Gene-expression study reveals 2-in-1 root armor protects plants from environmental stressors, fights climate change

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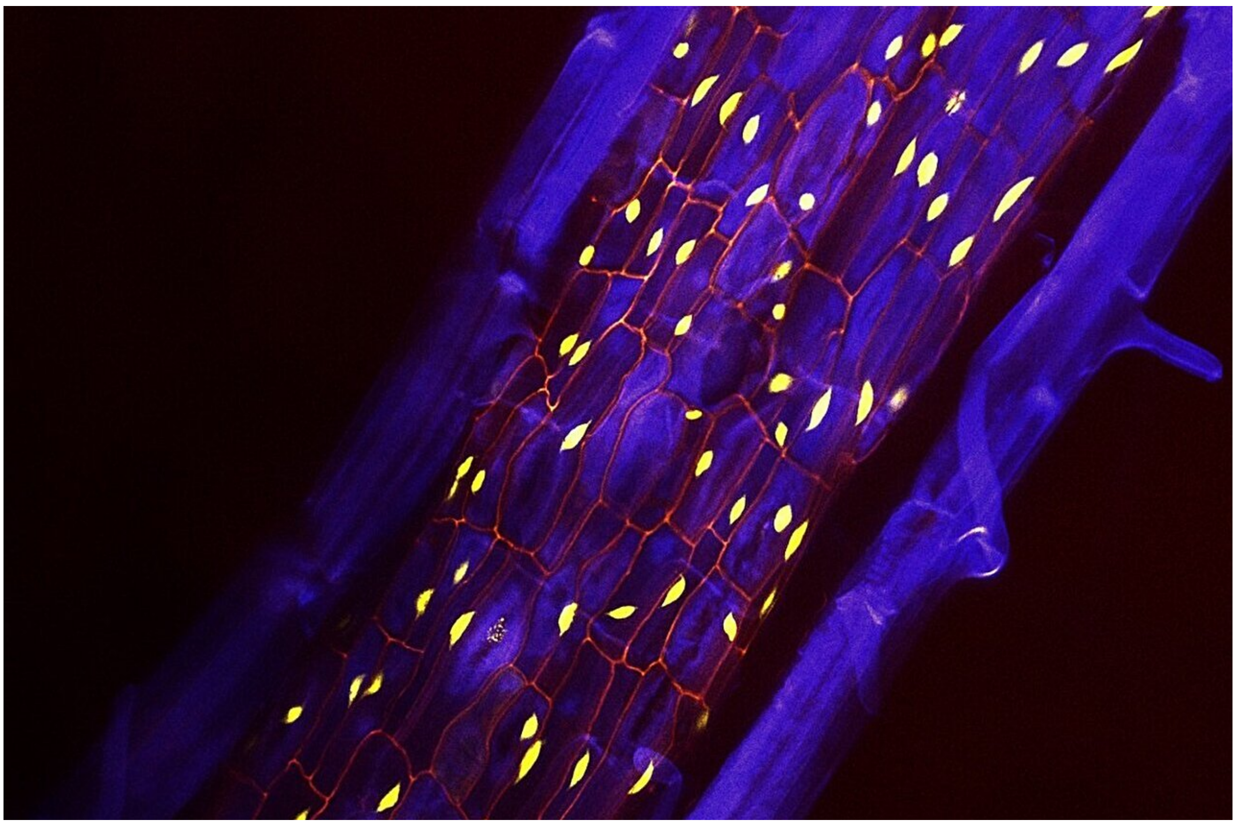

Section of a plant root showcasing the periderm and its carbon-capturing phellem cells. Credit: Salk Institute

Plants may burrow into the ground and stretch toward the sun, but they're ultimately stuck where they sprout—at the mercy of environmental threats like temperature, drought, and microbial infection.

To compensate for their inability to up and move when danger strikes, many plants have evolved ways to protect themselves by altering their physiology, such as building armor around parts of their body and roots called the periderm. However, since many plant biologists who study tissue development look at young plants, later-in-life periderm development has remained relatively unexplored.

Salk Institute researchers have debuted the first comprehensive gene expression atlas of the plant periderm at the single-cell level. The atlas provides new information about the different kinds of cells that make up the periderm and which specific genes and biological processes control their development.

This includes important insights into phellem cells, which are rich in suberin—a molecule that helps capture and store excess carbon from the atmosphere for a long time. Scientists can now use this information to stimulate growth of the protective periderm in plants facing environmental stress due to climate change.

They can also potentially boost phellem cell growth genes to produce plants with enhanced carbon-capturing and storing abilities—a central goal of Salk's Harnessing Plants Initiative.

The findings were published in *Developmental Cell* on January 9, 2025.

"Plants play a crucial role in capturing carbon from the atmosphere and storing it in the soil," says Professor Wolfgang Busch, senior author of the study, director of the Harnessing Plants Initiative, and Hess Chair in Plant Science at Salk.

"The protective outer layer of plant roots, called the periderm, is made up of many cells that can store carbon in a form that will be very durable.

"By creating a detailed map of how these root cells form and mature, we can better understand and potentially encourage this process to help plants hold on to more carbon in highly durable forms. In doing so, we can create more resilient plants with hardier roots that also help us fight climate change."

When a plant first takes root, it dedicates itself to primary growth, focusing on the length of new roots. With maturity comes secondary growth, shifting the focus to thickening existing roots and creating periderm armor. This protective periderm contains phellem, phellogen, and phelloderm cells, each with distinct responsibilities and genetic profiles that had yet to be fully described in previous studies.

Of these various periderm cells, the team was most interested in phellem cells because of their high suberin content. Suberin is central to Salk's Harnessing Plants Initiative, in which scientists optimize plants to serve as a natural and sustainable method of carbon sequestration. Unfortunately, carbon stored in leaves and stems can degrade quickly and become easily re-released into the atmosphere.

In contrast, the suberin in a plant's roots can hold carbon deep in the soil for long stretches of time. Suberin has also been shown to make plants more resistant to root rot, indicating that it serves a protective purpose in addition to carbon storage.

Previous periderm studies consisted of bulk analyses that, despite providing valuable insights, were not able to capture cell type specificity.

To correct this, the Salk team applied modern single-cell sequencing techniques that could capture the distinct genetic profiles of each periderm cell type. They also tracked how gene expression changed as each cell type developed in the roots of Arabidopsis thaliana—a flowering weed in the mustard family commonly used in plant research.

"Collecting this level of detail in mature plants across time has never been achieved before," says first author Charlotte Miller, a research scientist in Busch's lab.

"Other studies grind up entire roots and study them in bulk, but single-cell analysis allowed us to understand the genetic development of each individual cell type in the periderm. This means we can be far more precise and efficient in engineering robust, resilient, climate-change-fighting plants."

The researchers' single-cell time-course sequencing revealed that phellem cell development can be dissected into multiple genetically distinct but interconnected phases. This stepwise development was marked by key genes like MYB67, which the team discovered was playing a large role in regulating the development process.

By piecing together the cells' genetic profiles at different periods in their development, the team hopes to eventually determine a gene or set of genes that could be used to encourage plants to make more phellem cells, contain more suberin, and capture more durable carbon.

The periderm atlas also yielded important insights into other non-phellem cells. This data will help clarify the transitional stages in periderm development, like how phellogen cells give rise to phellem cells. Miller is particularly excited to continue studying these phellogen cells, noting that their stem-cell-like ability to differentiate into other cell types so late into the plant's development is surprising.

As for Busch, he looks forward to seeing how suberin-containing cells plug up holes made by new lateral root growth—a destructive process where new roots break through the plants' skin.

These responsive, suberin-rich cells may not be a part of the periderm, but knowing more about the periderm cell types and suberin content may aid in future understanding of this root creation process wherein root systems branch out extensively while avoiding infection.

"Our work not only advances plant science but also opens the door to creating more robust crops and enhancing carbon sequestration through plant roots, providing solutions to both agricultural and climate challenges, which is a key goal of Salk's Harnessing Plants Initiative," says Busch.

More information: A single nuclei transcriptome census of the Arabidopsis maturing root identifies that MYB67 controls phellem cell maturation., *Developmental Cell* (2025). DOI: 10.1016/j.devcel.2024.12.025. www.cell.com/developmental-cel … 1534-5807(24)00764-0

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