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Interaction between shape and lipid flow in bilayer membranes

PADMINI RANGAMANI, UC Berkeley, ASHUTOSH AGRAWAL, University of Houston, KRANTHI MANDADAPU, Sandia National Laboratories, GEORGE OSTER, DAVID STEIGMANN, UC Berkeley — Biological membranes have unique mechanical properties: they are fluid in-plane but elastic in bending. The most popular continuum mechanics model of the lipid bilayer is the Helfrich model. This model has provided insight into many membrane phenomena. However, it is an equilibrium model for an elastic membrane and does not capture any dynamic effects. The theory of intra-surface viscous flow on lipid bilayers is developed by combining the equations for flow on a curved surface with those that describe the elastic resistance of bilayers to flexure. The model is derived directly from balance laws and thus augments alternative formulations based on variational principles. Conditions holding along an edge of the membrane are emphasized and the coupling between flow and membrane shape is simulated numerically. Simulations of the model show that membrane shape changes involve the interaction between flow and surface deformation that are intrinsically non-linear effects. In response to an applied lateral pressure normal to the membrane, the shape of the membrane changes. Simultaneously, the surface flow field evolves over time to accommodate the deformation. Using this model, we can study the formation of membrane tubes and many biological phenomena.

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