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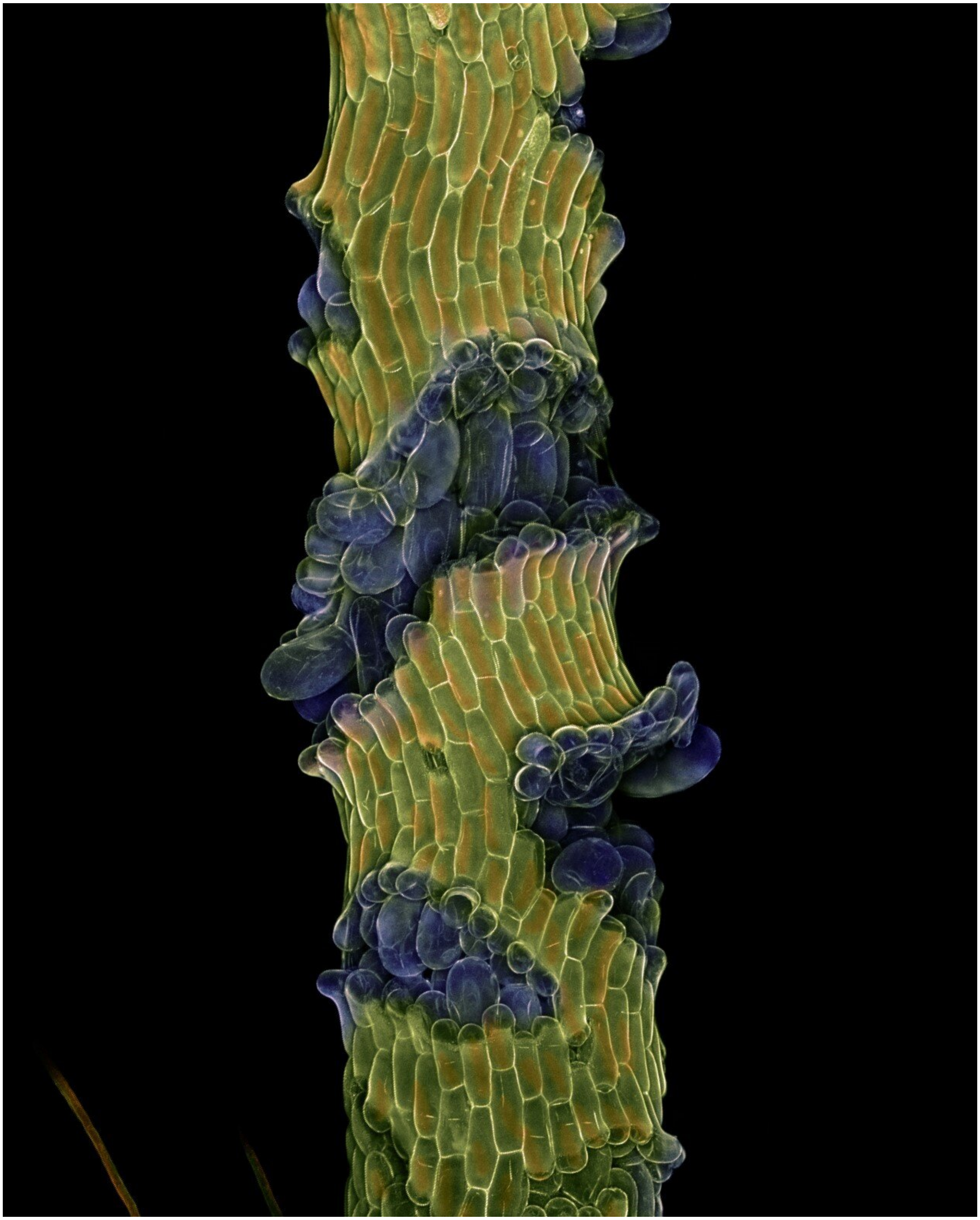
The clue is in the glue: Study shows how plants hold it together during growth

June 22 2023



Arabidopsis stem with weakened cell adhesion treated with an inhibitor of the growth hormone brassinosteroid, which slows epidermal growth, causing mechanical stresses and opening cracks as epidermal cells are pulled apart. Credit: Rob Kesseler and Robert Bellow.

An obscure aquatic plant has helped to explain how plants avoid cracking up under the stresses and strains of growth.

The finding, by researchers Dr. Robert Kelly-Bellow and Karen Lee in the group of Professor Enrico Coen at the John Innes Centre, started with a curious observation in a dwarf mutant of the carnivorous plant Utricularia gibba.

The stems of this floating plant are filled with air spaces, and this hollowness means that the vascular column inside the stem can buckle when under stress. This effect would not be apparent in most plants, which have solid stems.

The researchers saw that in a dwarf mutant the central column was wavy instead of straight. They hypothesized that this wobbly spine was caused by an internal conflict, a disparity between what was happening inside the plant stem and the epidermis or skin. Computational modeling by co-author Dr. Richard Kennaway showed this idea could account for what was observed.

The paper is published in the journal *Science*.

"We realized that in these types of dwarf, only the epidermis, the skin of the stem, wants to be short, the internal tissue still wants to be long hence the buckling effect," explains Professor Enrico Coen of the John Innes Centre, an author of the study.

"This was a surprise—previously people had thought that dwarf varieties, which are very important in agriculture, would be dwarf because everything in the stem is affected to grow less, but in fact it's just the skin in this case, creating a sort of straitjacket."

Further investigations revealed that the Utricularia gibba dwarf mutant lacked a growth hormone called brassinosteroid. The researchers theorized that this hormone normally allows the skin to stretch, giving a more forgiving "straitjacket" and allowing the plant stem to elongate.

To test this idea, they used a mutant in the model plant Arabidopsis that weakens the glue between cells, to see if reducing brassinosteroid would cause major cracks to form in the skin of the stem as a result of the stresses.

"That is exactly what we saw," explains Professor Coen. "Normally an Arabidopsis stem with weakened glue will crack slightly because the hormone is there to loosen the straitjacket. But when the hormone was missing, the skin was completely ripped off and the plant was almost skinless."

Computational modeling by co-author Professor Richard Smith showed brassinosteroid hormone was likely easing the straitjacket by loosening fibers in the epidermal cell walls.

"Plant cells are stuck together and are forced to behave in a coordinated way just by their pectin, their glue, that binds them. What we show in this study is that this is an incredibly powerful force; the glue is so strong you only need to change growth in one layer and the other cells will follow," explains Professor Coen.

"Previous studies have emphasized that plants send molecular signals to grow in a coordinated way, and this is still a part of the explanation. But what our study shows is that the glueyness of plant cells is also a vital component in coordinating growth. Sticking together is very important."

Co-author Dr. Christopher Whitewoods at the Sainsbury Laboratory, Cambridge University, emphasizes the potential importance of these findings for future research. "The fact that mechanical interactions between cell layers control growth in the stems of two wildly different species raises the question of whether they control other aspects of plant development, such as the complex internal patterning of leaves. We are excited to test whether this is the case."

The findings shed light on dwarfing varieties of crops, like wheat and rice, which underpin agriculture's Green Revolution, explaining how genes control their growth and how we might improve their efficiency in future.

Their findings also relate to developmental processes in animals, such as formation of crocodile skin cracks and shaping of the intestine, where mechanical interactions between layers are also thought to play a part.

Many hypotheses look promising to begin with, but then fail to last the full experimental course. Not so in this case, reflects Professor Coen.

"The first glimpse of the wobbly tissue in our dwarf aquatic plant was exciting because as soon as we saw that, we had an idea of what might be going on. But the biggest excitement came from testing the idea in a completely different system.

"Nature is elusive. Ninety-nine percent of nice ideas fall flat on their face when put to a critical test. But occasionally an idea survives and you then know that nature has revealed one of its secrets to you," he says.

More information: Robert Kelly-Bellow et al, Brassinosteroid coordinates cell layer interactions in plants via cell wall and tissue

mechanics, *Science* (2023). DOI: 10.1126/science.adf0752.
www.science.org/doi/10.1126/science.adf0752

Provided by John Innes Centre

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