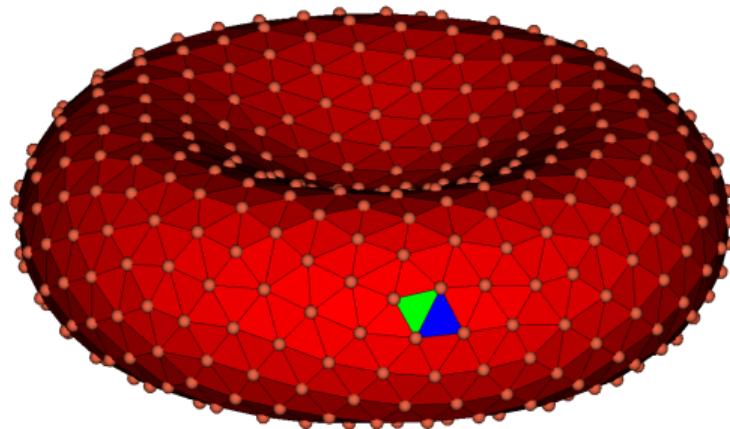
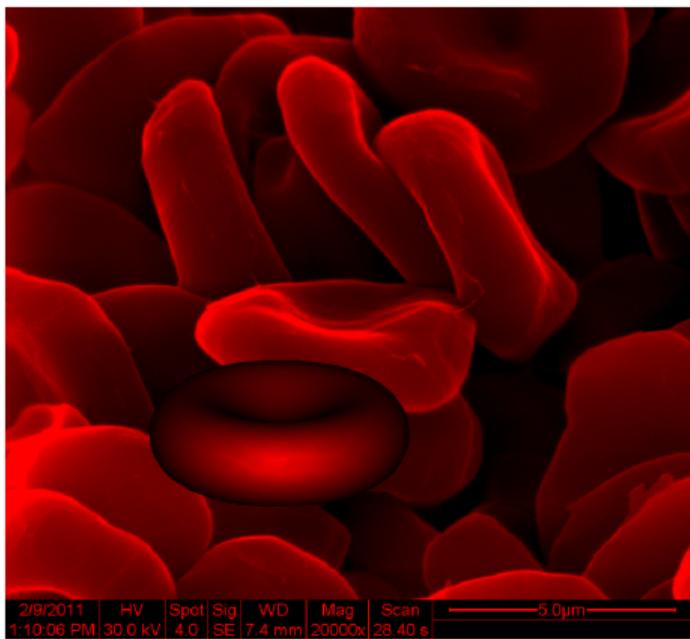


Bending models with spontaneous curvature and area-difference elasticity

S. Litvinov,
collaborators: X. Bian, P. Koumoutsakos

cse-lab.ethz.ch

Model





NO BUCKLING

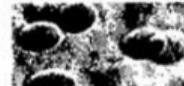
$\tau = 3.7 \text{ Pa}$



BUCKLING



$\tau = 49 \text{ Pa}$



EXTENSION RATIO $> \sqrt{2}/1$

$< \sqrt{2}/1$

WHEN EXPOSED TO SHEAR



UNIFORM



(1) (2) (1)

NON-UNIFORM

MEMBRANE CONFIGURATION DURING "TANK-TREADING"



GRADUAL



SUDDEN

CHANGE IN MEMBRANE CURVATURE DURING SWELLING



SODIUM
SALICYLATE

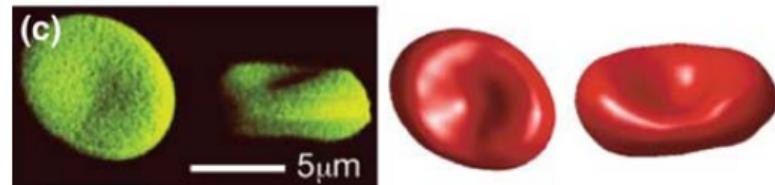
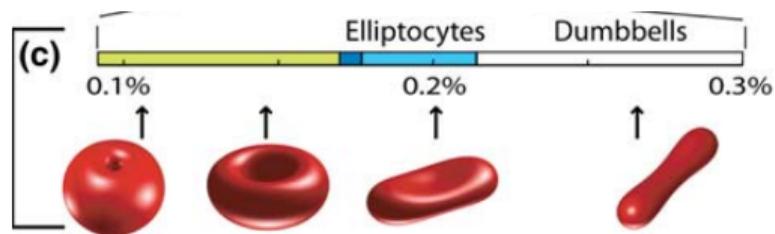
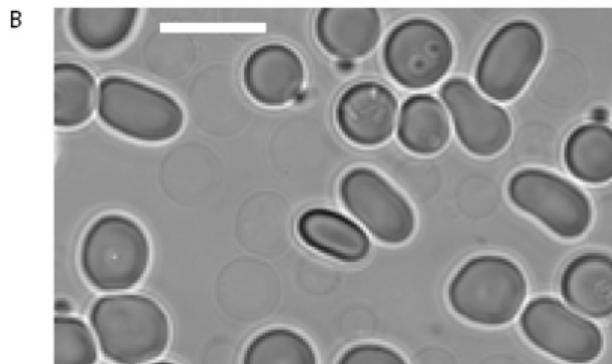
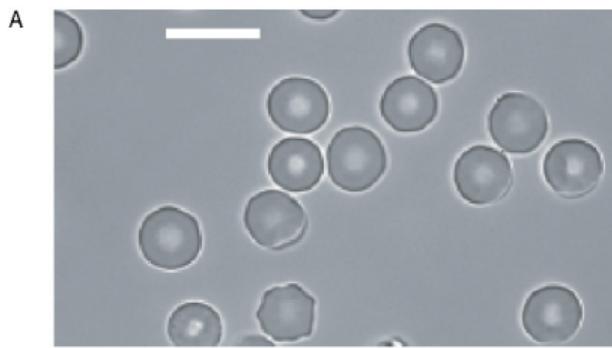
LOW



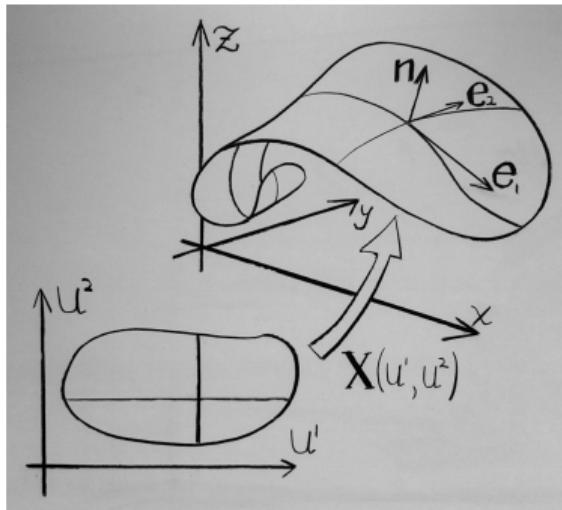
HIGH

RESISTANCE TO CHEMICALLY INDUCED POSITIVE CURVATURE

Elliptocytes or ovalocytes



Curvature



$$\mathbf{x} = \mathbf{x}(u^1, u^2) \quad \mathbf{e}_\alpha = \mathbf{x}_{,\alpha} \quad g_{\alpha\beta} = \mathbf{e}_\alpha \mathbf{e}_\beta \quad \mathbf{n} \propto \mathbf{e}_1 \times \mathbf{e}_2$$

$$H_{\alpha\beta} = \mathbf{e}_\alpha \mathbf{n}_{,\beta} \quad H = \text{trace}(\mathbf{H}) = H_{\alpha\beta} g^{\alpha\beta}$$

Energy

$$G \propto \int H^2 dA, \quad M \propto \int H dA$$

Minimal G

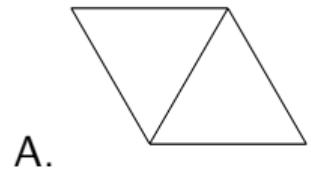
SC G and M

BC $G, M = M_0$

ADE G and $(M - M_0)^2$

SC-ADE G and M and $(M - M_0)^2$

Models

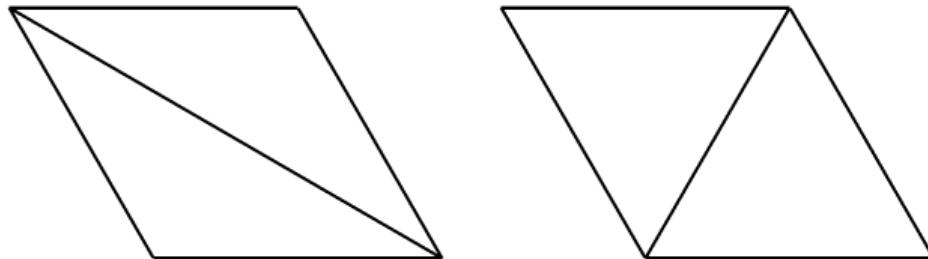


C. operators for energy

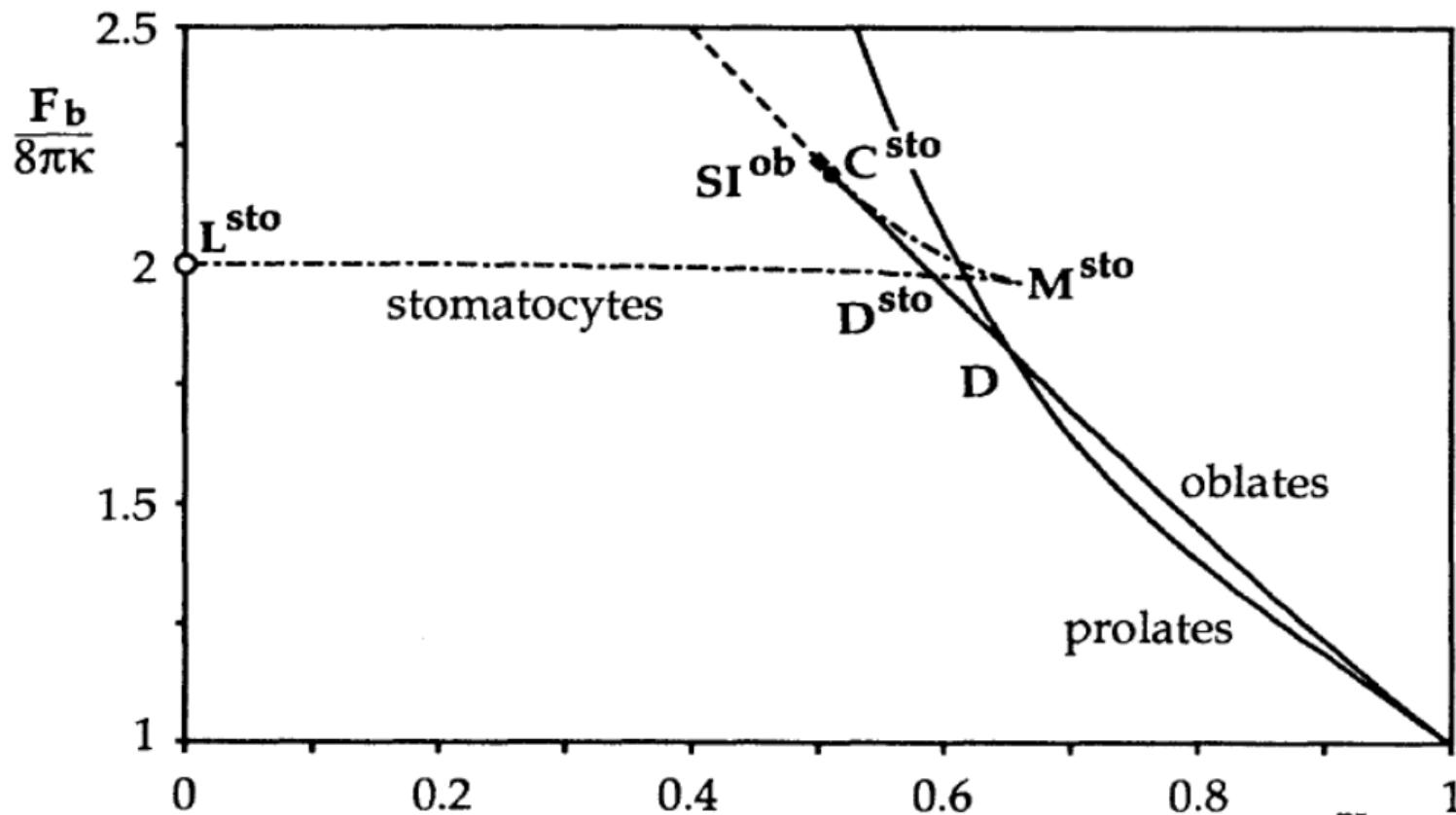
D. operators for force

Regularization

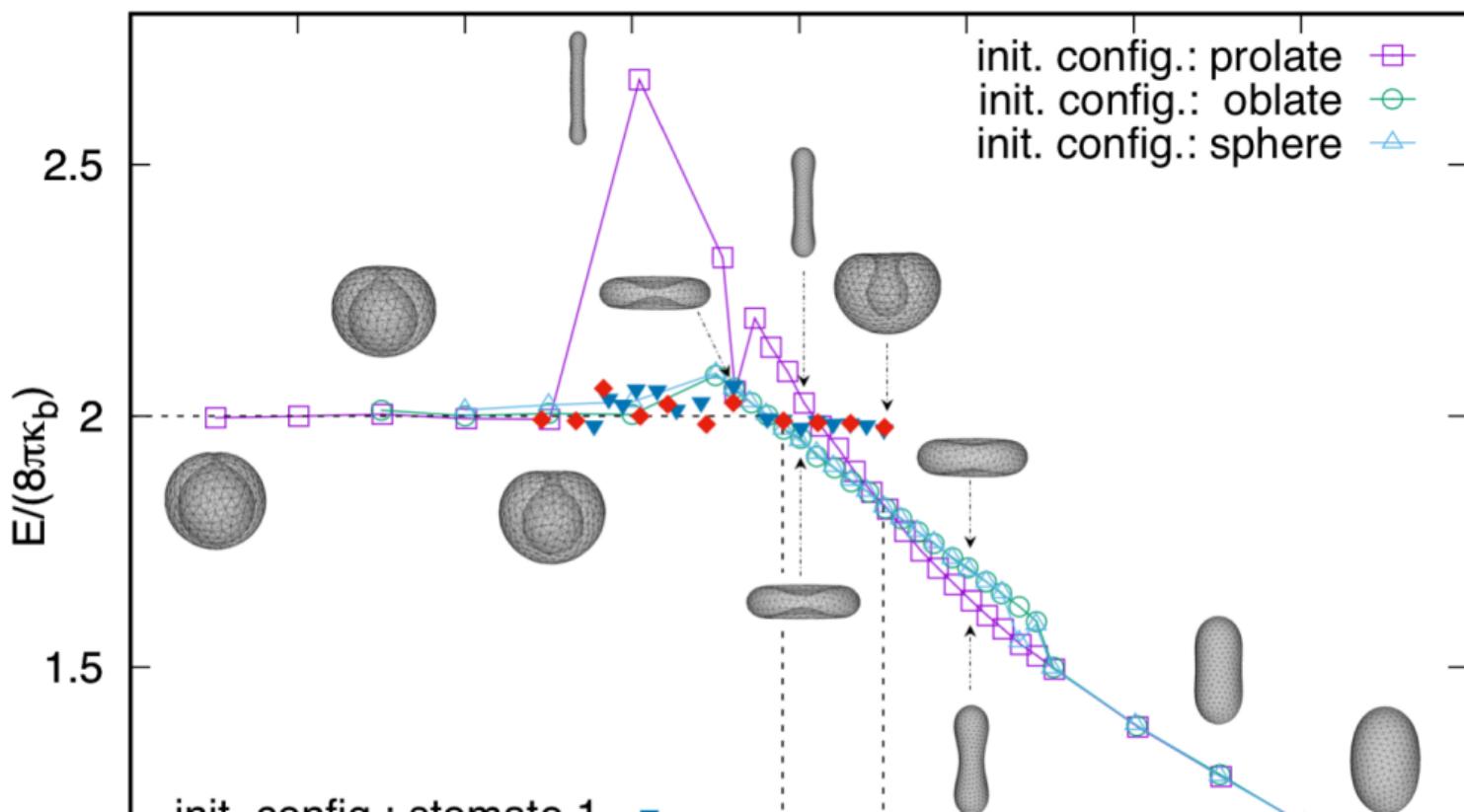
- Constrain area of each triangle
- “Edge rotation”



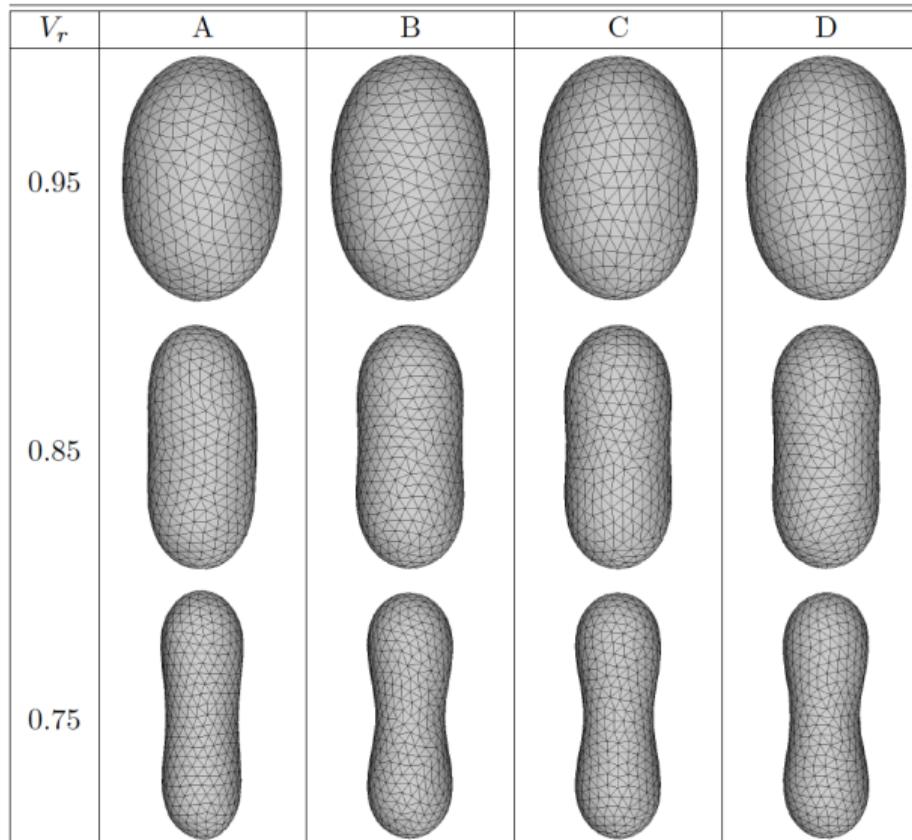
Minimal



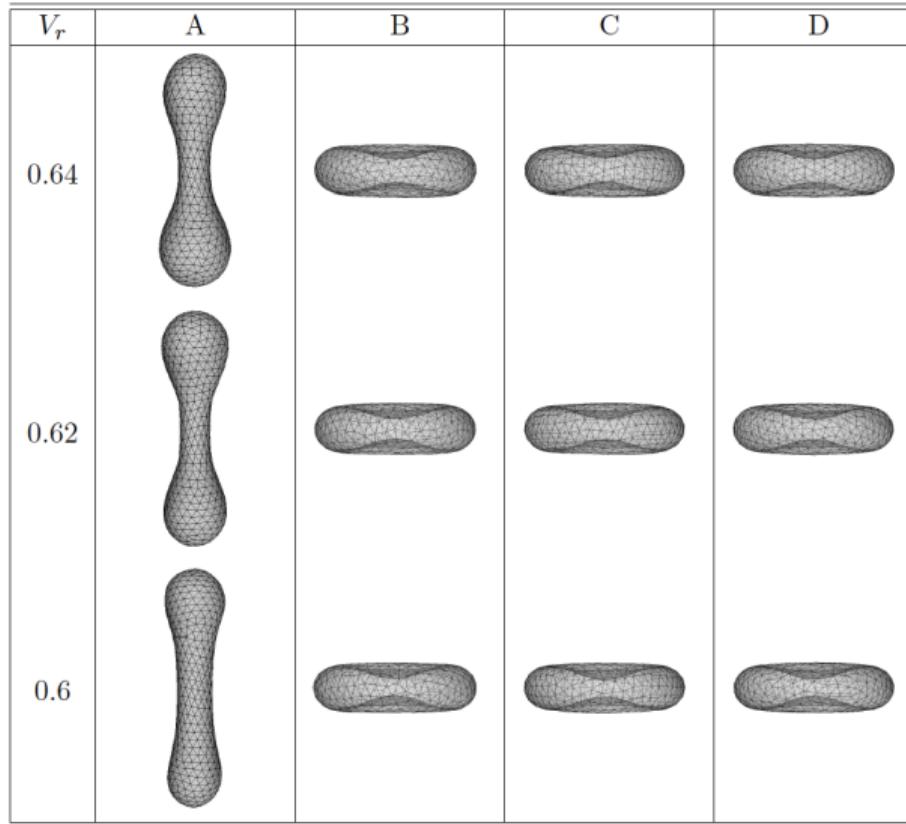
Minimal



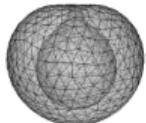
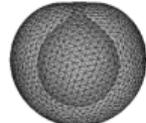
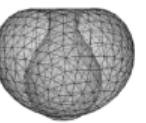
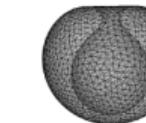
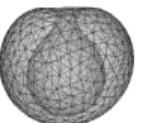
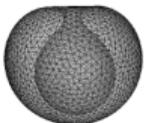
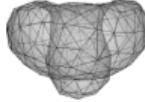
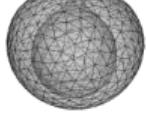
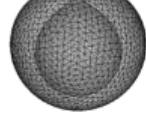
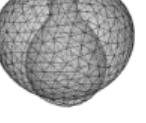
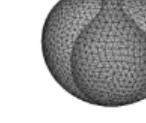
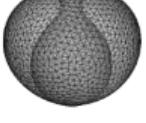
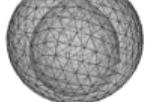
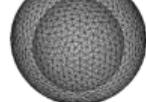
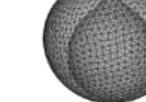
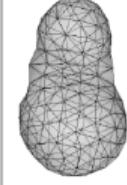
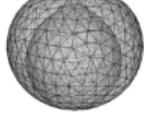
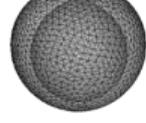
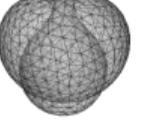
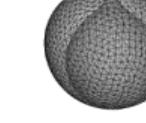
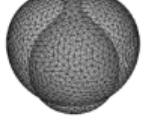
Minimal



Minimal



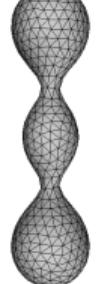
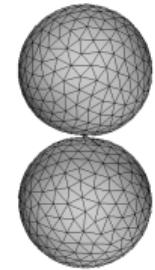
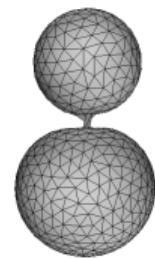
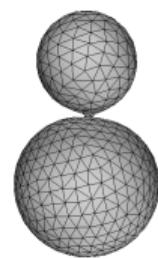
Minimal

V_r	B: $N_t = 320$	B: $N_t = 1280$	B: $N_t = 5120$	C: $N_t = 1280$	C: $N_t = 5120$	D: $N_t = 1280$	D: $N_t = 5120$
0.45							
0.4						NA	
0.35						NA	
0.3						NA	
0.25						NA	NA

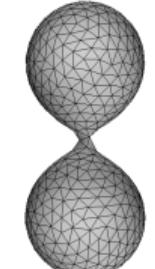
SC

V_r 0.736 0.718 0.707 0.65 0.57 0.52

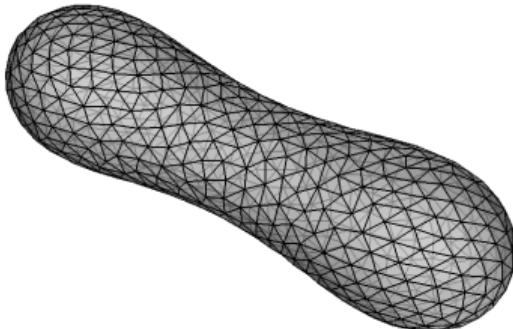
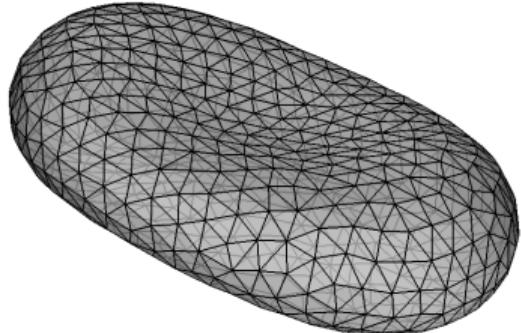
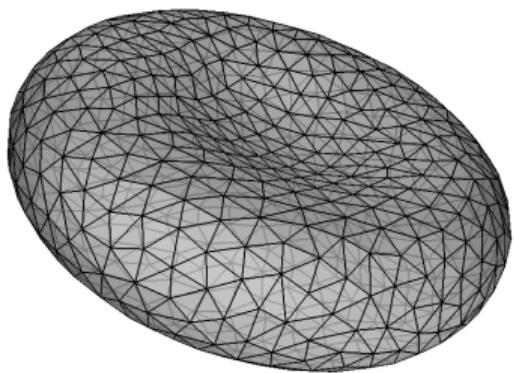
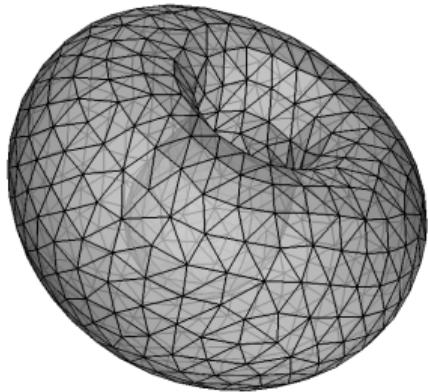
A



C



ADE





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- Khairy K., Howard J. Minimum-energy vesicle and cell shapes calculated using spherical harmonics parameterization Soft Matter 7.5 (2011) 2138-2143.
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