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Multiscale modelling of biological problems

Abstract

Problems involving multiple scales are ubiquitous in biology and their modelling presents a number of mathematical and computational challenges. In this talk we discuss two such problems.

In the first part of the talk, we consider problems from theoretical ecology for the dynamics of two competing species that reside in a heterogeneous environment. In particular, we wish to understand the role played by heterogeneous motility on invasion behaviour in mathematical models for competition between motile species. We study the effect of rapidly oscillating periodic motilities while performing simultaneous homogenization and strong competition limits. The limit problem is shown to be a free boundary problem of Stefan type with effective coefficients. We will also discuss the implications our analysis has on invasiveness of a species. The results will be supported by numerical simulations.

In the second part of the talk, we consider the derivation, analysis and simulation of mathematical models for cellular signalling processes in biological tissues. A coupled system of nonlinear bulk-surface partial differential equations is used to model the dynamics of signalling molecules in the inter- and intra-cellular spaces as well as for the cell membrane resident receptors. Using multiscale analysis techniques, we derive a macroscopic two-scale model for signalling processes defined on the tissue level. A two-scale numerical method is developed and implemented for simulations of the macroscopic bulk-surface problem and numerical results will be presented illustrating the role cell scale heterogeneities play in the dynamics of macroscopic concentrations.