Membrane Shape Transformation Induced by Banana-Shaped Proteins

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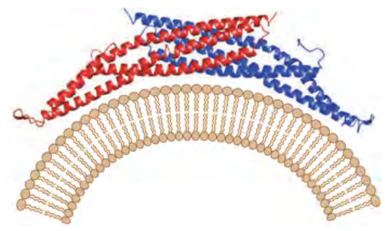
Shape deformations of biomembranes are controlled by various proteins. Many of these proteins contain a binding module known as the BAR (Bin-Amphiphysin-Rvs) domain, which consists of a banana-shaped dimer. We have revealed anisotropic spontaneous curvatures of banana-shaped domains induce assembly of the protein rods and change membrane shapes using implicit-solvent meshless membrane simulations. The protein rods cooperatively induce tubulation as well as formatin of percolated rod networks, striped bumps, polygonal tubes, and polyhedral vesicles [1-6].

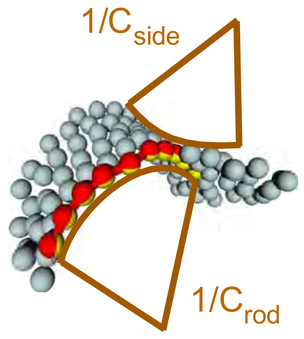
BAR domain



McMahon & Gallop, Nature 438, 590 (2005).

Membrane and Protein Models

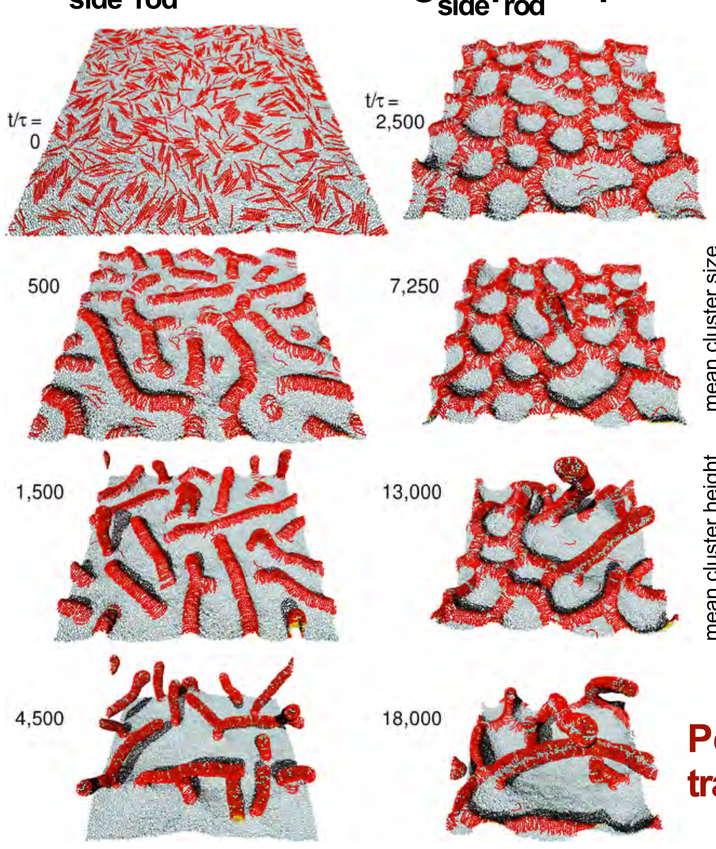
Membrane particles, which have orientational degrees of freedom, self-assemble to form one-layer membrane. A protein rod is modeled by a linear chain of membrane particles.
No direct attractive interactions are taken between the rods. The rods are assembled by membrane-mediated interactions.

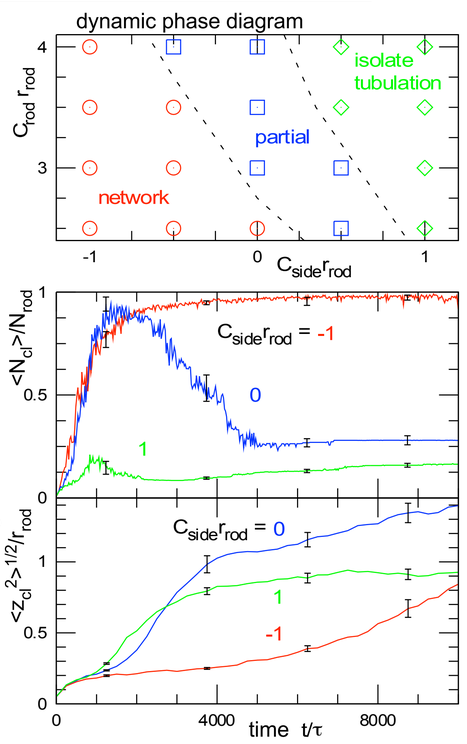


Tubulation from Flat Membrane [3,6]

Tubulation via percolated network at high rod density $\phi_{rod} = 0.4$

$C_{side}r_{rod}= 1$ $C_{side}r_{rod}= -1$



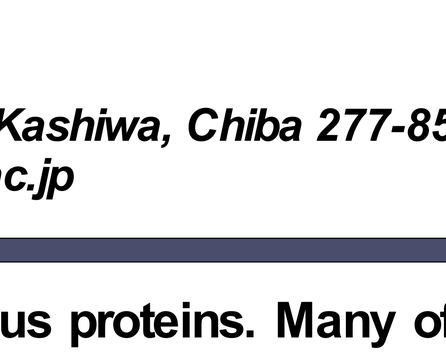


Percolated networks are transiently formed at $C_{side} < 0$.

Acceleration of tubulation by addition of small inclusions with isotropic spontaneous curvature

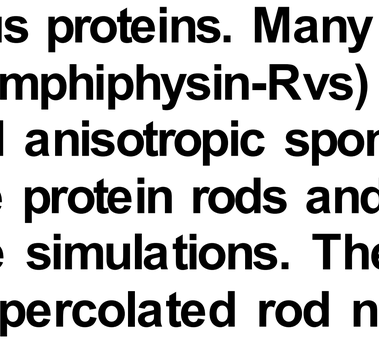
Membrane Structures Induced by Two Types of Protein Rods [5]

$C_{r1}r_{rod}= 4$
$C_{r2}= 0$

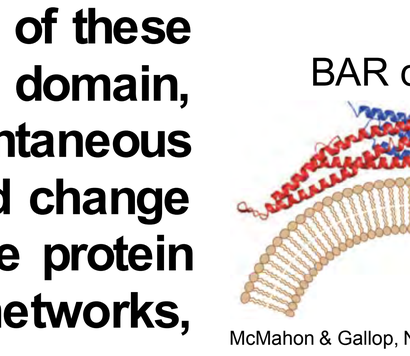


$C_{r2}r_{rod}= -1$

$C_{r2}r_{rod}= -2$

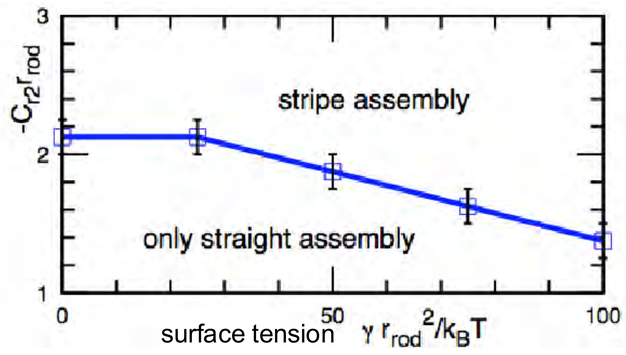


straight assembly



$C_{r2}r_{rod}= -3$

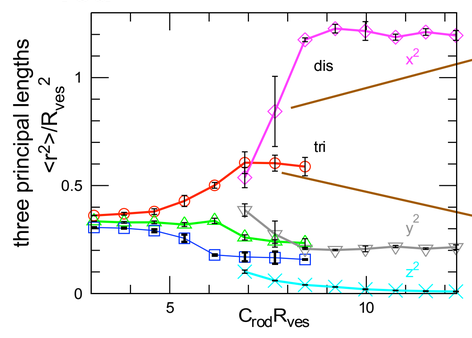
stripe assembly

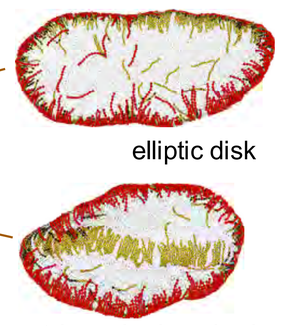


Two types of rods of opposite curavatures form straight and stripe bumps. Positive tension stabilizes stripe assembly.

Rod Self-assembly on Vesicle [1-6]

$\phi_{rod} = 0.3$





elliptic disk

triangular hosohedron

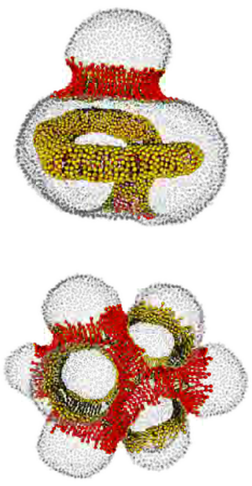
$\phi_{rod} = 0.4$

tetrahedron

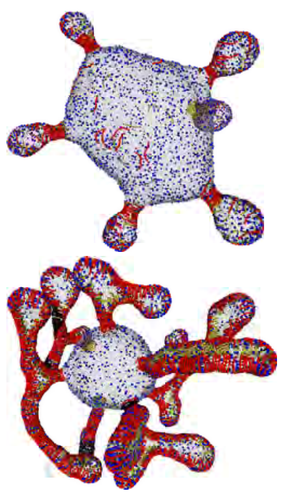
triangular prism

Formation of polyhedral vesicle

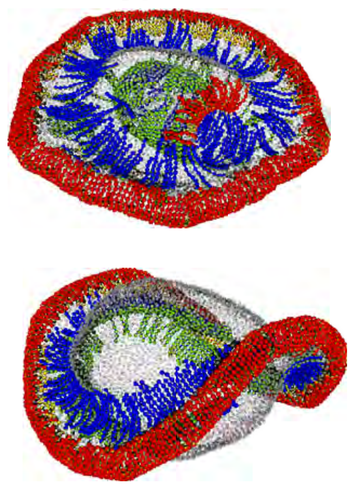
rods of negative side curvature



rods with isotropic inclusions



two types of rods



[1] H. Noguchi, EPL **108**, 48001 (2014).
[2] H. Noguchi, J. Chem. Phys. **143**, 243109 (2015).
[3] H. Noguchi, Sci. Rep. **6**, 20935 (2016).
[4] H. Noguchi, Phys. Rev. E **93**, 052404 (2016).
[5] H. Noguchi and J.-B. Fournier, Soft Matter, **13**, 4099 (2017).
[6] H. Noguchi, Soft Matter, **13**, 7771 (2017).