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MECHANISMS OF SYMMETRY-BREAKING AND PATTERN FORMATION DURING DEVELOPMENT: INSIGHTS FROM MATHEMATICAL MODELLING

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Cells and tissues are objects of the physical world, and therefore they obey the laws of physics and chemistry, notwithstanding the molecular complexity of biological systems. A natural question arises about the mathematical principles at play in generating such complex entities from simple laws. In this talk, I show how different pattern formation concepts may stand challenges arising from the current experimental research. Specifically, Turing-style morphogen-based models are compared to mechano-chemical models exhibiting de novo pattern formation. The latter are using geometric singular perturbation allowing separating fast and slow-scale subsystems. Patterning potential of mechano-chemical interactions is investigated using two classes of mathematical models coupling dynamics of diffusing molecular signals with a model of tissue deformation. The first class of models is based on energy minimization that leads to 4-th order partial differential equations of evolution of infinitely thin deforming tissue (pseudo-3D model), coupled with a surface reaction-diffusion equation. The second approach (full-3D model) consists of a continuous model of large tissue deformation coupled with a discrete description of spatial distribution of cells to account for active deformation of single cells. We discuss analytical and numerical challenges of the proposed models and compare the resulting patterns of tissue invagination and evagination to those observed in developmental biology.

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