Problems: Julia M Yeomans

Concrete problem

1. Draw diagrams to convince yourself why extensile (contractile) active nematics are unstable to bend (splay) distortions.

2. A simple model of a self-propelled particle i which gives the correct far flow field is a rod centred at $\boldsymbol{x}_i$ along $\hat{\boldsymbol{n}}_i$ with equal and opposite forces $\pm f\hat{\boldsymbol{n}}_i$ acting at its ends, at $\boldsymbol{x}_i + a\hat{\boldsymbol{n}}_i$ and $\boldsymbol{x}_i - a'\hat{\boldsymbol{n}}_i$.

(i) Write down the force per unit volume due to a collection of these swimmers.
(ii) Taylor expand, and hence identify the stress.
(iii) Coarse-grain to shown that the active stress is $-\zeta Q$.

If you get stuck see R. A. Simha and S. Ramaswamy, Phys. Rev. Lett. 89, 058101 (2002).

Open ended problems

1. Active topological defects

The aim of this problem is to engage with the literature on active nematics. There are now many examples of active (and passive) topological defects in biological materials. Can you find some of these and explain
- why the material is behaving as an active nematic (or maybe not)
- does the dynamics fit standard active nematic theories, or do we have to worry about differences?
- do the topological defects have any biological relevance?

One way to find relevant papers is a forward search on Saw et al, Nature 544, 212 (2017)
https://www.nature.com/articles/nature21718

2. Modelling epithelia

This is a much harder alternative but I'd like to hear your thoughts and ideas (I don't know the right answers): -

Cells are active. What is the most physically realistic way to include active dynamics in cell models such as vertex or phase field models?

Some references to get you started, but discussing might be as helpful:

Alert & Trepat Physical Models of Collective Cell Migration Ann Rev Cond Matter Phys 11 (2020)
https://doi.org/10.1146/annurev-conmatphys-031218-013516
Zhang & Yeomans Active Forces in Confluent Cell Monolayers Phys Rev Lett 130, 038202 (2023)
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.130.038202
Lin et al Structure and Rheology in Vertex Models under Cell-Shape-Dependent Active Stresses Phys. Rev. Lett. 130, 058202 (2023)
https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.130.058202
Brauns et al eLife preprint
https://elifesciences.org/reviewed-preprints/95521