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Modeling membrane superstructures: Caveolae, Lipid Droplets, Migrasome

Abstract:

Caveolae, the flask-shaped pits covered by caveolin-cavin coats, are abundant features of the plasma membrane of many cells. Besides appearing as single membrane indentations, caveolae are organized as superstructures in the form of rosette-like clusters. Here we propose that clustering of caveolae is driven by forces originating from the elastic energy of membrane bending deformations and membrane tension. We substantiate this mechanism by computational modeling, which recovers the unique shapes observed for the most ubiquitous caveolar clusters consisting of two, three, four and five caveolae.

Membrane tubules of few tens of nanometer cross-sectional diameters and micron-scale lengths represent a basic structural component of intra-cellular organelles, such as endoplasmic reticulum and Golgi Complex, and emerge from plasma membranes in the course of cell crawling on extra-cellular matrices and substrates. The tubular membranes serve as platforms for formation of peculiar cell organelles, Lipid Droplets and Migrasomes, whose properties are to be understood in terms of simple physics.

Lipid Droplets can be regarded as lenses of hydrophobic substance (triacylglycerol, sterol esters) growing up between the two membrane leaflets into micron-large buds, which, possibly, detach from the membrane to form emulsion-like droplets. We address the micromechanics of these organelles to gain understanding of physics behind their formation and evolution.

Migrasomes are large vesicles growing on the tip or branch points of long nanotubules pulled out of cell body in the course of the cell movement along an external substrate. We propose that the migrasome formation is a result of a local increase of the membrane bending rigidity generated by protein clusterization. We analyze, computationally, the process of migrasome formation and recover the migrasome shapes.