

Deformation of a lipid membrane in response to a local pH modification

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During cell life, membranes are submitted to an inhomogeneous and variable environment. These local variations of the membrane's environment can be strongly related to biological processes. For instance, in the inner membrane of mitochondria, ATP synthesis is tightly coupled to the local pH. It is therefore interesting to study the response of a lipid membrane to a local modification of its environment.

Giant unilamellar vesicles (GUVs) are model membranes constituted of amphiphilic lipid molecules that self-assemble into closed bilayers in water. We have carried out experiments in which a GUV is submitted to a local pH increase created by microinjecting a basic solution close to the membrane. This local pH increase causes a local dynamic deformation of the membrane [1, 2].

We have developed a theoretical description of the response of a membrane to a local injection of a reagent in the surrounding solution. We have shown that the local chemical modification of the external monolayer of the membrane results in a local change of its plane-shape equilibrium density and of its spontaneous curvature. We have studied the dynamics of a membrane subjected to such a local change of its physical properties. Our theoretical description is based on a local version of the area-difference elasticity membrane model, for which we have derived the elastic force densities in each monolayer [3]. We started by studying the dynamics of the membrane in the simplified case of a single-Fourier mode constant reagent concentration field. It enabled us to show that changing the plane-shape equilibrium density of the external monolayer and changing its spontaneous curvature yield different dynamics. When the plane-shape equilibrium density is modified, the friction between the two monolayers of the bilayer membrane plays a crucial part, which slows down the dynamics [2].

We have now extended our theoretical model to take into account the specific profile of the concentration of the membrane-modifying reagent (with all its Fourier modes), and its time evolution when the reagent diffuses in the solution that surrounds the membrane. We have solved numerically the equations describing the dynamics of the membrane in this case. We have shown that the effect of the diffusion of the reagent is generally important, but that there are experimentally accessible cases where the dynamics is dominated by processes intrinsic to the membrane, such as the relative sliding of its two monolayers. We are going to compare the predictions of our extended theoretical model to experimental results regarding the dynamics of the membrane deformation during and just after the local delivery of a basic solution.

References

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