A Mechanochemical Model for Cell Polarity

ZHANG Lei
Beijing International Center for Mathematical Research, Center for Quantitative Biology, Peking University
Email: zhangl@math.pku.edu.cn

Cell polarization toward the attractant is related to both physical and chemical factors. Most existing mathematical models are based on reaction diffusion systems and only focus on the chemical process during cell polarization. However, experiments reveal that membrane tension may act as a long-range inhibitor for cell polarization. Here we present a mathematical model that incorporates the interplays between Rac, filamentous actin (F-actin), and cell membrane tension for the formation of cell polarity. We also test the predictions of this model with singe cell measurements on the spontaneous cell polarization of cancer stem cells (CSC) and non-cancer stem cells (NCSS) as the former have smaller cell membrane tension. Both our model and experimental results show that the cell polarization is more sensitive to stimuli under low membrane tension, and high membrane tension improves the robustness and stability of cell polarization so that polarization is persistent under random perturbations. Furthermore, our simulations for the first time reproduce the results from the aspiration-release experiment and the pseudopod-neck-cell body morphology severing experiment, demonstrating that aspiration (elevation of tension) and release (reduction of tension) result in decrease and recover of the activity of Rac-GTP, respectively, and relaxation of tension leads to the formation of new polarity of the cell body when the cell with morphology of pseudopod-neck-body is severed.