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What lies beneath: Growth of root cells remarkably dynamic, study finds

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Heart cells beat together as the heart pumps. Single-celled amoebae pulsate as they move. But pulsing plant cells? That's precisely what certain plant cells do as they grow, says a study publishing online this week in the *Proceedings of the National Academy of Sciences*.

Using sophisticated video imaging techniques, a team led by UW-Madison botany professor Simon Gilroy captured the growth of tiny extensions of individual root cells, called root hairs. Blanketing the surfaces of roots by the millions, these long, skinny projections hugely expand the surface area for water and mineral uptake from the soil, but how they form has remained something of a mystery.

When the scientists trained their cameras on the hairs, rather than witnessing a slow, steady lengthening, they were surprised to see the hairs undergoing rhythmic pulses of growth every 20 seconds, orchestrated by rapid-fire changes in pH and levels of reactive oxygen species (ROS).

The findings show that plants are hardly the slow or even static beings we normally take them for, says Gilroy. Instead, they're responding to cues and regulating their growth on timescales of seconds to milliseconds — a realm usually associated only with animal responses.

"This is one of the first real-time views of plant growth," says Gilroy, who recently came to UW-Madison from Penn State University. "And what everyone notices is that plants are actually much more dynamic than you'd think by looking at them just sitting there, soaking up the sun."

What makes the feat even more remarkable is that, unlike animal cells, enlarging plant cells must contend with a cell boundary made of cellulose that is, pound for pound, stronger than steel. Known as the cell wall, the reinforcement is needed because the insides of plant cells are under tremendous water pressure, or turgor, Gilroy explains.

In the case of root hairs — which grow from their tips — this means the cell must somehow make the wall just flexible enough at the tip so that it stretches from that internal force without bursting. At the same time, the cell must quickly strengthen the wall directly behind the tip once growth has taken place.

"The plant cell has to work out where to make the wall stiff, where to make it loose, and control this so finely that the turgor pressure doesn't absolutely shoot the end off the cell and kill it," says Gilroy. "It's always been a conundrum: How on earth does a plant cell do this?"

Based on previous work, Gilroy's team hypothesized that a drop in pH at the tip might trigger growth, since acidity is known to loosen the cellulose matrix and let the cell wall stretch. Their first idea was that the plant cell carefully doles out just the right number of protons — which control pH — to create a gradient of acidity that results in steady elongation.

What they saw instead was much more lively. When protons flow into the wall, the wall stretches and the tip lengthens as expected. But rather than letting this continue, the plant cell sucks the protons back out again almost immediately, causing the pH to rise and the cellulose strands to lock in place once more. After a brief pause, another influx of protons loosens the wall again and the tip extends a little more.

Why the stops and starts? Because the root hair is at such risk of weakening the wall too much and bursting, Gilroy thinks it takes a quick breather to check on things.

"There's a lot of regulation invested in slowing things down and waiting to see if the cell is okay, before going on," says Gilroy. Because the effects of pH are reversible, the wall is easily strengthened or loosened again if a mistake is made.

That's only half the story, though. As growth proceeds, the portion of the wall once located at the growing tip moves further back, and the cell needs to make it permanently rigid to prevent further stretching. This is where the highly reactive form of oxygen, ROS, comes in, says Gilroy. In addition to the falling and rising of pH, his team has documented a burst of ROS just behind the tip during each growth pulse. There, ROS cross-links the wall, rendering it permanently stiff.

"Everything's coordinated. It's like a dance," says Gilroy. What's more, the entire complicated ballet occurs up to three times a minute.

"If you pick up your potted plant, every 20 seconds probably 10 million of these events are going on in the root system, provided the plant has a big one," says Gilroy.

The same goes for the roots that snake everywhere underground. It gives you a whole new perspective on what's going on under your feet.

Source: UW-Madison

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