M2 internship and PhD thesis (2018)

Order-disorder transition in tissue monolayer

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Summary

Foams, emulsions, and biological tissues are examples of *soft cellular systems*: they are constituted of highly deformable units (bubbles, drops, cells), interacting through attractive adhesive interactions and soft steric repulsions. When highly compacted, they tile perfectly the available space (3D) or plane (2D), *i.e.* without gaps or overlaps.

In some cases the tiling is ordered, consisting predominantly of hexagons (in 2D), and in others it is disordered and includes a distribution of *topological defects* (polygons with $n \neq 6$ sides).

In the case of biological tissues, the structure is essential for their function. Unlike foams and emulsions, biological tissues are **active cellular systems**: they consume (chemical) energy to produce motion. A transition between ordered and disordered structure is often observed in developing epithelia, in both directions: some are initially hexagonal and evolve into a disordered pattern whereas others undergo the disordered-hexagonal transition. The evolution of the structure is primarily done through the three following elementary structural changes: *i)* neighbour swapping; *ii)* cell division; *iii)* cell death. The bidirectionality of the structural transition in developing epithelia supports the assertion that cell proliferation may not be an essential element of epithelial morphogenesis.

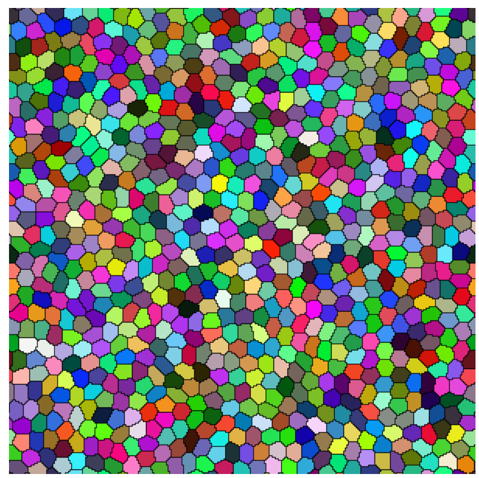

Figure 1: Example of cellular pattern obtained using Cellular Potts model. Here, every color represents a different domain.

The aim of the present study is to numerically investigate the order-disorder transition in two-dimensional biological tissues. The simulations will be performed using the Cellular Potts Model which is a standard computational model for soft cellular systems [1]. We will characterize this transition and explore the effect of the three elementary structural changes listed above. We will analyze the two situations where these structural changes are uniformly distributed in the epithelium, or actively triggered in response to the local environement of each cell. We will compare the evolution of the disorder in these out-of-equilibrium systems with the order-disorder transition which has been recently characterized in two-dimensional foams under thermal agitation, and with the many existing theories for the melting of two-dimensional solids. In particular, we will investigate whether the orientational and translational orders are lost simultaneously or in two successive phase transitions, as predicted by the Kosterlitz, Thouless, Halperin, Nelson and Young (KTHNY) theory.

[1] https://en.wikipedia.org/wiki/Cellular_Potts_model

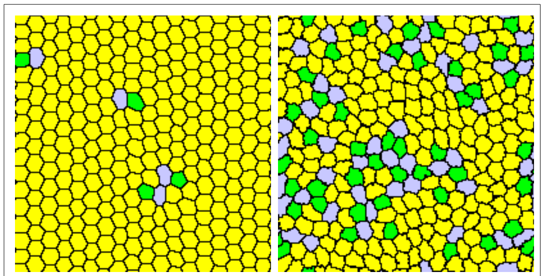

Figure 2: Order-disorder transition. Yellow: 6-sided domains; green: 5-sided domains; purple: 7-sided domains.