Math 218: Seminars on Mathematics for Complex Biological Systems

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Modeling rapid diffusion state switching during cellular polarization of a C. Elegans zygote

Abstract:

Morphogen gradients play a vital role in developmental biology by enabling embryonic cells to infer their spatial location and determine their developmental fate accordingly. The standard mechanism for generating a morphogen gradient involves a morphogen being produced from a localized source and subsequently degrading. While this mechanism is effective over the length and time scales of tissue development, it fails over typical subcellular length scales due to the rapid dissipation of spatial asymmetries. Single-particle tracking experiments have recently found that C. elegans zygotes rely on space-dependent switching diffusivities to form intracellular gradients during cell polarization. We analyze a model of switching diffusivities to determine its role in protein concentration gradient formation. In particular, we determine how the presence of switching diffusivities modifies the standard theory and show that space-dependent switching diffusivities can yield a gradient in the absence of a localized source. Our mathematical analysis yields explicit formulas for the intracellular concentration gradient which closely match the results of previous experiments and numerical simulations. We further consider how this mechanism of switching diffusive states interacts with a locally varying periodic microstructure in the cell, and use homogenization theory to show that at the typical cellular scales involved, such a microstructure does not necessarily need to be resolved in fine detail in order to accurately capture the dynamics of the system.

Hosts: Li-Tien Cheng, Bo Li, and Ruth Williams

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2:00 PM
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