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Biological membranes at large length scales: Biological applications and computational modeling

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Biological membranes, such as the plasma membrane surrounding cells, perform an astonishing variety of essential functions: they provide structural support, regulate trafficking, and control endocytosis and fusion events, among others. Some of these capabilities are due to a membrane's elastic properties: at typical length scales of hundreds of nanometers, it can be thought of as a two-dimensional fluid sheet that exhibits significant fluctuations. This mesoscopic picture can be used to model several biological processes, including the formation of cellular protrusions due to interactions between the cytoskeleton and the cell membrane. We show that a membrane can bundle polymerizing actin filaments, thereby enabling the formation of tubular structures that resemble filopodia observed in motile cells. To study this and similar processes that involve the cell membrane over large length scales, we have developed a new computational model that correctly captures the effects of bending rigidity and fluidity. We show that our model exhibits an elastic response to perturbations that is consistent with the Canham-Helfrich description of lipid bilayers, while also providing a computationally efficient way to capture the effects of shape fluctuations.