Shape transformations of multicomponent biological membranes

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Abstract

Segregation of membrane components plays an important role in cellular life and functioning. The primary aim of this thesis is to provide a deeper understanding of the physical mechanisms responsible for the segregation of membranes components in multicomponent biological membranes coupled with the membrane shape transformations.

Diverse functions of cells strongly depend on the shape of the membrane surface and its composition. The lateral distribution of the membrane components on fluid lipid membrane may have a direct influence on cell shape transformations. One of the possible explanations of this phenomenon is based on the hypothesis that the non-homogeneous lateral distribution and segregation of membrane constituents depends on the coupling between the geometry of membrane surface and the non-homogeneous lateral distribution of membrane components. It is assumed that each of the membrane constituents prefers to occupy a membrane region with a membrane curvature comparable to its intrinsic curvature .

The suggested mechanism of non-homogeneous lateral distribution of membrane components may be especially important in the process of formation and stabilization of membrane tubular structures without application of an external pulling/pushing force.

The main goals of this thesis were to check the following hypotheses:

1. the change of the membrane shape may cause the lateral redistribution and segregation of membrane components.

2. The formation of membrane tubular structures might be strongly influenced by intrinsic geometry of membrane constituents and their accumulation in a membrane regions with favorable membrane curvature.

We developed a set of computer programs, which were used to minimize directly the membrane free energy functional within the framework of two theoretical descriptions of membrane elasticity: the spontaneous-curvature (SC) model and the deviatoric elasticity (DE) model.

The results presented in this thesis show that the lateral redistribution of membrane components may occur only for a certain range of the values of the model parameters such as the vesicle size, vesicle relative volume, area of constituents and their intrinsic geometry, and elastic moduli of components. The change of vesicle shape may induce the migration of membrane components to the regions with the favorable local curvature that matches better the intrinsic curvatures of membrane components. The lateral distribution of membrane components and the membrane curvature are strongly coupled.

Another an important result of our work is the observation that elongation of the vesicle, following the application of an external force, may lead to the formation of the membrane tubular protrusions, occupied mainly by the component with large spontaneous curvature. Thus, stretching the vesicle can be an effective mechanism of segregation of the membrane components with different intrinsic curvatures.

We have shown that the lateral redistribution and accumulation of anisotropic membrane components may lead to the formation of thin tubular protrusions without the application of active (external) pulling force. It is important to note that, when the membrane components are isotropic, the membrane cylindrical protrusions may be created only due to application of active (external) force.