Living Droplets: Cell Spreading as a Wetting Problem

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Abstract

The shape taken by cells is intrinsically linked to the mechanics of their cytoskeleton, particularly the actomyosin cortex, a gel which organizes as a thin sheet localized beneath the cell membrane. Within this cortex, the myosin generates a mechanical
tension that can be modeled as a surface tension. However, the 3D mechanical balance at the surface of cells, either isolated or in tissue, is not fully understood. As a cell spreads on a flat substrate, it resembles a water droplet, except that the surface concavity reverses from convex to concave near the triple line formed with the substrate. The change in curvature is a key indicator of the mechanical balance governing cell shape, indicating the presence of additional phenomena that modify cell balance. Fluorescence microscopy images reveal the presence of a structure of intermediate filament proteins (vimentin), forming a cortex beneath the actomyosin one, which appears to influence the morphology.
In this work, an approach is explored to calculate the shape of cell while spreading, treating it as a solution to the Young-Laplace equation, similar to problem of wetting of water droplets and capillary bridges.
Our methodology views the interfaces within the cells, shaped by the actomyosin and vimentin cortices, as portions of surfaces of revolution of constant mean curvature (such as unduloids and nodoids).
Then, using pointwise experimental geometric data, such as the contact radius with the substrate, radius at the inflection point, and the cell height, we solve an inverse problem that leads to the determination of pressures and tensions. As a result, a comprehensive reconstruction of the cell 3D-geometry is achieved, which corresponds well with the observations. The findings from this work open up new possibilities in understanding how cell compartment volumes might be influenced by osmotic processes within the cell. While this study provides significant insights into the static case, it also sets the stage for the explorations into the dynamics of cell shape.
This contributes to a broader perspective on the changes of cell shape and its mechanical equilibrium, laying the groundwork for future investigations into the mechanical functions of cell cortices.

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