A touching story: The ancient conversation between plants, fungi and bacteria

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The mechanical force that a single fungal cell or bacterial colony exerts on a plant cell may seem vanishingly small, but it plays a heavy role in setting up some of the most fundamental symbiotic relationships in biology. In fact, it may not be too much of a stretch to say that plants may have never moved onto land without the ability to respond to the touch of beneficial fungi, according to a new study led by Jean-Michel Ané, a professor of agronomy at the University of Wisconsin-Madison.

"Many people have studied how roots progress through the soil, when fairly strong stimuli are applied to the entire growing root," says Ané, who just published a review of touch in the interaction between plants and microbes in the journal *Current Opinion in Plant Biology*. "We are looking at much more localized, tiny stimuli on a single cell that is applied by microbes."

Specifically, Ané, Dhileepkumar Jayaraman, a postdoctoral researcher in agronomy, and Simon Gilroy, a professor of botany, studied how such a slight mechanical stimulus starts round one of a symbiotic relationship —that is, a win-win relationship between two organisms.

It's known that disease-causing fungi build a structure to break through the plant cell wall, "but there is growing evidence that fungi and also bacteria in symbiotic associations use a mechanical stimulation to indicate their presence," says Ané. "They are knocking on the door, but not breaking it down."

After the fungus announces its arrival, the plant builds a tube in which the fungus can grow. "There is clearly a mutual exchange of signals between the plant and the fungus," says Ané. "It's only when the path is completed that the fungus starts to penetrate."

Mycorrhizae are the beneficial fungi that help virtually all land plants absorb the essential nutrients—phosphorus and nitrogen—from the soil. Biologists believe this ubiquitous mechanism began about 450 million years ago, when plants first moved onto land.

Mechanical signaling is only part of the story—microbes and plants also communicate with chemicals, says Ané. "So this is comparable not to breaking the door or even just knocking on the door, but to knocking on the door while wearing cologne. Clearly the plant is much more active than we thought; it can process signals, prepare the path and accept the symbiont."

Beyond fungi, some plants engage in symbiosis with bacteria called rhizobia that "fix" nitrogen from the atmosphere, making it available to the plant.

Rhizobia enable legumes like soybeans and alfalfa to grow without nitrogen fertilizer.

When Ané and his colleagues looked closer, they found that rhizobium symbiosis also employs mechanical stimulation. When the bacterium first contacts a root hair, the hair curls around the bacterium, trapping it.

The phenomenon of curling has been known for almost 100 years. "But why would nature develop such a complicated mechanism to entrap a bacterial colony?" Ané asks. "We propose the purpose is to apply mechanical stimulation" so the plant will start building a home for the rhizobium—for mutual benefit. "We have preliminary evidence that when the entrapment is not complete, the process of colonization does not happen," he says.

Again, the two-step communication system is at work, Ané adds. "The curling process itself can only begin when the plant gets a chemical signal from the bacterium—but the growing tube inside the root hair that accepts the bacteria requires something else, and nobody knew what. We propose it's a mechanical stimulation created by entrapping, which gives the bacterial colony a way to push against the root."

In many respects, this symbiosis parallels the older one between plants and beneficial fungi, Ané says. Indeed, he says legumes have "hijacked" the mycorrhizae system. "Plants used the symbiosis toolkit to develop this relationship with mycorrhizae, and then used it again for bacteria. This dual requirement for chemical and mechanical signals is present in both associations, even though the association between rhizobia and legumes is only 60 million years old."

Provided by University of Wisconsin-Madison

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