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Quantifying and modelling epithelial morphogenesis

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In the course of animal development, the shape of macroscopic tissues emerges from collective cell dynamics. The challenge faced by researchers in the field is to understand the mechanism by which morphogenetic processes of each individual cell (i.e., when, where, and how much individual cells grow, divide, move, and die) collectively lead to the development of a large tissue with its correct shape and size.

Answering this question requires a coarse-grained description and modelling of cell and tissue dynamics at an appropriate length scale. In a previous study, we developed coarse-grained measurement methods for stress and kinematic fields. These methods are now emerging as powerful tools used for exploring the mechanics of epithelial tissues. Given the advancement of experimental measurement methods, one can expect that a theoretical model for kinematics and kinetics in a deforming tissue, which can be compared with the experimentally observable fields, will further advance our understanding of the mechanical control of tissue morphogenesis.

Here, we present a new continuum model of epithelial mechanics. This model incorporates stress and deformation tensors, which can be compared with experimental data. Using this model, we elucidated dynamical behaviour underlying passive relaxation, active contraction-elongation, and tissue shear flow. This study provides an integrated scheme for the understanding of the orchestration of morphogenetic processes in individual cells to achieve epithelial tissue morphogenesis.

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