How do plants form a single layer of epidermis on the surface of leaves?

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Abstract

The shoot epidermis, which covers the surface of plant leaves and stems, protects plants from dehydration, pathogens, and herbivores. This study reveals the mechanism by which the epidermis forms exclusively at the surface of plant organs. We found that when the leaf epidermis is removed—exposing the underlying green photosynthetic cells (mesophyll cells) to the surface—the *ATML1* gene, a master regulator of shoot epidermis formation, is activated in these exposed mesophyll cells. This *ATML1* activation requires a release from the mechanical pressure exerted by outer tissues. When young epidermal cells were injured, the underlying mesophyll cells accumulate *ATML1* protein and transdifferentiate into epidermal cells. These results suggest that plant cells can sense physical force, which informs their position within the plant and guide their differentiation into either epidermal or mesophyll cells.

Background & Results

Plant cell fate is determined largely by cell position rather than lineage. In many plants, epidermal differentiation occurs exclusively in the outermost layer, making it a good model for studying position-dependent cell fate decision. When young epidermal cells divide perpendicular to the surface (periclinal division), the inner daughter cells lose their epidermal fate and develop into mesophyll cells. This observation suggests that each plant cell can recognize its position within the plant body and differentiate into the appropriate cell type.

Our previous studies demonstrated that the *ATML1* gene has the ability to induce epidermal cell differentiation in *Arabidopsis thaliana*. *ATML1* is transcribed in surface cells of organs, and genetically modified plants that express *ATML1* in all cells produced epidermal cells even in internal tissues. Conversely, inactivation of *ATML1* abolished epidermal cell formation on the leaves.

In this study, we investigated the mechanism by which *ATML1* transcription and epidermal differentiation occur only in surface cells. When the leaf epidermis was removed *ATML1* transcription was activated in the exposed mesophyll cells. The *ATML1*-positive mesophyll cells were deformed and protruded outward from the leaf, suggesting a release from the mechanical pressure exerted by the epidermis. When we applied pressure to the peeled leaf, both the protrusion and *ATML1* transcription in the mesophyll cells were inhibited. This result suggests that plant cells recognize their outermost position by sensing a release from compression and activate *ATML1* transcription. Furthermore, injury to the young epidermis leads to *ATML1* expression and the formation of new epidermal cells from underlying mesophyll cells, suggesting that the surface-dependent activation of *ATML1* plays a role in regenerating the epidermis, a protective tissue.

Significance of the research and Future perspective

Our study addressed a long-standing question in plant biology: why only surface cells become epidermis. We propose that cells recognize their position through release from mechanical pressure, which triggers *ATML1* activation. This mechanism provides insights into position-dependent cell fate determination and may lead to agricultural innovations for developing drought- and pathogen-resistant plants by controlling epidermal formation and regeneration.

The shoot epidermis protects plants from dehydration, pathogens, and herbivores

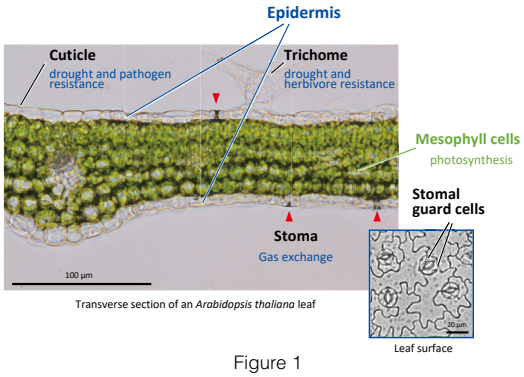

Figure 1

***ATML1* promotes epidermal cell differentiation**

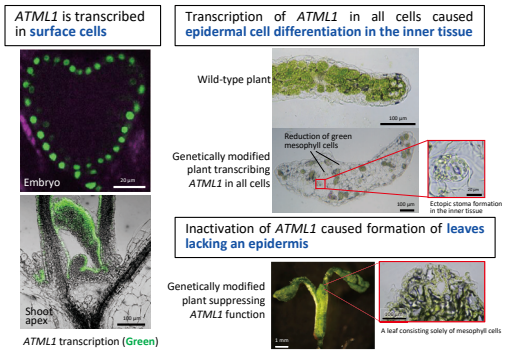

Figure 2

Plant cells sense physical forces to recognize their position and decide whether to differentiate into epidermal or mesophyll cells

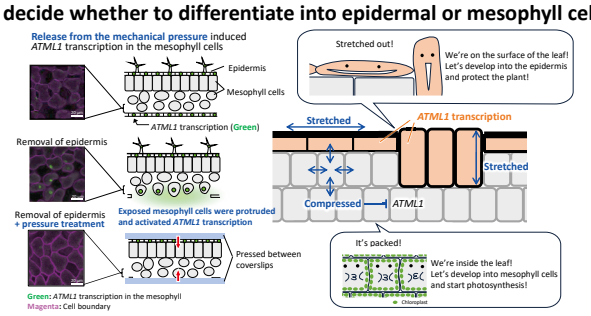

Figure 3

Patent

Treatise

Iida, Hiroyuki; Mähönen, Ari Pekka; Jürgens, Gerd et al. Epidermal injury-induced derepression of key regulator *ATML1* in newly exposed cells elicits epidermis regeneration. Nature Communications. 2023, 14, 1031. doi: 10.1038/s41467-023-36731-6

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Keyword plant developmental biology, positional information, cell fate decision, regeneration