Going With the Flow: Mechanics of Cell Motility and Metastasis

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Abstract: Water plays a fundamental role in many aspects of cell dynamics. From first principle considerations as well as recent microfluidic experiments, it is now clear cell shape changes and cell movement can be driven by water as well as from the dynamics of the cytoskeleton. The water-driven mode of cell migration is mediated by osmotic pumping of ions (osmotic engine model) across the cell membrane, and is especially important in cancer metastasis. It is not clear what determines the relative contributions of actin and water to the observed cell movement. Here, we consider a 2-phase hydrodynamic model of cell movement, incorporating actin flow and water flow, frictional forces from cell adhesions, and movement of the cell membrane. When all of the mechanical forces are considered, we find that the frictional resistance experienced by the migrating cell can determine the relative contribution of actin and water to the observed cell speed. More generally, osmotic regulation is an important aspect of cell mechanical behavior, and determines slow deformation mechanics of tissue cells. We find that there is a feedback control system that couples membrane tension to actomyosin contraction, which explains how cells respond to mechanical forces. Osmotic pumping is also responsible for water reabsorption in the kidney, can generate many kinds of slow movements observed in cells, including the constriction dynamics (cytokinesis) important during cell division.

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