Phase Transitions in the Self-Organization of Neural Rosettes

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Keywords: collective behavior, stem cells, neural tube development

Neural rosettes are biological multi celullar structures that develop from the self-organization and differentiation of human induced Pluripotent Stem Cells (hiPSCs). This process models the emergence of the embryonic spinal cord primordium, the neural tube. Errors in the formation of the neural tube are the cause of two severe diseases, the spina bifida and anencephaly. While this phenomenon is recognized as an example of self-organization, we do not understand the fundamental mechanics that guides this process. An explanation based on stem cell differentiation lacks the ability to describe the emergence of spatial organization, and an explanation based on patterning models lacks the ability to explain how different groups of cells can collectively migrate and generate the neural tube. A truly interdisciplinary approach that combines stem cell biology, and active/soft matter physics is required to understand this process. We show that, a developing neural rosette can be modeled as an active material that undergoes a sequence of phase transitions. These phase transitions are the result of single cells‘ decisions which are encoded in the cells’ DNA as responses to the cells’ environment and external signals. We conclude that neural rosette development is a multi-scale self-organization process that involves both cell differentiation and tissue development. To understand rosette formation growth, migration, and cell type evolution must be understood together.