Plant phyllotaxis

Plant organs, such as leaves and flowers, are initiated at the shoot apex resulting in regular patterns called phyllotaxis. These patterns have long inspired scientists due to their high symmetry and their connections to classical mathematics. Recently, ever more detailed molecular experiments have revealed that auxin and its polarly located efflux mediator protein PIN1 are at the heart of the pattern forming mechanism. We present a computational model, based on feedback between auxin and PIN1 localization, which bridges the gap between modeling and molecular experiments.

The model

A model environment is developed that allows for simulation of plant shoot development at a cellular resolution including cell growth and proliferation, mechanical interactions, gene regulatory networks, and molecular reactions and transport.

Auxin transport model

Central for phyllotaxis is an auxin pattern mechanism, where the new primordia appear at auxin peaks. Data indicates that PIN1 polarizes towards young primordia and positions where new primordia are about to form. Our main hypothesis is a feedback from auxin in neighboring cells to PIN1 cycling rates leading to a PIN1 polarization towards neighboring cells with higher auxin concentration. The model is based on the chemiosmotic transport theory, where auxin is passively transported through membranes while its anion transport is mediated by PIN1 and AUX1. Experimental estimates are used for most model parameters.

Phyllotaxis simulations

A simple cell growth/division and mechanical model is included with the molecular model to produce a phyllotaxis model capable of producing spiral and other patterns on a growing epidermal tissue.

Molecules involved

The model is based on polarized auxin transport mediated by PIN1, together with unpolarized transport including both passive membrane transport as well as transport mediated by AUX1.

Auxin

The plant hormone auxin is involved in many aspects of plant development. At the shoot apical meristem, auxin is transported to the positions of new primordia.

PIN1

The family of PIN proteins mediates polarized auxin transport in different plant tissues, where PIN1 is most important for phyllotaxis as a knockout creates a pinformed plant.

AUX1

AUX1 is included in a family of proteins and has been shown to mediate auxin influx to the cells.