Physics of living matter

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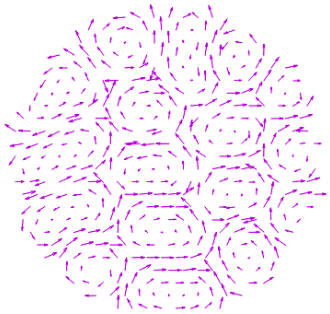
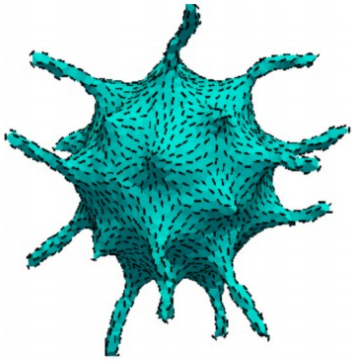
Almost all the dynamic processes in living organisms are nonequilibrium in nature. This is because cells & tissues in the organisms continuously burn chemical fuel ATP to run dynamic processes like cell division, differentiation, morphogenesis, signalling and many others, that define the state of "living". We work in a relatively new field called active matter physics, which combines knowledge from statistical mechanics, elasticity theory and fluid dynamics, to explain many of the puzzling observations on living matter.

We build **theoretical models** to explain biological phenomena. These models are essentially coupled differential equations of various scalar and tensor fields (for example, mass density, velocity, mechanical stress etc) which evolve in space and time and give rise to interesting spatio-temporal patterns. The work involves learning physics of fluids, membranes, liquid crystals and polymers (the so called soft matter physics) which collectively constitute living matter. The challenge here is to understand how these different types of material components interact with each other following physics principles and manage to collectively operate like living machines. The work will be a mixture of analytical (pen and paper) and numerical (computer programing). No background in biology is needed. Here are some figures that have emerged from our research trying to explain experimental observations.

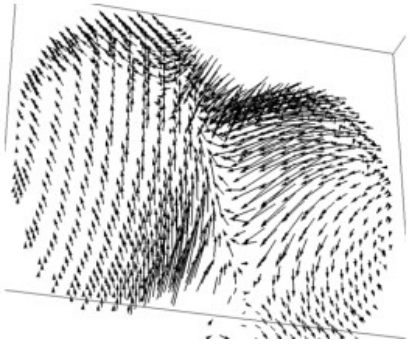
Self assembled patterns of rod like virus (modeled as liquid crystals).



Formation of membrane tubes from a vesicle



Counter rotating flows on cell during division



References :

[1] *Curvature Instability of Chiral Colloidal Membranes on Crystallization*, L. Saikia, T. Sarkar, M. Thomas, V. A. Raghunathan, A. Sain, and P. Sharma. Nat. Commun. 8, 1160 (2017). https://www.nature.com/articles/s41467-017-01441-3

[2] *Tubulation pattern of membrane vesicles coated with bio-filaments*, Gaurav Kumar, N. Ramakrishnan, and A. Sain, Phys. Rev. E 99, 022414 (2019).

[3] Ongoing work; also see *Dynamics and stability of the contractile actomyosin ring in the cell*, M. Chatterjee, A. Chatterjee, A. Nandi, and A. Sain, Phys. Rev. Lett. 128, 068102 (2022). https://drive.google.com/drive/folders/1BcizCgfKvDQAfoLPix1Am9lhm_U3lsm2?usp=drive_link