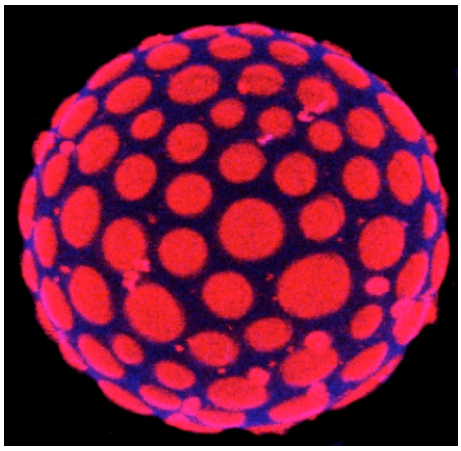
Solving membrane shapes

MEP or BEP - BN / Idema group - theoretical biophysics

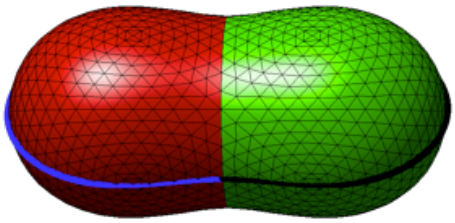
There is no life without cells, and there are no cells without membranes. The plasma membrane separates inside from the outside of the cell, and the various organelles within the cells are also bounded by membranes. Next to their function as boundaries, membranes are also home to many proteins, responsible for sensing, signaling, and food uptake.



Membrane vesicle showing liquid disordered domains (red) in a background of a liquid ordered phase (blue).
Image source: Baumgart et al., Nature 425:821, 2003.

Biological membranes consist of a bilayer of lipid molecules, and are quasi-two-dimensional objects. Within the plane of the bilayer, the lipids can move around freely as in a liquid. However, unlike ordinary liquid, there are two liquid phases, depending on the level of organization of the lipid tails: liquid ordered and liquid disordered. These two phases spontaneously separate, and form domains of one phase in the background of the other, as shown in the picture on the right. Because curving the membrane costs energy, the domain patches interact by deforming the membrane, much like two bowling balls put on a mattress will attract each other by deforming that mattress.

In this project, you will study the shape of membrane domains by numerically minimizing the functional describing the membrane energy. You'll compare your numerically found shapes to analytical approximations of the optimal shape. You'll also use your numerical results to study the effect of domain crowding (as in the picture). A currently open question that you will address is how the presence of nearby neighbor domains affects the domain shape, and the interaction potential the domains experience. The results will not only answer a scientific question, but can potentially also be used to suggest specific membrane composition for drug delivery processes.



Numerically determined shape of a membrane vesicle with two domains (red & green); comparison to analytical solution (blue & black lines).