Shape Deformations of Multi-Component Vesicles

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Deformations of cell membranes, such as fusion, adhesion, budding, and pore formation, play important roles in the maintenance of living cell systems. In cell systems, the membrane deformations are managed by complex interplays between membrane proteins and lipids. It is hypothesized that one role of the membrane proteins is to introduce a local spontaneous curvature by interacting with the membranes [1], although the relationship between the local spontaneous curvature and the shape deformations has not been demonstrated. In this context, we have been investigating the shape deformations of giant unilamellar vesicles (GUVs) induced by the local spontaneous curvature of the membranes [2-4].

We have introduced the local spontaneous curvature in the membrane by coupling spontaneous curvatures of lipids with a phase separation. For binary membranes composed of immiscible lipids having different geometries, the local spontaneous curvature and the bending modulus depend on the local composition of the membrane. The heterogeneity of membrane coupled with the line energy at the phase boundary brings new shape deformation branches. For example, the binary GUV composed of the inverse-cone-shaped lipids and cylinder-shaped lipids showed adhesion through the domains rich in inverse-cone-shaped lipids by forming an hourglass-like interbilayer structure called a stalk. A fluorescent lipid transfer experiment strongly implied that a stalk formed between adhering vesicles [2]. On the other hand, in the binary vesicle composed of cone- and cylinder-shaped lipids, the main chain transition of cone-shaped lipids reduces the surface area, which results in the pore formation. The segregated cone-shaped lipids form the cap at the edge of bilayer and the cylinder-shaped lipid in gel state solidifies the main body of the GUV. These effects stabilize the pore below the main chain transition temperature. By the pore formation, the binary GUVs showed different morphologies at the rim of the pore (smooth-, rolled-, and wrinkled-rim) depending on the concentration of the cone-shaped lipid, indicating the asymmetric distribution of the cone-shaped lipid in the bilayer. The exchange of lipids through the capped rim and the coupling of the local composition of membrane with the membrane curvature brings a local asymmetry in composition between the inner and outer leaflet, which causes vesicle shape deformations, such as the formation of rolled-rim.

We believe that our results provide new insight into the physical basis of the shape deformation of cellular membranes.

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