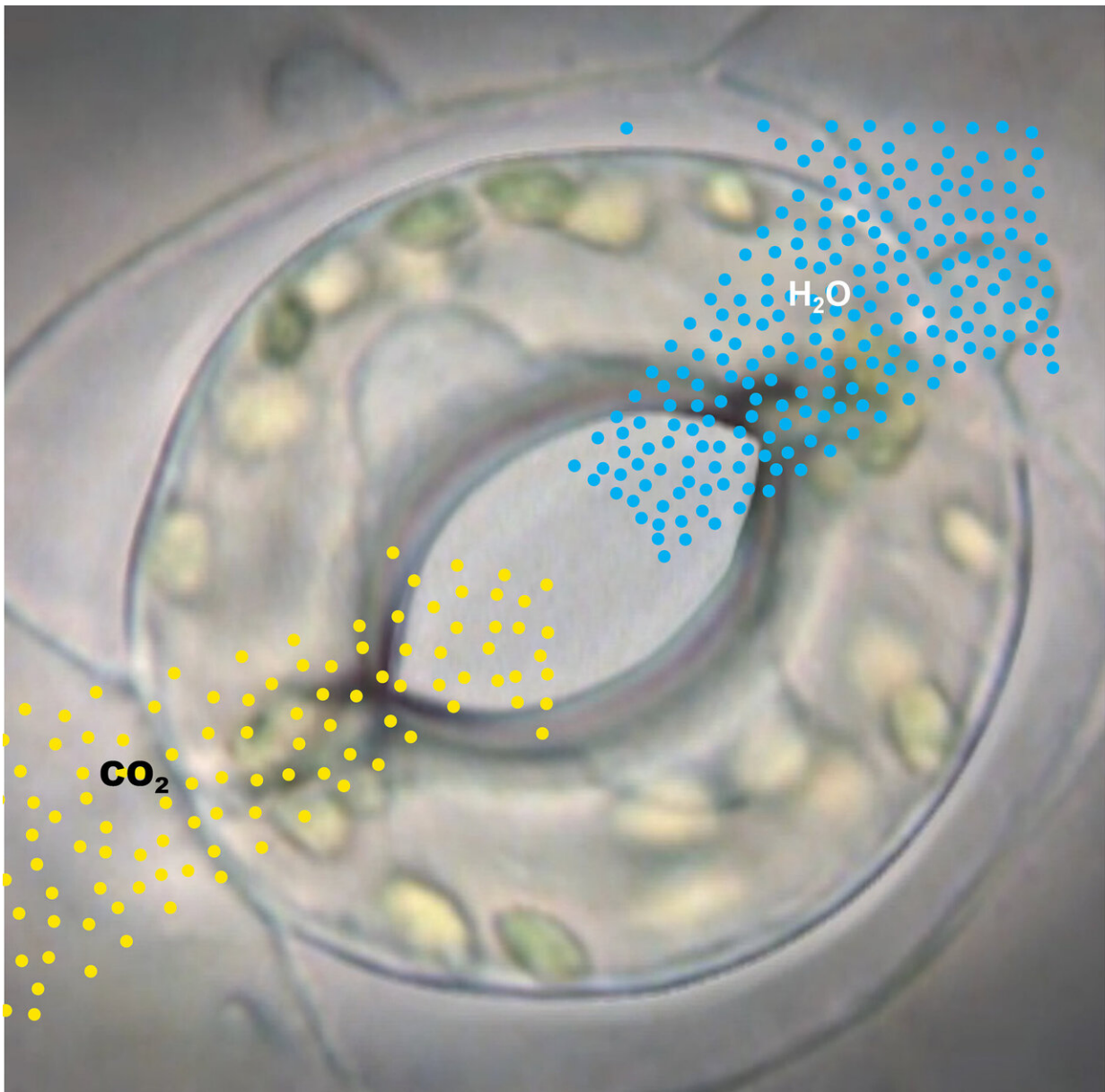


How plants measure their carbon dioxide uptake

August 26 2019



Gas exchange through the stomata: Carbon dioxide is taken in; at the same time a hundred water molecules (H₂O) escape for each CO₂ molecule that is taken up. Credit: Hedrich & Peter Ache / University of Wuerzburg

When water is scarce, plants can close their pores to prevent losing too much water. This allows them to survive even longer periods of drought, but with the majority of pores closed, carbon dioxide uptake is also limited, which impairs photosynthetic performance and thus plant growth and yield.

Plants accomplish a balancing act—navigating between drying out and starving in dry conditions—through an elaborate network of sensors. An international team of plant scientists led by Rainer Hedrich, a biophysicist from Julius-Maximilians-Universität (JMU) Würzburg in Bavaria, Germany, has now pinpointed these sensors. The results have been published in the journal *Nature Plants*.

Microvalves control photosynthesis and water supply

When light is abundant, plants open the pores in their leaves to take in [carbon dioxide](#) (CO₂) which they subsequently convert to carbohydrates in a process called photosynthesis. At the same time, a hundred times more [water](#) escapes through the microvalves than carbon dioxide flows in.

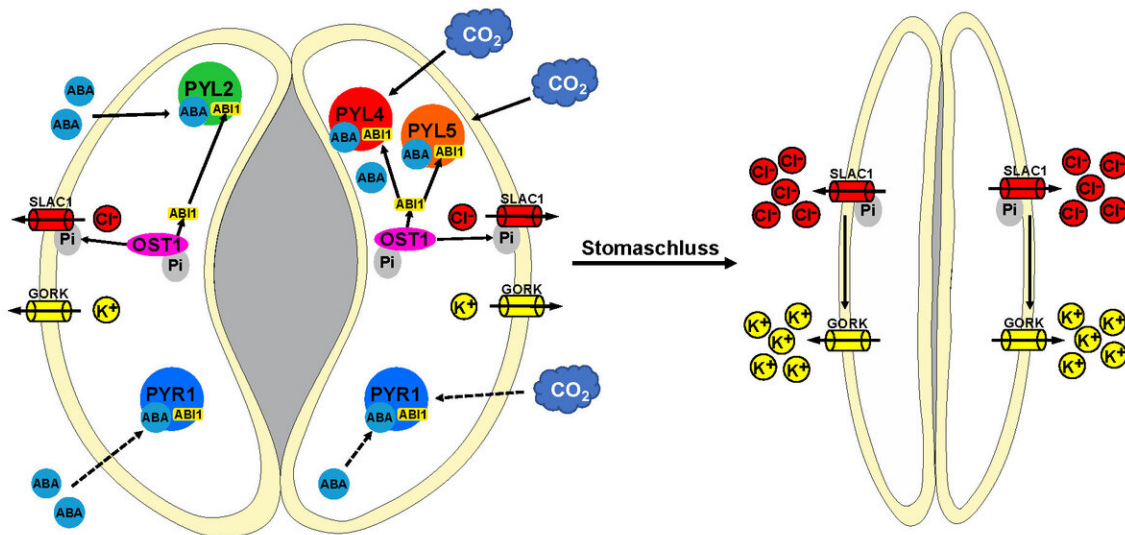
This is not a problem when there is enough water available, but when soils are parched in the middle of summer, the plant needs to switch to eco-mode to save water. Then plants will only open their pores to perform photosynthesis for as long as necessary to barely survive. Opening and closing the pores is accomplished through specialised guard [cells](#) that surround each [pore](#) in pairs. The units comprised of pores and

guard cells are called stomata.

Guard cells have sensors for CO₂ and ABA

The guard cells must be able to measure the photosynthesis and the water supply to respond appropriately to changing environmental conditions. For this purpose, they have a receptor to measure the CO₂ concentration inside the leaf. When the CO₂ value rises sharply, this is a sign that the photosynthesis is not running ideally. Then the pores are closed to prevent unnecessary evaporation. Once the CO₂ concentration has fallen again, the pores reopen.

The water supply is measured through a hormone. When water is scarce, [plants](#) produce abscisic acid (ABA), a key stress hormone, and set their CO₂ control cycle to water saving mode. This is accomplished through guard cells which are fitted with ABA receptors. When the hormone concentration in the leaf increases, the pores close.



Involvement of the ABA receptors in ABA- and CO₂-induced closure of the stoma. When in drought stress mode, the plant produces large amounts of the ABA hormone that acts on the guard cells (left, left guard cell) and binds to the primary player, PYL2, and the secondary player, PYR1. High CO₂ levels (left, right guard cells) cause PYL4, 5 and to some extent PYR1 to become more sensitive and bind ABA at low intracellular concentrations. In both cases, the ABI1 phosphatase is bound, enabling the OST1 kinase to first activate itself and then the SLAC1 anion channel. The resulting efflux of anions depolarises the membrane potential, which in turn activates the GORK potassium output channel. The efflux of osmotically active salts causes water to flow out of the guard cells. They shrink and the stoma closes (right). Credit: Heike Mueller & Peter Ache / University of Wuerzburg

Analysing the CO₂-ABA network

The JMU research team wanted to shed light on the components of the guard cell control cycles. For this purpose, they exposed Arabidopsis species to elevated levels of CO₂ or ABA. They did so over several hours to trigger reactions at the level of the genes. Afterwards, the stomata were isolated from the leaves to analyse the respective gene expression profiles of the guard cells using bioinformatics techniques. For this task, the team took Tobias Müller and Marcus Dietrich on board, two bioinformatics experts at the University of Würzburg.

The two experts found out that the gene expression patterns differed significantly at high CO₂ or ABA concentrations. Moreover, they noticed that excessive CO₂ also caused the expression of some ABA genes to change. These findings led the researchers to take a closer look at the ABA signalling pathway. They were particularly interested in the ABA receptors of the PYR/PYL family (pyrabactin receptor and pyrabactin-like). Arabidopsis has 14 of these receptors, six of them in the guard cells.

ABA receptors under the microscope

"Why does a guard cell need as many as six receptors for a single hormone? To answer this question, we teamed up with Professor Pedro Luis Rodriguez from the University of Madrid, who is an expert in ABA receptors," says Hedrich. Rodriguez's team generated Arabidopsis mutants in which they could study the ABA receptors individually.

"This enabled us to assign each of the six ABA receptors a task in the network and identify the individual receptors which are responsible for the ABA- and CO₂-induced closing of the stomata," Peter Ache, a colleague of Hedrich's, explains.

Guard cells use ABA as currency in calculations

"We conclude from the findings that the guard cells offset the current photosynthetic carbon fixation performance with the status of the water balance using ABA as the currency," Hedrich explains. "When the water supply is good, our results indicate that the ABA receptors evaluate the basic hormonal balance as quasi 'stress-free' and keep the stomata open for CO₂ supply. When water is scarce, the drought stress receptors recognise the elevated ABA level and make the [guard cells](#) close the stomata to prevent the plant from drying out."

Next, the JMU researchers aim to study the special characteristics of the ABA and CO₂ relevant [receptors](#) as well as their signalling pathways and components.

More information: The role of Arabidopsis ABA receptors from the PYR/PYL/RCAR family in stomatal acclimation and closure signal integration, *Nature Plants* (2019). [DOI: 10.1038/s41477-019-0490-0](https://doi.org/10.1038/s41477-019-0490-0) , [nature.com/articles/s41477-019-0490-0](https://www.nature.com/articles/s41477-019-0490-0)

Provided by University of Würzburg

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