maple began pumping out anti-herbivore phenols when placed in a growth chamber next to saplings with shredded leaves. They described it as plant communication. "People were really excited," said Karban. "The popular press went wild with this."

That reception made many scientists nervous. The 1979 film "[The Secret Life of Plants](#)" (after a 1973 book of the same name) had wowed audiences with time-lapse photography that made plants seem to writhe with vitality as they unfurled their leaves and pushed out roots. The film claimed that science had proven that plants were conscious and could sense human emotions. "It made people think the whole field was hokey," said Farmer.

Then, in 1984, both talking tree papers were picked apart by the eminent ecologist John Lawton (who was later knighted). [Lawton said that](#) Baldwin's study was poorly designed and that Rhoades must have accidentally spread an insect disease that slowed the bugs' growth. His criticism nearly

stopped the research dead in its tracks. Rhoades, whom Karban calls the “unheralded father of the field,” couldn’t get funding to replicate his studies and eventually quit science to run a bed and breakfast. People stopped talking about plant communication; the field went dark.

Airborne Messages

Not everyone was swayed by Lawton’s criticism. Among the renitent was Ted Farmer, then a postdoc in the Washington State University lab of renowned plant hormone expert Clarence Ryan. Farmer and Ryan worked with local sagebrush, which produce copious amounts of methyl jasmonate, an airborne organic chemical that Ryan thought plants were using to ward off insect herbivores. In their experiment, when damaged sagebrush leaves were put into airtight jars with potted tomato plants, the tomatoes began producing proteinase inhibitors — compounds that harm insects by disrupting their digestion. Interplant communication is real, they said in [a 1990 paper](#): “If such signaling is widespread in nature it could have profound ecological significance.”



When sagebrush is damaged by grasshoppers and other pests, it releases chemicals that seem to warn neighboring plants of danger.

The paper was “enormously carefully conducted, properly replicated and very convincing,” said Karban. But he still had his doubts. Does this really happen among wild plants, or is it an unusual phenomenon induced by lab conditions? Karban had just started work at a field station in a part of northern California that was thick with sagebrush and wild tobacco, a tomato cousin. He repeated Farmer’s experiment in the wild. When he clipped sagebrush plants, imitating the injuries caused by the sharp teeth of insects and inducing the plants to produce methyl jasmonate and other airborne

chemicals, the wild tobacco nearby started pumping out the defensive enzyme polyphenol oxidase. This seemed to have real consequences. At the end of the season, these tobacco plants had much less leaf damage than others from grasshoppers and cutworms. Karban cautioned that it's difficult to say definitely whether the airborne chemicals were directly responsible for the decrease in damage, but the results are nonetheless intriguing.

During the next decade, evidence grew. It turns out almost every green plant that's been studied releases its own cocktail of volatile chemicals, and many species register and respond to these plumes. For example, the smell of cut grass — a blend of alcohols, aldehydes, ketones and esters — may be pleasant to us but to plants signals danger on the way. [Heil has found](#) that when wild-growing lima beans are exposed to volatiles from other lima bean plants being eaten by beetles, they grow faster and resist attack. Compounds released from damaged plants prime the [defenses of corn seedlings](#), so that they later mount a more effective counterattack against beet armyworms. These signals seem to be a universal language: sagebrush induces responses in tobacco; chili peppers and lima beans respond to cucumber emissions, too.

Plants can communicate with insects as well, sending airborne messages that act as distress signals to predatory insects that kill herbivores. Maize attacked by beet armyworms releases a [cloud of volatile chemicals](#) that attracts wasps to lay eggs in the caterpillars' bodies. The emerging picture is that plant-eating bugs, and the insects that feed on them, live in a world we can barely imagine, perfumed by clouds of chemicals rich in information. Ants, microbes, moths, even hummingbirds and tortoises (Farmer [checked](#)) all detect and react to these blasts.

Eavesdropping Plants

Despite the growing evidence that plants are capable of communication, many plant scientists still question whether this cross talk is biologically meaningful. "Interplant communication through volatiles works well in the lab, but nobody's convincingly shown it works in the field," said Farmer. Even though he was one of the first to publish evidence that plants are capable of exchanging information, he calls himself a "skeptic" — he thinks there's not yet enough evidence that this actually plays a significant role in plant lives. "But I wouldn't want to stop people working on it," he added. "I think it's promising and exciting."



Ian Baldwin, an ecologist at the Max Planck Institute in Germany, thinks we should try to think like plants rather than anthropomorphize them.

For both Karban and Heil, the outstanding question is evolutionary: Why should one plant waste energy clueing in its competitors about a danger? They argue that plant communication is a misnomer; it really might just be [plant eavesdropping](#). Rather than using the vascular system to send messages across meters-long distances, maybe plants release volatile chemicals as a faster, smarter way to communicate with themselves — Heil calls it a [soliloquy](#). Other plants can then monitor these puffs of airborne data. Bolstering this theory, most of these chemical signals seem to travel no more than 50 to 100 centimeters, at which range a plant would mostly be signaling itself.

The possibility that plants routinely share information isn't just intriguing botany; it could be exploited to improve crop resistance to pests. [A 2011 report](#) found that commercial corn hybrids seem to have lost the wild maize plant's ability to release chemicals that attract parasitic wasps that kill stem borer moths. If these defensive traits could be bred back into crops, they could reduce the need for pesticides. [Another possibility](#) might be to grow plants with particularly sensitive or potent defensive responses alongside field crops. Like a canary in a coal mine, these sentinels would be the first to detect and react to danger, alerting neighboring crops.

Whether or not such practical applications come to pass, the science of plant talk is challenging long-held definitions of communication and behavior as the sole province of animals. Each discovery erodes what we thought we knew about what plants do and what they can do. To learn what else they're capable of, we have to stop anthropomorphizing plants, said Baldwin, who is now at the Max Planck Institute in Germany, and try instead to think like them, to phytomorphize ourselves. Imagining what it's like to be a plant, he said, will be the way to understand how and why they communicate — and make their secret lives a mystery no longer.

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