812

Active Self-Organization of Nematic Architectures on a Curved Deformable Biological Surface

Waleed Mirza[1], Marino Arroyo[1], Alejandro Torres Sánchez[2]
[1]Universitat Politècnica de Catalunya, Spain. [2]European Molecular Biology Laboratory, Spain

Abstract

A biological surface, such as the actomyosin cortex or lipid bilayer, functions as the interface between an organelle and its environment. From a mechanical viewpoint, it is a major determinant of shape and essential biological morphogenetic processes such as division or migration. One of the reasons they can perform such diverse functions is that they exhibit a dual solid-fluid behavior [1]. As solids, they store elastic energy when stretched or bent but cannot store elastic energy on long time-scales under in-plane shear, a situation in which flow as viscous fluids on a two-dimensional surface. Furthermore, most of the biological surfaces are inherently active, i.e., their mechanical behavior is thus strongly affected by a sustained power input at a local scale, which induces material flows and deformations. In presence of curvature, in-plane active and passive mechanics and transport of chemical species on the surface couple to out-of-plane forces and deformations. A further layer of complexity is introduced in a sub-class of active surfaces called active nematic surfaces, in which internal constituents with head-tail symmetry exhibit a broken rotational symmetry field or nematic order. A spatial variation of nematic order together with activity and the curved geometry has been shown to lead to emergent behaviors such as self-organization of anisotropic architectures. In this work, we systematically develop a generic theoretical model for active nematic gels on three-dimensional deformable surfaces using Onsager's variational framework [2]. The resulting model tightly couples shape dynamics, nematic dynamics, density dynamics, and interfacial hydrodynamics. To solve the coupled theoretical model in its full non-linearity, we develop a numerical finite element-based framework on a time-incremental version of Onsager's formalism. We next exercise the numerical frameworks to explore the self-organization of actin nematic architectures on a compressible actomyosin cortex surface in morphogenetic phenomena. More specifically, we study the role of nematics dynamics in the self-organization of actin bundles in cell division, pseudoclevage, and migration. Lastly, we perform numerical simulations to explore self-organized flows resulting from an interplay between nematic architectures and curvature on an incompressible biological surface. Here, we explore the interplay between nematic defects, activity, and shape dynamics leading to spontaneous in-plane and out-of-plane deformations in liquid crystal vesicles.

References:
[1] Torres-Sánchez, Alejandro, et al. "Modelling fluid deformable surfaces with an emphasis on biological interfaces." Journal of fluid mechanics 872 (2019): 218-271.
[2] Arroyo, Marino, et al. "The Role of Mechanics in the Study of Lipid Bilayers." (2018): 287-332.