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Mechanical Forces and Geometric Properties in Tissue Phase Transitions: Insights from Active Vertex Model

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During the embryonic stage, mechanical forces such as contraction, stretching, and bending play a crucial role in forming structured cell groups and patterns. However, it is still unclear how these different forces affect pattern formation in developing tissues. In order to understand how these different factors affect tissue dynamics and cellular rearrangements we used the active vertex model. By including passive forces representing competition between cellular adhesion and contractility, as well as active forces, included as vertex motility in randomly selected directions we obtained phase diagram of the tissue. The phase diagram indicated that increasing active forces alone or in combination with increasing passive forces resulted in fluidization of the tissue. Next, we investigated geometric properties of the tissue, such as the cell shape index, number of cell vertices, average cell area, and more, to derive observables that could distinguish fluid-like from solid-like tissue behavior. The results show that in the fluid state, cells are elongated with a higher number of vertices, while in the solid state, they are more compact, suggesting that tissue state can be determined through geometric properties. In the next step, we considered a group of cells with varying geometric properties, specifically compact cells with higher contractility. Our simulation showed that this group can form an elongated pattern, which may be related to processes like cell sorting or branching.

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