Shape Deformation of Vesicle Coupled with Phase Separation

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One of the most fascinating properties of lipid membranes is that they easily deform their shapes according to external circumstances, which gives them the basic physical aspects of biomembrane functionalities such as endocytosis and exocytosis in biomembrane transport. These shape deformations well described by an area-difference free energy (ADE) model [1], which consists of two terms, the Helfrich bending energy and the elastic energy originating from area difference between inner and outer leaflets under constraints of fixed total volume and total surface area [2]. The important parameters to determine the shape of the vesicle are excess area defined by a ratio of the total area to total volume, and the intrinsic area difference. If we add salts outside of the vesicle, the excess area increases with elapse of time due to the osmotic pressure difference and the vesicles show a parade of deformation with repeating bifurcations as shown in Fig.1.

On the other hand, multi-component vesicles show a phase separation, which forms domain structure on the vesicle [3]. In this case the domain boundary energy governs the total free energy and leads the domain coarsening and the budding. Recently we found that the dynamical coupling between the shape deformation and the phase separation brings astonishing shape deformation pathways.

Figure 2 shows shape deformation pathways of a starfish (tripod) vesicle composed of DOPC/DPPC/cholesterol. When the temperature decreases below the immiscibility temperature, numerous small domains appear on the vesicle randomly

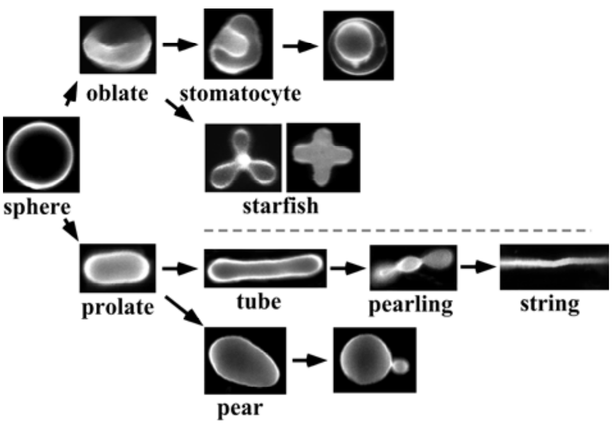

Fig. 1 Shape deformation pathways of homogeneous vesicle.

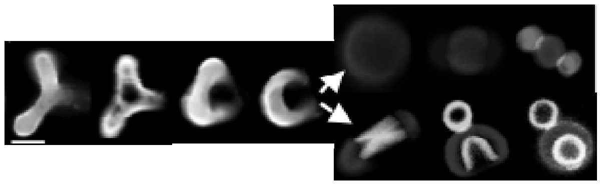

Fig. 2 Shape deformation pathways from tripod vesicle induced by phase separation

and grow with the diffusion-and-coalescence manner. During the coarsening process, the domains tend to migrate to a junction of the tripod because the domains with a stiffer bending modulus prefer the least curvature region on the vesicle. The domains grow to two large domains in the two sides of vesicle and simultaneously the outer matrix deforms to circular shape to optimize the bending energy. Thus the most stable shape of the phase separated vesicle is the oblate (or circular biconcave) with two large domains. Further elapse of time, the vesicle starts the budding stage in order to decrease the domain boundary energy. For the budding of the oblate vesicle, two pathways are observed, one is that both domains deform to the outside of the vesicle and the other is that one domain buds toward inside and another one buds toward outside. This bifurcation is determined by the excess area of the vesicle. The shape deformation pathways strongly depend on the start shape, namely the excess area and the area difference, although very similar deformation pathways are observed for the other starfish vesicles. We will discuss the kinetic pathways based on a multi-domain ADE model.

References

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