SCIENCE

THE MYSTERIES OF PLANT ‘INTELLIGENCE’

Scientists are debating whether concepts such as memory, consciousness, and communication can be applied beyond the animal kingdom.

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Illustration by Lucy Murray Willis

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SAVE

On a freezing day in December 2021, I arrived in Madison, Wisconsin, to visit Simon Gilroy's lab. In one room of the lab sat a flat of young tobacco and *Arabidopsis* plants, each imbued with fluorescent proteins derived from jellyfish.

Researchers led me into a small microscope room. One of them turned off the lights, and another handed me a pair of tweezers that had been dipped in a solution of glutamate—one of the most important neurotransmitters in our brains and, research has recently found, one that boosts plants' signals too. "Be sure to cross the midrib," Jessica Cisneros Fernandez, then a molecular biologist on Gilroy's team, told me. She pointed to the thick vein running down the middle of a tiny leaf. This vein is the plant's information superhighway. Injure the vein, and the pulse will move all over the plant in a wave. I pinched hard.

On a screen attached to the microscope, I watched the plant light up, its veins blazing like a neon sign. As the green glow moved from the wound site outward in a fluorescent ripple, I was reminded of the branching pattern of human nerves. The plant was becoming aware, in its own way, of my touch.

But what exactly does it mean for a plant to be *aware*? Consciousness was once seen as belonging solely to humans and a short list of nonhuman animals that clearly act with intention. Yet seemingly everywhere researchers look, they are finding that there is more to the inner lives of animals than we ever thought possible. Scientists now talk regularly about animal cognition; they study the behaviors of individual animals, and occasionally ascribe personalities to them.

Some scientists now posit that plants should likewise be considered intelligent. Plants have been found to show sensitivity to sound, store information to be accessed later, and communicate among their kind—and even, in a sense, with particular animals. We determine intelligence in ourselves and certain other species through inference—by observing how an organism behaves, not by looking for a psychological sign. If plants can do things that we consider indications of intelligence in animals, this camp of botanists argues, then why shouldn't we use the language of intelligence to describe them too?

From the July/August 2021 issue: A better way to look at trees

It's a daring question, currently being debated in labs and academic journals. Not so long ago, treading even lightly in this domain could upend a scientist's career. And plenty of botanists still think that applying concepts such as consciousness to plants does a disservice to their essential plantness. Yet even many of these scientists are awed by what we are learning about plants' capabilities.

A single book nearly snuffed out the field of plant-behavior research for good. *The Secret Life of Plants*, published in 1973, was as popular as it was irresponsible; though it included real science, it also featured wildly unscientific projection. One chapter suggested that plants could feel and hear—and that they preferred Beethoven to rock and roll. Another suggested that a plant could respond to malevolent thoughts.

Many scientists tried to reproduce the most tantalizing "research" presented in *The Secret Life of Plants*, to no avail. According to several researchers I spoke with, this caused the twin gatekeepers of science-funding boards and peer-review boards to become skittish about plant-behavior studies. Proposals with so much as a whiff of inquiry into the subject were turned down. Pioneers in the field changed course or left the sciences altogether.

A decade after the book's publication, a paper by David Rhoades, a zoologist and chemist at the University of Washington, reopened questions of plant communication. Rhoades had watched a nearby forest be decimated by an invasion of caterpillars. But then something suddenly changed; the caterpillars began to die. Why? The answer, Rhoades discovered, was that the trees were communicating with one another. Trees that the caterpillars hadn't yet reached were ready: They'd changed the composition of their leaves, turning them into weapons that would poison, and eventually kill, the caterpillars.

Scientists were beginning to understand that trees communicate through their roots, but this was different. The trees, too far apart to be connected by a root system, were signaling to one another through the air. Plants are tremendous at chemical synthesis, Rhoades knew. And certain plant chemicals drift through the air. Everyone already understood that ripening fruit produces airborne ethylene, for example, which prompts nearby fruit to ripen too. It wasn't unreasonable to imagine that plant chemicals containing other information—say, that the forest was under attack—might also drift through the air.

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Still, the idea that a plant would defend itself in this way was heretical to the whole premise of how scientists thought plants worked. Plants were not supposed to be that active, or have such dramatic and strategic reactions. Rhoades presented his hypothesis at conferences, but mainstream scientific journals were reluctant to take the risk of publishing something so outlandish. The discovery ended up buried in an obscure volume, and Rhoades was ridiculed by peers in journals and at conferences.

But Rhoades's communication experiments, and others that came immediately after, helped establish new lines of inquiry. We now know that plants' chemical signals are decipherable not just by other plants but in some cases by insects. Still, four decades on, the idea that plants might communicate *intentionally* with one another remains a controversial concept in botany.

One key problem is that there is no agreed-upon definition of *communication*, not even in animals. Does a signal need to be sent purposefully? Does it need to provoke a response in the receiver? Much as *consciousness* and *intelligence* have no settled definition, *communication* slip-slides between the realms of philosophy and science, finding secure footing in neither. Intention poses the hardest of problems, because it cannot be directly determined.

From the March 2019 issue: A journey into the animal mind

The likely impossibility of establishing intentionality in plants, though, is no deterrent to Simon Gilroy's sense of wonder at their liveliness. In the '80s, Gilroy, who is British, studied at Edinburgh University under Anthony Trewavas, a renowned plant physiologist. Since then, Trewavas has begun using provocative language to talk about plants, aligning himself with a group of botanists and biologists who call themselves plant neurobiologists, and publishing papers and a book laying out scientific arguments in favor of plant intelligence and consciousness. Gilroy himself is more circumspect, unwilling to talk about either of those things, but he still works with Trewavas. Recently, the two have been developing a theory of agency for plants.

Gilroy is quick to remind me that he is talking strictly about *biological* agency, not implying intention in a thoughts-and-feelings sense. But there's no question that plants are engaged in the active pursuit of their own goals and, in the process, shape the very environment they find themselves rooted in. That, for him, is proof of plants' agency. Still, the proof is found through inferring the meaning behind plants' actions rather than understanding their mechanics.

"When you get down to the machinery that allows those calculations to occur, we don't have the luxury of going, *Ah, it's neurons in the brain*," Gilroy told me. His work is beginning to allow us to watch the information processing happen, "but at the moment, we don't know *how* it works."

That is the essential question of plant intelligence: How does something without a brain coordinate a response to stimuli? How does information about the world get translated into action that benefits the plant? How can the plant sense its world without a centralized place to parse that information?

A few years back, Gilroy and his colleague Masatsugu Toyota thought they'd have a go at those questions, which led them to the experiment I participated in at the lab. Their work has shown that those glowing-green signals move much faster than would be expected from simple diffusion. They move at the speed of some electrical signals, which they may be. Or, as new research suggests, they may be surprisingly fast chemical signals.

Given what we know about the dynamics of sensing in creatures that have a brain, the lack of one should mean that any information generated from sensing ought to ripple meaninglessly through the plant body without producing more than a highly localized response. But it doesn't. A tobacco plant touched in one place will experience that stimulus throughout its whole body.

> No brains, the dissenting papers claim, means no intelligence.

The system overall works a bit like an animal nervous system, and might even employ similar molecular players. Gilroy, for his part, does not want to call it a nervous system, but others have written that he and Toyota have found "nervous system–like signaling" in plants. The issue has even leaked out of plant science: Researchers from other disciplines are weighing in. Rodolfo Llinás, a neuroscientist at NYU, and Sergio

Miguel Tomé, a colleague at the University of Salamanca, in Spain, have argued that it makes no sense to define a nervous system as something only animals can have rather than defining it as a physiological system that could be present in other organisms, if in a different form.

Convergent evolution, they argue, wherein organisms separately evolve similar systems to deal with similar challenges, happens all the time; a classic example is wings. Flight evolved separately in birds, bats, and insects, but to comparable effect. Eyes are another example; the eye lens has evolved separately several times.

The nervous system can reasonably be imagined as another case of convergent evolution, Llinás and Miguel Tomé say. If a variety of nervous systems exist in nature, then what plants have is clearly one. Why not call it a nervous system already?

"What do you mean, the flower remembers?" I ask.

It's 2019, and I'm walking through the Berlin Botanic Garden with Tilo Henning, a plant researcher. Henning shakes his head and laughs. He doesn't know. No one does. But yes, he says, he and his colleague Maximilian Weigend, the director of a botanical garden in Bonn, have observed the ability of *Nasa poissoniana* —a plant in the flowering Loasaceae family that grows in the Peruvian Andes—to store and recall information.

The pair noticed that the multicolor starburst-shaped flowers were raising their stamen, or fertilizing organs, shortly *before* a pollinator arrived, as if they could predict the future. The researchers set up an experiment and found that the plant in fact seemed to be learning from experience. These flowers, Henning and Weigend found, could "remember" the time intervals between bee visits, and anticipate the time their next pollinator was likely to arrive. If the interval between bee visits changed, the plant might actually adjust the timing of its stamen display to line up with the new schedule.

In a 2019 paper, Henning and Weigend call *Nasa poissoniana*'s behavior "intelligent," the word still appearing in quotation marks. I want to know what Henning really thinks. *Are* plants intelligent? Does he see the flower's apparent ability to remember as a hallmark of consciousness? Or does he think of the plant as an unconscious robot with a preprogrammed suite of responses?

Henning shakes off my question the first two times I ask it. But the third time, he stops walking and turns to answer. The dissenting papers, he says, are all focused on the lack of brains—no brains, they claim, means no intelligence.

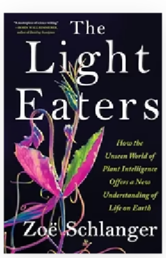
"Plants don't have these structures, obviously," Henning says. "But look at what they do. I mean, they take information from the outside world. They process. They make decisions. And they perform. They take everything into account, and they transform it into a reaction. And this, to me, is the basic definition of *intelligence*. That's not just automatism. There might be some automatic things, like going toward light. But this is not the case here. It's not automatic."

Where *Nasa poissoniana*'s "memories" could possibly be stored is still a mystery. "Maybe we are just not able to see these structures," Henning tells me. "Maybe they are so spread all over the body of the plant that there isn't a single structure. Maybe that's their trick. Maybe it's the whole organism."

It's humbling to remember that plants are a kingdom of life entirely their own, the product of riotous evolutionary innovation that took a turn away from our branch of life when we were both barely motile, single-celled creatures floating in the prehistoric ocean. We couldn't be more biologically different. And yet plants' patterns and rhythms have resonances with ours—just look at the information moving through Gilroy's glowing specimens.

Mysteries abide, of course. We are far from understanding the extent of "memory" in plants. We have a few clues and fewer answers, and so many more experiments still to try.

This article was adapted from Zoë Schlanger's new book, The Light Eaters: How the Unseen World of Plant Intelligence Offers a New Understanding of Life on Earth*. It appears in the* June 2024 *print edition with the headline "The Mysteries of Plant 'Intelligence.'"*



The Light Eaters: How the Unseen World of Plant Intelligence Offers a New Understanding of Life on Earth

By Zoë Schlanger