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Cell Polarization by Wave-Pinning: Conditions, Stochastic Behaviour, and Relevance to Plant Development

Cell polarization is an important response of eukaryotic cells to external cues, which allow cells to sense and react to signals in their environment.

Members of the family of Rho GTPases have emerged as important components of the polarization machinery of cells: these switch-like proteins have a distinct active (membrane-bound, low diffusivity) and inactive form (mostly cytoplasmic, high diffusivity), and localization of the active form (accumulation in a small portion of the cell) has been shown to act as a necessary cue for cell polarization (e.g. rearrangement of the cytoskeleton). To this end, Rho localization (short timescale) signals the cell where its front and back are and this information is usually imprinted in more committed processes such as cytoskeleton remodelling (long timescale).

Mori et al. [1] established a reaction-diffusion system as a model of the dynamics of Rho GTPases and derived conditions under which their model predicts Rho localization. These conditions include mass conservation, uniformity of the inactive form, and an invasion criterion on a local pulse in the active form. Mori et al. named this mechanism wave-pinning due to the nature of how the Rho localization pattern forms over time.

We provide a short overview of Rho localization due to wave-pinning, conditions for wave-pinning, and discuss biological properties and phenomena that wave-pinning is capable of reproducing. Furthermore, we introduce local pulse analysis (LPA) as a useful tool for determining conditions that meet an invasion criterion necessary for wave-pinning.

In a recent effort, [4], we studied a stochastic version of the wave-pinning mechanism (spatial Gillespie algorithm, [2], [3]) which models Rho localization in a low copy-number regime of Rho: this model includes biologically relevant stochastic noise, and behaves markedly different from the deterministic model established by Mori et al. We discuss differences between the determinstic model, [1], and our stochastic model, and reason about conditions under which wave-pinning is lost in the latter.

Relevant to plant science, our current work focuses on plant homologues of the Rho GTPase family, Rho of Plants (ROP), and a model of ROP localization due to wave-pinning established by Grieneisen et al. In this effort we attempt to find links between ROP localization as a result of auxin gradients (external signal), and localization of auxin efflux carriers (PINOID, PIN) as a readout of cell polarization.

We hope that linking short-timescale ROP localization with long-timescale PIN localization will reveal biologically relevant feedback loops between external auxin gradients, internal cell polarization, and eventual modification of the external auxin gradient. We argue that feedback loops of this kind may be relevant for the development of the plant embryo and establishment of biological phenomena such as the auxin maximum in the quiescent centre of the root.

References

[1] Y. Mori, A. Jilkine, and L. Edelstein-Keshet *Wave-pinning and cell polarity from a bistable reaction-diffusion system* Biophysical Journal, 2008, **94** 3684–97

[2] D. T. Gillespie, *A general method for numerically simulating the stochastic time evolution of coupled chemical reactions*, Journal of Computational Physics, 1976, **22** 403–434

[3] R. Erban, J. Chapman, and P. Maini, *A practical guide to stochastic simulations of reaction-diffusion processes*, http://arxiv.org/abs/0704.1908, 2007

[4] G.R. Walther, A.F.M. Marée, V.A. Grieneisen, and L. Edelstein-Keshet, *Deterministic Versus Stochastic Cell Polarization by Wave Pinning* Submitted for Publication, 2011