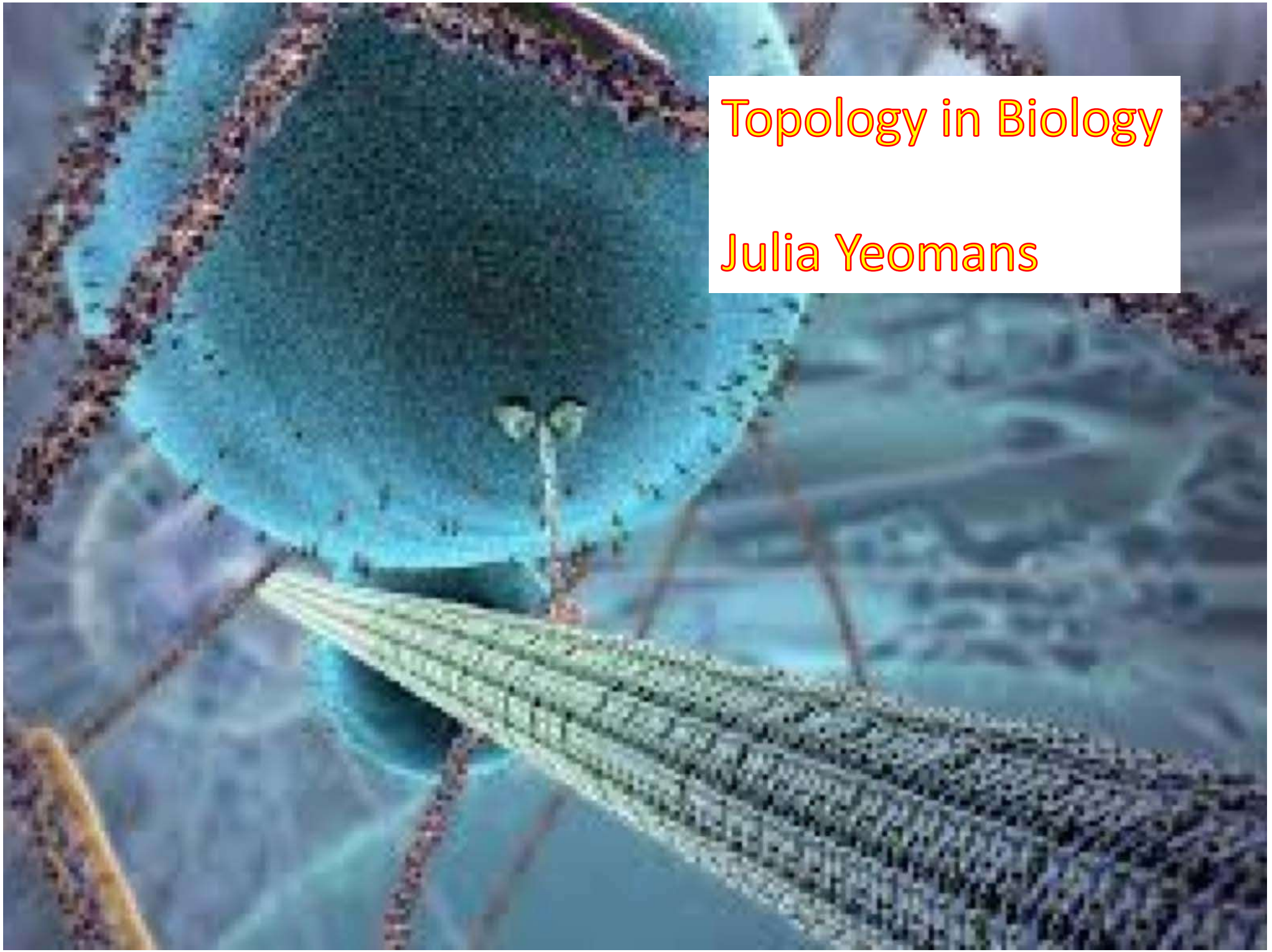
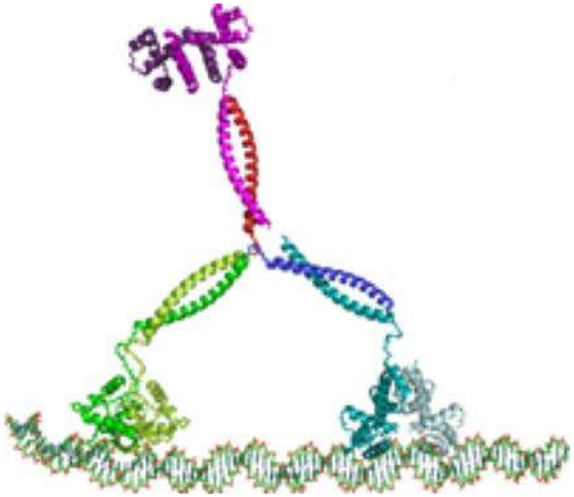

Topology in Biology
Julia Yeomans

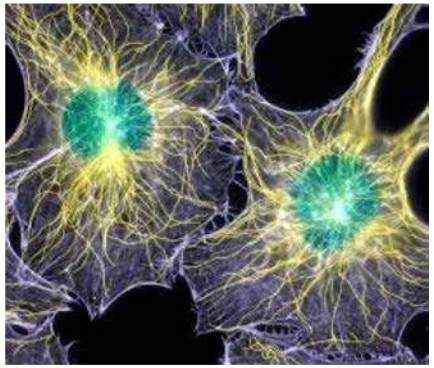
Active matter:

takes energy from the environment on a single particle level and uses it to do work

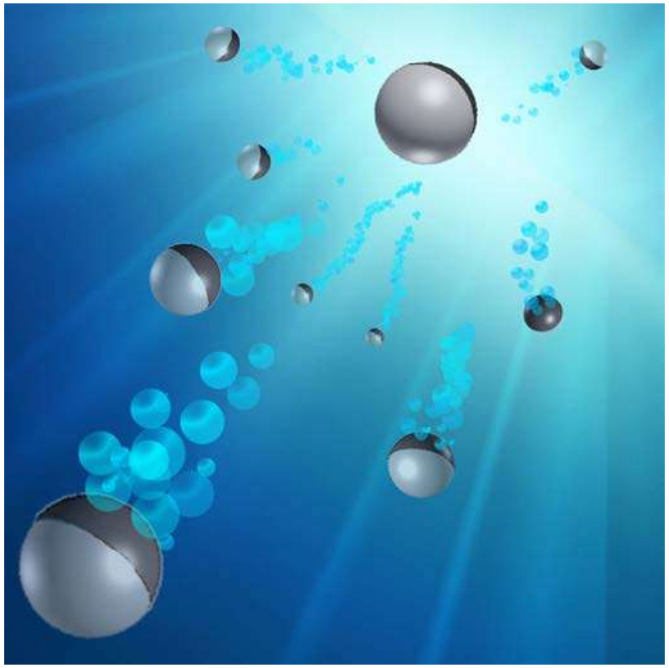
molecular motors

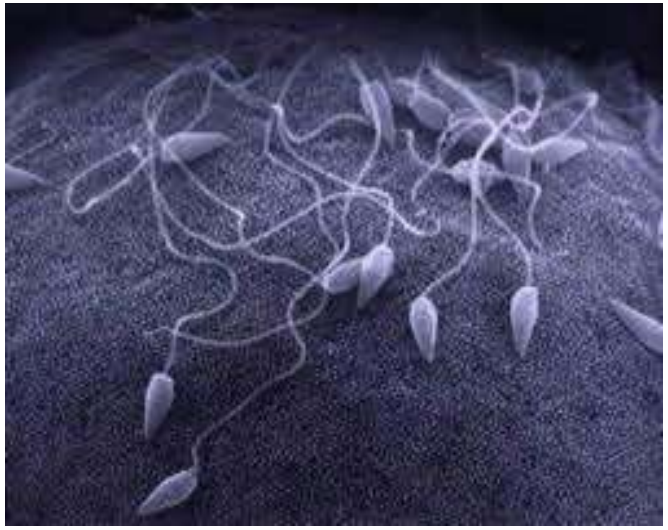


cells



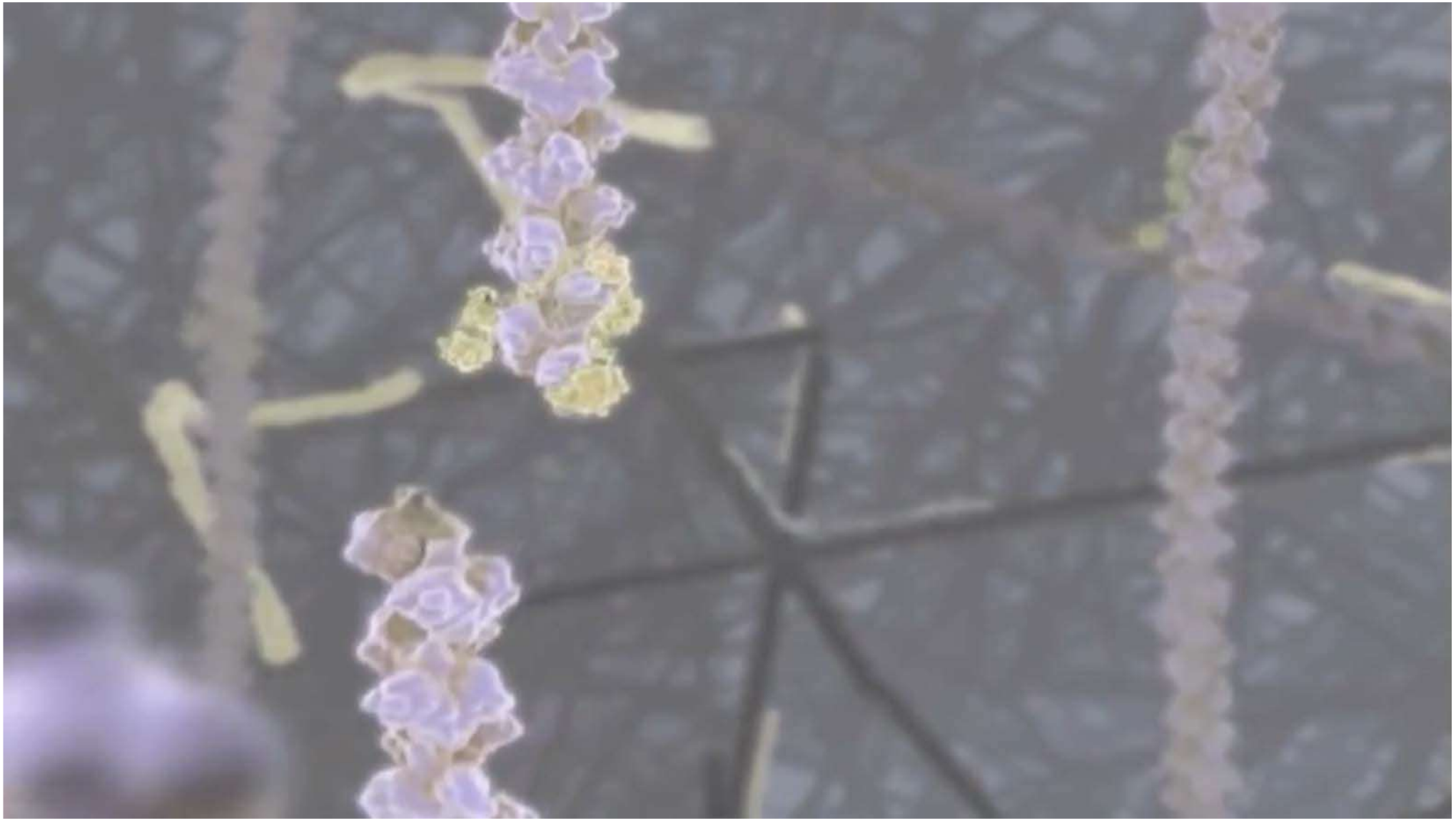
active colloids



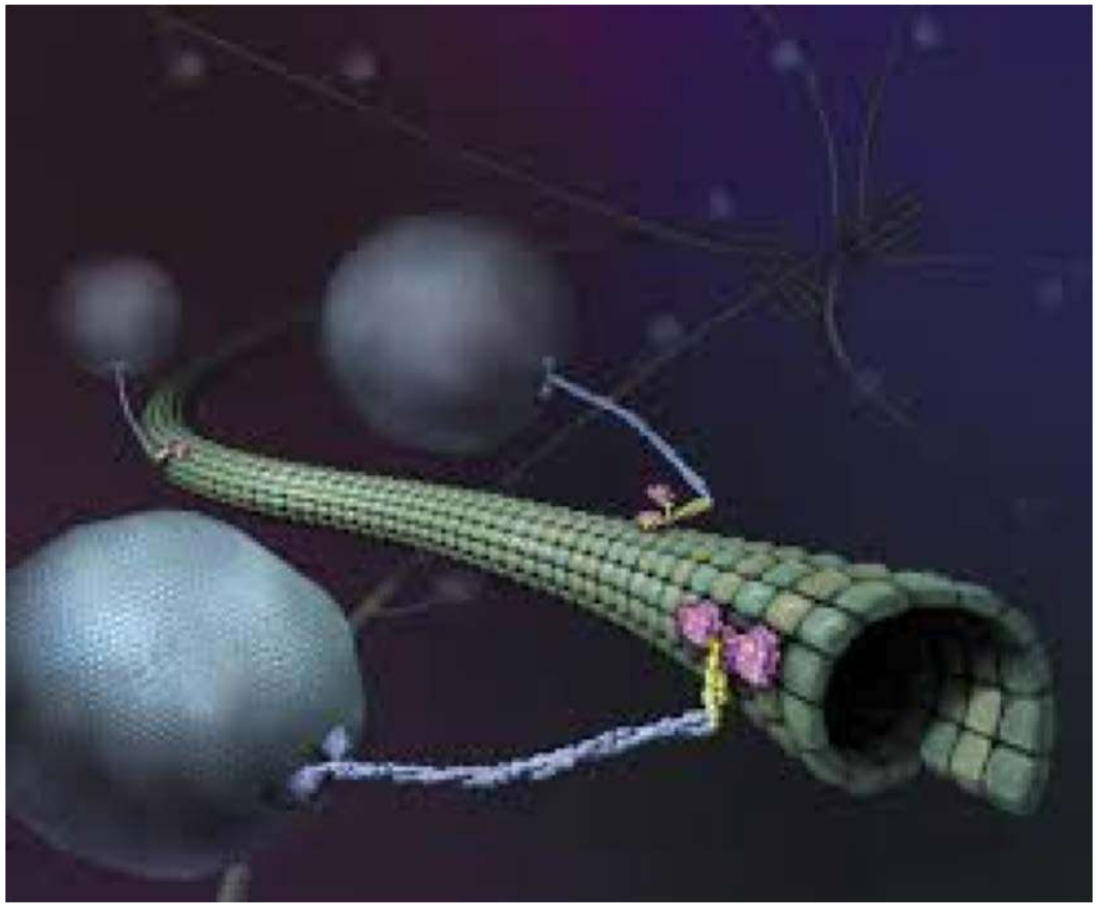


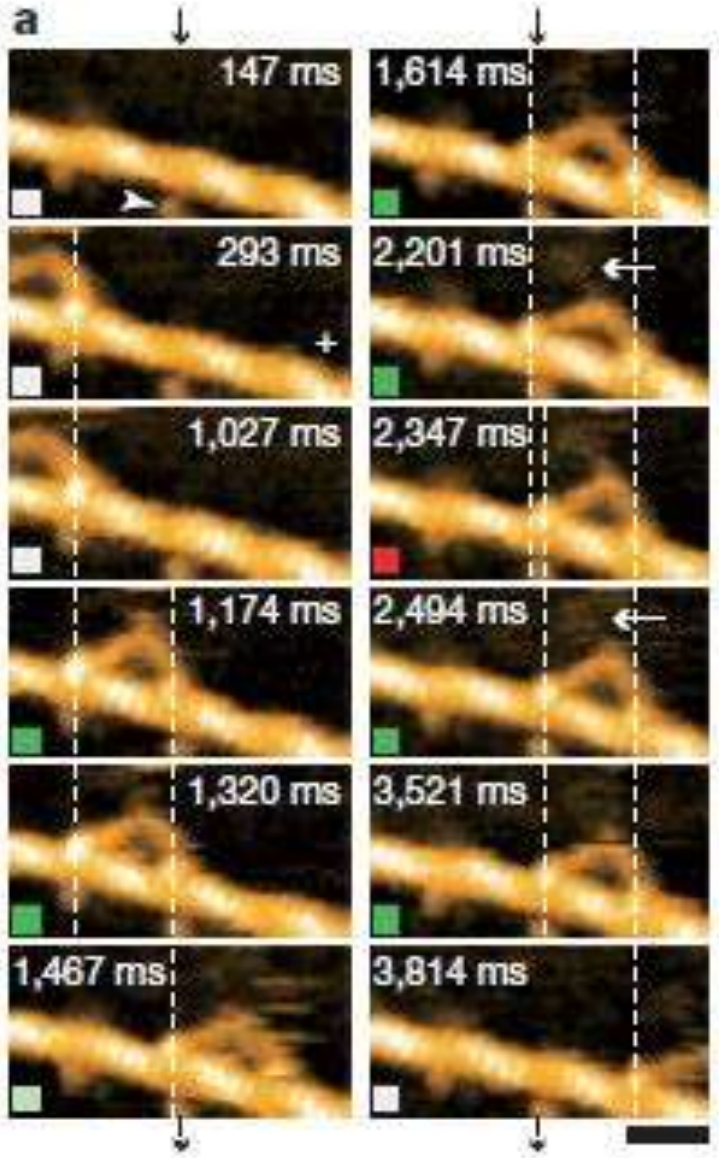
microswimmers

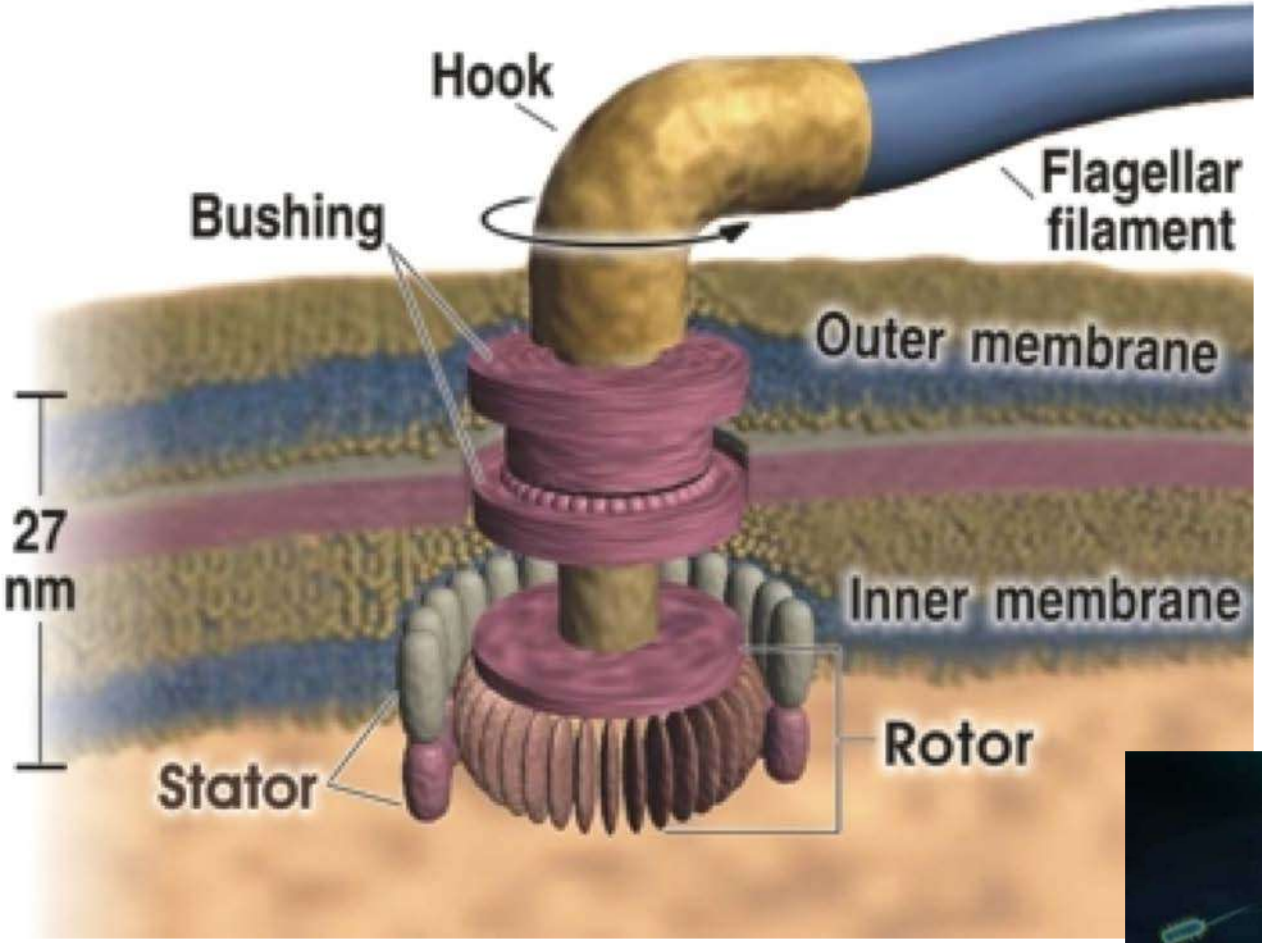
animals

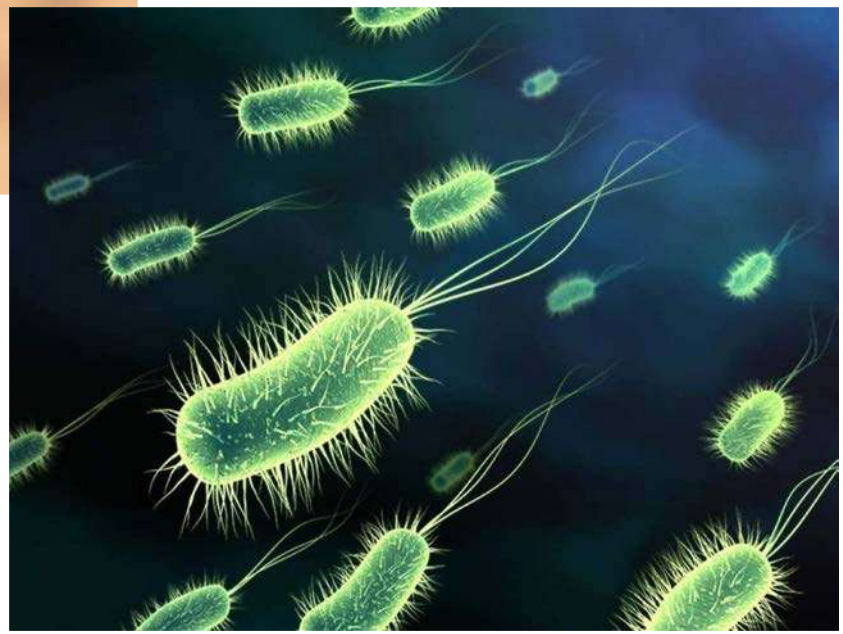


Kinesin walking, from Inner Life of a Cell

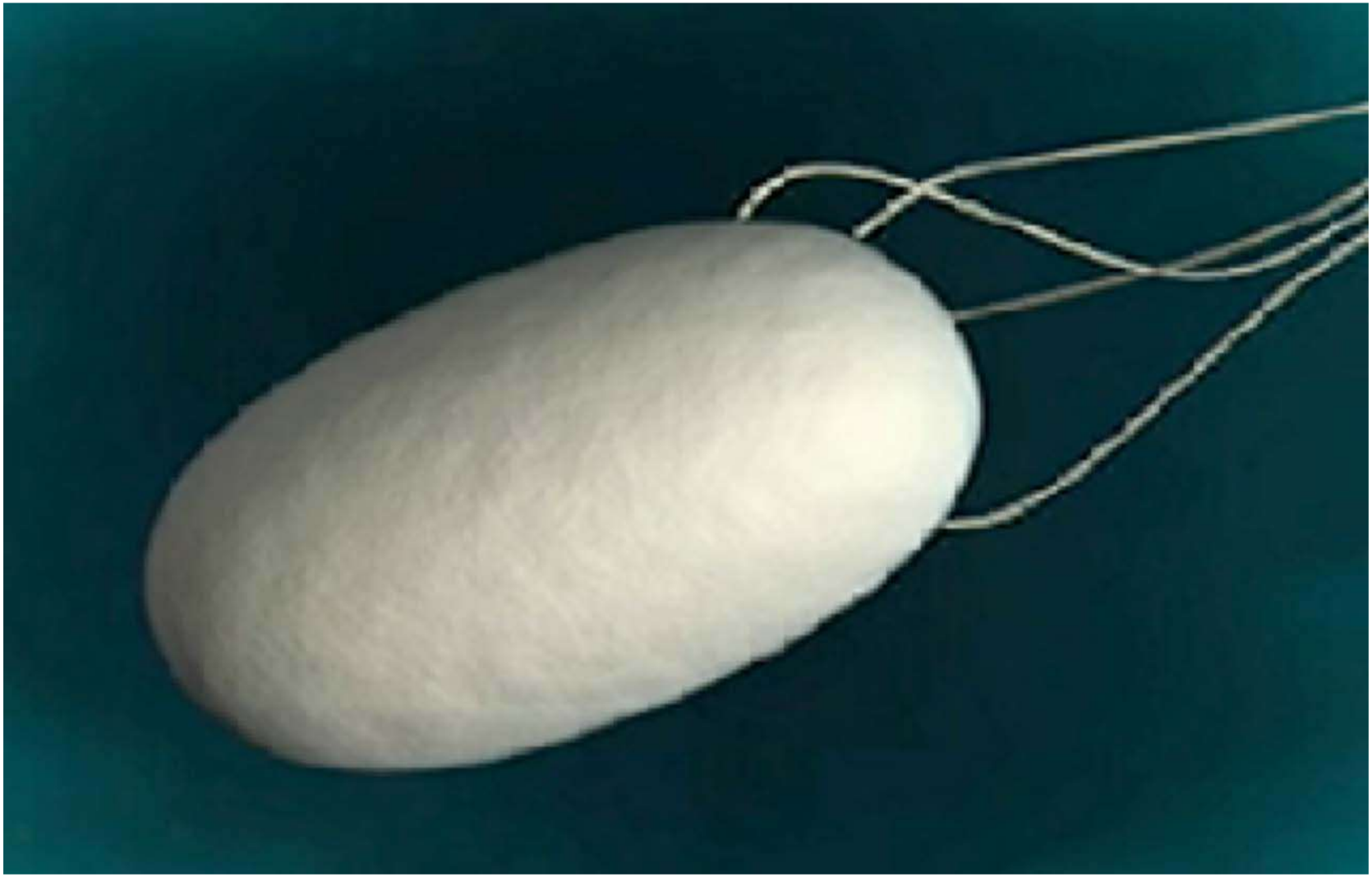



a
147 ms
1,614 ms
293 ms
2,201 ms
1,027 ms
2,347 ms
1,174 ms
2,494 ms
1,320 ms
3,521 ms
1,467 ms
3,814 ms



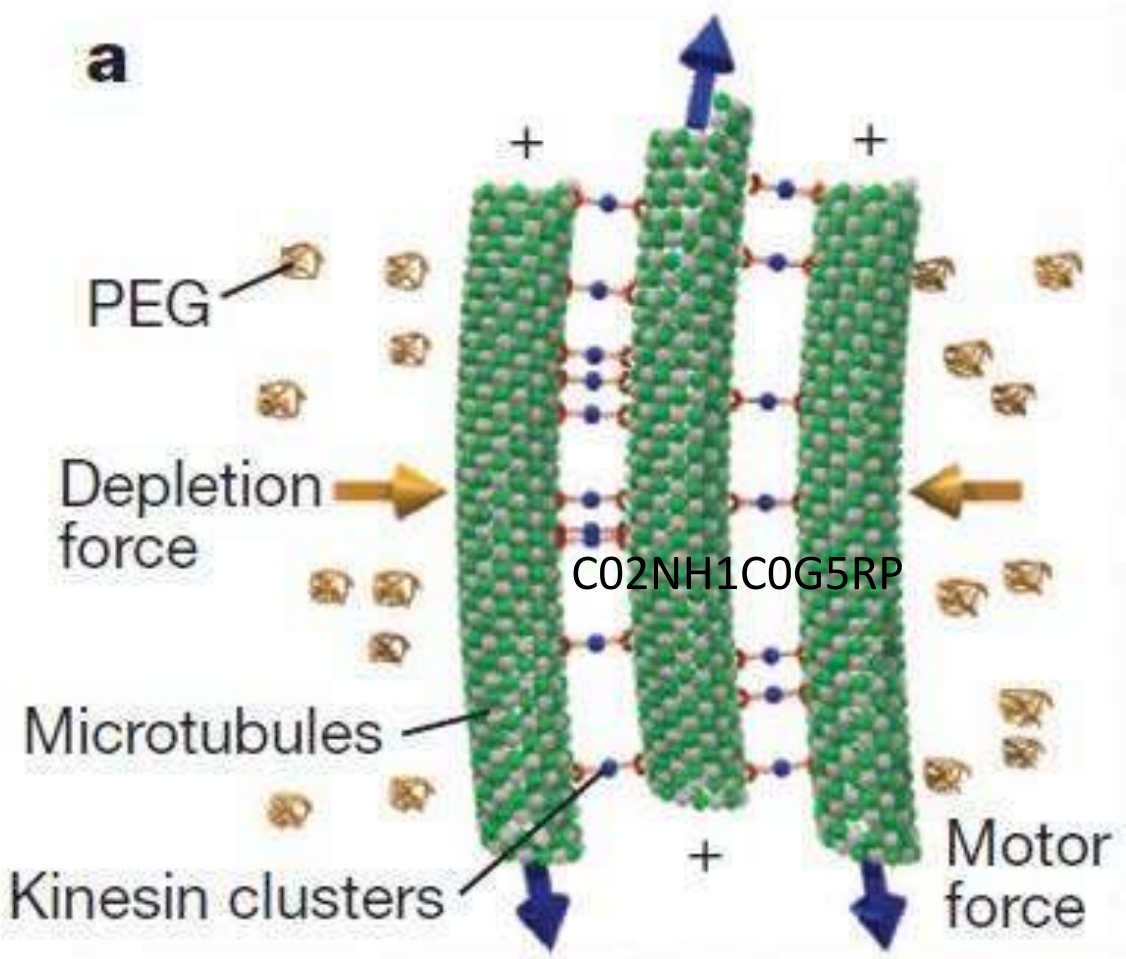


Bacterial flagellar motor



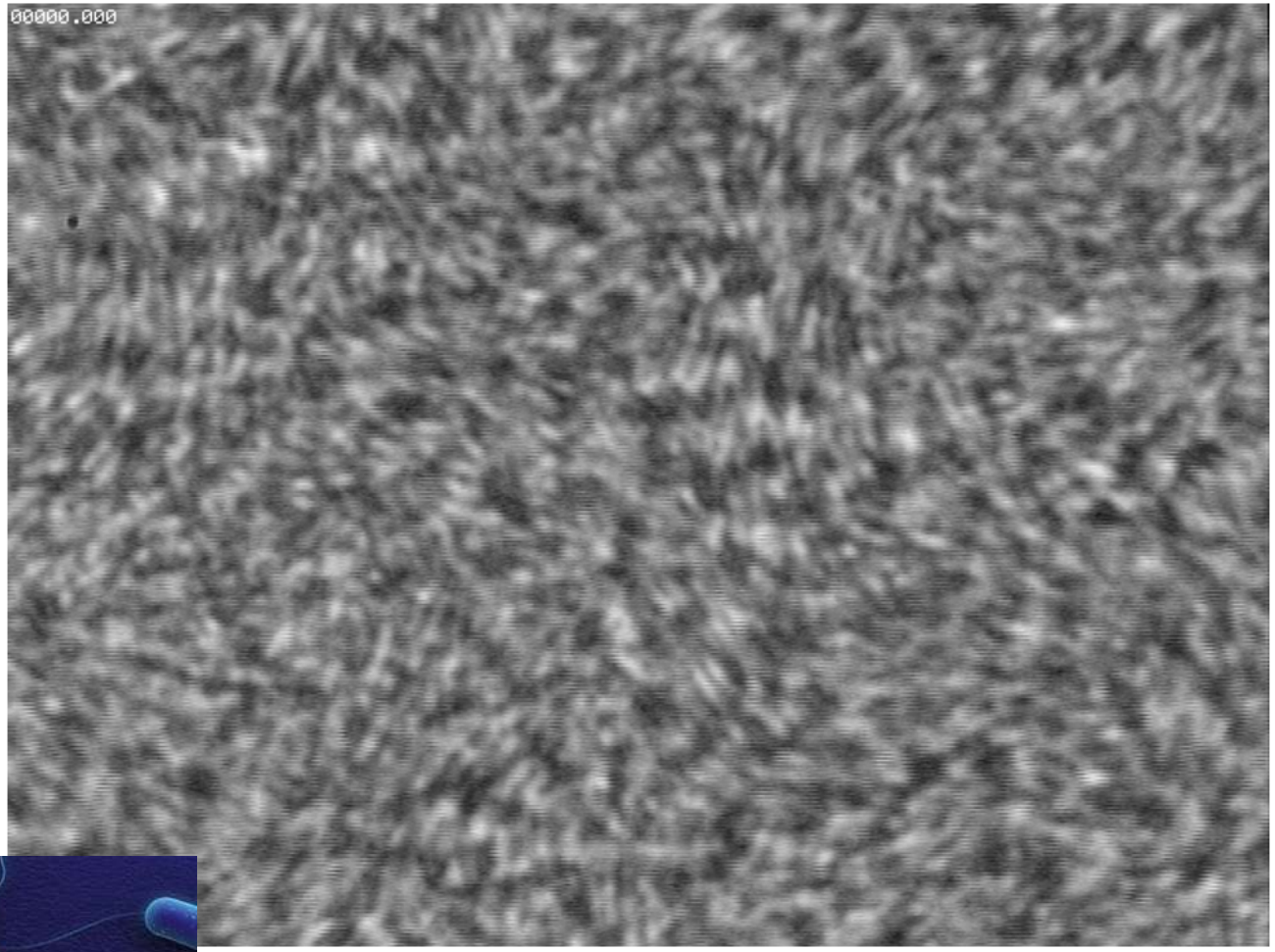
active matter is out of equilibrium – and it is meant to be out of equilibrium

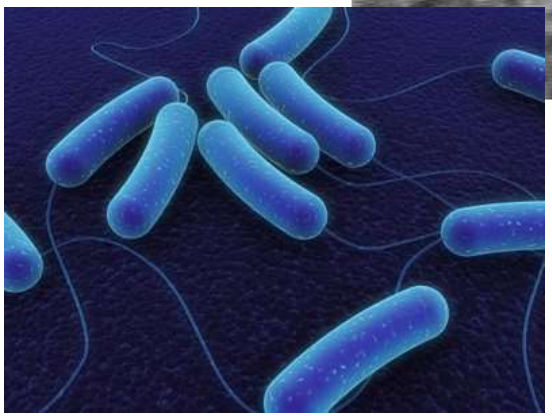
active matter is out of equilibrium – and it’s meant to be out of equilibrium



Sanchez, Chen, DeCamp, Heymann, Dogic, Nature 2012

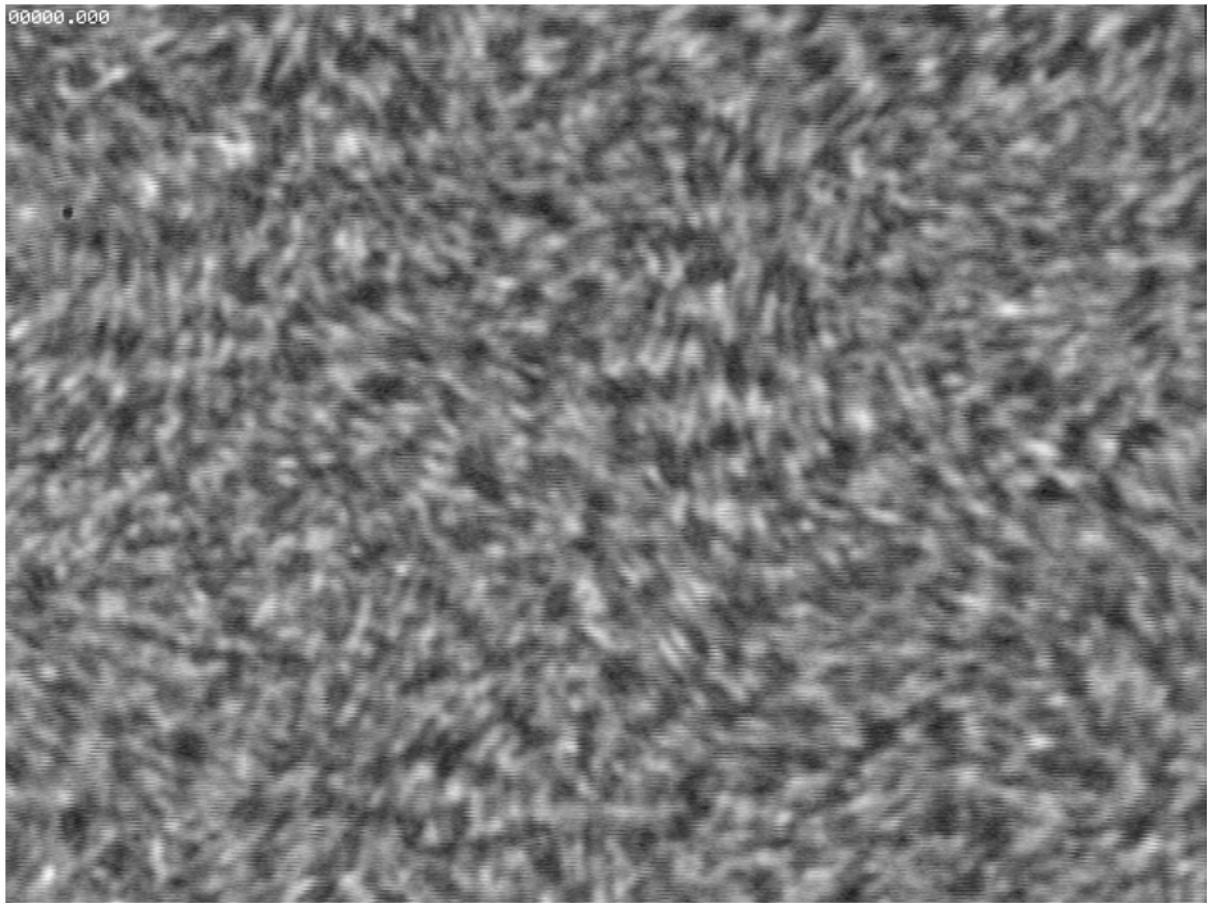
Active turbulence



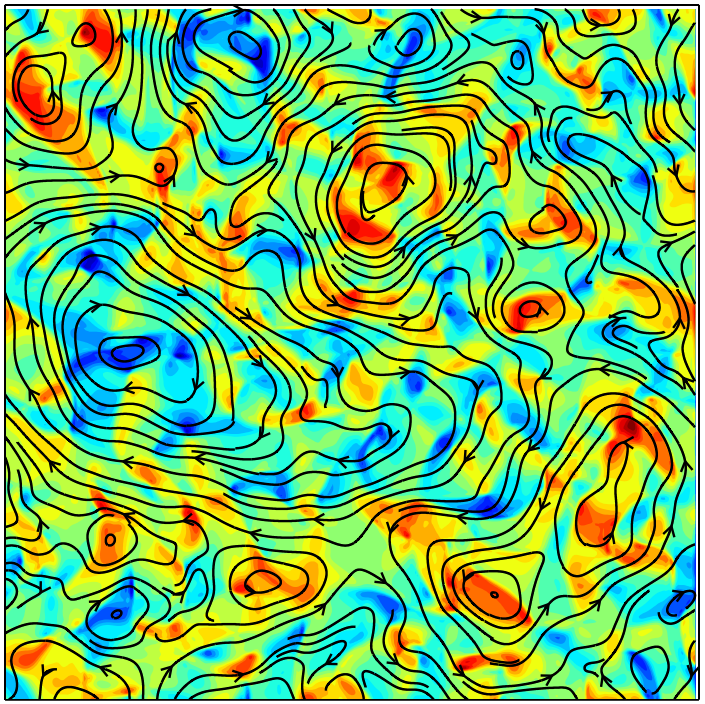


Dense suspension of microswimmers

Active turbulence

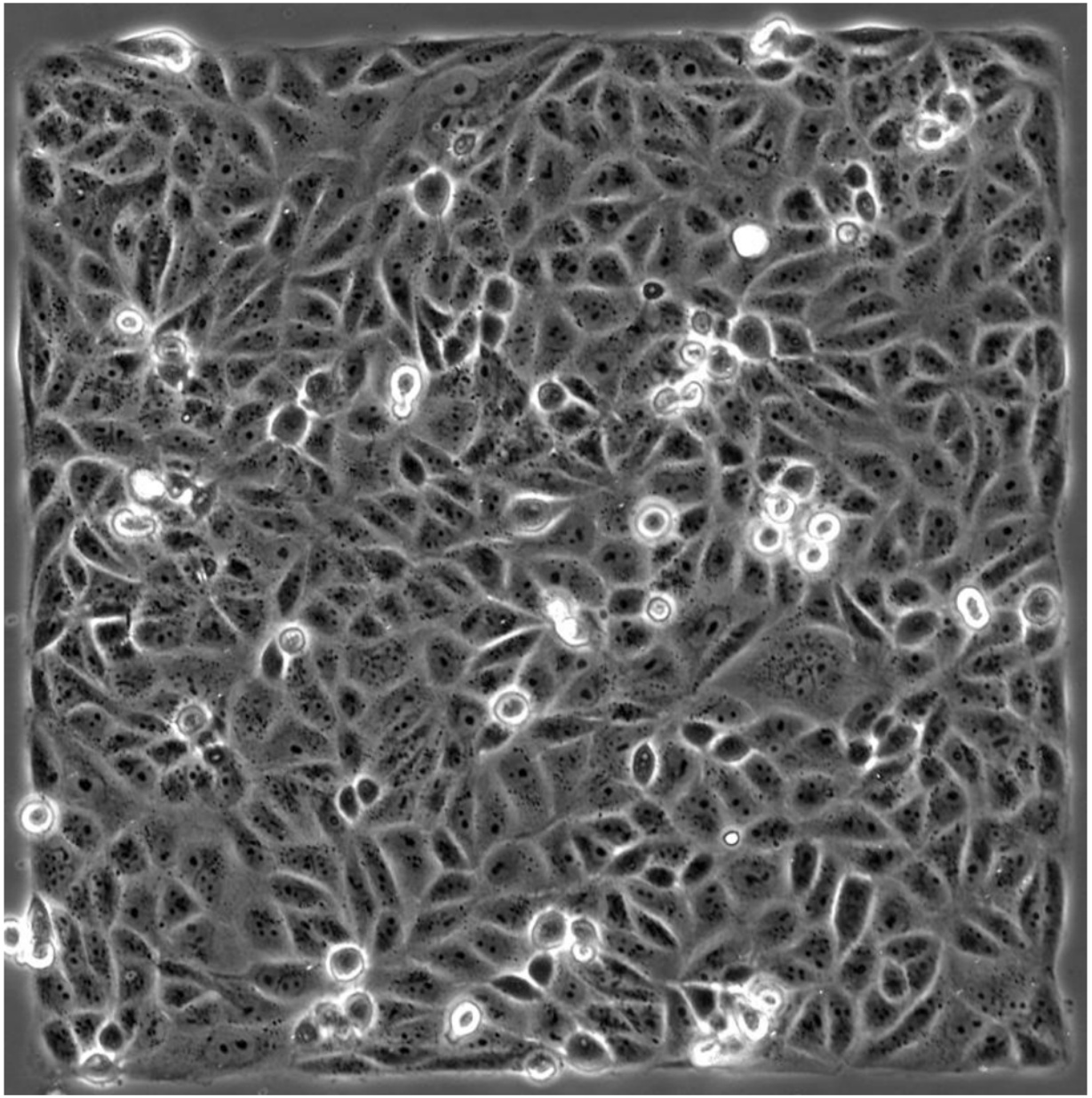


Dense suspension of microswimmers

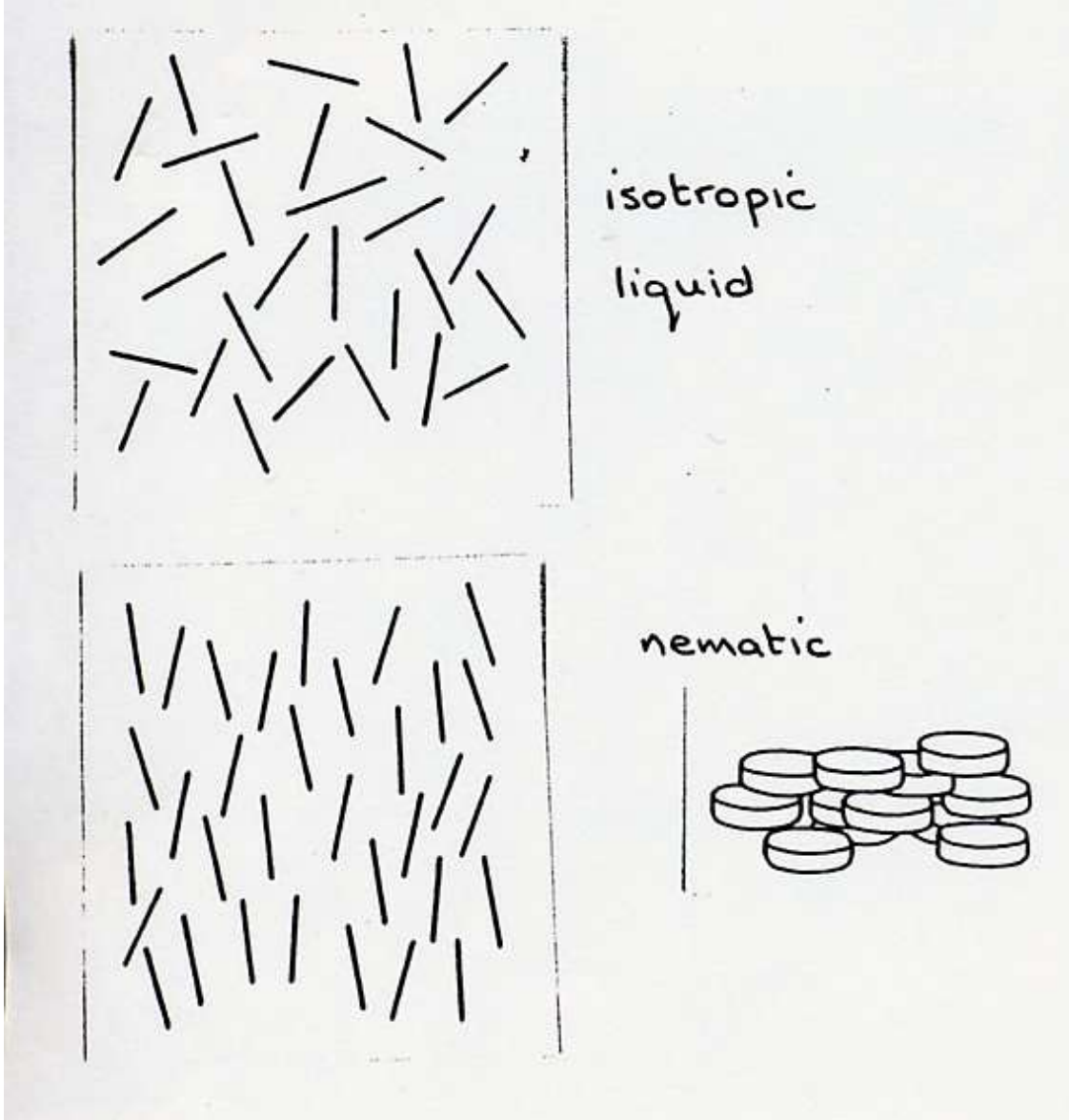


Vorticity field

Active turbulence: eukaryotic cells

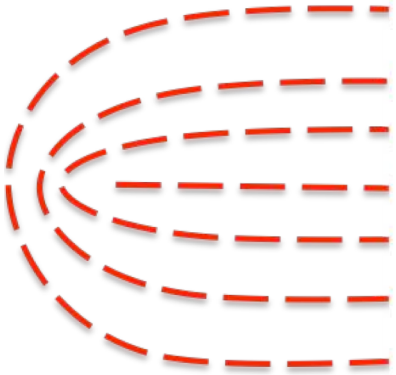


Liquid crystals

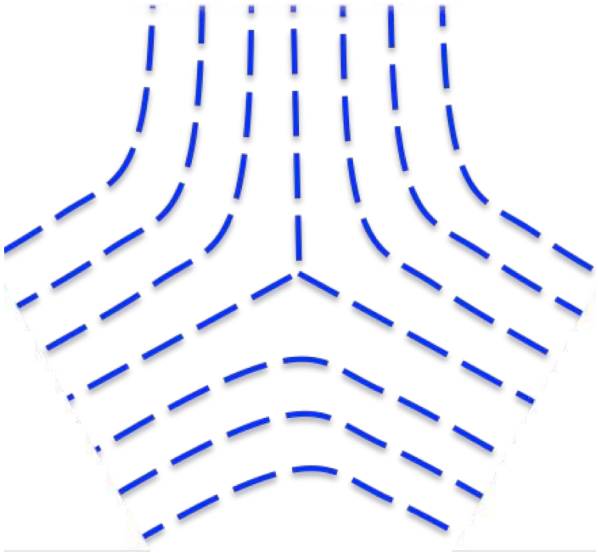


nematic symmetry

Topological defects in nematic liquid crystals



$m = +\frac{1}{2}$



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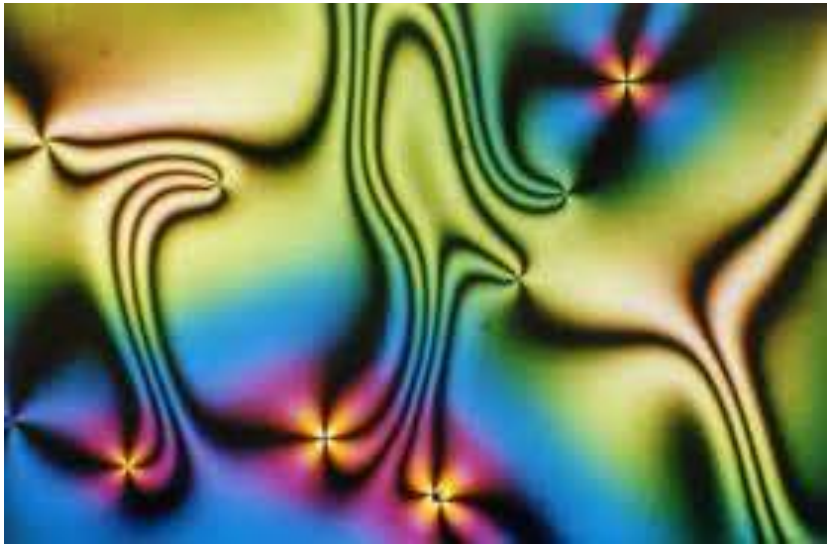
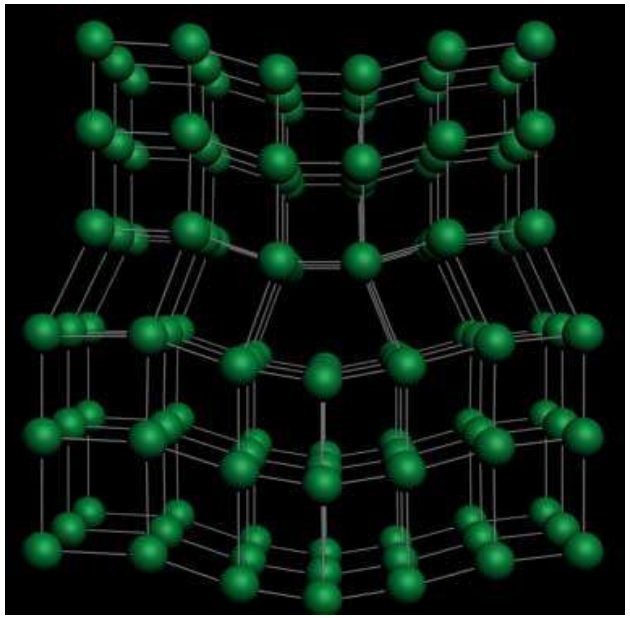
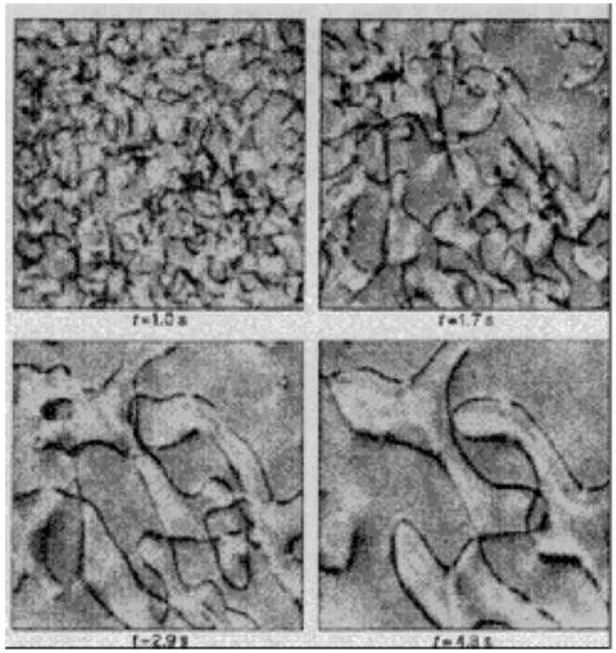


liquid crystals



crystal dislocations



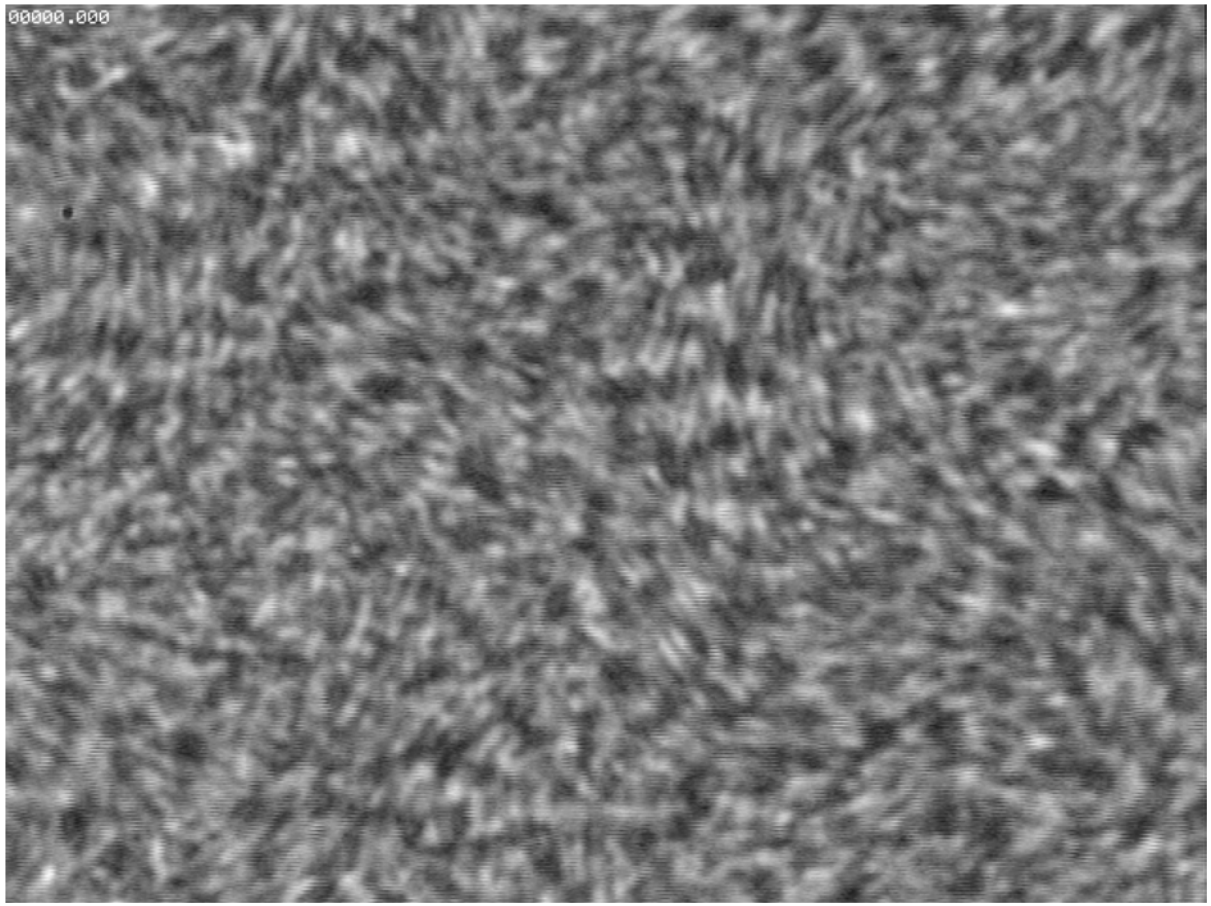
cosmic strings in the early universe

magnetic monopoles in spin ice

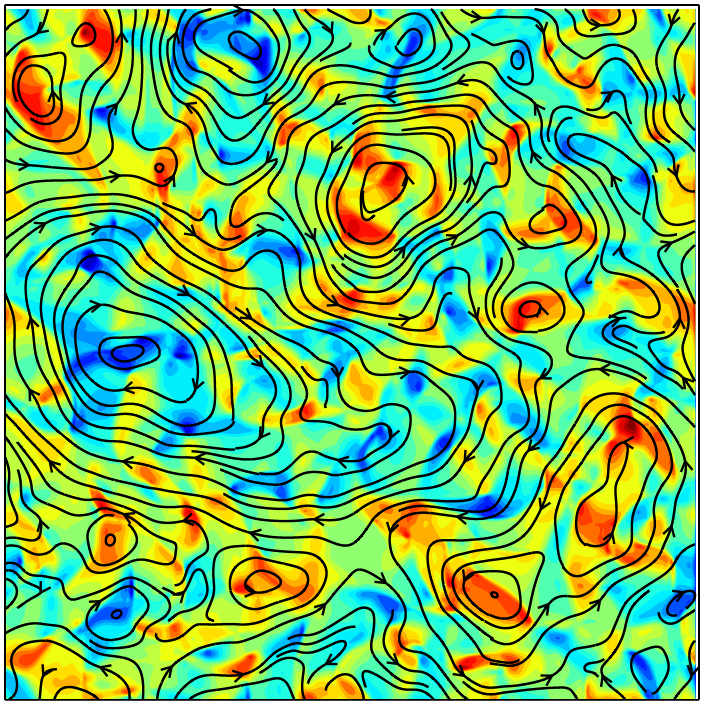
topological insulators

quantum vortex in a superfluid

Active turbulence

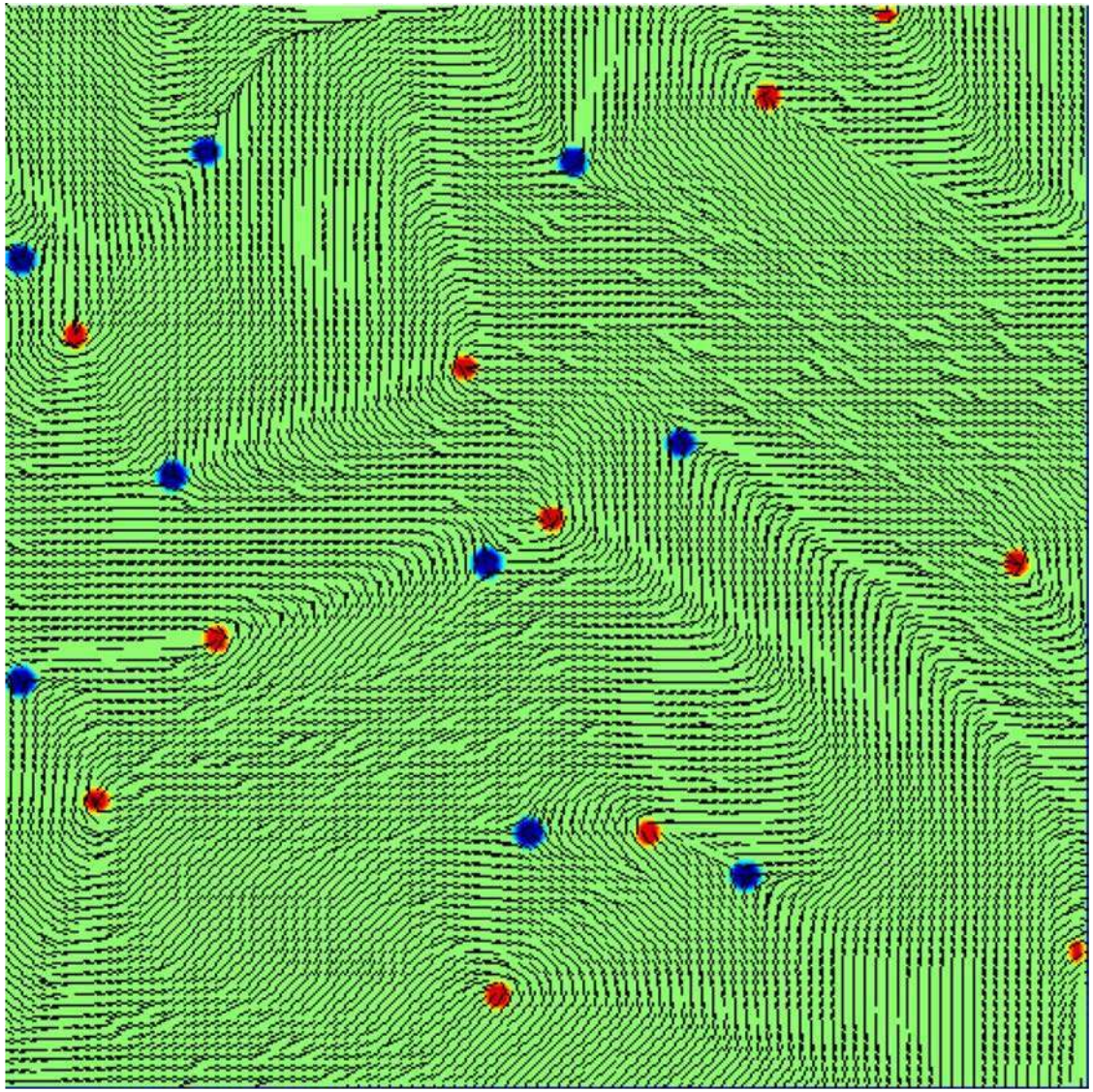


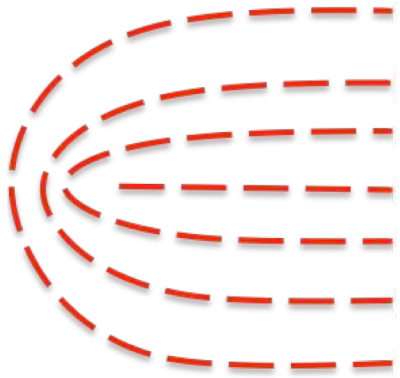
Dense suspension of microswimmers



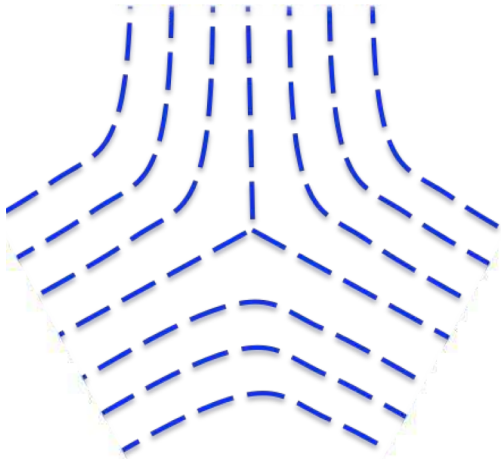
Vorticity field

Active turbulence: topological defects are created and destroyed



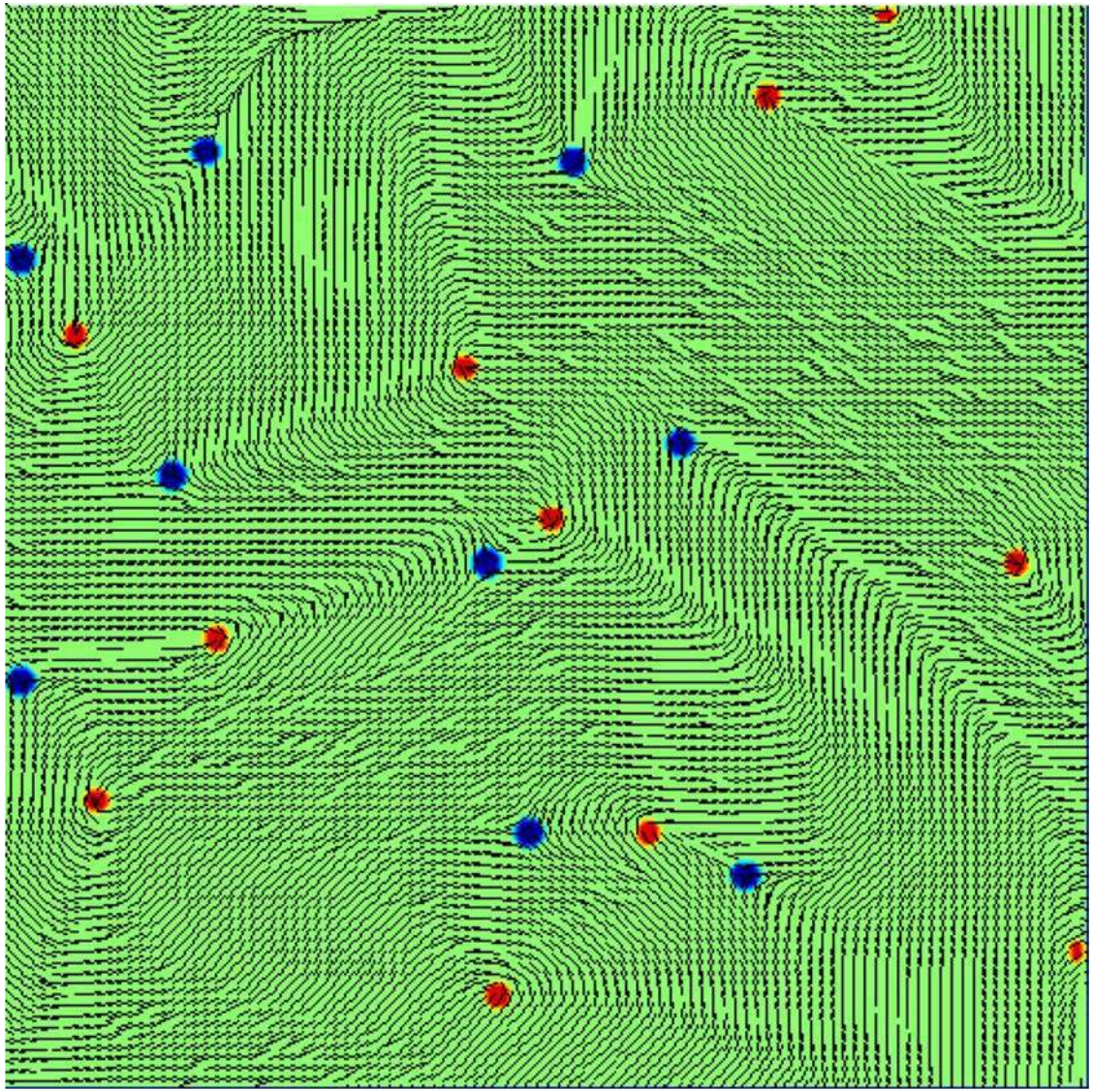


$$m = +\frac{1}{2}$$

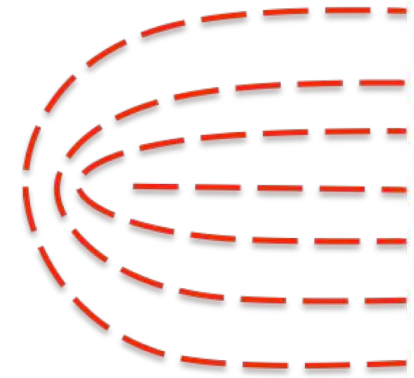


$$m = -\frac{1}{2}$$

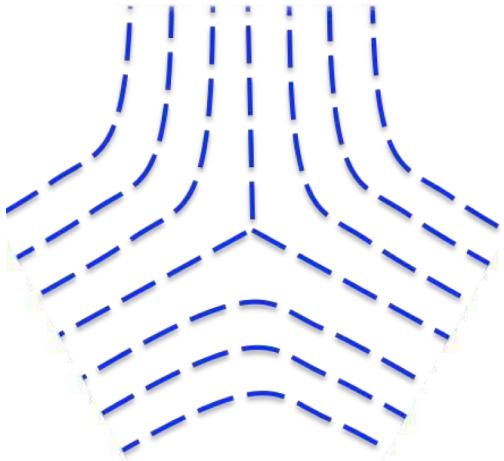
Active turbulence: topological defects are created and destroyed



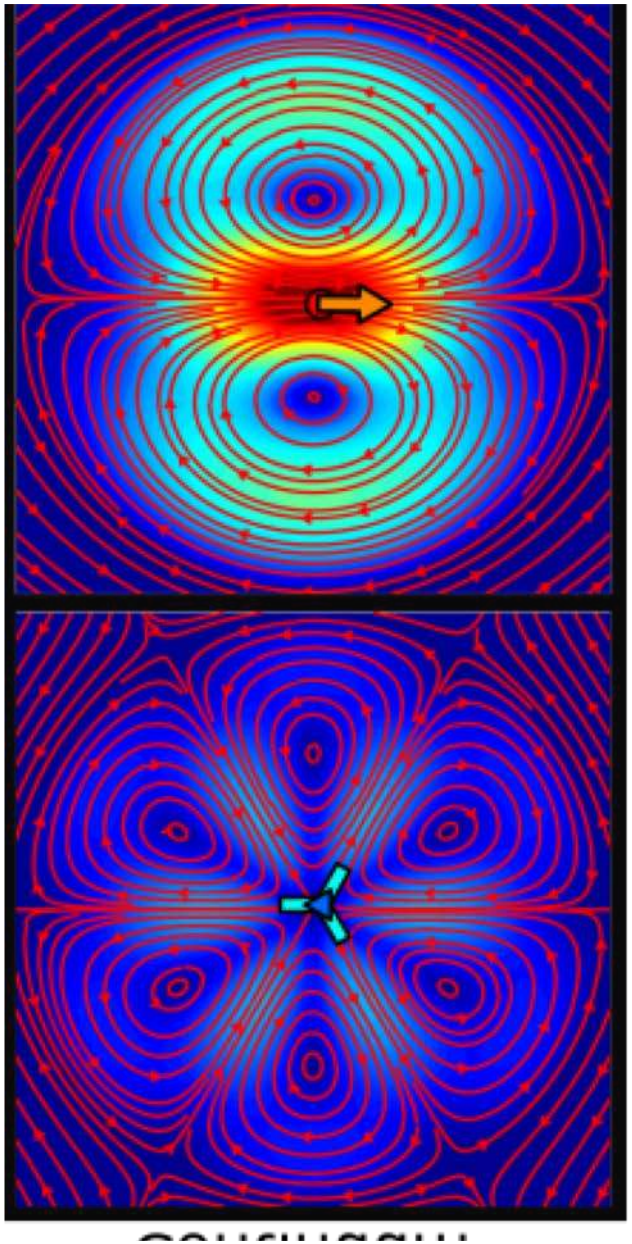
Topological defects are self motile

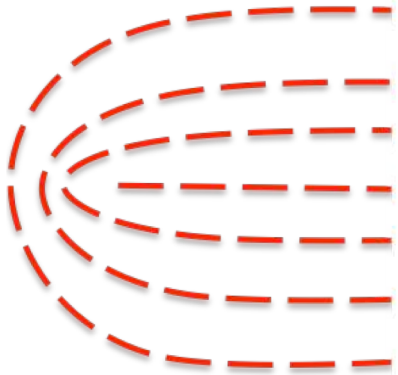


$$m = +\frac{1}{2}$$

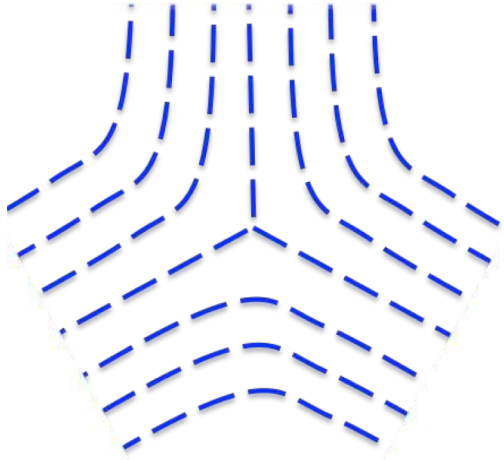


$$m = -\frac{1}{2}$$

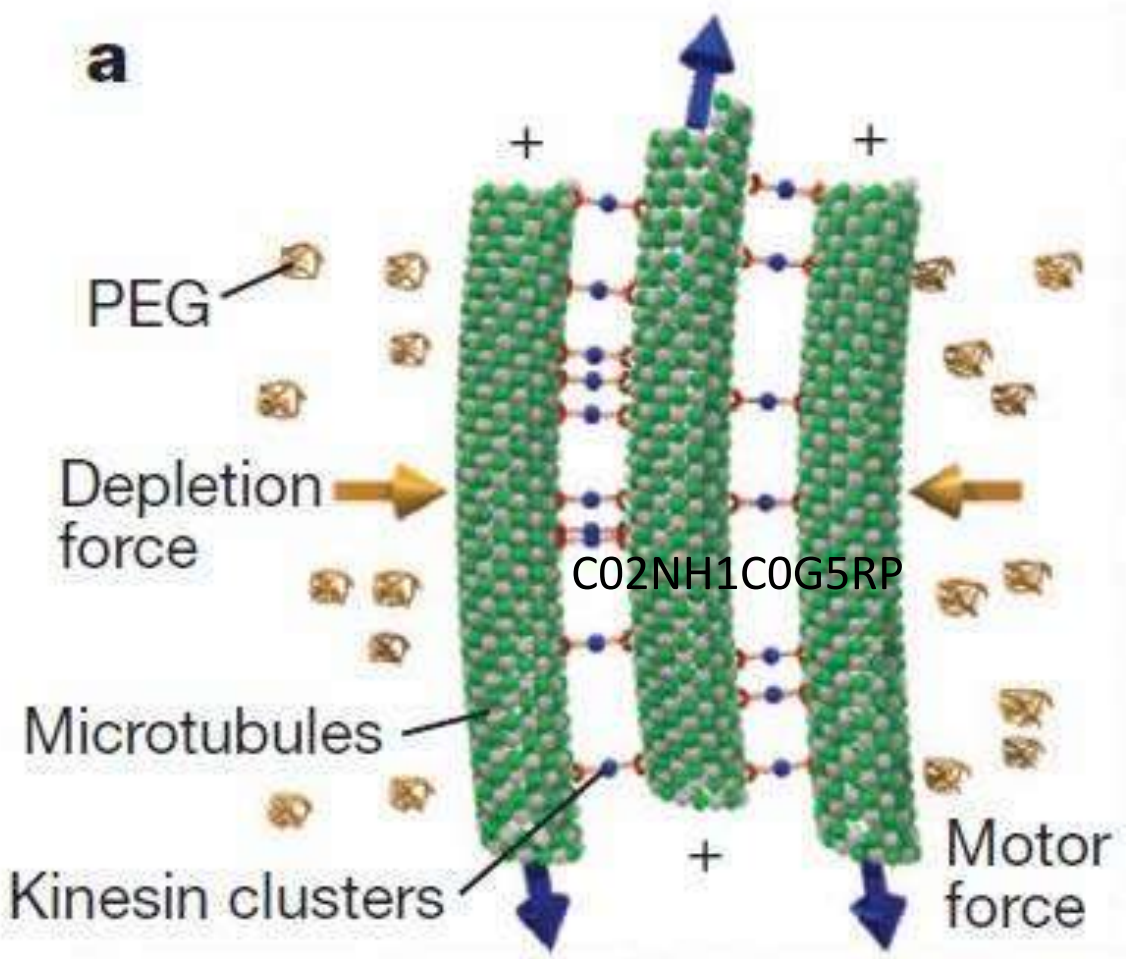




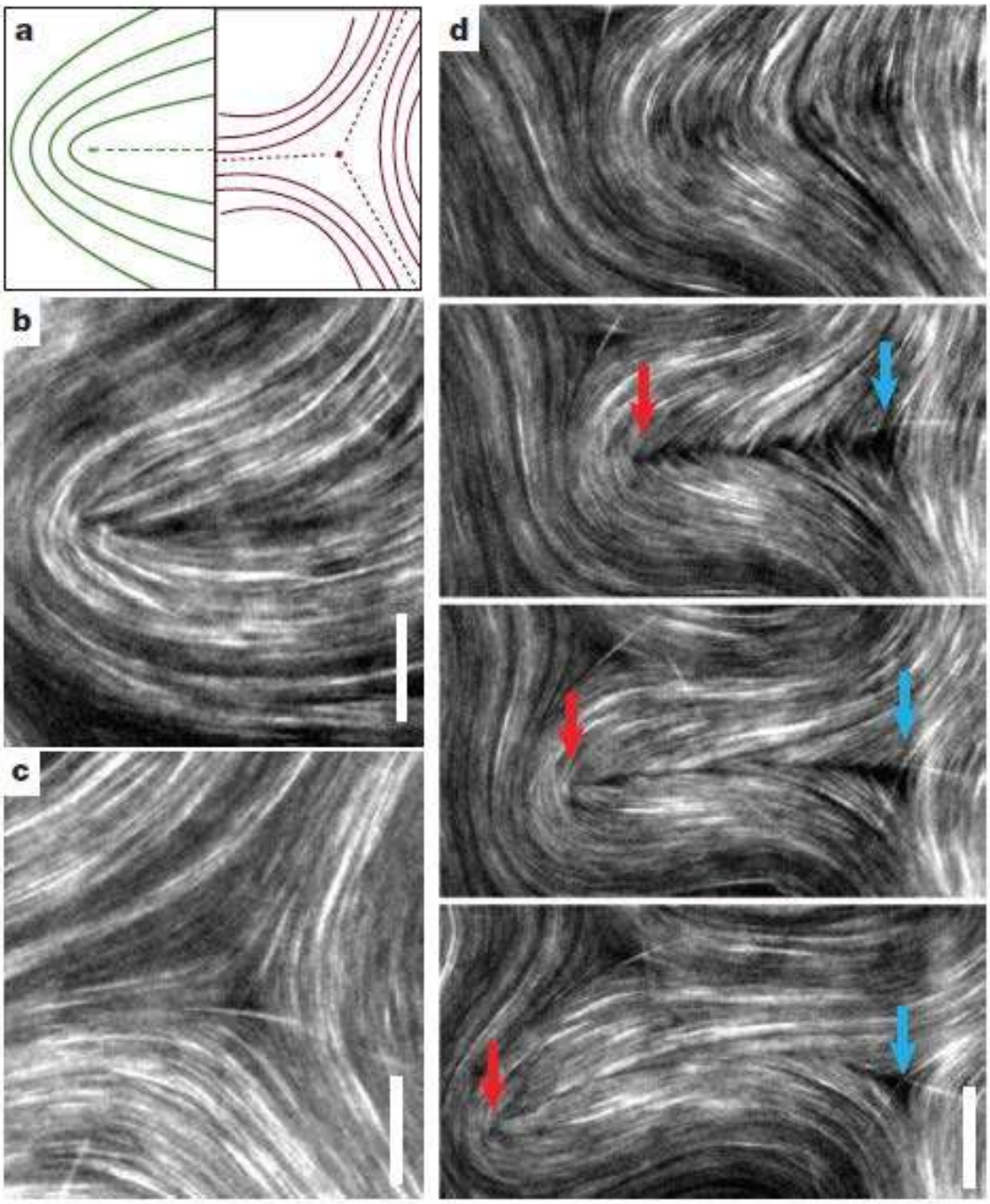
$$m = +\frac{1}{2}$$

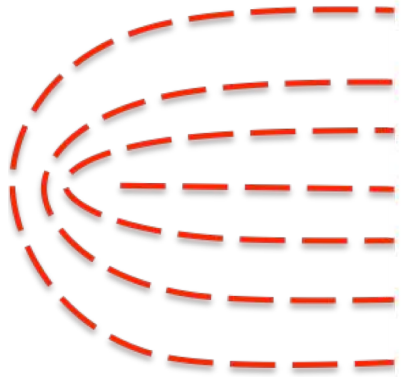


$$m = -\frac{1}{2}$$



Sanchez, Chen, DeCamp, Heymann, Dogic, Nature 2012





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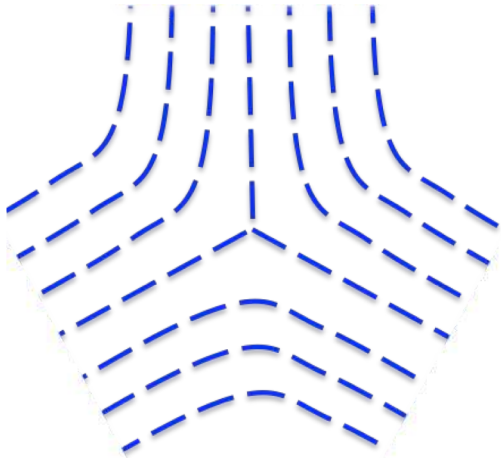
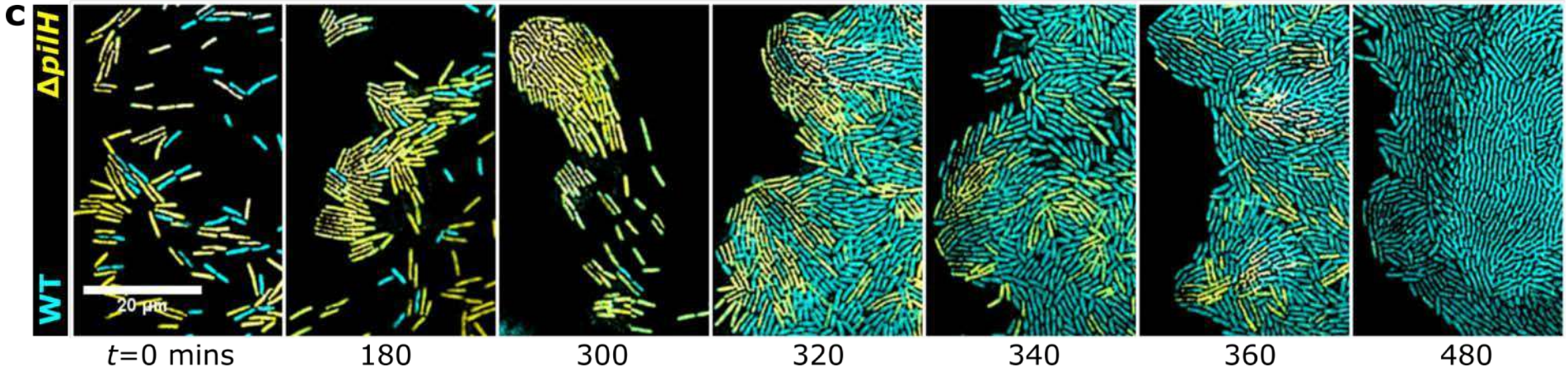


$$m = -\frac{1}{2}$$

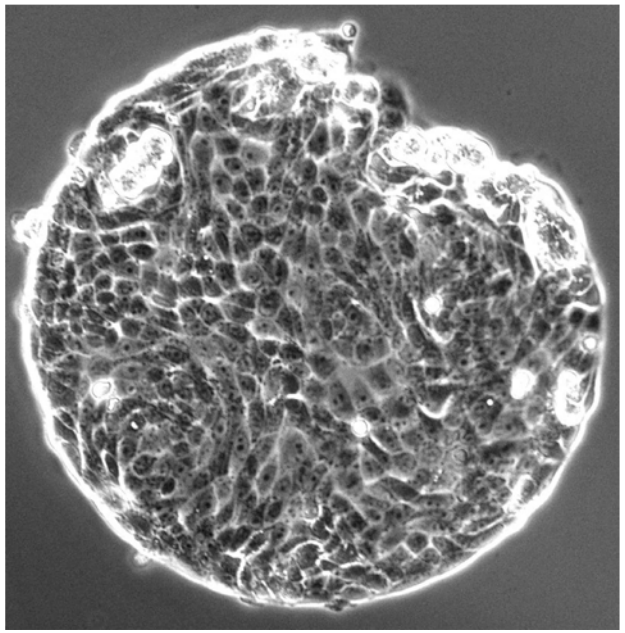
Sanchez, Chen, DeCamp, Heymann, Dogic, Nature 2012

L. Giomi, M.J. Bowick, Ma Xu, M.C. Marchetti, PRL 110, 228101

Topological defects in colonies of bacteria



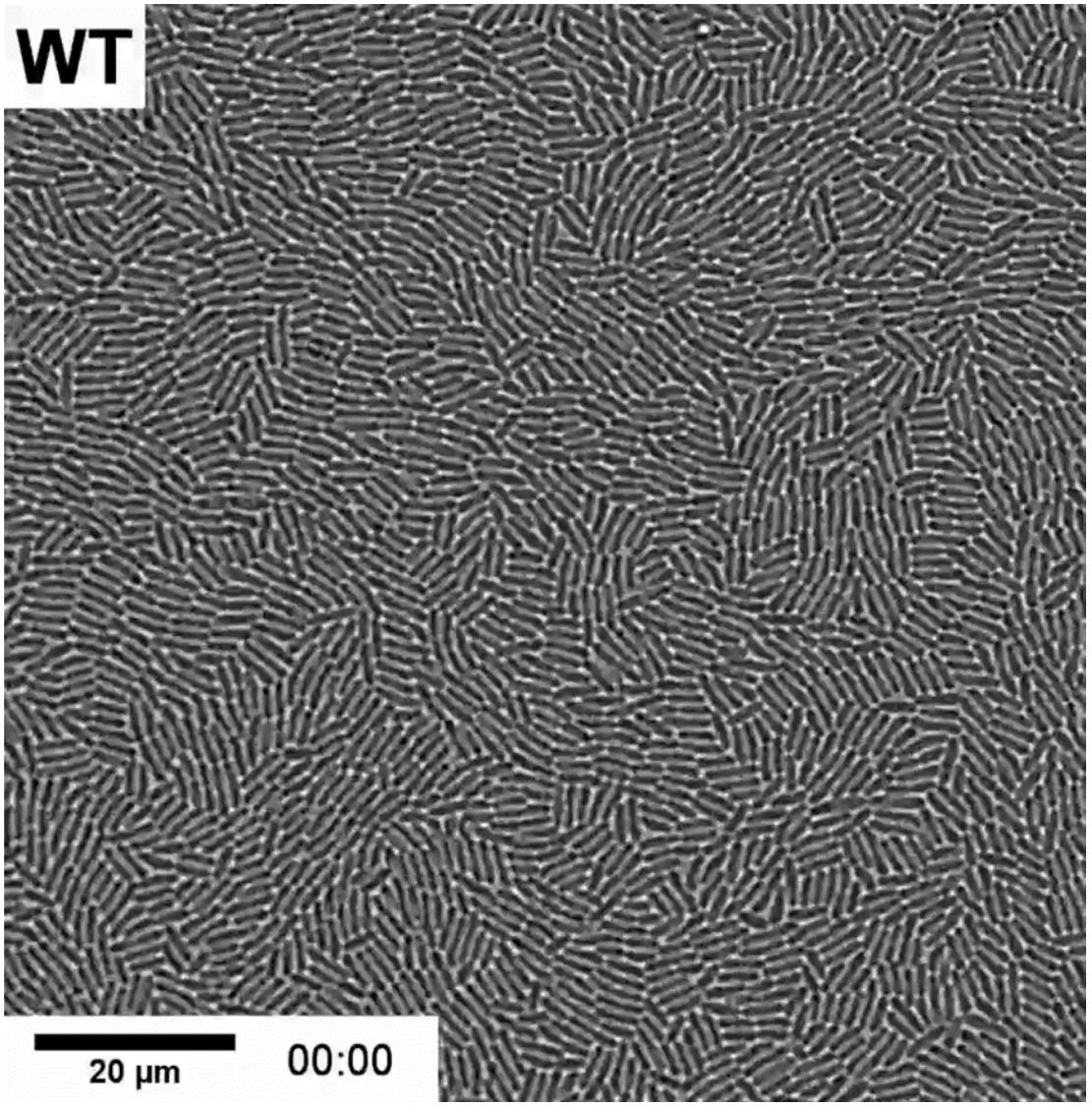
Topological defects in eukaryotic cells



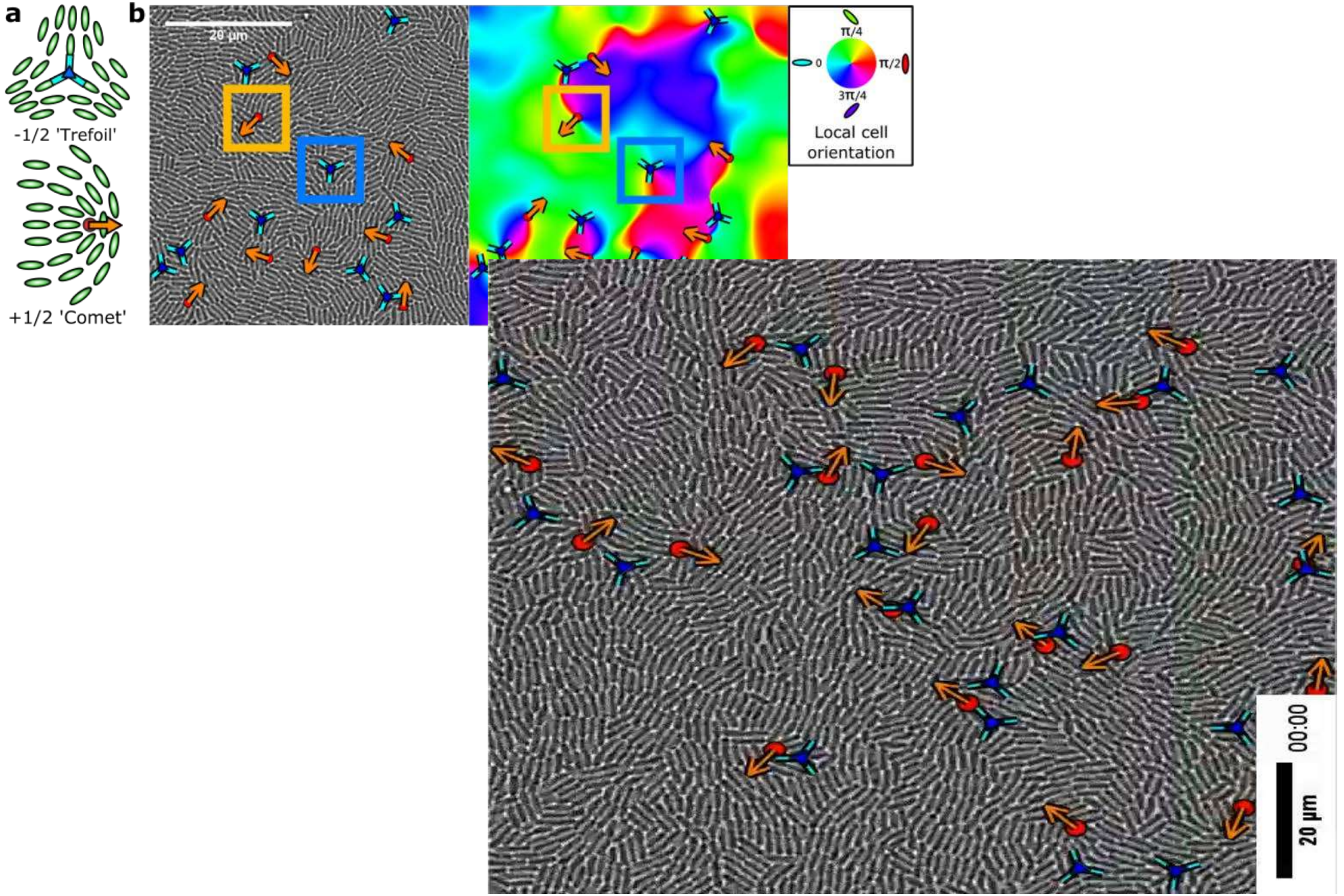
Pseudomonas aeuriginosa

twitching motility using Type IV Pili

reversals

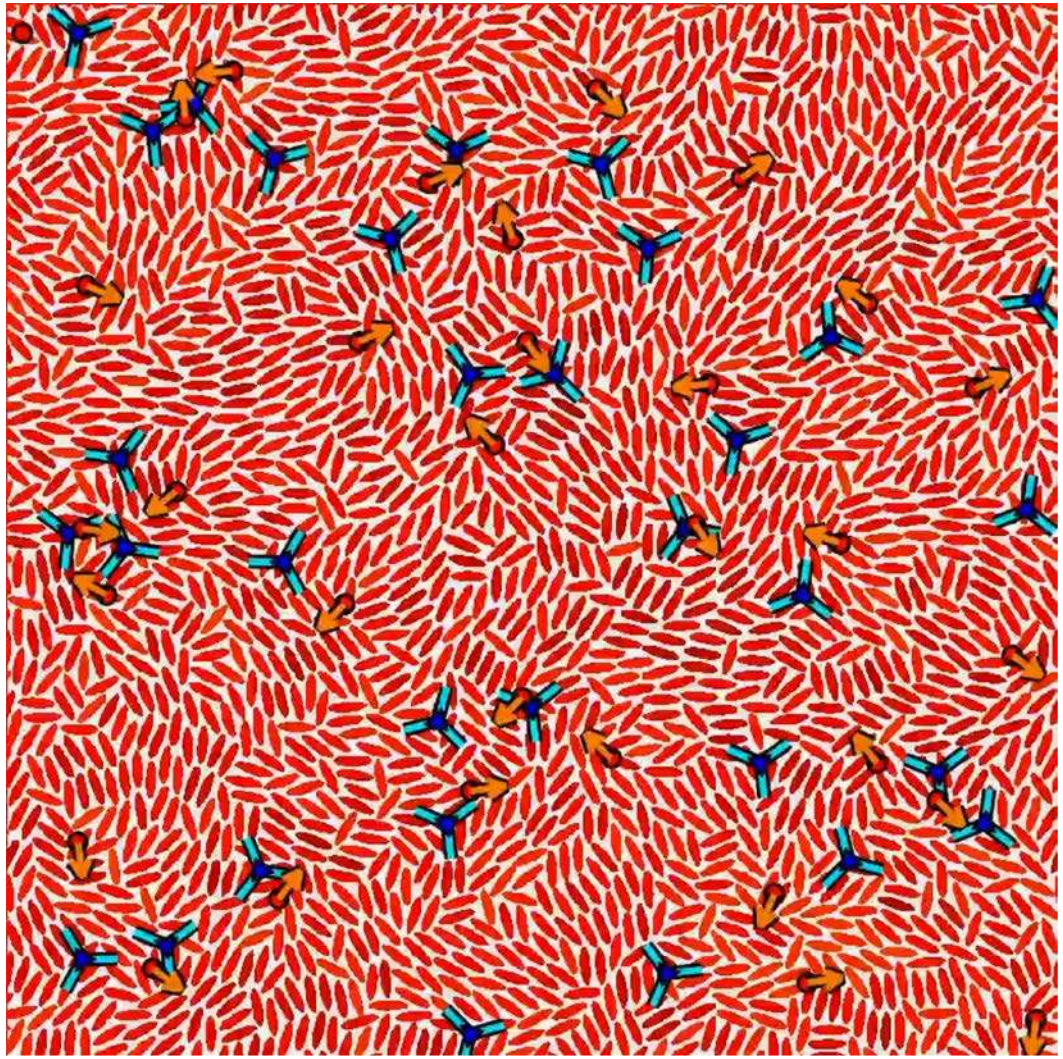


Topological defects



Models

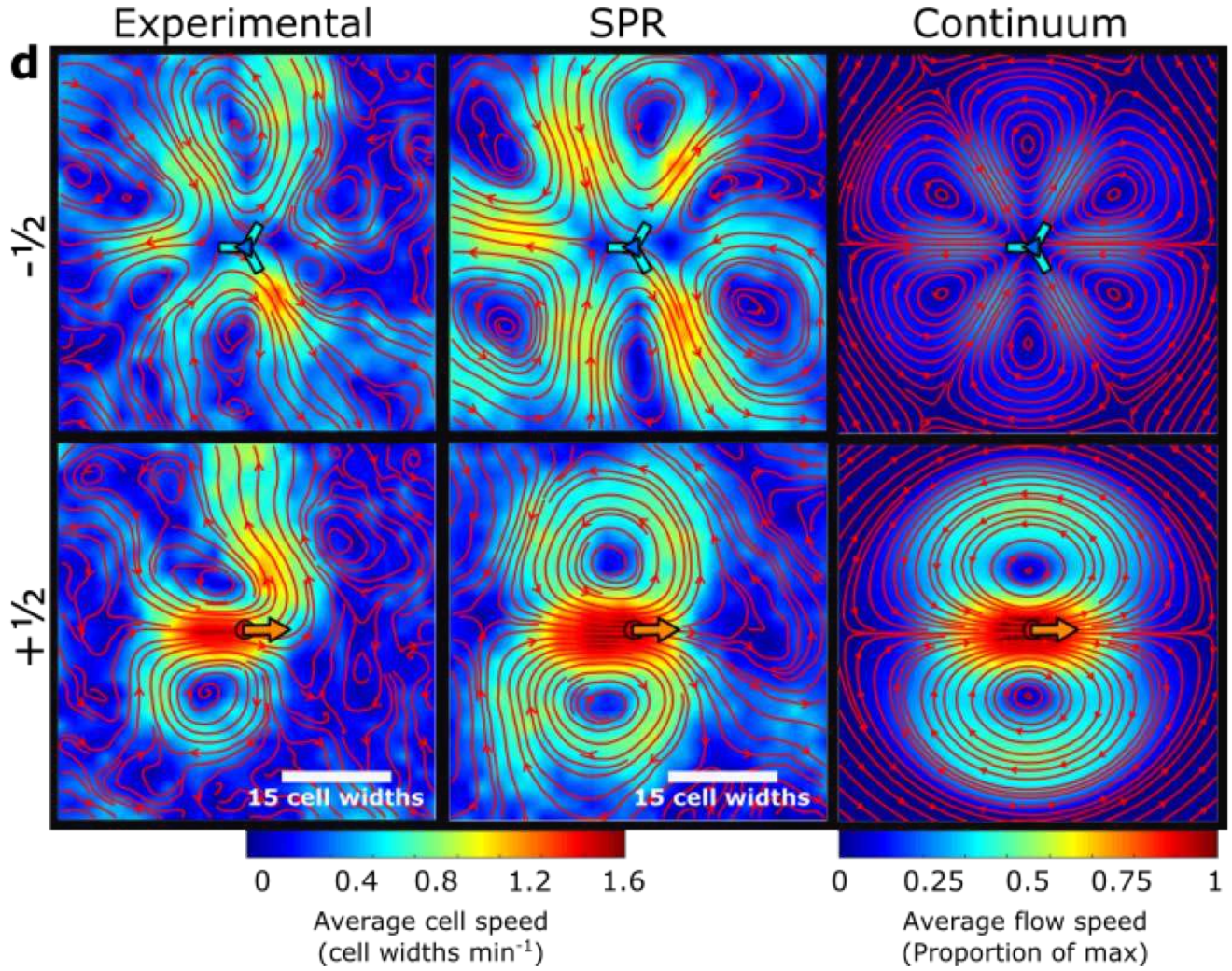
2. Self-propelled rods



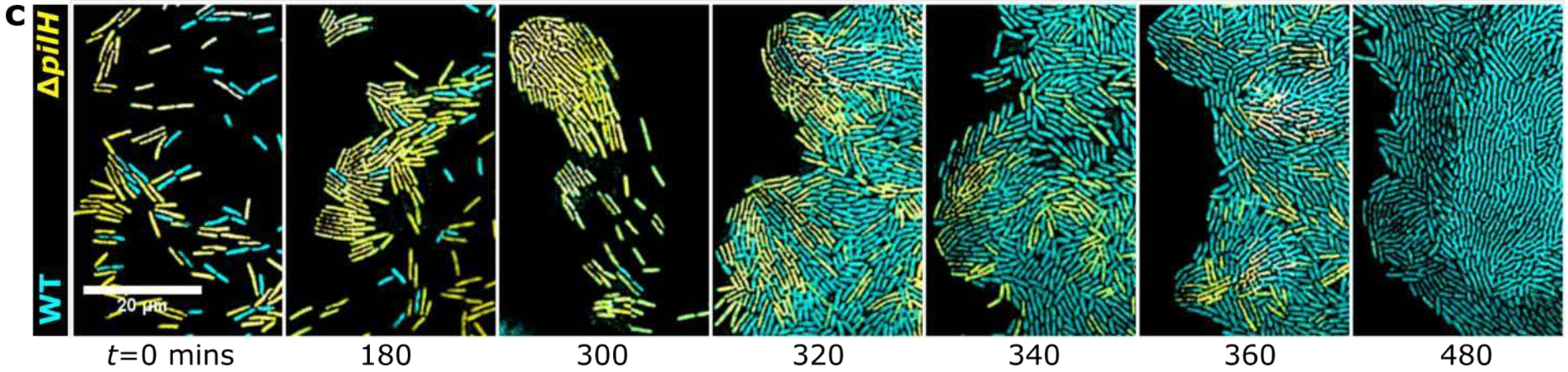
Hard rods (Yukawa potentials)

Each rod subject to a constant driving force

Models: comparing velocity fields



Topological defects in colonies of bacteria



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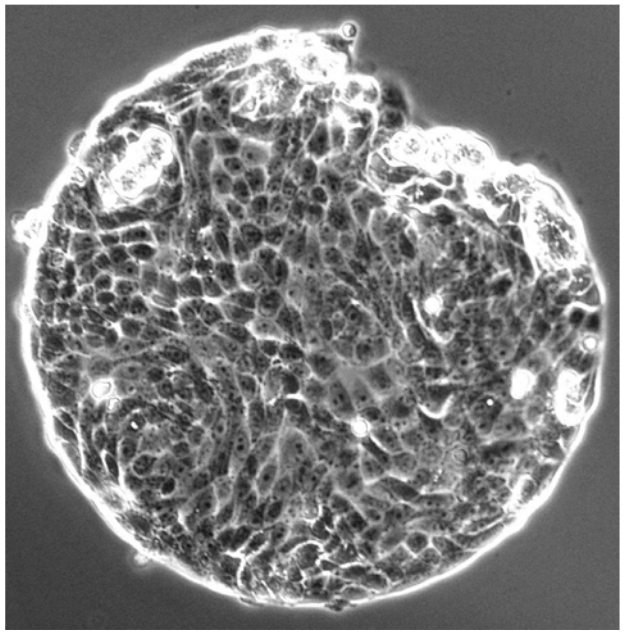
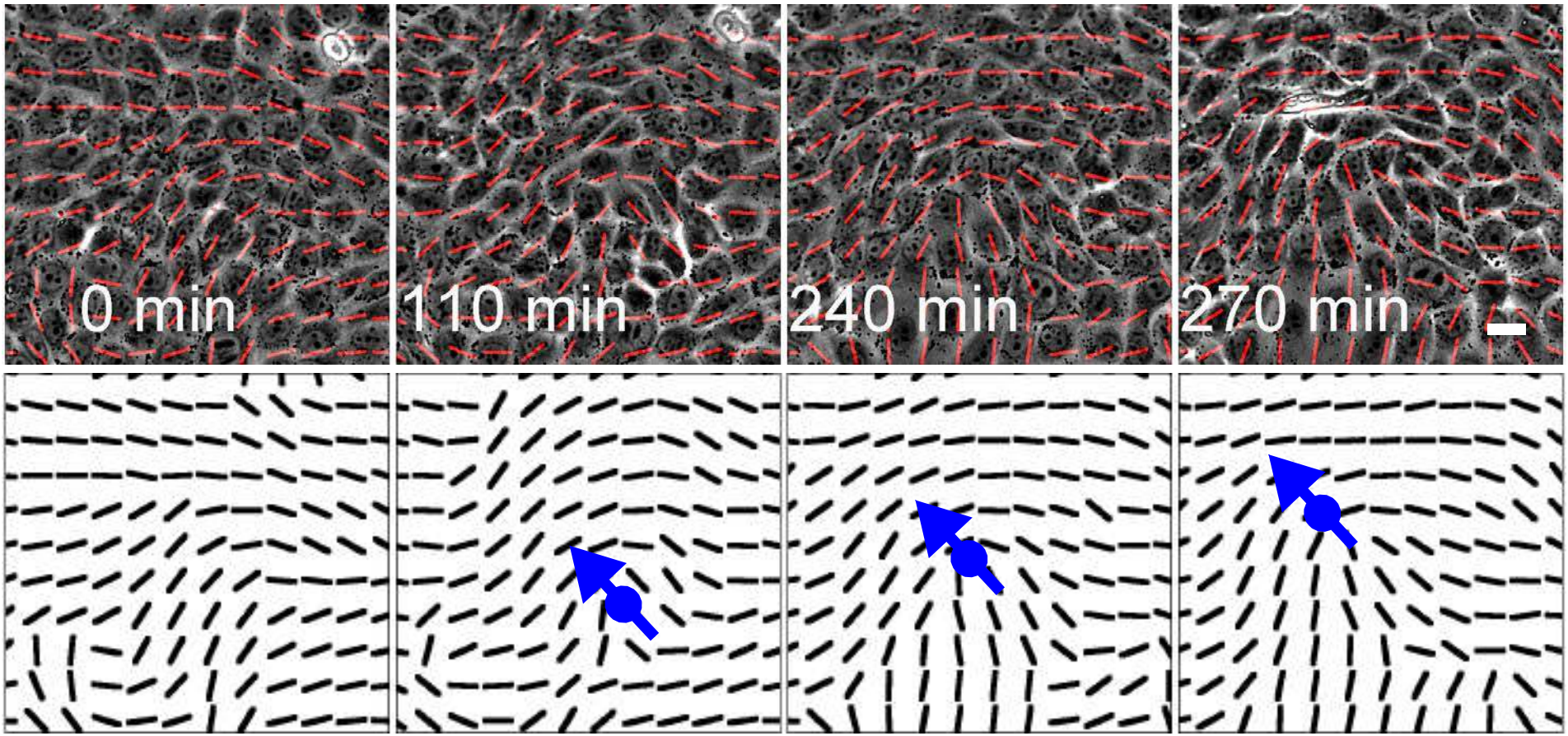


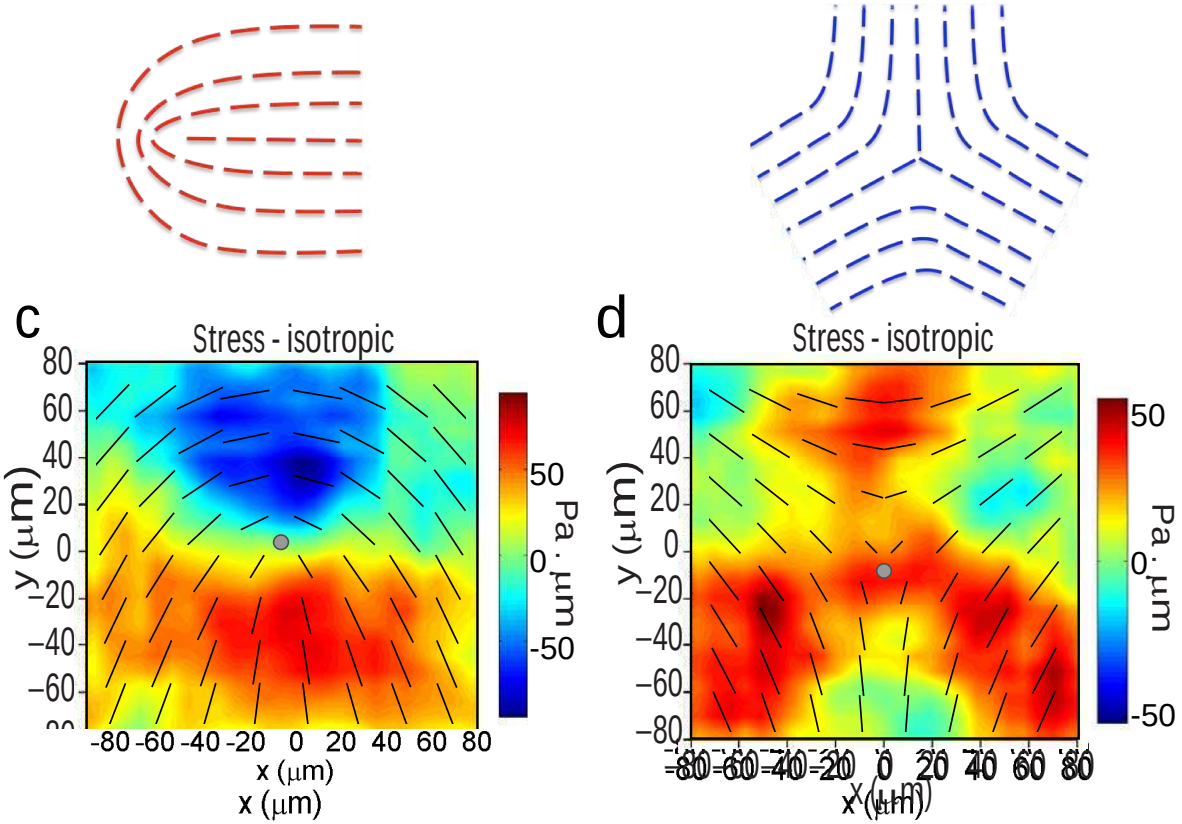
Topological defects in cell layers



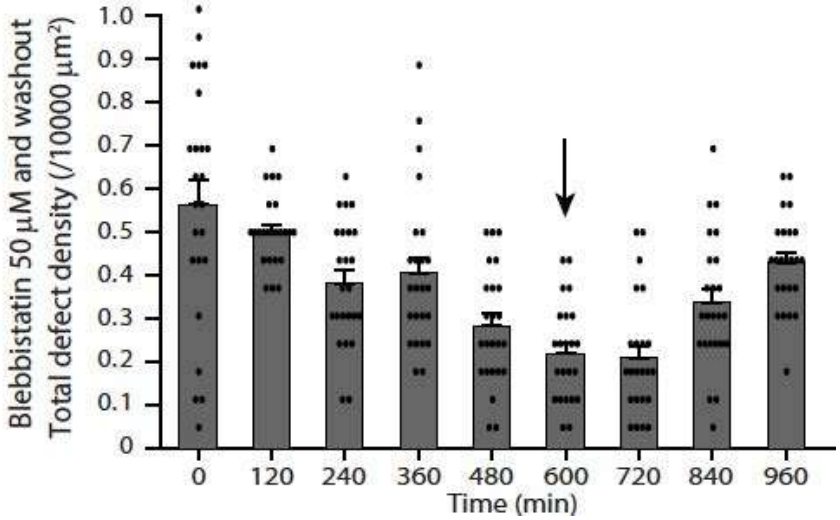
Isotropic stress around a topological defect

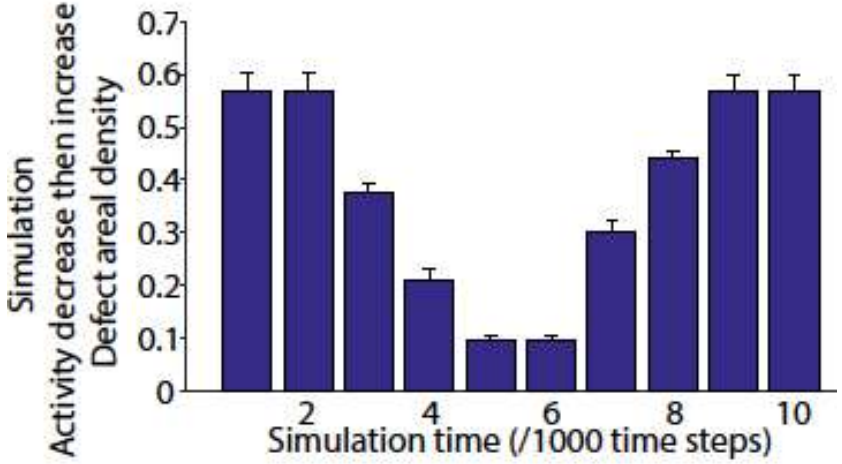
experiment

simulations



‘Turning off’ motility

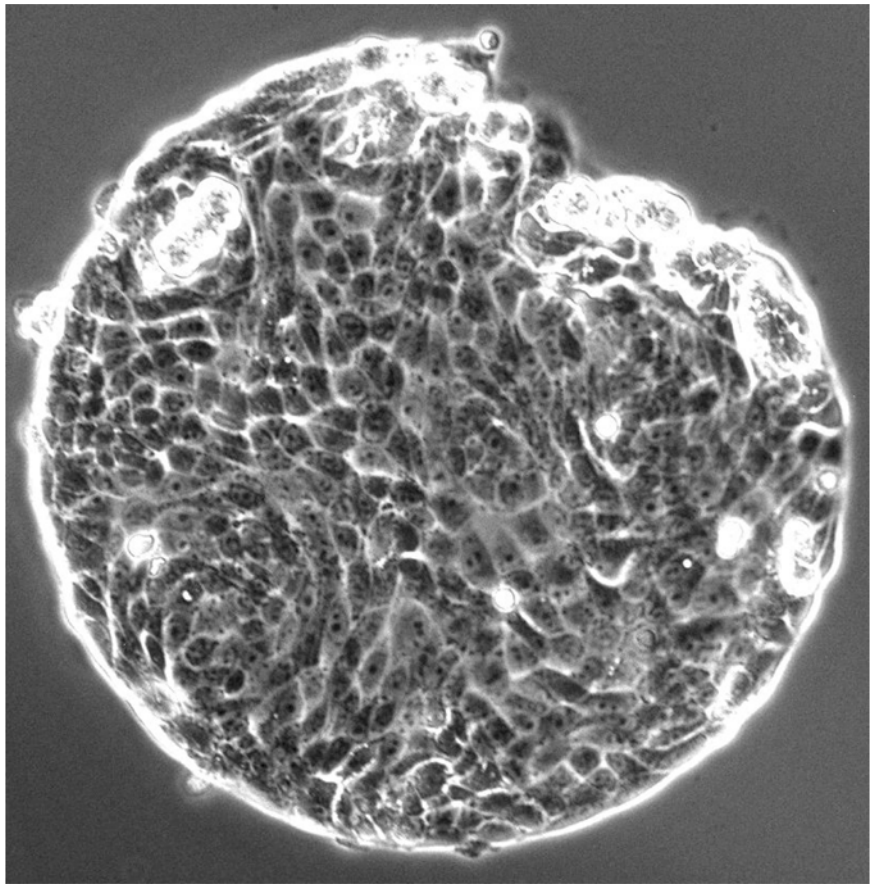




Topological defects in epithelia govern the extrusion of dead cells

T. Beng Saw, A. Doostmohammadi et al, Nature 544 212 (2017)

Topology in biology?



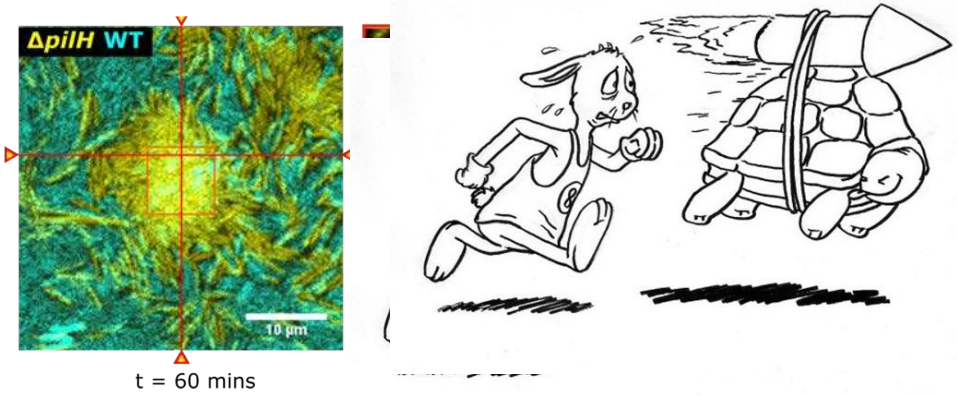
Positions of apoptosis correlated with +1/2 topological defects

High stress drives YAP from nucleus to cytoplasm which is a signal for cell death

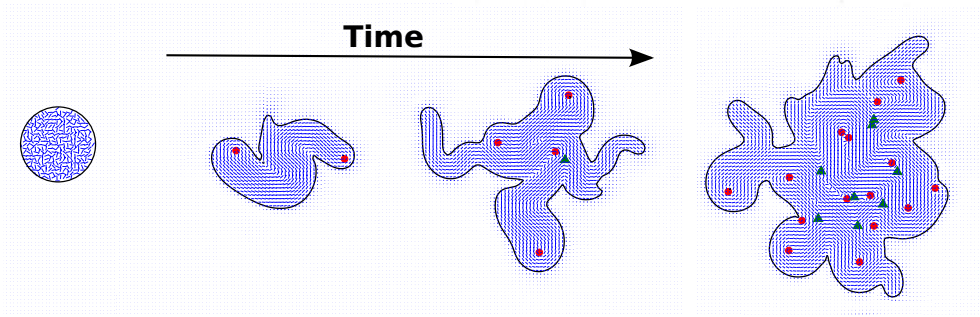
Cell dies and is ejected from the monolayer

Topological defects turn up in biological systems – and, at least in model systems, have biological relevance

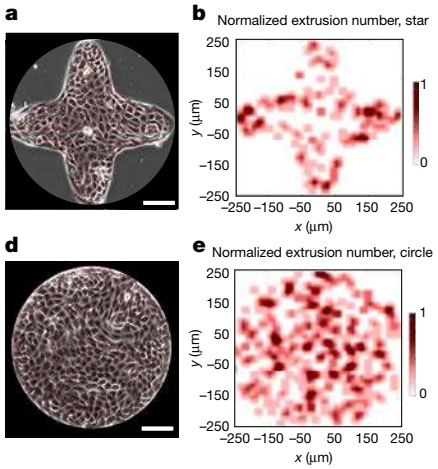
- nucleation sites in bacterial monolayers



- colony shape



- Cell death in epithelial cell layers



Oliver Meacock,
Oxford Zoology

William (Mack) Durham
Sheffield

Kevin Foster
Oxford Zoology

Amin Doostmohammadi
Oxford Physics

Kristian Thijssen
Tyler Shendruk
Mitya Pushkin
Sumesh Thampi
Thuan Beng Saw
Vincent Nier
Philippe Marcq
Benoit Ladoux