A minimal model for fluid-like collective cell migration

Debarati Sarkar[1], Gerhard Gompper[1] and Jens Elgeti[1]

[1] *Institute of Complex Systems and Institute for Advanced Simulation, Forschungszentrum Juelich, 52425 Juelich, Germany*

The collective dynamics of cell plays the key role in many fundamental biological processes like morphogenesis, tissue repair and tumor metastasis etc. Madin-Darby canine kidney (MDCK) cells have been established as one model system to study collective cell migration. On adhesive substrates, cells grow in roughly circular colonies, expanding with time and displaying fascinating motile behavior. Two aspects of their motion lie at the heart of this study: (a) Cells move throughout the colony, forming large scale patterns like swirls or fingers at the edge; reflecting a fluid like behaviour of the cell colony. At the same time, (b) the colonies are extremely cohesive. The colony is not maintained by a constant flux of cells leaving and entering from the surrounding. Instead, the surrounding is devoid of cells, one might say these colonies display liquid-vacuum coexistence.

The active Brownian particle (ABP) model has been used intensively to model such motile cell colonies.
However, ”normal” ABP’s show either liquid-gas coexistence - with a finite density of cells away from the colony, or crystallize, if the adhesion is strong enough to prevent particles from escaping.

We propose a novel particle-particle interaction potential that allows for cells to move, despite strong adhesion. We show that this model results in colonies with fluid like properties while remaining cohesive in nature at the same time. Furthermore, these colonies can be under tensile stress, as reported for growing MDCK colonies [1]. In combination with velocity alignment, cells can escape the mother colony collectively. A group of cells can form a finger that eventually pinches of.

[1] X. Trepat et al., Nat. Phys. **5**(6), 426–430 (2009).

[2] A. Puliafito, et al., Proc. Natl. Acad. Sci. USA **109**(3), 739–744 (2012).

[3] M. Basan et al., Proc. Natl. Acad. Sci. USA **110**(7), 2452–2459 (2013).

[4] Y. Fily, and M. C. Marchetti, Phys. Rev. Lett. **108**, 235702 (2012).

[5] J. Stenhammar, D. Marenduzzo, R. J. Allen, and M. Cates, Soft Matter **10**, 1489, (2014).

{6} G. S. Redner, A. Baskaran, and M. F. Hagan, Phys. Rev. E **88**, 012305 (2013).