



Design Principles of Cellular and Developmental Systems

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My research aims to understand the dynamical processes responsible for organization in cellular and multi-cellular (developmental) systems. In this talk, I will focus on two aspects of this work. First, I will discuss a joint modeling and experimental investigation aimed at determining how the early mammalian embryo spatially self-organizes. The central question of this work is how early embryonic structures (the blastocyst to be specific) are robustly and reproducibly constructed. I will use multi-scale stochastic modeling to investigate how cell-cell communication and stochastic aspects of gene regulation influence and lead to robust development of the early embryonic structures. I will also discuss how mathematical assumptions about the nature and source of gene expression stochasticity can fundamentally alter model dynamics in ways that should be considered. Subsequently, I will discuss how cells use complex and nonlinear signaling to regulate their cytoskeleton, giving rise to a diverse array of cellular morphologies and behaviors (e.g. polarity, wave-like dynamics, and different types of migration). In the course of this discussion, I will highlight a newly developed class of singular perturbation methods that provide a highly efficient and automatable way to map the non-linear properties of complex, nonlinear, and spatial regulatory systems. These techniques fill a void between simple (but limited) linear analysis techniques and more thorough (but in most cases impractical) fully non-linear PDE methods.