Stochastic models for cell polarization and crawling

Amoeboid motion in cells such as Dictyostelium discoideum is characterized by irregular trajectories that require stochastic modeling to be accurately captured. Previously a reaction-diffusion system has been fitted to the experimental trajectories of single cells. Here we compare and bridge two distinct modeling strategies: phenomenological external noise (previously fitted to the experimental trajectories) and intrinsic fluctuations arising from a finite number of molecules. We utilize a stochastic reaction-diffusion framework coupled with a phase-field description of cell shape. The internal noise is formulated using the chemical Langevin equation to incorporate molecular discreteness. Through numerical simulations, we characterize how the nature of fluctuations influences pattern formation and motility. Our results demonstrate that while both models can reproduce characteristic cell speeds and diffusive behavior, they exhibit an inverted dependence on the reaction parameter. We find that the original dynamics can be effectively recovered by the first-principles model provided that temporal correlations are considered. We conclude that while internal noise offers a more biologically grounded representation, the presence of temporal memory in fluctuations is a critical distinguishing factor for replicating experimental phenotypes.

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