Defect coarsening in blood vessel network formation: self-organization through alignment of elongated cells

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Blood vessel growth is key to numerous processes in healthy and diseased individuals, including wound healing and cancer. Early during embryonic development, a type of cells called endothelial cells, aggregate and self-organize into a primitive blood vessel network that later expands and matures to form the circulatory system. How cells can organize into networks is still poorly understood.

One class of explanatory models, deriving from the classic Keller-Segel equations, is based on chemotaxis: these models assume that cells secrete a chemical that attracts other cells. Simulation models have shown that only if cells have an elongated shape [2], this mechanism form networks (see Figure 1), whereas round cells form heaps of cells

Recent simulations suggest that networks form due to a defect-coarsening effect [3]. The cells align with one another and form the meshes of the network. Over time, the meshes may co-align and coalesce, such that over a long time all cells align and network collapses. Because a cluster of aligned cells appears to have much slower rotational diffusion coefficients than a single cell, one cells aligns quickly with a mesh, but two clusters of aligned cells align very slowly with each other. This suggests that network formation is a "stalled", transient phenomenon.

The aim of this project is to study the transient and long-term behavior of this system in more detail. In this project you can combine exploratory, agent-based and Cellular Potts simulations with theory development. The mathematical techniques and project details are open to discussion. Possible directions include PDE models of particle

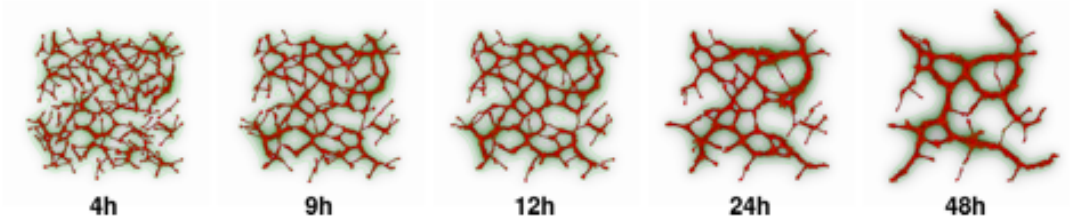

Figure 1: Simulated blood vessel network formed out of elongated cells, coarsening over time

alignment (e.g., based on [1, 4]) and mean-field Potts model approximations (e.g., [5]).

References

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