Modeling Convergent Extension by way of Anisotropic Differential Adhesion

Abstract

by

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Cell sorting and convergent extension are both widely observed in experiments on different embryos but phenomenology suggests no strong connection between these two development mechanisms. Typically, the former involves automatic segregation of mixed cells from different tissues while the latter entails longitudinal tissue extension, resulting from latitudinal elongation and convergence of aligned cells. In archetypal experiments, sorting cells bunch together in clusters while convergent extension maintains rank and file organization among cells to some degree. Based on these observations, cell sorting and convergent extension seem to have little in common.

However, with adaptation, the standard explanation for cell sorting provides a plausible analytic model for convergent extension. In analogy with the spontaneous separation of oil from water, established theory correctly predicts the outcomes of sorting experiments. Cells from different tissues exhibit different degrees of stickiness. Differential adhesion between sorting cells gives rise to abstract surface tensions which amount to immiscibility of tissues. Formally equivalent analysis explains convergent extension in terms of differential adhesion between long sides and short ends of adjacent prolate cells within extending tissues. Considered from this perspective, the long sides and short ends sort with respect to one another as requisite alignment develops during convergent extension. Theoretically, abstract

surface tensions distinguish stable equilibrium cell configurations of minimal energy for convergent extension, as previously recognized for cell sorting.

Simulations offer a practical means of testing theories, with strict control over all parameters. In particular, The Extended Potts Model employs clusters of discrete elements to represent cells on a lattice, with probabilistic displacement of cell boundaries such that small changes in energy drive gradual tissue development. For cell sorting, simulations yield all configurations predicted by surface tension arguments using suitably adjusted isotropic binding between different types of cells. For convergent extension, simulations show that anisotropic differential adhesion can account for tissue extension accompanied by elongation and alignment of constituent cells, as predicted analytically. No simulation can prove that a modified cell sorting algorithm fully accounts for convergent extension in real tissues but successful simulations, incorporating no alternative mechanisms, suggest that anisotropic differential adhesion may be influential.

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