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Balancing the pressure: how plant cells protect their vacuoles

Water-filled vacuoles provide the inner pressure plant cells need for structural support. However, damage to the plant's cell wall risks vacuole rupture and cell death. The Dagdas group at the Gregor Mendel Institute of Molecular Plant Biology (GMI) discovered a novel quality control mechanism that protects the vacuole's integrity upon cell wall damage. The study was published on February 7th in Nature Plants.

Plants droop and shed their leaves when parched, but with a splash of water, their stems regain strength and their leaves unfurl. This dramatic transformation is a clear signal for us to reach for the watering can – and it demonstrates a delicate balance at the cellular level, which lies at the heart of plant's rigidity.

The structural support of a plant depends on the unique balance between two elements: The strong, flexible cell wall provides structural support, while the vacuole, a large cellular compartment filled with water, acts like a water balloon, pressing against the cell wall. The delicate pressure balance between the inside and the outside of the vacuole provides plants with strength, flexibility, and the ability to grow upright without collapsing under their own weight.

This balance can be upset when the cell wall is damaged, causing the highly pressured vacuole to rupture and release its contents, which can lead to cell death. While the mechanisms that ensure quick repair of the cell wall are well studied, we as yet understand little about how the vacuole is protected from rupturing upon the sudden change in pressure.

To address this question, the Dagdas team used genetic and functional analyses in Marchantia polymorpha and Arabidopsis thaliana. The team identified a conserved quality control mechanism by which cell wall damage triggers the conjugation of the molecule ATG8 to the vacuole's membrane, a process known as ATG8ylation. The research team showed that ATG8, which is normally located in small cellular vesicles that mediate autophagy, is quickly relocated to the vacuole membrane upon disruption of the cell wall.

Importantly, the team showed that any alterations of the described pathway block the relocation of ATG8 to the vacuole membrane, leading to vacuole rupture and cell death.

The team aims to further study how the plant cell senses the damage to the cell wall, as well as how exactly ATG8 conjugation protects vacuolar integrity. "Unraveling this process will be essential to understanding how plant cells protect themselves from external disruptions such as pathogens and environmental insults," says Jose Julián, co-first author of the work and postdoctoral fellow in the lab of Yasin Dagdas. "We will test whether ATG8 helps the vacuole membrane to stretch, so that it can accommodate the pressure differential or, instead, whether ATG8 helps isolate and remove damaged sections of the membrane."

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ATG8ylation of vacuolar membrane protects plants against cell wall damage

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