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On shape and force – from single to interactive cell motion

One of the fundamental organization forms of tissue in multi-cellular organisms is the epi- or endothelium, in which the cells assemble into a single-layered structure supported by a strong basal membrane. If an injury damages this barrier, the cells perform a so-called epithelial-mesenchymal transition: they break their mutual connections and start to migrate. Here we study the mechanics of cell motion in these effectively two-dimensional environments, where both cooperation and individualism contribute to the biological function.

The motility mechanics of individual cells can be understood in terms of two-phase flow models [1]. Extending our earlier 1D work [2], we project the underlying hyperbolic-elliptic PDE system of Stokes type onto the unit circle. At the lamella tip we incorporate enhanced actin polymerization by prescribing suitable pressure BCs. This enables us to obtain both shape dynamics and the migration trajectory of a quasi 2D model cell simultaneously. The corresponding simulations exhibit a correlation between migration speed and cell shape, as observed in experiments.

For cooperative motility, we argue that the cells' motion is governed by essentially the same microscopic stochastic process: cadherin cell-cell adhesion molecules merely add an attractive interaction. In this way, cytoskeletal contraction stresses propagate across adjacent cells and determine the shape of the border in between. The geometry of this stress-induced competition for space can be formalized by means of Voronoi tessellations. In order overcome the conventional polygonal cell approximation, we propose a consistent generalization to partition space into individual cells with piecewise spherical or elliptic border [3]. Combined with aforementioned stochastic motility processes, the model tissue displays characteristic morphogenetic rearrangement patterns.

References

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