NUS National University of Singapore | Department of Biological Sciences
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SEMINAR

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Mechanical Force Controls Chemical Signals in Creating Plant Pattern

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We have found that physical forces control plant morphogenesis as much as do chemical signals – as the physical forces in developing plant tissues control the transport of chemical signals, as well as controlling the behavior of each cell.

One example is development at the shoot apical meristem, the collection of stem cells at the tip of each shoot, that is the source of new leaves and new flowers. The predominant chemical signal inducing new flowers in the meristem is auxin, which is directed in a complex flow pattern by asymmetric distribution of the PIN1 auxin efflux carrier. We have shown that efflux carrier position is controlled by mechanical stress. Auxin not only induces new primordia of leaves and flowers, but also changes the physical properties of the cell wall. These physical changes alter the stress pattern in the meristem surface, which in turn regulates the position of the auxin efflux carrier. The feedback between auxin concentration and physical stress creates the dynamic auxin patterns that cause successive auxin peaks, creating the patterns in which leaves and flowers appear. The stress pattern in the meristem also regulates the microtubule cytoskeleton of meristematic cells, and consequently it may also dictate the plane of cell division. The microtubule cytoskeleton, in addition, determines directions of cellulose synthesis in the cell wall, and thus the anisotropic reinforcement of the cells, controlling their subsequent direction of cell growth. This in turn leads to changes in the stress pattern, and therefore to changes in auxin flow, which feeds back on the stress pattern.

These sets of feedbacks – physical stress on hormone transport, hormone concentration on cell wall strength, physical stress on cytoskeleton, and cytoskeleton on cell wall reinforcement; followed by cell wall anisotropy controlling cellular expansion, and therefore changes in physical stress – create a supracellular, tissue-wide feedback system that defines plant morphogenesis, and that has been amenable to computational modeling. The present set of models, by virtue of including physical stress and its effects, successfully predicts many of the behaviors of cells in the shoot apex.

Artwork by Ann Nee, DBS, NUS