Advance in understanding cellulose synthesis

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Cellulose is a fibrous molecule that makes up plant cell walls, gives plants shape and form and is a target of renewable, plant-based biofuels research. But how it forms, and thus how it can be modified to design energy-rich crops, is not well understood. Now a study led by researchers at the Carnegie Institution's Department of Plant Biology has discovered that the underlying protein network that provides the scaffolding for cell-wall structure is also the traffic cop for delivering the critical growth-promoting molecules where needed.

The research, conducted in collaboration with colleagues at Wageningen University in the Netherlands and published in the advance online publication (AOP) of *Nature Cell Biology* on June 14th, is a significant step for understanding how the enzymes that make cellulose and determine plant cell shape arrive at the appropriate location in the cell to do their job.

"Cellulose is the most abundant reservoir of renewable hydrocarbons in the world," remarked Carnegie's David Ehrhardt, a coauthor. "To understand how cellulose might be modified and how plant development might be manipulated to improve crop plants as efficient sources of energy, we need to first understand the cellular processes that create cellulose and build cell walls."

Plant cells have rigid walls that cannot easily change shape. There are many cell types, spiky trichomes to fend off bugs and sausage-shaped guard cells that regulate the plant's breathing pores, as examples. In a previous study using the model plant *Arabidopsis*, Ehrhardt and team used groundbreaking imaging techniques to watch the molecules that create this array of shapes. It provided the first direct evidence for a functional connection between synthesis of the cell wall and an array of protein fibers—called microtubules—that provide the scaffolding that allow diverse plant cell shapes to be created as the cell wall pushes outward.

In that study, the group engineered plants to produce a fluorescent version of cellulose synthase, the enzyme that creates cellulose fibers. They also included a fluorescent version of tubulin, the protein from which microtubules are built. Using advanced imaging techniques, they tracked the motion of single fluorescent molecules, and found that cellulose synthase moves along "tracks" defined by the microtubules.

In this paper, the researchers looked at how the association between the cellulose synthase complexes and microtubules begins. The scientists were able to watch individual cellulose synthase complexes as they were delivered to the plasma membrane—the permeable film that surrounds the cell, but is inside the cell wall— and found that the microtubules not only guide where the complexes go as they build the cell wall, but microtubules also organize the trafficking and delivery of the cellulose synthase complexes to their place of action.

They also looked at the role in trafficking of a structural element called the actin cytoskeleton that helps move organelles and maintains the cell's shape. They found that it appears to be required for the general distribution of the cellulose synthase complexes, whereas microtubules appear to be required for final positioning.

When there is a disruption of the complexes through a stressor such as a rapid change in water movement (osmotic stress), active cellulose synthase complexes disappear and organelles accumulate just under the plasma membrane. These organelles contain cellulose synthase and are tethered to the microtubules by a novel mechanism. Previously Ehrhardt and team found that plant microtubules move by shortening at one end while lengthening at the other end. They do this one tubulin molecule at a time, in a process the researchers call treadmilling. They now think that the tethering discovered in this research allows the cellulose synthase-containing organelles to stay with the treadmilling microtubules for prolonged periods in times of stress. They found that when the stress abates, these organelles deliver the cellulose synthase to the membrane.

Source: Carnegie Institution