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A model of plasma membrane flow and cytosis regulation in growing pollen tubes

In plant sexual reproduction, pollen tubes carry the male genetic information from pollen grains to ovules. These single cells traverse the entire female tissue to reach the eggs. Astonishing high expansion rates and total lengths are achieved: rates of 1 mm/h in lily flowers and lengths of 30 cm in maize. This extreme growth rates and total lengths demand perfect coordination of cell wall expansion, cell wall material deposition and membrane recycling.

During growth, pollen tubes have to have a well defined and tightly regulated distribution of cell wall extensibility. Regulation is achieved by influencing the esterification degree of the cell wall material (mostly pectins) through Pectin Methyl Esterases (PME), which activity is in turn regulated by an inhibitor (PMEI). Distinct patterns of PME and PMEI are found in pollen tubes. While PME is widely distributed along the flanks of the pollen tube, PMEI is only present at the apical cell wall. To achieve these distinct distributions, these enzymes are subjected to specific cytosis patterns. The cell wall material, pectin, reaches also the wall by means of exocytosis. It stands to reason that, mechanics of growing pollen tubes can only be understood completely, if the patterns of endocytosis and exocytosis are also considered.

We present a theoretical approach to understand these patterns. A model of cytosis regulation is developed and simulations presented. We address in particular the question on the minimal assumptions needed to describe the patterns reported recently by Zonia and Munnik, [1]. The movement of plasma membrane in the tip is described by using concepts of flow and conservation of membrane material. After obtaining the central equations, relations describing the rates of endocytosis and exocytosis are proposed. We find that two cytosis receptors (for exocytosis and endocytosis), which have different recycling rates and activation times, suffice to describe a stable growing tube. The simulations show a very good spatial separation between endocytosis and exocytosis, and separation is shown to depend strongly on exocytic vesicle delivery. The model shows also that most vesicles in the clear zone have to be endocytic, in accordance with the literature. Membrane flow is essential to maintain cell polarity, and bi-directional flow is a natural consequence of the proposed mechanism. For the first time, a model addressing plasma membrane flow and cytosis regulation was posed. Therefore, it represents a missing piece in an integrative model of pollen tube growth, in which cell wall mechanics, hydrodynamic fluxes and regulation mechanisms are combined.

References

[1] Zonia and Munnik, *Uncovering hidden treasures in pollen tube growth mechanics*, Trends in Plant Science **14:** 318–327.