Morphological variation of double-bilayer vesicles and toroidal vesicles

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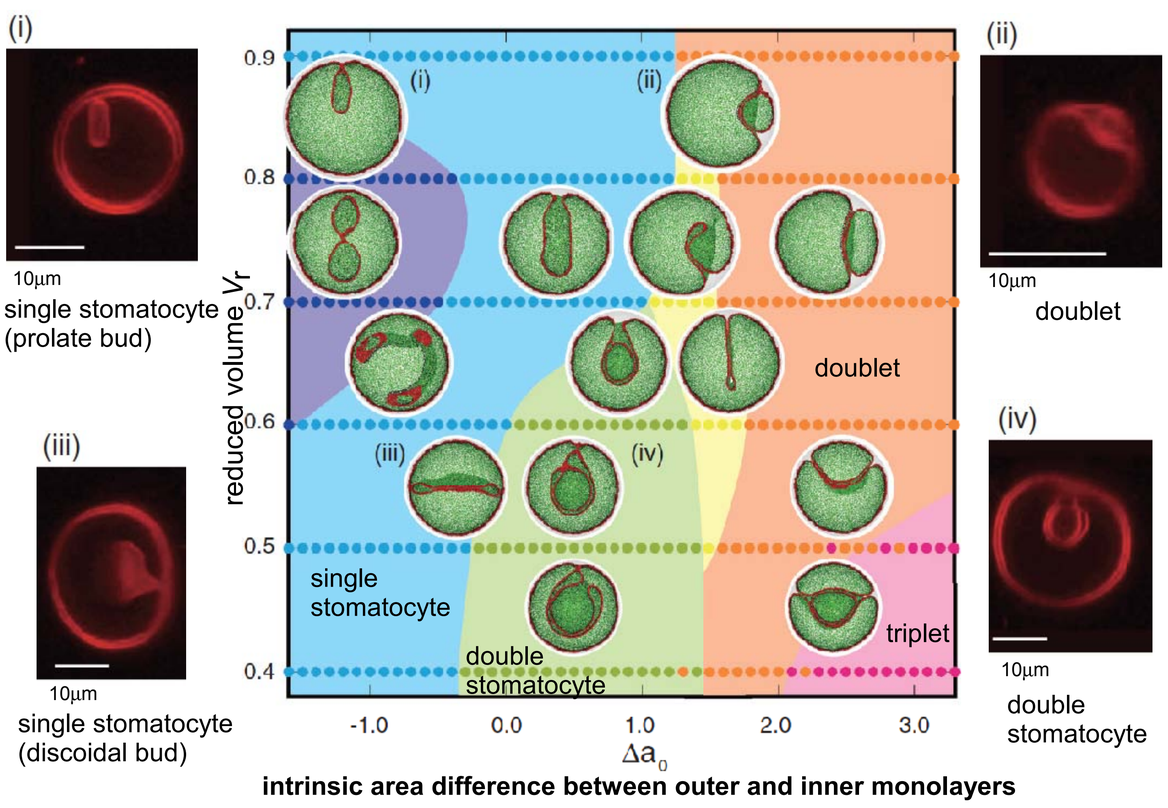
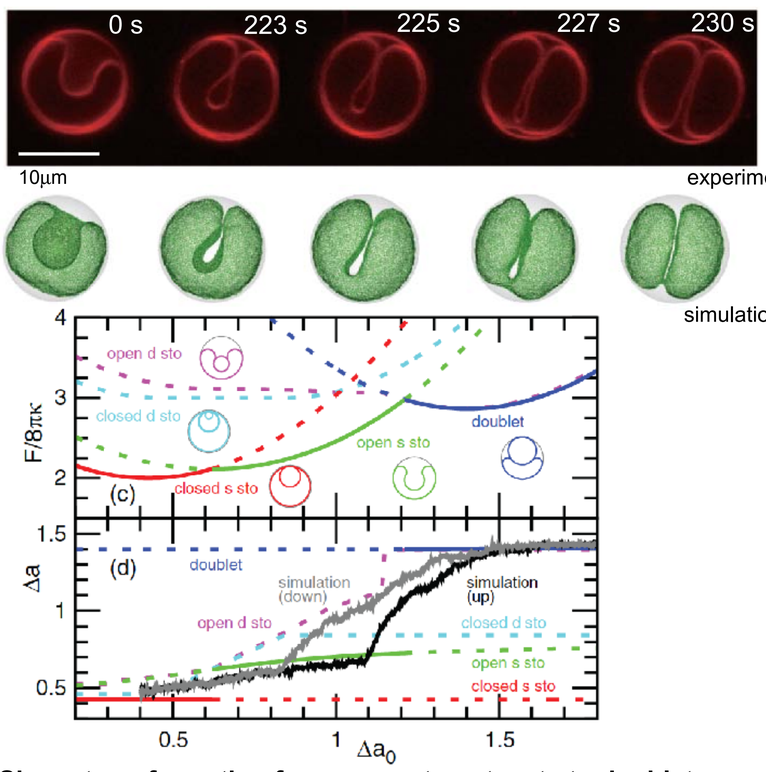
Morphologies of lipid vesicles are studied numerically by a dynamically-triangulated membrane model with area-difference elasticity and experimentally by fast confocal laser microscopy. For double-bilayer vesicles, the confinement by a outer vesicle was revealed to induce several novel shapes of the inner vesicles, that had been never observed in unilamellar vesicles [1]. For toroidal vesicles with genus 1 and 2, several non-axisymmetric shapes are found as thermal equilibrium states [2]. Our simulations reproduce our experimental results of both double-bilayer vesicles and toroidal vesicles.

Vesicle confined in spherical vesicle [1]

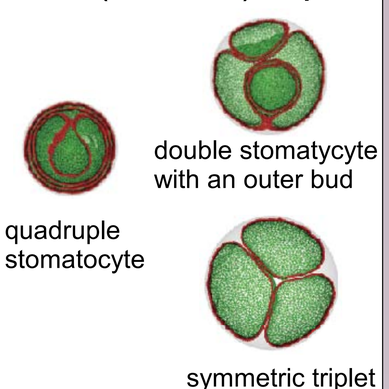


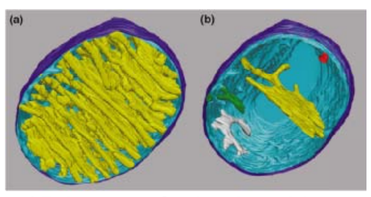
intrinsic area difference between outer and inner monolayers



Shape transformation from open stomatocyte to doublet

other (metastable) shapes





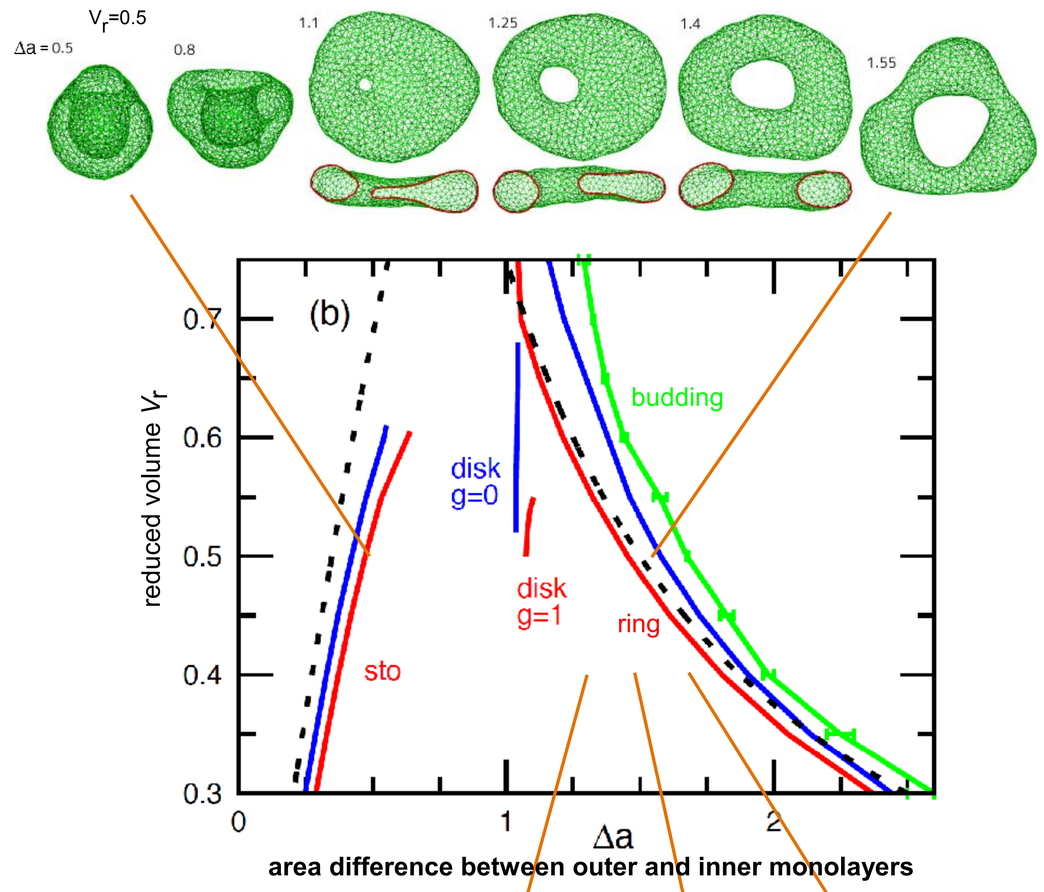
3D image of mitochondria constructed from electron microscopy

Frey and Mannella, Trends Biochem. Sci. 25, 319 (2000).

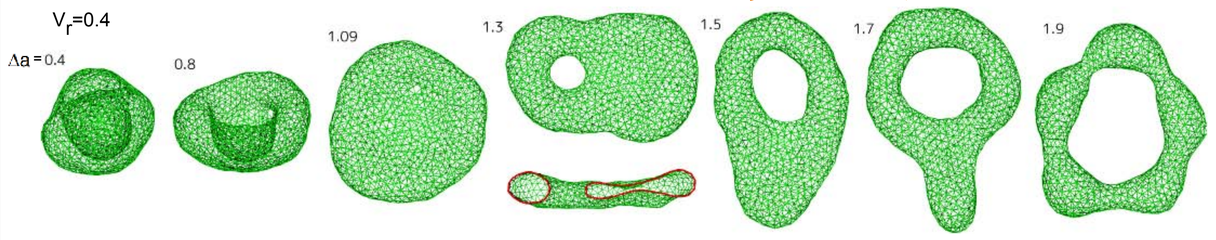
We found various vesicle shaps: double and quadruple stomatocytes, slit vesicle, and vesicles of two or three compartments with various shapes.

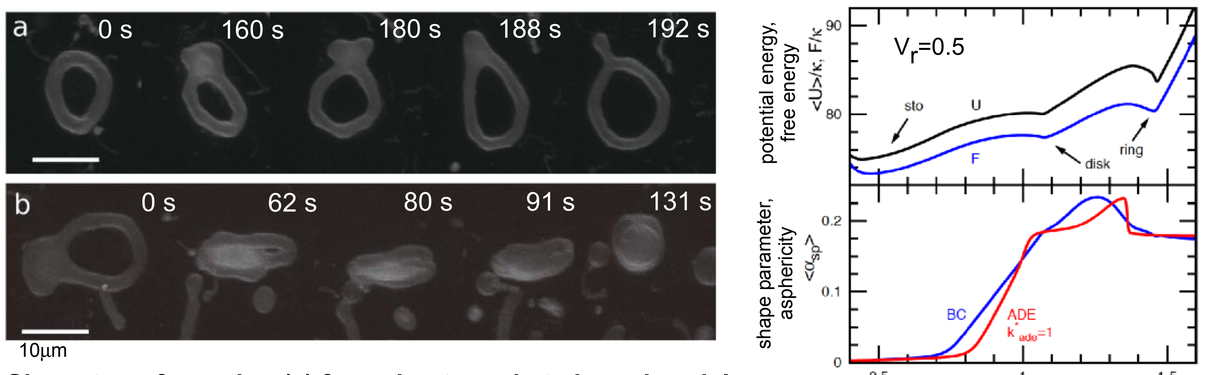
Mitochondrion consists of two bilayer vesicles. Our study demonstrated that tubular and discoidal invaginations of mitochondrial crista can be formed by the confinement without any proteins.

Genus-1 toroidal vesicles [2]

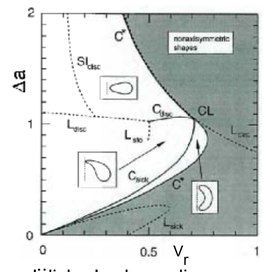


area difference between outer and inner monolayers





Shape transformation (a) from ring to racket-shaped vesicle (b) from handled discocyte to stomatocyte



Jülicher's phase diagram

Juelicher et al. J. Phys. II 3, 1681 (1993).

We found various non-axsymmetric vesicle shapes such as handled discocytes and polygonal toroidal vesicles in thermal equilibrium even in the region that Jülicher's study considered axisymmetric shapes based on the stability analysis of axisymmetric shapes.

[1] A. Sakashita, M. Imai, and H. Noguchi, Phys. Rev. E 89, 040701(R) (2014).
[2] H. Noguchi, A. Sakashita, and M. Imai, Soft Matter 11, 193 (2015).