Shape-Motion Feedback in Rapidly Migrating Cells

Franck Raynaud[1], Mark E. Ambühl[1], Chiara Gabella[1], Hélène Troyon[1], Charles Brepsant[1], Ivo F. Sbalzarini[2], Jean-Jacques Meister[1], and Alexander B. Verkhovsky[1]*

[1]Laboratory of Cell Biophysics, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland; [2]MOSAIC Group, Center for Systems Biology Dresden, Max Planck Institute of Molecular Cell Biology and Genetics, D-01307 Dresden, Germany.
Mailing address, alexander.verkhovsky@epfl.ch
* Corresponding Author

Keywords: *cell migration, polarization, protrusion-retraction switch, actin-myosin system, cell volume*

Abstract

The ability to spontaneously break symmetry and move directionally is an essential property of most eukaryotic cells. It is believed that a directional mechanism at a scale of the whole cell, e.g. a global gradient of cytoskeletal and/or signaling components, orchestrates cell edge dynamics according to the overall motion direction. This concept is limited, however, in that external directional stimuli in combination with internal diffusible signals interacting through feedback loops, or a feedback from the motion itself, have to be considered to establish polarity axis. We examine the edge dynamics of polarizing and persistently migrating fish epidermal keratocytes, and propose a novel and simple principle of self-organization of cell activity in which local cell edge dynamics depends on the distance from the cell center, but not on the position with respect to a global polarity axis. We validate this principle in experiments with confined and micro-surgically manipulated cells and implement it in a stochastic model that faithfully reproduces cell migration behavior. Our findings indicate that spontaneous polarization, persistent motion, and cell shape are emergent properties of the local cell edge dynamics controlled by distance from the cell center. The distance-sensing mechanism is not dependent on myosin-II activity or microtubule system, but is sensitive to the perturbations of the cell volume and/or three-dimensional shape. Possible mechanisms based on reaction-diffusion and contact angle variation at the cell edge are discussed.